DESIGN DEVELOPMENT OF AN INDIGENOUS TRICYCLE RICKSHAW

Thesis submitted in partial fulfillment of the requirement
for the award of the Degree of
Doctor of Philosophy

Amarendra Kumar Das

Department of Design

INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
Guwahati-781039
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Under supervision of

Debkumar Chakrabarti, Ph D

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Certificate

30th November 2007

The research work presented in this thesis entitled 'Design Development of an Indigenous Tricycle Rickshaw' has been carried out under my supervision and is a bonafide work of Mr. Amarendra Kumar Das. This work submitted for the degree of Doctor of Philosophy is original and has not been submitted for any other degree or diploma to this institute or to any other institute or university. He has also fulfilled all the requirements including mandatory coursework as per the rules and regulations for the award of the degree of Doctor of Philosophy of Indian Institute of Technology Guwahati.

Debkumar Chakrabarti, PhD
Associate Professor,
Department of Design
Indian Institute of Technology Guwahati
Guwahati 781 039
Asom, India

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I express my sincere gratitude to all those people who helped me during the present research work and acknowledge the support received from various institutions, therefore I dedicate my works to all of them.

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North Eastern Development Finance Corporation (NEDFI), Guwahati funded the development expenditures of the interim model of Dipbahan (the tricycle rickshaw that was designed, developed and technology for its manufacturing was transferred to SMEs under this research work was branded as Dipbahan) and continued support for further work. NEDFi also introduced Dipbahan^{+} through their Micro Credit scheme in Agartala in Tripura and Imphal in Manipur.

Centre for Rural Development (CRD), Guwahati participated in the design development of Dipbahan, manufactured it and introduced this through the Rickshaw Bank Micro Credit scheme.

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National Associates, Guwahati associated in development of composite components for the Dipbahan^{+} and it's derivatives like Dibahan Pariskar and Dipbahan Ankur.

Tim Steel Innovatives, Guwahati for participated and sponsored the design development expenditure for the 2nd generation Dipbahan and it's derivatives like Dibahan Pariskar and Dipbahan Ankur. M/s Tim Steel Innovatives manufactured Dipbahan^{+} and this made possible for its introduction in various other states.

West Bengal State Marketing Board spearheaded introduction of Dipbahan^{+} in the state of West Bengal which in turn encourages the work to fine tune.

Xuoni Axom, an NGO of Dispur, Guwahati for undertook the trial of Dipbahan Pariskar for implementing solid waste garbage collection from households and it's disposal as a

economically viable proposition and as means of income generation for unemployed youth using Dipbahan Pariskar.

I sincerely acknowledge the supports of all the above institutions and persons involved in this endeavor.

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I must sincerely admit that the research work became productive due to the fact that my wife – Kaberi and my kids – Ruchi and Roni had borne all the hardship by allowing me to be free to work unhindered. Their support would remain an inspiration for me for ever…

Das A K

Abstract

The localised issues of meeting transportation needs of vast masses of population that can not afford a personal vehicle and to meet the limitations of public transportation systems needs consideration for alternative viable means that are contextual. Human powered tricycle rickshaw still fulfills this need. In addition to this, there are variations based on tricycles used as delivery vans with boxy storage compartments, goods carrier and school children van to name a few that are put to use to fulfill the localized transportation need. The current practice for meeting the localized transportation needs of the population is varied and is dependant on the region, cultural, economic, geographical locations and the local administration. However to meet local transportation needs for transporting various goods, tricycle based vehicles are extensively used. There are various advantages associated with these vehicles (Rajvanshi, 2002). These are:

Non-polluting modes of transportation (air pollution, noise pollution etc.)
Cost effectiveness with increasing fuel prices for short distances.
Provides for income generation for the vast unemployed youths of the country.
Lower cost of capital for each vehicle and each employment generated.
Load on road infrastructure is less.

The best strategy for containing the vehicular pollution is through HPV (Human Powered Vehicles) (Ballantine and Grant, 1998) like tricycle/Trike/Rickshaws are not given due importance because of people's perception (http://www.itdp.com, http://www.sustrans. org.uk, Dec 2006) about these mode of transport as slow moving, low grade, low-tech, unsafe product and associated status of rickshaw as a mode of transport used by poor people (Wheeler, 1998). In comparison to motorized vehicle development, not much research in this field has been carried out to improve these. This mind set leads to a tendency on part of the population in growing cities of developing countries to disband these vehicles from cities (http://list.jca.apc.org /public/sustran-discuss, Dec, 2006) and urban areas attributing the increased vehicular pollution in these areas to these vehicles due to slow moving nature and for creating traffic snarl (http://www.sustrans. org.uk, Dec, 2006). Although HPVs can never be substitute for present day automobiles for long distance travel, it is a very good mode of local transport within residential localities in case of short distance from main road served by other public transport such as bus, local train or metro routes.

Common people's perception (http://www.johost.eu, Sept, 2006) regarding the existing varieties of tricycle rickshaw is of poor quality, aesthetics, ergonomics as well as safety from the point of view of passenger and rider i.e. rickshaw puller.

i. Poor quality attributed to current practice of assembly of tricycle rickshaw out of factory made parts along with locally made body in a cottage industry.
ii. Rickshaw's existing form not being contemporary does not appeal to many.
iii. Ergonomic aspect- for passengers and for the puller.

iv. Safety associated with existing traditional rickshaw in present road condition where both the puller and the passengers are fully exposed to other vehicles on road and are not protected from moving vehicles.

It is confirmed that there is a need to design a new tricycle rickshaw to be used as a means of localized transportation that can also initiate change in the people's perception about the traditional rickshaw with its conventional look and initiate philosophical change in our attitude for meeting the need through environment friendly and sustainable way.

The second aspect is the transfer of design and technology developed to the actual users and manufacturer. Many institutions in India have developed new and improved technologies. In spite of much effort done by various agencies for design and technology transfer, development as expected has not taken place. One factor that is hindering dissemination and transfer of technology may well have been inadequate information available to the potential manufacturer, specifically Small Enterprises.

Thus it is important to study the method for transfer of design and technology and other factors associated with this. Experts in this area feel that Technology is only one component in the chain of events that implant S&T for the rapid development. The human element is equally important – sincerity, honesty, integrity and managerial skill and leadership quality (Kunnumkal and Sant, 2002; Chidambaram, 2002).Various models for successful implementation of technology transfer is being proposed and tried out. The research is also in this direction of finding out an implement able model of Design and Technology transfer. The research is based on the hypothesis that for successful implementation of design and technology inputs by small enterprise, it is essential that a holistic approach incorporating Design, Prototyping and Manufacturing System Management for Technology Transfer to Small Enterprise is essential. It is assumed that if a proper methodology can be incorporated in the Design concept generation stage itself for the product to be implemented by the targeted Small enterprise in a participatory way, the process of transfer of design and the related technology transfer to the Small Enterprise will be easier, hassle free and effective. Thus present hurdle of transferring design and technology from lab to field faced by the academic institution/ research laboratories/ industries specifically related to product can be eliminated. This could be tried out, with an immediate and relevant need for localized HPV i.e. tricycle rickshaw including a contemporary design and development, demonstration of its effectiveness and manufacturing technologies to Small Enterprise. Based on the above, the present study aimed at design development of an indigenous tricycle rickshaw with contemporary aesthetics suitable for Indian conditions, better usability for the puller as well as for the passengers and sufficient space for luggage and goods. Prototyping and manufacturing system management for the tricycle rickshaw with the participation from small enterprises was an integral component of the research.

The research methodology follows Design Research as the main emphasis. In this approach, the experimental component of the research itself is carried out through solving an existing design problem. Followed by a literature survey of the tricycle rickshaw, the need of undertaking a new design development work was justified. The actual design of a tricycle

rickshaw for passengers – a Human Powered Vehicle in the Indian context was considered. The design strategy adopted was human centered product design. Product design methodology model formulated by Asimow (Asimow, 1962) was used for design iteration

The result of this research work is a new design of a tricycle rickshaw. The designed tricycle rickshaw branded as Dipbahan was prototyped and its manufacturing system management was evolved through participation of small enterprise. Design methodology and technological processes were demonstrated to the manufacturers (Small Enterprises). As a part of the research process, effectiveness of traditional method of Technology Transfer to Small Enterprise was studied to assess and to evolve an effective method for the same through Design, Prototyping and Manufacturing System Management in participation with Small enterprise. The model of the tricycle rickshaw along with the manufacturing process and technology was transferred to one small enterprise. The design and technology transfer to the Small Enterprise has been successfully implemented and the Dipbahan was successfully introduced in the market. The interim feedback received by the Small Enterprise led to manipulation and modification of the design as well as technology where all ingredients essential for the successful product introduction and implementation was jointly implemented. A few attempts at product diversification and modification based on the basic design developed herein for multiple uses has also been tried out to suit other applications and to see the effect of participation of Small Enterprises and resulted in a garbage disposal van, branded as Dipbahan Pariskar. It was observed that for successful implementation of design and technology by small enterprise, Design, Prototyping and Manufacturing System Management as a part of an integrated package is essential.

Individual entrepreneurs seem to imitate a successful design to meet the demand locally. Various design and fabrication including imitation of the new tricycle rickshaw was observed after the interim Dipbahan model was launched in market and these were documented. Apart from legal issues on these developments, it should be seen that no hazards are caused in terms of creating new products without involvement of experts; this invites a practice of participation of user-manufacturer-expert system. Thus an experiment was carried out to make a school van where all the components of the above participatory model were involved. The product was successfully developed for commercial introduction.

The study mentions various achievements, scopes for further research and recommendation including precautions to be taken for uncontrolled design development in this area and suggestion for setting up monitoring group for appropriate and sustainable development.

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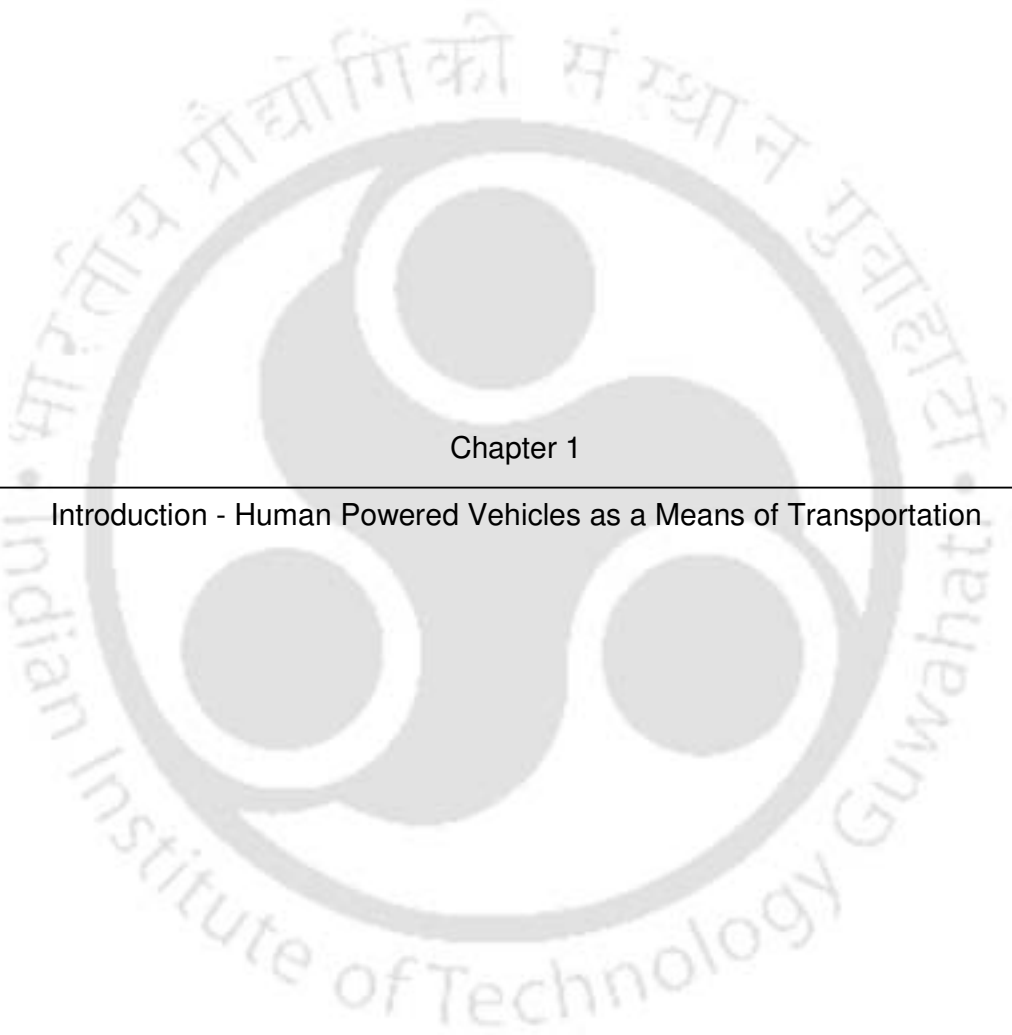
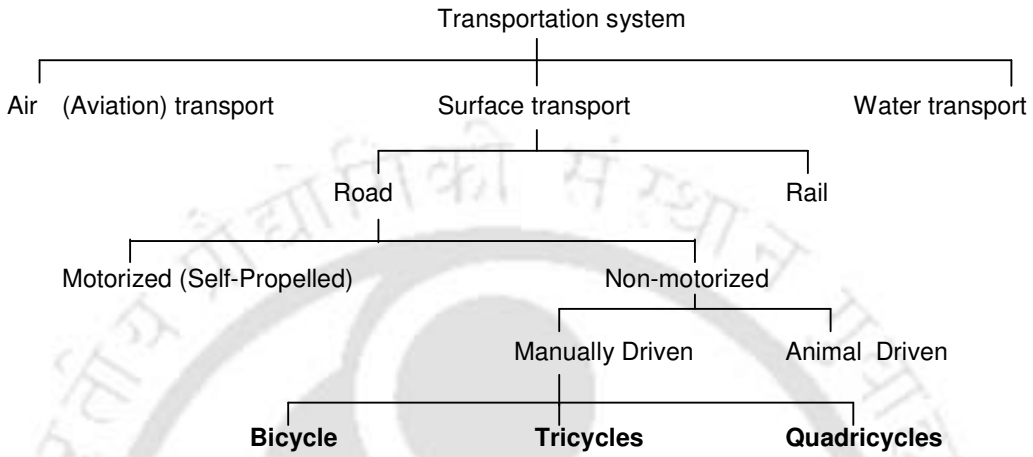


Chapter 1

Introduction - Human Powered Vehicles as a Means of Transportation

1.1 Transportation system and it's evolution

Transportation plays a very vital role in today's fast moving world. Various means of transportation can be self propelled or manually driven. Every normal human being is using either one or the other form of transportation facilities available. Transportation system can be classified as: -



In the above flow diagram, branching of surface transport is only shown up to bicycle, tricycle and quadricycle that are relevant to the area of research. At the local transportation scenario, these three types of Human Powered Vehicles (HPVs) are extensively used and satisfy various needs of self as well as for passengers, live stocks and goods. In Indian situation, even bicycle is used to transport another person to different places and hence considered here. Looking into appropriateness in design and contextual implications is the main focus of this work. Tricycle category includes a tricycle passenger rickshaw. Hand pulled rickshaw although a manually driven one is neither a bicycle nor a tricycle. However although hand pulled rickshaw has been covered in the literature survey, it is banned all over the world including its last place of use in Kolkata (p 38) in India and hence not covered. Wheel chair in India is confined to interiors in a house and not seen in public places and hence not included in the diagram.

1.2 Human Powered Vehicles as a means of transportation

The concepts of bicycle and tricycle have evolved in a contemporary period. Tricycle perhaps ensured balancing aspect that in case of a bicycle, it is to be learnt. This chapter covers a brief historic account of development of self driven bicycle and in a more stable form as a tricycle used for transportation along with various aspects of mechanical advantages and smoothness in operations. The idea of a wheeled vehicle powered by the muscular effort of man dates back to the early seventeenth century. One such vehicle on 4 wheels is credited to Herrin Garthener (Gupta and Murthy, 1980) a seventeenth century mechanic. In this vehicle the rider sat on a saddle and caused the vehicle to move by pulling an endless rope which went around and drove a pair of wheels.

1.2.1 Evolution of the bicycle

Walking Machine

The muscular power was put to practical use in a two-wheeled machine around 1820. In 1816, a Frenchman named J. N. Niepee (Gupta and Murthy, 1980) rode a machine consisting of two same-size in-line wheels, connected by a wooden beam. The rider sat on this beam and propelled this vehicle by thrusting his feet alternately on the ground. This machine was called as **Walking Machine** and was later known as **Dandy** or a **Hobby-horse**. The **Celerifere** was another similar early bicycle precursor invented in 1790 by Frenchmen, Comte Mede de Sivrac (Ballantine and Grant, 1998) without any steering. In 1818, Baron Drais von Sauerbronn (Gupta and Murthy, 1980; Ballantine and Grant, 1998) of Mannheim improved Hobby horse by adding a rest for the arms (Fig 1.1, www.pedalinghistory.com, Dec, 2006). The steerable front wheel in his bicycle was mounted on a fork. The machine became known as the **Draisienne**. Many such machines were sold to the aristocracy of that period but soon went out of fashion because these did not have any practical use except for providing some fun.

The credit of evolving a machine (Fig. 1.2, Gupta and Murthy, 1980) that could be reasonably used to some advantages for traveling goes to Kirkpatrick MacMillan (Gupta and Murthy, 1980), a Scottish blacksmith. In 1830, he fixed crank to the rear wheel of a Walking machine, which were connected by two long rods to pedals suspended from the front end of the frame. Through this modification he was able to propel his machine without touching the ground. He is now recognized as the inventor of the bicycle.

Fig. 1.1 The Walking Machine/ Draisienne or Hobby horse.

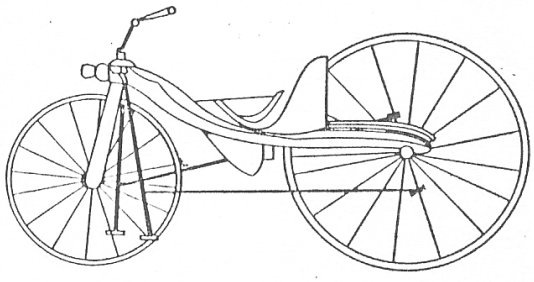


Fig. 1.2 MacMillan's bicycle

Introduction to Commercialisation

The next important development was in 1865, the introduction of the rotary crank by Lallement (Gupta and Murthy, 1980), a Frenchman. Lallement sold his idea to his employer, Michaux (Gupta and Murthy, 1980; Ballantine and Grant, 1998) who was the first to sell bicycles on a somewhat commercial scale.

References in this section are from (Gupta and Murthy, 1980), (Ballantine and Grant, 1998), www.pedalinghistory.com, Dec, 2006

His two-wheeled riding machine (Fig. 1.3, www.pedalinghistory.com, Dec, 2006) had rotary cranks fitted to a slightly larger front wheel and was pedaled like the children's tricycles of today. It had wooden wheels with iron tyres. There was also a lever shoebrake on the rear wheel. The front wheel was carried on a fork which was pivoted at the front end of the frame for steering purposes. This machine was known as **Velocipede** ("fast foot") (www.pedalinghistory.com, Dec, 2006). The Velocipede was nicknamed the **Boneshaker** (Gupta and Murthy, 1980), because its wooden wheels with iron rims gave a very rough ride over cobble-stoned roads of the day. Rubber tyres that softened the ride were introduced in 1869 (Gupta and Murthy, 1980). A later development saw the introduction of light wire-spoke construction which greatly reduced the weight of the wheels and yet maintained their strength. The flexibility of wire spokes also helped to make riding smooth (Gupta and Murthy, 1980). In 1870, the first all metal machine appeared. (Previous to this metallurgy was not advanced enough to provide metal that was strong enough to make small and light parts out of it).

Bicycle

The pedals were still attached directly to the front wheel with no free wheeling mechanism. Thus one turn of the pedal moved the vehicle only through a distance equal to the circumference of this wheel. By increasing the diameter of the front wheel and simultaneously reducing that of the rear wheel (to maintain the overall weight same), greater speeds could be obtained. Thus, the **High Wheel Bicycle** (www.pedalinghistory.com, Dec, 2006) -a two-wheeled riding machine also called as **Tall Ordinary** or **Penny Farthing** (Gupta and Murthy, 1980) came into being (Fig. 1.4, www.pedalinghistory.com, Dec, 2006). This machine was the first one to be called a **bicycle** ("two-wheels"). In later models the front wheel size kept on increasing. On some models it was 56 inches (1.42 m), on some 64 inches (1.63 m) and one bicycle even had

Fig. 1.3 The Velocipede or Boneshaker

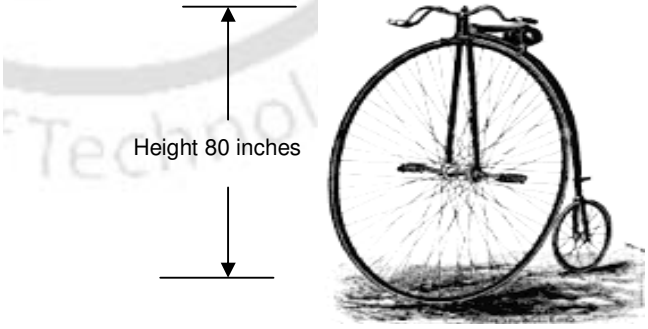


Fig. 1.4 The High Wheel bicycle or Penny Farthing

The **Tall Ordinary** suffered from the disadvantage that as the driver had to sit directly over the front wheel, the increased size of the front wheel made getting on and off hazardous. Many modifications were tried but none was successful.

Due to the risk involved with the High Wheel Bicycle, the public started shifting from bicycles to adult tricycles that was actually the **High Wheel Tricycle** (Fig. 1.5, en.wikipedia.org/wiki/tricycle, Dec, 2006) for transportation. Many mechanical innovations now associated with the automobile were originally invented for tricycles. Rack and pinion steering, the differential and band brakes are to name a few.

Safety bicycles through geared rear wheel drive

Further improvements in the design of bicycle were became visible, many with the small wheel in the front to eliminate the tipping-forward problem. These designs became known as **High-Wheel Safety bicycles** (Fig 1.6, www.pedalinghistory.com, Dec, 2006). The older high-wheel designs had been known as bicycles and started to be referred to as "ordinary bicycles" in comparison with the new-fangled designs, and then simply as "ordinaries."

Fig. 1.5 The High Wheel tricycle

Fig. 1.6 The High Wheel Safety

The next breakthrough in bicycle design took place in 1876 when Lawson of England reintroduced the rear wheel drive. He first designed a lever driven bicycle. The further improvement in metallurgy sparked the next innovation, or rather return to previous design. With metal that was now strong enough to make a fine chain and sprocket small and light enough for a human being to power, the next design was a return to the original configuration of two same-size wheels. In 1879, Lawson introduced a chain transmission rear-driven machine. Now, instead of just one wheel circumference for every pedal turn, through the gear ratios, by using a large sprocket ratio can have a speed the same as the huge high-wheel and the need for very large wheel was done away with. The rider could be seated safely at an appropriate distance from the road. He called it a **Safety Bicycle** and this concept of rear-driven chain-transmission safety machine came to stay (Fig. 1.7 p 6, www.pedalinghistory.com, Dec, 2006)

Fig. 1.7 The Hard Tyred Safety

Fig. 1.8 The Pneumatic Tyred Safety

Introduction of Tubular frame

At about this time other important changes were made in bicycle construction. Tubular frames and forks were used which reduced the weight of the bicycle. Ball bearings introduced 1877 greatly increased the efficiency of the machine. The bicycles still had the hard rubber tires, and in the absence of the long, shock-absorbing spokes, the ride they provided was much more uncomfortable than any of the high-wheel designs. Many of these bicycles had front and/or rear suspensions. These designs competed with each other, choice being the High-wheel's comfort or the Hard Tyred safety's safety, but the next innovation tolled the death of the high-wheel design.

Introduction of Pneumatic tyre and Rover safety bicycle

The air-filled (Pneumatic) tyre introduced in 1888 by J. B. Dunlop made the ride still smoother. Now that comfort and safety could be had in the same package in terms of the **Pneumatic Tyred Safety** (Fig. 1.8, www.pedalinghistory.com, Dec, 2006) and that package was getting cheaper as manufacturing methods improved, everyone clamored to ride the bicycle and it became a popular mode of locomotion. It was in 1885 that the bicycle finally acquired the form that by and large, still persists today. The **Rover safety bicycle** first used the diamond frame construction which gave it great strength with minimum weight and cost. In 1898, Yale introduced a shaft drive to dispense with the dirty chain.

Versatile features of bicycle

Ladies consigned to riding the heavy adult tricycles that were only practical for taking a turn around the park, could now ride a much more versatile machine and still keep their legs covered with long skirts. The bicycle craze killed the bustle and the corset, instituted "common-sense dressing" for women and considerably increased their mobility. In 1896 Susan B. Anthony said that "the bicycle has done more for the emancipation of women than anything else in the world." (www.pedalinghistory.com, Dec, 2006). It was a practical investment for the working man for transportation, and gave him a much greater flexibility for leisure.

Except for refinements in details and accessories, the bicycle shape and design have changed little thereafter. Recently there have been a spate of design changes (Wilson and Papadopoulos, 2004) but they do not seem to have gained much acceptance and the bicycle still remains essentially of Rover's safety type. One of the more promising of these recent developments is the Sind bicycle. It uses 16 inch (41 cm) wheels compared to the standard 22 or 24 inch (56 or 61 cm) wheels. This permits a still lower saddle position and far more safety. Also, such a bicycle is easier to lift on to a curb or stairs since one can hold it nearer to its centre of Gravity. The luggage rack is at such a level that the vertical position of centre of Gravity is maintained and hence the balance of the bicycle does not change when carrying a load.

Table-1.1, p. 8 provides an overview of chronological evolution of bicycle along with the name of inventors.

The history of evolution of bicycle illustrates that only one thing at a time was changed and after a major modification in form was initiated, a spate of small adjustments followed. Through this the designers tried to derive the maximum from that form. As an example, a number of modifications were carried through in order to obtain maximum comfort and utility from the front wheel pedal-driven bicycle. When this concept of the front wheel pedal drive bicycle could not meet the demands of safety that was threatened by too large a front wheel it was abandoned. After the above development rear wheel chain transmission machine was invented. This new concept also went through a series of changes and evolved to a near perfect form.

Table-1.1 Chronology of evolution of bicycle with period and inventors

Year	Configuration/Improvement	Inventor
1490	Concept of bicycle **-** sketched a facsimile of the modern bicycle in, which never left the drawing board	Italian artist/scientist Leonardo Da Vinci
1790	2 wheels connected by a wooden beam without steering, rider sitting on this beam propels the machine by thrusting feet on the ground.	Frenchman Comte Mede de Sivrac
1816	*Dandy* or *Hobby-horse*- Two wheels connected by a wooden beam with steering, rider sitting on this beam propels the machine by thrusting his feet on the ground.	Frenchman J. N. Niepee
1818	*Draisienne*-Added rest for arms, steerable front wheel mounted on a fork	Baron von Sauerbronn of Mannheim
1830	Fitted crank to the rear wheel connected by two treadles suspended from the front end of the frame. Machine could be propelled without touching the ground	Scottish blacksmith Kirkpatrick MacMillan - inventor of the bicycle.
1865	Rotary crank	Frenchman Lallement
1865	*Velocipede* ("fast foot") or *Boneshaker*- two-wheeled riding machine with rotary cranks fitted to a slightly larger front wheel and pedaled like the children's tricycles. It had wooden wheels with iron rims, a lever shoebrake on the rear wheel and the front wheel carried on a fork and pivoted at the front end of the frame for steering purposes	French father and son team of carriage-makers Pierre and Ernest Michaux
1869	Rubber tyre	
1870	All metal bicycle	
1871	*Penny Farthing* or *High* or *Ordinary bicycle*- the first really efficient bicycle, consisting of a small rear wheel and large front wheel pivoting on a simple tubular frame with tires of rubber.	British engineer James Starley.
1876	*Safety bicycle*- original configuration of two same-size wheels, reintroduced rear wheel drive, a lever driven bicycle, the rider seated safely at an appropriate distance from the road	England Lawson
1877	*The Rover Cycle* - a company formed to build bicycles, for people to 'rove" around the countryside.	John Starley and William Sutton
1877	*Ball bearing*	
1879	*Safety bicycle*- this concept of rear-driven chain-transmission safety machine, a chain transmission rear-driven machine incorporating gear ratios, by using a large sprocket ratio	England Lawson
1885	*The Rover safety bicycle*-diamond frame construction provides strength with minimum weight and cost, the form that still persists today	
1888	The air-filled (Pneumatic) tyre introduced	Irish veterinarian J. B. Dunlop
1898	Shaft drive to dispense with the dirty chain.	Yale
1899	Patent for a parcel carrier for bicycles	African American inventor Jerry M. Certain

1.2.2 Evolution of the tricycle

There are many commonalities between present day bicycle and tricycle even though these evolved separately. These are in terms of operation, parts they share and process of manufacture. As the name indicates, a **tricycle** (often abbreviated to **trike**) is a three-wheeled vehicle. 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 19th century. The first recorded usage of this word is in 1828, denoting a "three-wheeled horse-drawn carriage." However tricycles have evolved to include various forms of propulsion including pedals for manually powered ones and steam and internal combustion engines for mechanized powered ones, electric motors for electrical powered ones. The abbreviation trike is popularly used for denoting tricycle has been in use since 1883. In this discussion, only HPVs are covered.

The most commonly found type of tricycle at present is the child's toy pedal tricycle that existed from the development of this type of HPV. Early tricycles were mostly for adults (Fig.1.5 p. 5, Fig. 1.09 and Fig. 1.10, en.wikipedia.org/wiki/tricycle, Dec, 2006). Adult pedal tricycles can be traced back to 1868. Single seater tricycles for adults are much less common in India than bicycles.

Fig. 1.09 Antique tricycle

Fig. 1.10 19th century tricycle used in Iran

1.2.3 Classification of tricycle

Tricycles can be classified based on several criteria. Most commonly used are based on user and use a tricycle is put to and based on physical lay out of the 3 wheels in the tricycle. Importance of lay out of wheels is for stability of the tricycle and the sophistication of the tricycle depends on the user and the use it is put to.

1.2.3.1 Classification of tricycles based on the user and use

Currently available manually propelled tricycles can be classified based on user and use as:

References in this section are from http://en.wikipedia.org/wiki/Tricycle, http://en.wikipedia.org/wiki/Velomobile, http://en.wikipedia.org/wiki/Cycle_rickshaw, http://answer.com, http://www.workbike.org/research/pedalline.html etc.

1. **Kid's tricycle**- small tricycles with pedals directly turning the front wheel are often used by children who have not yet learned to balance a bicycle,
2. **Transportation tricycles -** for the passengers and goods like cycle rickshaw,
3. **Disabled persons Tricycles -** specifically for lower limb disabled,
4. **Recumbent** tricycle - for adult, and
5. **Sports tricycles** - for adult.

Tricycles for adults may be upright or recumbent. Upright tricycles are often preferred by persons with mobility problems. Recumbent tricycles are suitable for long-distance travel, including cycle touring. Recumbent and sports tricycles are not common in India.

In addition to the tricycle rickshaw, there are context specific variations of tricycles used as delivery vans with boxy storage compartments, goods carrier, school children van, vending van etc. Also many more tricycles with advanced forms currently exist.

Fig. 1.11, 1.12, 1.13, 1.14, 1.15 (en.wikipedia.org/wiki/tricycle, Dec, 2006), 1.16 (p 11, www.grup10.com, Dec,2005), 1.17 (p 11, http://answer.com, Dec, 2006) , 1.18 (p 11, www.mainstreetpedicab.com, Dec, 2006) and 1.19 (p.11, ALIMCO) are images of the tricycles meant for different uses where technology used varies from simple to sophisticated. Aerodynamic forms have evolved in terms of claddings etc. for sports.

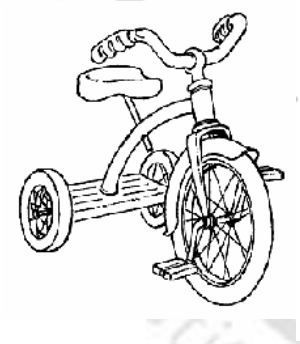


Fig. 1.11 Kid's tricycle

Fig. 1.12 Lady Trike

Fig. 1.13 Commercially Available Adult tricycle

Fig. 1.14 Modern tricycle

Fig. 1.15 Recumbent tricycle

Fig. 1.16 Velomobiles (HPV)

Fig. 1.17 Velotaxi

Fig. 1.18 Tricycle Rickshaw

Fig 1.19 Tricycle for lower limb disable

Considering the prevalence of tricycle rickshaws across India, a small development in this area would serve a large population that uses this mode of transportation. With this view, for experimentation in this research work, two categories of tricycle were considered.

1. Disabled person's tricycle
2. Tricycle — Passenger Rickshaw
   School children van
   Garbage disposal
   Delivery van etc.

In the first category, tricycles for disabled persons, specifically for lower limb disabled and in the second category, tricycles rickshaw for common passengers and retaining basic features of cycle rickshaw its variations to serve many different purposes were considered.

1.2.3.2 Classification of tricycles based on the layout of the wheels.

Normal tricycle generally consists of either of the two layouts:

Delta (Fig. 1.20, www.ice.hpv.co.uk, Dec, 2006), with two wheels at the back and one steered wheel at the front; Out of the two rear wheels, one or both may be driven.

Tadpole (Fig. 1.21, www.ice.hpv.co.uk, Dec, 2006), with one wheel at the back, usually driven and two wheels at the front that are steered.

Fig. 1.20 Delta Recumbent tricycle

Fig. 1.21 Tadpole Recumbent tricycle

All trikes do not fall into one of these two classes. For example, some early pedal tricycles used two wheels in tandem on one side and a larger driving wheel on the other. It is common for tricycles to have front and rear wheels of different sizes.

Upright trikes are usually deltas, although the Newton tadpole upright conversion is well regarded. In the United Kingdom, upright tricycles are sometimes referred to as "barrows". Many trike enthusiasts ("trikies") in the UK belong to the Tricycle Association, formed in the 1929. They engage in its day rides, tours and time trials. Massed start racing of upright tricycles is limited to one or two criteria such as in Bungay, Suffolk each year.

The tadpole trike while gaining popularity, is still mainly used by middle-aged former bicyclists who are tired of developing back pains and associated pains from normal wedgies (a term used in many recumbent forums denoting upright bicycles). Many trikes are homebuilt as trikes are still fairly expensive due to the use of high quality components and small order numbers. Most good adult trikes cost at least $US2000 so homebuilders can manufacturer their own frames and buy or use cheap 26" wheels instead of the expensive 20" wheels on commercial trikes.

In India, there is no manufacturer for single seater trike for adult. In abroad there are several of them. George Longstaff, Higgins and Pashley Cycles in the UK are manufacturer of upright trikes. Hase (producer of the largest-selling delta, the Kettwiesel), Inspired Cycle Engineering (producer of the Trice delta), AVD (builds the Burrows Windcheetah or Speedy) are manufacturer of recumbent trike. Australia's Greenspeed and Stein, a recent entrant from Eastern Europe also manufacture recumbent trike.

Fig. 1.22 Semi-open cargo trike Fig. 1.23 Closed cargo trike Fig. 1.24 Pick-up trike

Some tricycles are designed for load carrying (Fig. 1.22, Fig. 1.23 and 1.24, www.cyclemaximus.com, Dec, 2006). Others are designed for racing or for comfort. Velomobiles are (Fig. 1.16, p. 11) recumbent tricycles fully enclosed for all weather use and aerodynamic benefits. Tandem trikes are also made by companies like Greenspeed. They allow two people to ride in a recumbent position back to back with an extra-strong backbone frame to hold the extra weight (Fig. 1.25, http://en.wikipedia.org/wiki/Tricycle, Dec, 2006). Hand-crank trikes are also made by companies like Greenspeed and they allow arms to operate a crank, either as a sole source of power or a double drive with footpower.

Most cycle rickshaws (Fig 1.18, p. 11), used for carrying passengers for hire, are tricycles. The rickshaws 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 and on a limited basis in other places.

Fig. 1.25 Trice X2R back-to-back - A Special purpose recumbent tricycle

1.3 Localized transportation: Status of HPV

1.3.1 Present practice

The localized issues of meeting transportation needs of vast masses of population that can not afford a personal vehicle and that many lanes and streets are narrower to accommodate cars and buses, not to mention the fact that all roads, lanes and streets can not be connected directly with public transportation systems needs consideration for alternative viable means that are contextual. There is always a need for a feeder system

for the mass transportation systems. Human powered tricycle rickshaw fulfills this need. Whereas bicycles are mostly self ridden and used by individuals for meeting their own commutation needs; tricycle rickshaws are used as hired vehicles and a puller rides this and carries passengers for a fare. In addition to this, there are variations based on tricycles used as delivery vans with boxy storage compartments, goods carrier and school children van to name a few that are put to use to fulfill the localized transportation need.

The current practice for meeting the localized transportation needs of the population is varied and is dependant on the region, cultural, economic capabilities, geographical locations and local administration. In the Indian context, this need is served by bicycle, manually operated rickshaws and tricycle vans in one side and by the auto rickshaw (Motorized three wheeler), shared taxi operated by using 3 wheeler auto rickshaw, its bigger versions as well as four wheeler multi utility vehicles. Thus various automobile manufacturing companies from India as well as overseas are catering to this demand. Vehicle should carry limited number of people, consume less energy and cost within the limit of the common people. If an attractive, aesthetically good looking manually driven utility tricycle can be developed, a large number of populations even living on bare minimum resources would be benefited. It would also generate employment to a large number of unemployed youth as rickshaw pullers.

In addition to this, persons who can afford a two wheeler meet his commutation need by owning one. Member in the higher echelons in the society meets his requirement by owning a car. However to meet local transportation needs for transporting various goods tricycle based vehicles are extensively used. In many cases hand cart with 2 wheels pulled by a person are still used extensively in semi-urban and rural areas and are the only means of meeting local transportation needs including transporting sick patients to nearest medical facilities. There are also various advantages associated with the tricycle based human powered vehicles (Rajvanshi, 2002). These are:

- Non-polluting mode of transportation (air pollution, noise pollution etc.) during operation and also generates less pollution during manufacture compared to motorized mode of transport.
- Cost effective with increasing fuel prices for short distances.
- Provides for income generation for the vast unemployed youths of the country.
- Lower cost of capital for each vehicle and each employment generated.
- Due to low weight, Load on road infrastructure is less.
- Serves a large populations as pullers and passengers.

1.3.2 Associated shortcomings of current fuel driven local transportation system

a) Environmental concerns and powered vehicles

Transportation sector is the second largest contributor of atmospheric pollution. (http://www.greenspeed.us/electricbicycle.htm, Dec, 2006; http://oceanworld.tamu.edu/ resources/oceanographic-book/atmosphere.html, Dec, 2006; http:/www.veoliaenviron ment .com, Dec, 2007). Thus it is one of the greatest concerns to reduce this pollution. Energy sources used for propulsion of various modes of surface transport like automobiles are mostly petroleum products (Petrol, Diesel) and causes pollution due to combustion of these fuels. These fuels are also non-renewable. Electric vehicles run by charging the battery pack through electricity too pollutes if the fossil fuel (petroleum or coal) is used to generate electricity except transferring the pollution from the place of use of the vehicle to the place of generation of electricity. If electricity generated is hydro-electric, solar powered, wind powered or nuclear fuel based used for charging the batteries, electric vehicles are zero pollution emitting vehicles in case of green house gases. Pure electric vehicle itself is still not feasible for long range application, since charging of the battery pack takes time and to store energy for long range, the battery pack becomes very heavy and becomes inefficient and purpose self defeating. Thus present research and development is based on the strategy of using hybrid vehicles having electric propulsion for city use and petroleum fuel based internal combustion engine for charging these battery on highway in addition to propelling the vehicle. In a hybrid vehicle, first electricity is generated and then this electricity is used to run the electric motors as well as charging the battery pack. Cost of these vehicles is still out of reach of common people.

Fuel cells are still far away as a commercially viable proposition.

Electric vehicle based on harnessing solar energy using photovoltaic cell is still not viable in areas with low sunshine and on cloudy and rainy days when sunshine is not available.

Increase in Pollution from transportation sector in developing countries can be attributed to the following causes:

1. Increase in population leading to increase in need for transportation, commutation. This leads to increase in vehicular traffic and if road network is not enhanced proportionally which is difficult, free flow of traffic is obstructed and it results in traffic congestion and increased pollution.
2. With extension and expansion of cities and towns, the citizens are forced to travel from one place to another place, which is much far away from each other due to location of residence, place of work and various services. This increased travel requirement contributes to added vehicular traffic and resultant pollution.
3. Inefficient and unreliable public transport system leads to inconvenience for the passengers and this in turn forces the public to purchase personal means of

commutation affordable by them, whether it is a two wheeler or a car. Thus existing public transportation system itself is indirectly contributing to the increase in pollution.

4. Manufacturing Process of vehicles- present mode of transport like automobiles are manufactured using excess materials if considered for short distance and limited distance travel including in campus commuting. e.g. Maruti – M 800 car, smallest 'A' class car when used for single passenger commuting uses minimum 8 times the weight of the passenger in terms of weight of the car.

Thus most of the energy spent is in moving this mass rather than the person. If we use alternative modes like tricycle, the weight of the vehicle can be even less than the body weight of the person commuting.

b) Possible solution being tried out at present

With increase in numbers of vehicles and resultant increase in air pollution, present strategy adopted is an effort to reduce pollution through reduction in quantum of pollutant from the Internal Combustion (IC) engine by improving its efficiency. This has resulted in reduction of pollution to some extent, but there is a limit to which this can be achieved. Unless there is major invention, not much can be achieved any further.

Second approach is use of cleaner fuel like LPG, CNG etc. Even these fuels too generate carbon di-oxide.

Recent trend is for fuel cell. Present technology is yet to achieve economically viable breakthrough compared to internal combustion engine in terms of weight, distance range and speed achievable.

Purely electric vehicle too is restricted by its range and speed as mentioned earlier.

Hence hybrid vehicles are being tried. But again the source of energy remains the same i.e. Petroleum products in majority of cases.

1.3.3 Human Powered Vehicle (HPV): a relevant product

For short distance travel by self and a small group comprising 2-3 persons, the best strategy for containing the vehicular pollution may be through HPV (Human Powered Vehicles) (Ballantine and Grant, 1998). Tricycle/Trike/Rickshaws are not given due importance because of people's perception about these mode of transport as slow moving, low grade, low-tech, unsafe product and associated status of rickshaw as a mode of transport used by poor people (www.johost.eu, Sept, 2007). In comparison to motorized vehicle development, not much research in this field has been carried out to improve these modes of transportation, and always it is seen as transportation using human power is inhuman and ill fit in modern age. This mind set leads to a tendency on part of the population in growing cities of developing countries to disband these vehicles from cities and urban areas attributing the increased vehicular pollution in these areas to these vehicles due to slow moving nature and for creating traffic snarl. Although HPVs

can never be substitute for present day automobiles for long distance travel, it is a very good mode of local transport within residential localities & complexes and in case of short distance from main road served by other public transport such as bus, local train or metro routes. The practice still exists, a facelift in the product design to provide a new aesthetic look and to it make more efficient is a need of the day.

Society and contemporary design acceptance through aesthetic look.

To conclude, to change the situation, there is a need to design a tricycle rickshaw to change the people's perception as well as initiate philosophical change in society's attitude. *Whereas the designing of a rickshaw is a much easier task, changing a society's philosophical attitude is a much difficult and time consuming process and may need legal restrictions like banning of automobiles at city square and encourage HPV etc. Not only to design, challenge is also faced to transfer this through a comparatively established manufacturing process and facility prevailing in a society.*

1.4 Tricycle rickshaw design and technology transfer- a reference case study

Virtually no literature is available about the process of design of a three-wheeled tricycle rickshaw except the visuals of different types of tricycle rickshaw developed from time to time by different developers, organizations and institutions except for recumbent type of tricycle for single rider. There are instances of tricycle rickshaw design in India and abroad as well as design of tricycle for disabled persons. The two case studies may be cited as example for successful design and implementation and are presented below.

A: Tricycle rickshaw to carry passengers

The Institute for Transportation and Development Policy (ITDP) is one of the few organizations all over the world associated with the tricycle rickshaw development, specifically in the developing world. Their mission and activities are given as an excerpt from their website. "The Institute for Transportation and Development Policy (ITDP) was founded in 1985 in United States of America to promote environmentally sustainable and equitable transportation policies and projects worldwide. ITDP was created by leading sustainable transport advocates in the U.S. to counteract promotion of the U.S. model of costly and environmentally damaging dependence on the private automobile in developing countries." (www.itdp.com, Dec, 2006)

ITDP's programs include bus rapid transit, congestion pricing, pedestrianization, bicycle and pedestrian planning, brownfield revitalization, bicycle and cycle rickshaw modernization, the development of buyers' cooperatives among independent bicycle dealers and emerging work in health service delivery logistics. ITDP has also developed various models of tricycles to meet its objectives. Tricycles designed under their projects are shown in Fig. 1.26-1.28 (p. 19, www.itdp.com, Dec, 2006).

Following a decade of successful policy reform efforts, ITDP is now focused on helping local civic bodies and non-governmental organisations (NGOs) to implement projects to demonstrate reduction in transport emissions and accidents and improvement of the basic mobility of the poor. Working on projects simultaneously builds local knowledge and skills while generating public awareness of viable sustainable transport solutions.

ITDP prioritizes its involvement in projects based on the level of demonstrated local commitment to successful implementation, the availability of financial resources, and the potential benefits of the project, including the degree to which the project will demonstrate solutions to others. ITDP is currently most active in Indonesia, India, South Africa, Senegal, Ghana, Brazil, Mexico, China and Tanzania.

ITDP's projects are use to leverage additional resources from international development institutions, inspire these institutions to change their own priorities, encourage private sector participation, and encourage participatory and transparent decision-making.

Improving Cycle Rickshaw Technology: Indian experience

ITDP's Indian Cycle Rickshaw Modernization Project, implemented in close association with Asian Institute of Transport Development (AITD) and initially funded by US Agency for International Development (USAID) was provided design and technical support from Indian Institute of Technology Delhi (IITD). This project unlike many transport sector interventions aimed only at improving the environment, cleans the air and increases employment and income among the poor, while keeping the cost of the vehicle nearly constant. Close cooperation with the Indian bicycle industry, tourism industry, and marketing and public relations experts have been critical to the project's success. By 2005, over 100,000 modern cycle rickshaws (Fig. 1.26 and 1.27, p 19) have been manufactured by over 20 small businesses and sold in seven Indian cities: Delhi, Agra, Bharatpur, Brindavan, Mathura, Jaipur and Chandigarh.

ITDP's modern rickshaw design (Fig. 1.26 and 1.27, p 19) reduced the weight of the vehicles by more than 30%, from 80kgs in the traditional vehicle to 55kg. The integral tubular frame has excellent structural qualities and a multi gear system makes pedaling much easier. Surveys with operators demonstrated that incomes increased by 20% to 50% because they were able to work longer, attract new passengers, and because customer satisfaction rose along with better comfort and safety.

The project received extensive print and television media coverage that reached over 10 million Indians. Today, Indians view the cycle rickshaw as a viable and modern indigenous technology. The Chief Minister of Delhi, Sheila Dikshit, inaugurated the new vehicle fleet in Delhi. The project demonstrated that this human powered vehicle could attract 19% of its ridership from highly polluting 2 stroke-engine 3-wheeler vehicles, making the project's greenhouse gas emission reduction impact quantifiable.

References in this section are from http://www.itdp.com and www.independentliving.org, the web sites of The Institute for Transportation and Development Policy and Independent Living Institute respectively

Fig. 1.26 ITDP designed passenger rickshaw in India

Fig. 1.27 ITDP designed school bus rickshaw in India

Fig. 1.28 ITDP designed Becak in Indonesia

Indonesian extension (http://www.itdp.com and www.independentliving.org)

Based on successes in India, ITDP is replicating the project in Yogyakarta, Indonesia in partnership with the Centre for Tourism Research and Development, Gadjah Mada University, and Lembaga Pengembangan Inisiatif Strategis untuk Transformasi (LPIST, Institute for Propagation of Strategic Initiatives for Transformation). Air pollution in Indonesia's capital city exceeds international standards by four times, and is projected to increase by 60% or more in the next decade. As congestion worsens, average vehicle speed is slowing to 5km per hour. Jakarta's public transport system is steadily losing passengers because old and dirty buses are caught in traffic jams, while walking and cycling are increasingly difficult as sidewalks are scarce, badly designed and frequently obstructed.

ITDP is working to reverse these trends by building political support and local capacity for Bus Rapid Transit, non-motorized transport and traffic demand management projects. In Jakarta, ITDP is working closely with Pelangi, a local NGO.

Design shift- passenger unit at rear vs at front and delta vs tadpole

Although the traditional becak – a tricycle rickshaw found in Indonesia shares many characteristics with the Indian rickshaw, cultural differences required the project team to design the new becak from scratch, rather than modifying the Indian design. The biggest difference is that while the Indian rickshaw passenger sits behind the driver (a delta configuration of wheels), in Indonesia the driver is seated behind the passenger bench (a tadpole configuration of wheels). The traditional becak is reported to be much more comfortable than a traditional Indian cycle rickshaw, but it is also much heavier, around 100kg and very hard to steer.

The design team developed six different prototypes for use in Indonesia. One prototype was selected for successful commercialization. The German development corporation Gesellschaft fur Technische Zusammenarbeit (GTZ) Gmbh provided funding for the manufacture of prototype becaks. A fleet of 20 of this vehicle were produced, and leased to becak drivers all over Yogyakarta for market testing (Fig. 1.28). Based on feedback from these drivers, further modifications were made to the vehicle design.

B: Tricycle for Physically challenged users

The second case is for design development of a tricycle for disable person. The manual titled "Tricycle Production Manual" written by I. Oldenkamp (Oldenkamp, Boeijen, Flier , Toetenel, Vermeulen and Verweij, 1995) of Industrial Design Engineering, Delft University of Technology is available for a tricycle designed primarily for disabled people in Asia and is the result of a joint effort between four Asian organizations. Other co-writers of the manual are Annemiek van Boeijen, Paul Flier, Oscar Toetenel, Ruud Vermeulen, Joep Verweij. The Manual was part of the project Development of Tricycle Production in Developing Countries (DTP-project) undertaken during the period October 1992 - May 1995.

The project was financed by the Swedish International Development Agency (SIDA) through the Swedish Organization of Handicapped International Aid Foundation (SHIA), The supporting organizations of the project are: the Swedish Association of Persons disabled by Accidents or by Polio (RTP) and the Swedish Federation of Disabled Persons (DHR). Center for International Cooperation and Appropriate Technology (CICAT) at the Delft University of Technology (DUT) in the Netherlands initiated and coordinated the project. The project has been carried out by the Faculty of Industrial Design Engineering (FIDE) in close cooperation with the following mobility aids producing organizations in abroad, specifically in the target countries, e.g.:

1. Workshop for Rehabilitation and Training of the Handicapped (WORTH) in India;
2. Sarvodaya Economic Enterprise Development Services (SEEDS) in Sri Lanka;
3. McKean Rehabilitation Center (MRC) in Thailand and
4. Bavi Orthopedic Workshop (BOW) in Vietnam.

During a period of two years, a project-engineer, the manager (or designer) of the tricycle workshop and two technicians from each organization worked for the DTP-project. They collected information, carried out user tests, designed parts or completely new tricycles, built prototypes and optimized the tricycle production. They participated in the seminars and workshops held respectively in Thailand, the Netherlands, India and Sri Lanka and also participated in a design training in Thailand organized by CICAT/FIDE in cooperation with the Chiang Mai University (Chiang Mai, Thailand).

The tricycle design can also be used for disabled people in other comparable parts of the world by their producers. Most of the tricycles designed are suitable for disabled people with lower limb disabilities, i.e. who cannot walk but can use both arms. These users may have lost their mobility, due to polio or by an accident and have a leg amputation or are paralyzed. Using the hand driven tricycle they have the possibility and the mobility to travel independently. The targeted population being from South East Asia, the measurements (seat, footrest adjustment and propulsion mechanism) of this design are based on sitting anthropometric data common in this part of the world, i.e. persons with a body-length of 1.50 meter up to 1.75 meter (roughly to cover population between

5 –95 percentile). The measurements should be checked and, if necessary, adjusted for any users who do not fit into this group.

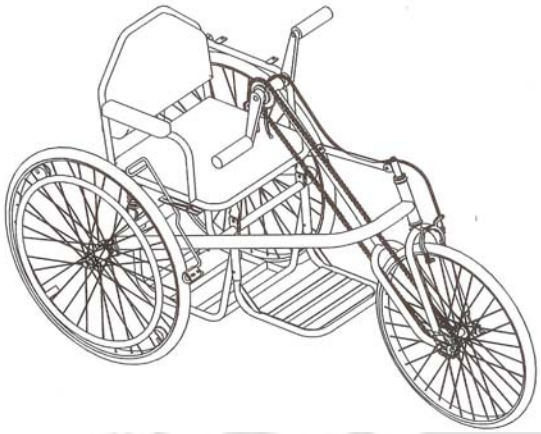


Fig. 1.29 Tricycle for physically challenged users

In spite of having many different tricycles in the world, this particular tricycle design for individual availability was done to overcome the shortcomings of those existing ones (Fig. 1.29). Some existing tricycles have problems with stability while others are not comfortable or are difficult to produce. In the new tricycle design, requirements concerning production, distribution and use have been taken into account as much as possible.

The designers had identified the following as most important requirement for the design of such tricycle.

Stability

The stability of the tricycle is very important for the safety of the user. This can be achieved by making the wheelbase wide enough and the center of gravity as low as possible but limited by the space needed for the legs of the user.

Driving comfort

The correct position of the propulsion handles is necessary for easy and comfortable driving. The propulsion mechanism has been made adjustable to accommodate the different arm lengths of users. The gear-ratio of the freewheels is 1:1. This ratio is selected to provide comfortable driving under average road conditions. In hilly places the freewheel of the front wheel should be larger than the freewheel at the propulsion handles.

Weight

Many existing tricycles are very heavy (more than 40 kg) which makes them difficult to drive. Due to the asymmetrical construction of this tricycle design, the weight is relatively low; around 30 kg.

Sitting comfort

The sitting comfort is another important issue, especially for disabled people who have to sit for long periods of time while self driving the vehicle. If the pressure on the buttocks is too high (due to a bad surface or a footrest which is too high) the blood circulation will be bad. For a comfortable seat the following dimensions are important: seat-depth, seat-width, seat height, back rest height, armrest-height, and footrest height and length. The footrest is adjustable to the individual user. Cushions are important to avoid pressure sores on the driver's buttocks and springs will absorb shocks during driving.

Production and maintenance

The tricycle can be produced with basic tools and locally available materials and is easy to repair. The measurement tolerances are made as large as possible to avail local skills of production and avoid assembly problems. Jigs and fixtures are not included in this manual. General designs cannot be given since they very much depend on locally available materials. Nevertheless the use of jigs and fixtures is strongly recommended.

Costs

Costs depend highly on local circumstances; material costs, labor costs, number of tricycles in the series, etc. They are intended, however, to be kept as low as possible.

The Tricycle Production Manual has been developed for basically skilled and equipped workshops in developing countries. The manual is, as much as possible, adjusted to the knowledge and experience of workshop workers in these countries. It contains mostly drawings and minimal text to keep the manual accessible to a large group of users.

The first part gives relevant information on tricycle design. The second part is a step-by-step guide to the production of the tricycle. The tricycle production is explained by means of three dimensional drawings and additionally supported by two-dimensional drawings. Measurements are limited to those which are strictly necessary for the drawings to be easily understood. Pictograms are used to indicate the production steps and actions. The structure and lay-out of the manual is clear and practical. The third part gives some ideas about additional features for the tricycle. The fourth part contains extra useful information and alternatives for production. The fifth and last part contains some relevant background information.

1.5 Motivation for the present study

The above two case studies express the need for context specific design development and there are scopes for development to suit the specific need of local people and place. This led to the present design development that suits localised short distance transportation of various needs and production and maintenance by local expertise followed by a participatory approach.

Hypothesis

If an efficient, aesthetically pleasing with a new look, cost effective, user friendly tricycle rickshaw is designed and made available, people would like it and if the manufacturing technology is made easy for transfer to local manufacturer would spread its use. It would generate local employment. Various need based modification can also be developed.

1.6 Aim and Objectives

The present study is aimed at Design Development of an indigenous Tricycle Rickshaw, its Prototyping and Manufacturing System Management for Small Enterprise for its production.

1.6.1 Objectives

The specific objectives are to:

i. Study the limitations of existing design being used at present and manufacturing technology of traditional tricycle rickshaw in Indian context.
ii. Study localized transportation using Human Powered Vehicles (HPV) for preservation of the ecology and as a means of sustainable development in the context of a developing country and its appropriateness.
iii. Design development of a tricycle rickshaw using appropriate technology for its manufacture.
iv. Design development of the tricycle for multiple use such as School van, delivery van, garbage disposal van etc.
v. To observe the design and technology transfer feasibility to the targeted beneficiary i.e. local Small enterprise with and without participation of the Small enterprise in design development process.

1.7 Methodology followed

In tune with the above objectives, design development of a tricycle rickshaw for passengers in the Indian context (Nadkarni, 1995) covered in detail in Chapter 3, under section 3.5 in pp 78-79 was considered along with its prototyping and manufacturing system management. The focus was on small enterprise, in many cases tiny enterprise for its manufacturing. The area of work was considered as a part of system design approach to Transportation design;

Environment friendly manually propelled tricycle•

Two themes were chosen:

A : Trike for single user–modifiable for lower limb disable person

B : Tricycle rickshaw for multiple use

- Passenger version
- School van
- Garbage disposal van
- Delivery van
- Vending cart etc.

The basis of research considers:

- A **tricycle** (often abbreviated to **trike**) - a three-wheeled vehicle specifically for lower limb disabled person and for passengers (rickshaw). In addition to the above, keeping the basic frame similar, extension of the same to be used as delivery vans, goods carrier, school children van etc. in Indian context.

- **Product design**:

The following steps are commonly followed:

1. Need identification/ creation and conceptualization to satisfy the context specific requirement of the period of time and prediction regarding scope of the need for near future.
2. Prototyping
   - mock up model to assist visualization, form study, ergonomics etc.;
   - functional prototypes- alpha model, beta model to assess functionality and target users trial for feedback for design refinement.
3. Production and
4. Marketing.

The research methodology followed is “Research by Design” also commonly called as Design Research as the main emphasis. In this approach, the experimental component of the research itself is carried out through solving an existing design problem. Main area of research is design development of an indigenous tricycle rickshaw where design, prototyping and manufacturing system management of a tricycle rickshaw was covered.

1.7.1 Design research

Design means "to invent and bring into being" (Webster's Dictionary and Thesaurus, 1992). Design deals with creating something new that does not exist in nature. The design of artifacts is an activity carried out for centuries by mankind. This activity also distinguishes the professions from the sciences. "Schools of architecture, business, education, law, and medicine, are all centrally concerned with the process of design" (Simon, 1996).

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.

Design research process involves the analysis of the use and performance of designed artifacts to understand, explain and to improve on the behavior aspects of artifacts.

Research has been defined as an activity that contributes to the understanding of a phenomenon (Kuhn,1996; Lakatos,1978). In design research, all or part of the phenomenon may be *created* as opposed to naturally occurring. The phenomenon is typically a set of behaviors of some entity(ies) that by the researcher or by a group - a research community finds interesting. In most western research communities

Understanding is knowledge that allows prediction of the behavior of some aspect of the phenomenon. Research methods or techniques are the set of activities a research community considers appropriate to the production of understanding (knowledge). Paradigmatic research communities have been observed to have nearly universal agreement on the phenomenon of interest and the research methods for investigating it. Pre-paradigmatic or multi-paradigmatic research communities are bound into a nominal community by overlap in sets of phenomena of interest and/or overlap in methods of investigation. Industrial design is an excellent example of a multi-paradigmatic community.

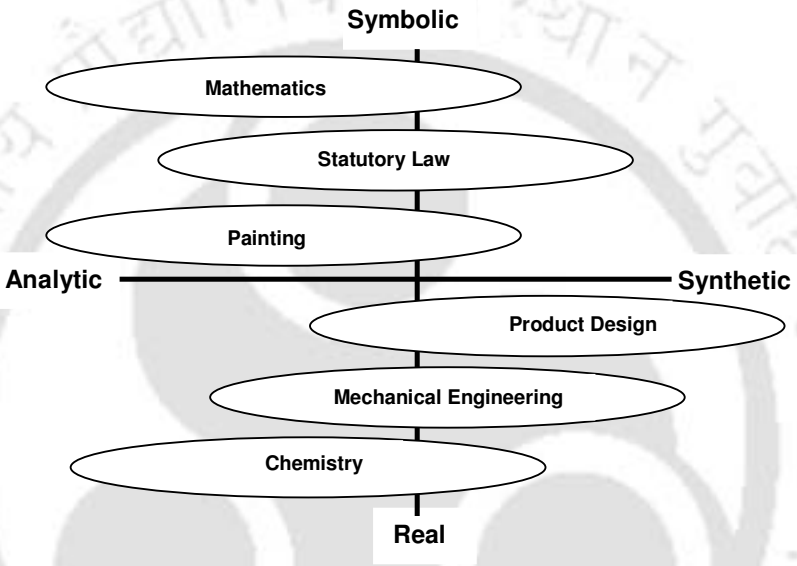


Fig. 1.30 A Conceptual Map of Disciplines

The relation of design to research can be discussed with reference to a conceptual map of disciplines (Figure 1.30) with two axes: Symbolic/Real and Analytic/Synthetic (Owen 1997). Disciplines are located on the map with respect to horizontal axis according to their defining activities: disciplines located on the left side of the map are more concerned with exploration and *discovery* and on the right side of the map are characterized more by invention and *making*. The map is divided vertically by the symbolic/real axis and characterizes the nature of the subjects of interest to the various disciplines and the nature of the phenomena that concerns the research community. Both axes being continuous, no discipline is exclusively concerned with synthesis to the exclusion of analytic activities. Similarly, no activity is exclusively concerned with the real to the exclusion of the symbolic. However the strong contrast along this axis between the physical science of chemistry that is more real and the abstract discipline of mathematics that is symbolic is strongly and accurately indicated in the diagram.

Design disciplines or the design components of multi-paradigmatic disciplines lie predominantly on the synthetic side of the map. Design disciplines from the ancient times

have a history of building their knowledge base through making – the construction of artifacts and evaluation of its performance after its construction. Example that can be cited is 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 disciple that provides a more recent example. Its knowledge base was built almost exclusively by analyzing the results of intuitively guided designs – experimentation at essentially full scale starting from the Montigolfer balloon onwards made during the period of 1st world war.

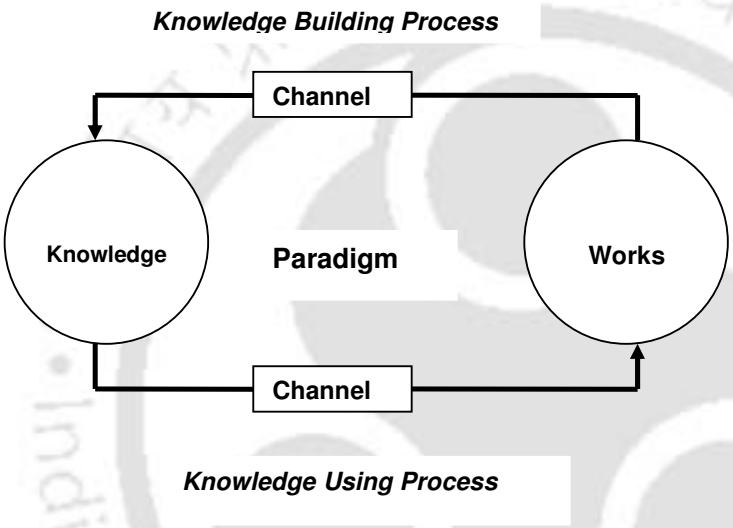


Fig. 1.31 A General Model for Generating and Accumulating Knowledge

A general model for generating and accumulating knowledge (Fig 1.31) presented by Owen is helpful in understanding design disciplines 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). 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 systems of conventions and rules under which the discipline operates. Channels embody the measures and values that have been empirically developed as ways of knowing as the discipline has matured. They may borrow from or emulate various aspects of channels from other disciplines. However they are special to the discipline and are products of its evolution.

The reasoning that occurs in the course of a general design cycle illustrated in Fig. 1.32, p 27 have been analysed by Takeda and others (Takeda, Veerkamp, Tomiyama, and Yoshikawam, 1990). This diagram has been interpreted as an elaboration of the *Knowledge Using Process* arrow in Fig. 1.32, p 27. The types of new knowledge that

arise from design activities and the reason that this knowledge is most readily found during a design effort is apparent from the flow of creative effort through this diagram.

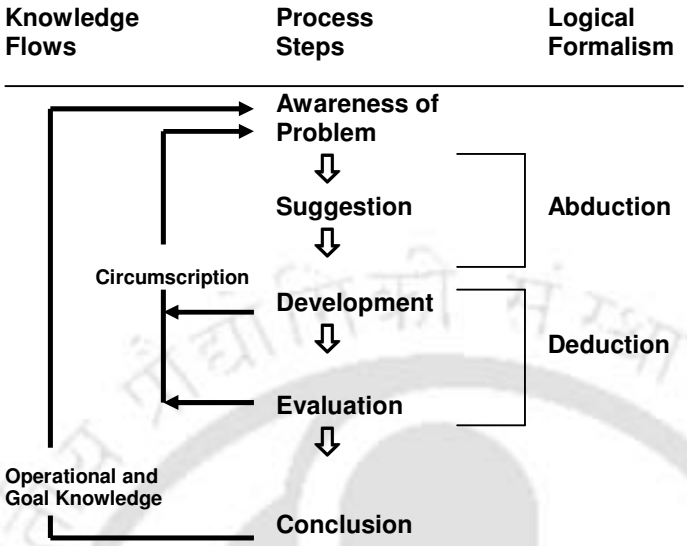


Fig. 1.32 Reasoning in the Design Cycle

* An operational principle can be defined as “any technique or frame of reference about a class of artifacts or its characteristics that facilitates creation, manipulation and modification of artifactual forms” (Dasgupta, 1996; Purao, 2002)

All design begins with *Awareness of a problem* in this model. Design research is also sometimes called as Improvement Research to emphasize the problem-solving/performance-improving nature of the activity. As shown in this model, s*uggestions* for a problem solution are abductively drawn from the existing knowledge/theory base for the problem area (Pierce, 1931). The next step performed is an attempt at implementing an artifact according to the suggested solution. In the diagram of the model, this stage is shown as Development. In the next step, partially or fully successful implementations are then evaluated. Evaluation is based on the functional specification implicit or explicit in the suggestion. In the course of the research (design) effort, *Development*, *Evaluation* and further *Suggestion* are frequently iteratively performed. The Circumscription arrow indicates the basis of the iteration, the flow from partial completion of the cycle back to Awareness of the Problem. Termination of a specific design project is indicated by Conclusion.

In the Fig. 1.32, the arrows labeled *Circumscription* and *Operation and Goal Knowledge* indicate new knowledge production. The *Circumscription* process is especially important in understanding design research. It generates *understanding that could only be gained from the specific act of construction*. Circumscription is a formal logical method (McCarthy, 1980) that assumes that every fragment of knowledge is valid only in certain situations. The applicability of knowledge can only be determined through the detection and analysis of contradictions. The design researcher *learns or discovers* when things

don't work according to theory. This happens many times due to the necessarily incomplete nature of any knowledge base rather than a misunderstanding of the theory. The design process contributes valuable constraint knowledge to the understanding of the always-incomplete-theories that abductively motivated the original design when interrupted and forced back to Awareness of Problem.

1.7.2 Outputs of design research

There is lack of consensus as to the precise objective – and therefore the desired outputs - of design research within design research communities. A broad perspective that explicates the types and levels of knowledge that *can* be derived from design research is presented.

Four general outputs for design research in contrast to natural science research (March and Smith 1995) are: constructs, models, methods, and instantiations.

Constructs are the conceptual vocabulary of a problem/solution domain and arise during the conceptualization of the problem and are refined throughout the design cycle. A working design (artifact) consists of a large number of entities and their relationships and hence the construct set for a design research experiment may be larger than the equivalent set for a descriptive (empirical) experiment.

A model is a set of propositions or statements expressing relationships among constructs and models are identified with problem and solution statements. Models are proposals for how things are and these differ from natural science theories primarily in intent. Design research focuses more on (situated) utility against a traditional focus on truth that natural science has. A model is presented in terms of what it does and a theory described in terms of construct relationships. A theory can always be extrapolated to what can be done with the implicit knowledge and a set of entities and proposed relationships can always be expressed as a theoretical statement of how or why the output occurs.

A *method* is a set of steps used to perform a task. Methods are goal directed plans for manipulating constructs so that the solution statement model is realized. In a design research method, the problem and solution statement expressed in the construct vocabulary is implicit. A method may well be the object of the research program in design research in contrast to natural science research. A more effective way of accomplishing an end result, sometimes a familiar or previously achieved end result – is valued since the axiology of design research stresses problem solving.

The final output from a design research effort is an *instantiation* which operationalises constructs, models and methods. It is the realisation of the artifact in an environment. An instantiation sometimes precedes a complete articulation of the conceptual vocabulary and the models (or theories) that it embodies due to the proactive nature of design research. This can be further emphasized by referring to the aeronautical engineering example given earlier. Aircraft flew decades before a full understanding of

how such flight was accomplished was available. As evident, it is unlikely the understanding would ever have occurred in the absence of the aircraft, a working artifact.

A list of design research outputs has been set forth by other authors (Rossi and Sein ,2003;Purao,2000). Except the fifth output mentioned as better theories, all other outputs can be mapped directly to March and Smith's list. This output, better theories is highly significant and merits inclusion in general list of design research outputs. Design research can contribute to better theories (or theory building) in at least two distinct ways, both of which may be interpreted as analogous to experimental scientific investigation in the natural science sense.

First, Methodological construction of an artifact is an object of theorizing for many communities (e.g. how to build more maintainable software) and therefore the construction phase of a design research effort can be an experimental proof of method or an experimental exploration of method or both.

Second, the artifact can expose relationships between its elements. It is tautological to say that an artifact functions as it does because the relationships between its elements enable certain behaviors and constrain others. However if the relationships between artifact (or system) elements are less than fully understood and if the relationship is made more visible than previously during either the construction or evaluation phase of the artifact, then the understanding of the elements has been increased, potentially falsifying or elaborating on previously theorized relationships. Theoretical relationships enter the design effort during the abductive reasoning phase of Fig. 1.32, p 27.

For some types of research, artifact construction is highly valued precisely for its contribution to theory. Human-Computer Interface (HCI) researchers state that "HCI artifacts themselves are perhaps the most effective medium for theory development in HCI" (Carroll and Kellogg, 1989). Table 1.2 summarizes the outputs that can be obtained from a design research effort.

	Output	**Description**
1	Constructs	The conceptual vocabulary of a domain
2	Models	A set of propositions or statements expressing relationships between constructs
3	Methods	A set of steps used to perform a task- how-to knowledge
4	Instantiations	A operationalisation of constructs, models and methods.
5	Better theories	Artifact construction as analogous to experimental natural science.

Table 1.2 Output of Design Research

A general Design Research Methodology as a variant of one shown in Fig. 1.32 (p 27) is widely used for Design Research by substituting the Logical Formalism column with a column labeled Output, Fig. 1.33 (p 30). This is logical and inevitable result of the fact that in Design Research *knowing* (Fig. 1.32, p 27) is *making* (Fig. 1.33, p 30) as evident from the discussion above.

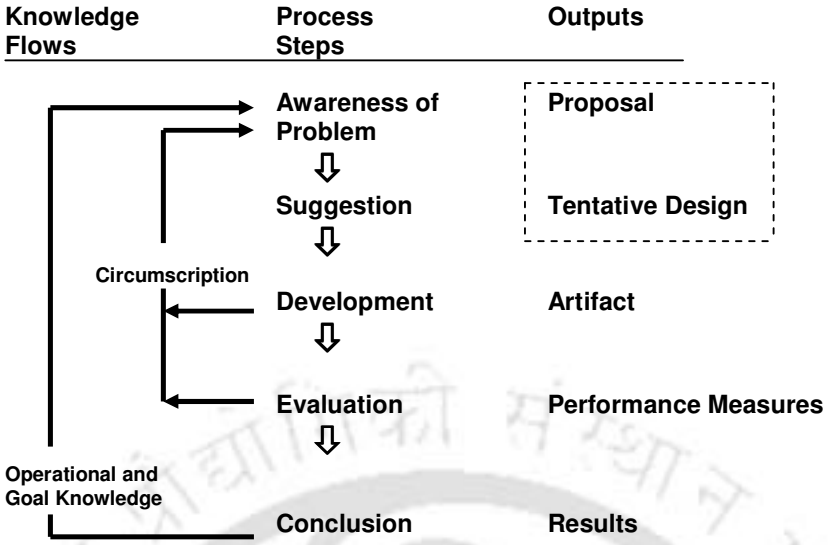


Fig. 1.33 General Methodology of Design Research

1.7.3 Research project process time

Research Project process time was planned as under:

Months

For Pilot project: Design and development of a Trike

1 Literature and Product survey on trike and tricycle for disable users, Data collection from field.

2-3 Primitive need validation based on Data collected and its analysis including interactions with users. Design problem formulation.

4 Design Conceptualisation-Preliminary Design and Detail Design

5 Prototyping for able bodied person, field trials and feed back and evaluation.

For main research project: Design and development of a Tricycle rickshaw for passenger

6 Literature and Product survey on tricycle rickshaw and its different versions, Data collection from field.

7 Primitive need validation based on Data collected and its analysis including interactions with users. Design problem formulation for a tricycle rickshaw.

8 Design Conceptualisation-Preliminary Design and Detail Design

9. Prototyping, Field trials and feed back.

10-11 Redesign based on feed back.

12 Transfer of Design and Technology to NGO, Centre for Rural Development through actual product transfer, training etc.

13 Commercial Introduction in the market.

14-16 Design development of the next version of the Dipbahan.

17-18 Transfer of Design and Technology to SMEs, Timsteel Innovatives and National Associates through product transfer, design development of jigs and fixtures, specialty machines and equipment design, process planning and training etc.

Followed by a literature survey of the tricycle rickshaw, the need of undertaking a new design development work was justified. The actual design of a tricycle rickshaw for passengers – a Human Powered Vehicle (HPV) in the Indian context was considered. The design strategy adopted was Human Centered Product design. This process places the human at the centre and focuses on various cognitive factors as they come into play during his interaction with things. Human Centered Product Design seeks to answer questions about users and their tasks and goals and then use the findings to initiate development and design. A product design methodology is to be practically demonstrated to the target manufacturer, in this case Small and Medium Enterprises (SMEs) in North Eastern Region of India. Design methodology to be adopted for this purpose should be simple to understand even by a layman while transferring design and technology and thus helps in subsequent design process by the target manufacturer in a conventional way. Product design methodology model formulated by Morris Asimow (Asimow, 1962) was found to meet this requirement and was used for design iteration (Chitale and Gupta, 1999) and discussed in Chapter 3 under section 3.5.1, pp 83-85.

The newly designed tricycle rickshaw branded as Dipbahan was prototyped and its manufacturing system management was evolved through participation of small enterprise. Design methodology and technological processes were demonstrated to the manufacturers (Small Enterprises) located in Guwahati. As a part of the research process, effectiveness of traditional method of Technology Transfer to Small Enterprise was studied to assess and to evolve an effective method for the same through Design, Prototyping and Manufacturing System Management in participation with Small enterprise.

The topic of the research not being fully quantitative, it was necessary to apply qualitative research methodology. Thus subjective responses mixed with direct observation formed the basis for results obtained in this research study. Emerging digital process such CAD/CAM and Rapid Prototyping and Tooling were studied for their applicability, advantages and limitations were taken into considerations in the context of area of research. For recent trend in design and technology transfer, various emerging technologies were studied that are being put to limited production or has a potential to be used for limited production and can be demonstrative in design and technology transfer (Balakrishan T, 1985; Bhatia, 2000; Kunnumkal and Sant 2001-2002; Johnson, Gostelow and Jones, 1999).

The model along with the manufacturing process and technology was transferred to one small enterprise, Centre for Rural Development, Guwahati, an Non Governmental Organisation. The interim feedback received from the Small Enterprise led to manipulation and modification of the design as well as technology where all the ingredients essential for the successful product introduction and implementation was jointly implemented. The entire process is presented below in total eight chapters.

It was observed that for successful implementation of design and technology by small enterprise, Design, Prototyping and Manufacturing System Management as a part of a integrated package is essential.

The research work also has its limitations. The thesis is based on specific context and hypothesis. The research outcome will be applicable only in those contexts. Findings may not be universally applicable. Research was carried out with participatory approach with NGO and SMEs that did not have their own design capability. If there is in house capability exists, outcome may be different.

Objective being a subject of employment generation and readily used product, a potentially vast market exists to cater to the need and advantage of non-existing competition for the new design in Indian context, specific to North Eastern Region.

1.8 Organization of the thesis

The Thesis has been divided into 08 (Eight) chapters.

In the first chapter titled **Introduction: Human Powered Vehicles as a Means of Transportation (pp 1 - 33)**, transportation system and its evolution specifically Bicycles and Human Powered Vehicles as a means of transportation is discussed followed by the discussion about localized transportation need- present practice and associated shortcomings. Attempt is made to understand the subject of the Need of Tricycle rickshaw design and technology transfer. Aim and Objectives of the doctoral research is included in this chapter along with organization of the thesis.

The second chapter titled **Tricycle Rickshaw Development: Issues and Contextual Relevance (pp 34 - 58)**, contains discussions regarding appropriateness of tricycle rickshaw as a means of localized transportation followed by evolution of rickshaw and tricycle rickshaw. These two are fundamentally different, rickshaw is actually hand pulled with 2 wheels and tricycle rickshaw is with 3 wheels foot pedaling ones but currently rickshaw is extensively used to denote a tricycle rickshaw. The chapter covers status and associated factors relevant to contemporary design development of tricycle rickshaw in both global and local situation.

The third chapter titled **A Conceptual Design of a New Tricycle Rickshaw (pp 59-110)**, presents earlier experience and trials from a single seater trike (a tricycle for single person) which was designed and developed for able bodied person and is modifiable for lower limb disabled persons as a pilot experiment prior to working on tricycle rickshaw for passengers. This was found to be useful and trial's outcome led to acceptance of some of the salient features for the tricycle rickshaw. This chapter also contains the product brief for actual design of a new tricycle rickshaw based on basic human needs, taking into consideration various design requirement and constraints, feasibility study carried out for new tricycle design and preliminary design concepts.

The forth chapter titled **Detailed Design of a New Passenger Tricycle Rickshaw: Dipbahan (pp 111-143)**, describes the detailed design process for the selected concept of the newly designed tricycle rickshaw branded as Dipbahan.

The fifth chapter titled **Prototyping and Testing of Dipbahan (pp 144-174)**, contains prototyping process of the newly designed tricycle rickshaw Dipbahan, its field testing, analysis of the test results and resultant design up-gradation.

The sixth chapter titled **Technology Transfer: State of the Art from the Point of View of Design Development Awareness and Context (pp 173-198)**, where economic development in India and role of design is discussed. Attempt is made to understand the Need of Design and Technology transfer, Definition of Rural Technology, other factors in transfer of technology and Models of technology transfer available.

The seventh chapter titled **Participatory Approach in Dipbahan^{+} Development and Transfer of Technology to Small Enterprise (pp 199-230)**, deals with the actual planning for production, distribution and extending the newly designed tricycle rickshaw based on it's modularity to facilitate design and fabrication of multiple versions such as School van, Garbage disposal van, Delivery van and Vending cart etc. through industry's participation. Actual design and technology transfer takes place in this phase. In the first phase, design and technology was transferred to an NGO, Centre for Rural Development, Guwahati by transferring the newly designed tricycle rickshaw to them to manufacture without much interaction with the designer. In the second phase two other Small enterprises were associated in the design and technology development starting from the planning of the production process in all details to planning for distribution etc. One Small enterprise M/s National Associates, Guwahati devoted only to manufacture of composite components and the other M/s Tim Steel Innovatives, Guwahati taking up the metal fabrication, assembly and marketing. This phase also included design of promotional materials for the tricycle rickshaw and various other activities including branding to support the introduction of the new tricycle rickshaw in a successful way. Documentation of various design and fabrication process including copying of this tricycle rickshaw by some local entrepreneurs is part of this chapter.

The last chapter titled **Conclusion: Achievements, Recommendations and Scopes for Further Work (pp 231-245)**, describes the achievements of the design developed here which is plying in many roads of North Eastern region of India as well as in mainland India, scopes for further research and recommendation including precautions to be taken for uncontrolled design copying and development in this area and suggestions for setting up monitoring group for appropriate and sustainable development.

DESIGN DEVELOPMENT OF AN INDIGENOUS TRICYCLE RICKSHAW

Chapter 2

Tricycle Rickshaw Development: Issues and Contextual Relevance

2.1 Tricycle rickshaw as a means of localized transportation

The localized issues of meeting transportation needs of vast masses of population that can not afford a personal vehicle and also due to the fact that many lanes and streets are narrower to accommodate cars and buses, not to mention the fact that all roads, lanes and streets can not be connected directly with public transportation systems and there is always a need for a feeder system for the mass transportation systems. Tricycle rickshaw can fulfill this need. In addition to this, there are tricycles used as delivery vans with boxy storage compartments, goods carrier, school children van etc. This mode of transport evolved more than a century and three decades ago and the whole evolution is an interesting one. As normally thought of rickshaw and tricycle rickshaw are two fundamentally different products; rickshaw is actually hand pulled with 2 wheels and tricycle rickshaw is with 3 wheels foot pedaling ones. But currently rickshaw is extensively used to denote a tricycle rickshaw.

2.1.1 Evolution of rickshaw

The term jinrikisha is Japanese and was first used in Japan in1874. It derives from ”Jin” meaning man plus “riki” meaning power plus ”sha” meaning vehicle, which literally means “human-powered vehicle”. This term was shortened colloquially to rickshaw (Fig. 2.1, p 36, www.shanghairickshaw.com, Dec, 2006) in 1887. There are several conflicting theories about the invention of the rickshaw. One theory in the “Encyclopedia Americana’ stated that it was invented by an American Baptist missionary in Yokohama, Japan, Jonathan Scobie, who wanted a convenient mode of transport for his invalid wife. However, the Japanese are also credited with the idea as outlined in “Japan, Described and Illustrated” edited by Captain F. Brinkley in 1897 (Brinkley, 1897), which say “a paralytic old gentleman of Kyoto finding his palanquin uncomfortable, built for himself a little cart which was the prototype of the present vehicle”. Other sources say that the design of the rickshaw was probably based on the old French brouette which was a sedan chair converted into a man–pulled vehicle by the addition of springs and two wheels attached to a low axle. The brouette was popular for a short time as a hired vehicle in the 18th century, and flourished in France but not in England.

It is now known that, despite many theories regarding the invention of the rickshaw, it had been developed in Japan by about 1868. The following year Yosuke Izumi, Tokujiro Suzuki and Kosuke Takayama began a trial manufacture of rickshaws in 1869 (year 2 of the Meiji era) and in 1870 gained approval from the Municipality of Tokyo to go into production.Their rickshaws were initially used in the Nihonbashi area of central Tokyo. The immediate popularity of the rickshaw was considerable. By the end of 1871 it was stated that 15,000 (Fig. 2.2, p 36, www.answers.com/rickshaw, Dec, 2006) hand pulled rickshaws were licensed in Tokyo alone and by the following year this number had increased to 40,000.

(References in this section are from http://en.wikipedia.org/wiki/Cycle_rickshaw,Dec, 2006)

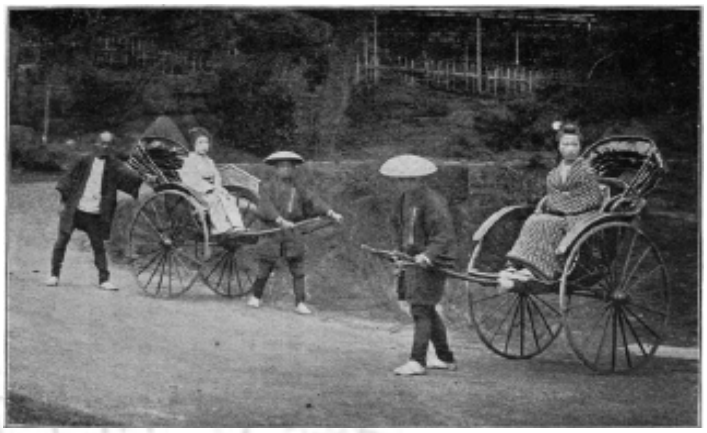


Fig. 2.1 A sample of Japanese Rickshaw in museum Fig. 2.2 Rickshaw plying in Japan

The government decided to grant no further license because they were ruining the trade of the boatmen on the canals. In spite of the boatmen's conflicting interests, the number of the rickshaws multiplied throughout the 1870s and the invention spread. It became the chief form of public transport in Japan. As one British diplomat's wife remarked "rickshaws corresponded to omnibuses in London".

After its invention in Japan by 1870, it created a huge impact throughout the East as a convenient, mobile and speedy form of personal transport which predated the development of the motor car and bus. Few horses were used in Japan specially in the army and occasionally in agriculture, and most of these rickshaws were hand pulled by human being, since human labour was cheaper than animal power.

The peak use of the rickshaw was reached in 1896 when 210,000 vehicles were recorded as being used daily in Japan. It was exported overseas from 1873, mainly to China and South East Asia and was specially popular in Shanghai and it was also locally manufactured. During the ensuing years the rickshaw gradually made its way south to Hong Kong, Singapore, Colombo (now Sri Lanka) and Mumbai (erstwhile Bombay).

As new methods of transportation were developed in Japan including railways, buses, automobile and river steamers, the demand for rickshaws gradually declined in the twentieth century. By 1938 there were only 13,000 in use although they had a brief revival after the end of World War II when there was an acute shortage of other means of transport. However, they now virtually disappeared as a form of public transport.

Around 1880 rickshaws appeared in India, first in Shimla and then, 20 years later, in Kolkota (Fig. 2.3, p. 37, www.shanghairickshaw.com, www.answers.com/rickshaw; Dec, 2006) which were in use till recent past. Here they were initially used by Chinese traders to transport goods; in 1914 they applied for permission to use them to transport passengers. Soon after, rickshaws appeared in many big cities in Southeast Asia (Fig. 2.4, p. 37 as used in Shanghai, http://www.shanghairickshaw.com, Dec, 2006); pulling a rickshaw was often the first job for peasants migrating to these cities.

Fig. 2.3 Rickshaw in Kolkata (Calcutta), 2004

Fig. 2.4 Rickshaw in Shanghai

Description of earlier rickshaw: Japanese rickshaws from the year 1897.

The details of the rickshaw described here are based on a typical hand pulled rickshaw displayed in a Japanese Museum (Fig. 2.5, http://www.shanghairickshaw.com, Dec, 2006). This rickshaw was purchased for the collection over a century ago when the rickshaw was approaching the height of its popularity in Japan. It is believed to have been manufactured in Japan in about 1880 although some replacement parts were probably added at a later date. As with many cultural items which were once in common use, very few rickshaws remain and the this example is considered to be relatively rare.

Dimension of rickshaws during 1880-92
Height: 135.0 cm,
Width : 90.0 cm,
Depth: 215.0 cm

(Obtained from Object number: H626, Museum rickshaw in Japan,)

Fig. 2.5 A typical Japanese Rickshaw

The rickshaw is a light, two wheeled cart consisting of a doorless, chairlike body, mounted on springs with a collapsible hood and two shafts. The chairback and sides are of black lacquerware over timber, as are the shafts. On the lower edges of the seating compartment is a riveted steel panel to give greater support. The wheels have 18 spokes, are tyred in steel and have timber hub with brass hub band. A steel axle joins both wheels and fully elliptical leaf springs (with three leaves in each spring) are bolted to the axle and side panel of the seat. Above the bracket to hold the spring is a crescent-shaped piece of decorative brasswork attached to the side of the chair. This depicts an angel with outstretched wings. The mudguards are also covered in black lacqurware with a simple linear decoration. The seat squab, arm rest and topside of the seat cushion are

upholstered in black, deep-cushioned leather and the seat and the underside of the cushion are covered in a blue and white striped cotton fabric. Underneath the seat there is a storage compartment. The floor of the chair is lined with an early type of black coloured linoleum with a slightly upraised decoration, the center of which is a drain hole with a brass surround. The hood consist of a frame of four bamboo strips with steel fitting and bollards over which an oilskin cover is stretched. The material was impregnated with linseed oil to repeal water and pigment for colour. The black hood is edged with 10mm cotton braid while the two shafts are covered in black lacquerware and brass trim.

2.1.2 Tricycle rickshaw in global situation

Earlier rickshaws were a mode of human-powered transport: a runner draws a two-wheeled cart which seats one or two persons. Hand-pulled Rickshaws were mainly used in Asia, but these are outlawed in many places and have been replaced by cycle rickshaws and fuel engine driven auto rickshaws. The term “rickshaw” is today commonly used for these vehicles as well. The last sizeable fleet of true hand pulled rickshaws can be found in Kolkota, India, where the rickshaw driver union resisted prohibition.

There are no clear details about the evolution of tricycle rickshaw. It evident from the evolution of bicycle and tricycle, that these evolved more or less independently and were contemporary in evolution, hand pulled rickshaw too evolved more or less in the same period i.e. 1860s. Question remains, whether a hand pulled rickshaw body was added to a tricycle or a bicycle front end was added to a hand pulled rickshaw with due modification (Wheeler, 1998). There are records of animal driven tricycle carriages used in France. In many cases a tricycle called asTrishaw in Malaysia, Mandalay and Singapore are clearly derived out of a bicycle with the addition of a side car. This definitely had not evolved out of original hand pulled rickshaw. Whatever be the evolution of the tricycle rickshaw, the purpose of their use is universally same, transporting passengers for a fare.

2.1.2.1 Tricycle rickshaw in South East Asia

A cycle rickshaw is also known as **trishaw**, from (tricycle rickshaw) is a human-powered vehicle (HPV) for hire. It has usually one or two seats for carrying passengers in addition to the driver. The vehicle is powered by the driver pedaling same way as that of a bicycle. As an improvement, there are versions having an electric motor assisting the driver. These vehicles are usually a tricycle in delta configuration, however some quadricycles exist in the category of HPV, and some bicycles with trailers are configured as rickshaws. In the most common versions of tricycle rickshaws, the driver typically pedals in front of the passenger seat, (Fig. 1.18, p11; Fig. 1.26, p19) but in Indonesia, these vehicles are of tadpole configuration, the driver seats in the rear (Fig.1.28, p19).

Tricycle rickshaws were used widely all over South East Asia including Japan and China.

These have largely replaced less efficient hand-pulled rickshaws. Cycle rickshaws are known by various different names in different regions. Below is a list -

In Bangladesh and India, it is known as ***Cycle rickshaw***, Fig. 2.6 (www.answer.com, Dec, 2006) and Fig. 2.7(Das A K);

In Cambodia and Vietnam, it is known as ***Cyclo*** (pronounced see-clo), Fig. 2.8 (www.answer.com, Dec, 2006);

In Indonesia, it is known as ***Becak*** ("bay chak"), Fig. 2.9 (en.wikipedia.org/wiki/tricycle, Dec, 2006) and Fig. 2.10 (en.wikipedia.org/wiki/tricycle, Dec, 2006);

In Malaysia, Singapore and Myanmar, it is known as ***Trishaw,*** Fig. 2.11 (http://minyos.its.rmit.edu.au), Fig. 2.12 (p 40, http://minyos.its.rmit.edu.au), Fig. 2.13 (p 40, www.answer.com, Dec, 2006) and Fig. 2. 16 (p 40, http://thewonderingeye.co.uk, Dec, 2006);

In Myanmar, it is also known as ***Saiker*** (from side car), Fig. 2.14 (p 40, www.yangonow.com, Dec, 2006 and Fig. 2.15 (p 40, www.yangonow.com);

In the Philippines, it is known as ***Tricycle;*** and

In Thailand, it is known as ***Samlor*** (lit. "three wheels"), Fig. 2.17 (p 40, http://frangipani.com/huahin/samlor.htm, Dec, 2006) and Fig. 2.18 (p 40 http://frangipani.com/huahin/samlor.htm, Dec, 2006).

Fig. 2.6 Rickshaws in Dhaka, Bangladesh

Fig. 2.7 Rickshaw in Agartala, India

Fig. 2.8 Cyclo in Ho Chi Minh City, Vietnam

Fig. 2.9 Becak of Indonesia

Fig. 2.10 The Becak from Medan, Indonesia

Fig. 2.11 Malaysian Trishaw

Fig. 2.12 Malaysian Trishaw (tadpole)

Fig. 2.13 Trishaws in Singapore

Fig. 2.14 Saiker in Yangon, Myanmar

Fig. 2.15 New style Saiker to seat two persons

Fig. 2.16 Trishaw in Mandalay

Fig. 2.17 Samlor of Thailand

Fig. 2.18 Samlor Puang Kang of Thailand

Comparisons of different tricycles from South East Asia shows that -

In Cambodia and Vietnam, the cyclo is a tricycle with passengers' seat at the front over the axle connecting the two wheels and rickshaw puller pedal from behind.

In India and Bangladesh, cycle rickshaw has the puller pedaling at the front and the passengers seat at the rear facing front.

In Thailand, samlor has two versions. One is almost similar to rickshaw available in India and the other is a bicycle with an attached side car.

In Malaysia, trishaw in use is of three varieties. In one variation, it is like an Indian rickshaw and in another version, it is same as a cyclo in Combodia and Vietnam and the third variation is a bicycle with a side car.

In Singapore and Mandalay, trishaw is a bicycle with an attached side car.

In Yangon, Myanmar, a Saikar is a bicycle with an attached side car.

In Indonesia, becak is same as cyclo, a tricycle with passengers' seat at the front over the axle connecting the two wheels and rickshaw puller pedal from behind.

In The Philippines, it is known as tricycle.

In addition to the transporting passenger in the above tricycle rickshaws, these are also used for transporting goods and vending various items. In many cases, these are specifically modified to suit the use.

In China, hands pulled rickshaws were banned after the Communist takeover in 1949. However Chinese manufacturers are making every type of cycle rickshaw available anywhere in the world to cater to all types of clients abroad and within the country. However, technologically these are not as sophisticated as the rickshaws manufactured in the west. But Chinese made rickshaws are comparatively of lower cost.

2.1.2.2 Co-existence of hand pulled rickshaw and tricycle rickshaw in India

As mentioned earlier in subsection 2.1.1 p 35, hand pulled rickshaws are in use in Kolkata from 1880 and then on still continue in Kolkata even after its prohibition by the government (Fig. 2.3, p 37). A runner draws a two-wheeled cart with a capacity to seat two persons. The rickshaw driver union resisted prohibition unless the rickshaw pullers are provided with alternative avocation to sustain their family.

Tricycle rickshaw has evolved over the decades in India and has got a form in delta configuration, is more or less similar all over the country. Old generation of rickshaw had foldable canopy made of cane and bamboo. The passengers are protected from sun and rain but the puller is exposed to the elements of nature. The main frame has been used to make many utility variations to suit various local needs from time to time.

2.1.2.3 Tricycle rickshaw and its derivatives and their use

Other use of Tricycle, if considered as variations of rickshaw exists in different forms. These are closed box type tricycle van various items including bakery products, fast moving consumer goods (Fig. 2.19 & 2.20, Das A K), open bed tricycle delivery van used for LPG cylinders (Fig. 2.21, Das A K), school children carrying van (Fig. 2.22, Das A K), passenger carrying van (Fig. 2.23, Das A K), garbage disposal van (Fig. 2.24, Das A K), vending cart (Fig. 2.25, Das A K) etc.

Fig. 2.19 Closed box type delivery van Delta configuration

Fig. 2.20 Closed box type delivery van Tadpole configuration

Fig. 2.21 Open bed delivery van

Fig. 2.22 Tricycle school van

Fig. 2.23 Tricycle passenger van

Fig. 2.24 Tricycle garbage disposal van

Fig. 2.25 Tricycle based vending cart

2.1.3 Advantages of tricycle rickshaw in present context

Various advantages of tricycle rickshaw are already mentioned briefly in 1st Chapter under sub-heading 1.3, p 13. Although these can never be substitute for present day automobiles for long distance travel, it can be a very good mode of local transport within residential localities & complexes and in case of short distance travel from main road served by other public transport such as bus, local train or metro routes. This works out better because these are non-polluting (air and noise pollution) during operation and also generates less pollution during manufacture compared to motorized mode of transport. Because of low weight the load on the road infrastructure is also lower. It also creates self employment for many people specifically lower strata of the society.

2.1.3.1 Economic issues: Employment Generation and Contribution to Economy

Many studies found operating a tricycle rickshaw commercially as a viable economic activity in a developing country like India (Rajvanshi, 2002). Tricycle rickshaw, used as a mode of localised transport, can contribute to income generation and employment for huge uneducated unemployed youths, wellbeing of their families and to the country's economic development itself.

The other aspect is that with growing population, there is still growing need for local transportation. If this need is entirely met through motorised vehicles, there will be additional import requirement of petroleum products. With soaring petroleum prices globally, this means additional outflow of foreign exchanges. This weakens the economic conditions of the country. Motorised vehicles require better road infrastructure and hence additional investment and its maintenance. Also for short distance travel, motorised vehicle may not be economically viable. Thus tricycle rickshaw used as a means of transportation contributes significantly to the economy of a country.

2.1.3.2 Social issues: Exploding population and employment generation

India has the distinction of having second largest population in the world. Most of the developed countries are witnessing negative growth of population. Against this scenario all developing countries including India still has a growing population rate increasing above 10 % per annum (http://www.censusindia.gov.in, Dec, 2006). Exploding population growth results in unemployment problem. Thus whereas in a developed country, the trend is for designing equipments and systems for reducing human workforce due to high labour cost, in a developing country, it is not always practicable. Social issue like unemployment needs immediate attention.

Many recent internal disturbances in the country such as insurgency, secessionist attitude of the young generation have been attributed to unemployment problem in the country by the economists and sociologists. Employment generation through heavy industrialization is a very capital intensive activity and questions raised is what is the employment generated for every million invested in an industry (Ranade, 2005). However this issue can be tackled through service activities like tricycle rickshaw for

localized transportation. It was found from market inquiry that here capital required per employment generation is low, in a range of Rs. 6,500.00 – 15,000.00 based on the version, whether it is for 2 passengers or for school children. Cost of the tricycle along with license fee constitutes the capital cost involved for employment generation. To make rickshaw pulling a socially acceptable avocation, it is essential that tricycle rickshaw is made better in areas that it lags behind (Wheeler, 1998) and provide for supportive services for the would be rickshaw pullers. If this can be achieved, employment generation is one of the strongest advantages that a tricycle rickshaw provides.

2.1.3.3 Ecological issues

There is global concern regarding various environmental and ecological issues such as global warming etc. Coupled with this, there are larger issues at global level of reducing pollution due to ever increasing consumption of hydrocarbon fuels by modern means of transportation systems at personal level. Energy sources used for propulsion of various modes of surface transport like automobiles are mostly petroleum products (Petrol, Diesel) and causes pollution due to combustion of these fuels. Transportation sector is the second largest contributor of atmospheric pollution (http://www.greenspeed.us/electricbicycle.htm, Dec, 2006; http://oceanworld.tamu.edu/resources/oceanographic-book/atmosphere.html, Dec, 2006; http:/www.veoliaenvironment .com, Dec, 2007). Thus it is one of the greatest concerns to reduce this pollution.

The best strategy for containing the vehicular pollution is through HPV (Human Powered Vehicles) (Ballantine and Grant, 1998) like tricycle/Trike/Rickshaws as a mode of transport for passengers and goods. The revival of this mode of transportation has been taking place gradually in the western countries, where it is recognized as the best mode of transportation and separate dedicated lanes for bicycles and tricycles are provided in most of the cities and towns. Also traffic signal system is installed to facilitate this mode of transport. If the same priorities are given in India too, this can contribute to reduced environmental pollution and cleaner ecology.

2.1.4 Status of tricycle rickshaw in the developed and developing countries

2.1.4.1 Rickshaw in developed countries

Cycle rickshaws are popularly known as **pedicab** (Pedal operated taxi Fig. 2.26, p 45, en.wikipedia.org/wiki/tricycle, Dec, 2006), **velotaxi** (cycle taxi, Fig. 1.17, p 11), and are also used in many European and North American cities (Fig. 2.27, p 45, en.wikipedia.org/wiki/tricycle, Dec, 2006). These are most often found near tourist attractions. There are several American and European manufacturers of cycle rickshaws. Cycle rickshaws made by these manufacturers often incorporate features not found in developing-world vehicles. These include hydraulic disc brakes, multiple gears to facilitate climbing inclined passages and lightweight fibreglass bodies (Fig. 1.17, p 11). To provide Internet connectivity in remote areas without electricity connectivity,

experimental rickshaws have been fitted with solar powered Internet terminals. Also unlike in the developing countries, tricycle rickshaws are purely used for designated work and each and every variety is specifically developed for that use (Fig. 1.22 Semi-open cargo trike, p 13; Fig. 1.23 Closed cargo trike, p 13; Fig. 1.24 Pick-up trike, p 13 and Fig. 2.28 Custom Flatbed, www.cyclemaximus.com, Dec, 2006).

Passenger pedicabs are used purely for passenger transportation mostly used for sight seeing and passenger hauls in short distance and does not have requirement of transporting additional luggage as in the case in the developing countries. Another kind of tricycles are Ad-Cycles (Fig. 2.29, www.pedicabs.net/Edinburgh, Dec, 2006), created as a unique and eye-catching form of outdoor advertising. The message of the advertiser is quite literally driven to the target audience and advertising campaign is much more direct more cost effective.

Fig. 2.26 Pedicab, a tadpole tricycle

Fig. 2.27 Rickshaw in New York City, a delta tricycle

Fig. 2.28 Custom Flatbed

Fig. 2.29 Ad-cycle in Edinburgh

Fig. 2.30 Rickshaw of Uppsala

The pullers of these pedicabs are also having full dignity and in many cases well educated and also acts as tour guide. Students also ply these on part time basis to earn their income to support their studies. There are also instances, where rickshaws from developing countries are imported and operated by the westerners in western cities. E.g. rickshaw shown in Fig. 2.30 in Uppsala in Sweden (Photograph by the author's friend Jina kohl) was imported from Asia.

2.1.4.2 Asian and developing countries

Rickshaws are not given due importance in developing countries because of common perception about these mode of transport as slow, low grade, low-tech product (Wheeler, 1998). Not much research has been carried out to improve these and the tendency of the people in growing cities is to disband these. This is the normal views held by common bureaucracy in many parts of India, where rickshaws are being banned slowly in busy city areas, in spite of motor vehicles being allowed in these places all over the country. Also pretext of banning these vehicles are *slow moving vehicles not allowed* and *no entry posts* are erected. If violated, local traffic police seize these rickshaws. Even issue of fresh licenses for new rickshaws are banned and numbers of fresh license issued is the number that fails to renew against old license. This issue is also discussed by ITDP in their website under various projects.

Rickshaws have been banned in Pakistan for quite some time, and they are often prohibited in congested areas of major cities (http://list.jca.apc.org/public/sustran-discuss, Dec, 2006). In Jakarta they are not permitted on major roads, but are still used to provide transportation within individual urban neighborhoods.

While they have been criticized for causing congestion (http://www.sustrans. org.uk, Dec, 2006), rickshaws are also often hailed as environmentally-friendly, inexpensive modes of transportation. In many Asian cities where they are widely used, rickshaw driving provides essential employment for poor men and recent immigrants from rural areas (Wheeler, 1998).

Rickshaws are so important in the lives of Asians that many movies were based on Rickshaw. A list of successful movies based on rickshaw and rickshaw pullers' life is given below. Vietnamese director Tran Anh Hung made a movie in 1995 named "*Cyclo"*, centered on a cycle rickshaw driver.

In India a Telugu movie titled "Orey Rickshaw" was made in 1990, where the tone of the story sympathises with the downtrodden. (Orey literally means "Hey", though in a derogatory tone)

Another Telegu movie "Rickshavodu" (Rickshaw Guy) had filmstar Chiranjeevi in the lead roles.

In a Bollywood movie titled "*Main Hoon Na",* produced in 2004*,* with Shahrukh Khan in the lead role, Cycle Rickshaw was dramatized in a climactic ending with Shahrukh Khan racing down hill against a sport utility vehicle manned by 6 terrorist fully armed.

In Assam, a film titled *"Aami Asomiya"* highlighted the fact that earning a livelyhood by running a tricycle rickshaw 'Dipbahan' designed and developed as an outcome of this present thesis work was a dignified job. This film was motivated by the success of Dipbahan in Guwahati city under Rickshaw Bank project. The hero was depicted as rickshaw puller using a Dipbahan.

2.1.5 Shortcomings of existing tricycle rickshaws in Indian context.

Although it is advocated by various international institutions like ITDP that the best strategy for containing the pollution is through HPV (Human Powered Vehicles) like tricycle/Trikes/ Rickshaws (http://www.itdp.com, http://www.sustrans. org.uk, Dec 2006) , these are not given due importance also because of the common perception (http://www.johost.eu, Sept, 2006) about these mode of transport as slow, low grade, low-tech and dehumanizing product (Wheeler, 1998). Not much research has been carried out to improve these and the tendency of the people in growing cities is to disband these (http://list.jca.apc.org /public/sustran-discuss, Dec, 2006). This requires a Philosophical change in contemporary society's attitude. A study was conducted to find out in details other factors that are involved and are either directly evident or latent.

2.1.5.1 **Ergonomic issues:** Human factors associated with tricycle rickshaw

Study of evolution of rickshaw indicates that a rickshaw runner had a hard life, with rigorous competition, long hours and low pay. Often the vehicle he pulled was his whole world where he ate, slept and worked. His meager possessions were kept in the compartment under the seat. These would have included a spare pair of straw sandals, a pipe and tobacco pouch and a paper lantern which he lit and hung on the shafts at night. Rickshaws always traveled in single file, and the runner in front called out the particulars of hazards to his comrades coming behind, such as quagmires, rice-laden carts and narrow bridges. The average speed of the rickshaw runner was 5 m.p.h (8km/h) and the usual distance covered was between 20 to 30 miles (32-48km) per day (www.shanghairickshaw.com, Dec, 2006). He ran at an easy gait and if the person being drawn was uncommonly heavy, or the route hilly, a second runner joined him either in pulling or pushing the rickshaw and the passenger was requested to pay an extra amount. It is little wonder that numbers of runners died early from heart and lung diseases. The rickshaw became very popular amongst the newly established middle class Japanese while some wealthy families employed their own runner for the family's exclusive use (www.shanghairickshaw.com, Dec, 2006).

Traditional Indian tricycle rickshaw does not provide comfort to the puller. A passenger travels a short distance each time but the puller operates it for the entire day. As he is not protected from harsh sunshine and rain, his efficiency gets reduced. People also get disgusted in hot summer when rickshaw puller refuses to carry passenger in spite of being free and prefers to rest under shade. Thus contemporary tricycle rickshaw needs to be redesigned for better ergonomic features for the passengers and for the puller. Rickshaws being fabricated locally are having high seats inclined very wrongly to the front direction. One cannot seat comfortably. Footboard height too is very high and is difficult to get on & off. Due to wrong inclination of the foot board it is inconvenient while seating on a moving rickshaw and passenger tends to lose balance.

2.1.5.2 Process of manufacture

The findings from the study carried out earlier through a visit to the local manufacturer revealed that the followings are the inherent deficiency of the existing tricycle rickshaw in local context due to the process of manufacturing employed locally.

A. Each rickshaw is made individually.

B. Various components are also made individually and there is no serious attempt at standardization of the components' exact size, shape and materials since black smiths make these. Details of the parts made this way are shown in the Table 2.1, p 49. Some Rickshaw making unit outsource the above items and only manufacture/ fabricates the wooden body.

C. Other components are procured off the shelf from components manufacturer. Details of these components are shown in the Table 2.2, p 50.

D. Wood is used to fabricate the main body to house the seat for the passengers and then covered with aluminium sheet etc. Most of these rickshaws are fitted with folding canopy made of bamboo covered with canvas or synthetic sheets readily available in the market.

The above items are assembled in a cottage workshop.

Description of the traditional fabrication process of a tricycle rickshaw in Guwahati (Diagram depicting the manufacturing process appended, Appendix 6, p 269)

1. Normally the facility used for fabricating a tricycle rickshaw as studied in Guwahati is cottage industry. It is found to be more or less same all over the country. In a few places it is comprised of integrated facility of black smithy, carpentry, tailoring and fitting. In other cases black smithy is eliminated and items made in the black smithy are outsourced. A black smithy hearth with manual bellows is common (Fig. 2.31, p 51) where mostly scrape iron material is used to fabricate various parts as listed in the Table 2.1, p 49..
2. Carpentry work is carried out in the same premise (Fig.2.32, p 51) for fabrication of the main body (Fig.2.33, p 51) to house the seat for the passengers in wood. Here a template is used for obtaining same form and size. This body is covered by aluminium sheet. Seat back for passenger is integrated with the body and made with coir fibre covered with foam leather and reskin material (Fig. 2.34, p 51). In most cases, decorative elements are also used. These are made using a variety of material such as aluminum tube and rods, laminates of various colors. This body also provides for storage space for the personal belongings of the rickshaw puller like clothes, lamp, document etc. The passenger's seat is placed on this body. It is fabricated in wood, springs fitted (Fig. 2.35, p 51), padded with coir fibre and foam, secured with jute made hessian and finally covered with reskin/ foam leather.

Table 2.1 Details of the parts fabricated locally through Black smithy and material normally procured from scrape

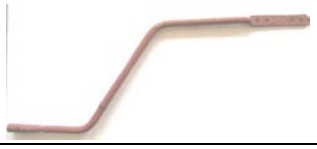
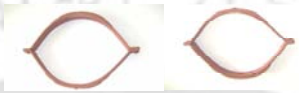
Sl. No.	Item	Visual Image of the item (not to scale)	Materials used for fabrication
1	Chassis element, the lower frame supporting the body and rear axle – a set of two Item no. T -1		Mild steel rod of 25mm diameter or square bar of 25mm or angle of 40mm X 40mm X 5mm, 4.100 kg each
2	Chassis element connecting the two elements of T -1 at the rear end, Item no. T -2		Mild steel rod of 20mm diameter, 1.350 kg
3	Semi-elliptical flat spring system – a set of two Item no. T -3		Mild steel flat bar of 40mm X 5 mm, 2.800 kg each
4	Bracket to connect the Semi-elliptical spring to main body – a set of two Item no. T -4		Mild steel angle of 40 mm X 45 mm X 5mm, 0.400 kg each
5	Bracket to attach the passenger's carriage to the chassis at the front end Item no. T -5		Mild steel flat bar of 30 mm X 4 mm, 0.400 kg
6	Bracket to attach the passenger's carriage to the chassis at the front end Item no. T -6		Mild steel flat bar of 25mm X 4 mm, 0.450 kg each
7	Bracket to connect the main body with the diamond frame – a set of two, Item no. T -7		Mild steel rod of 16 mm diameter, 0.750 kg each
8	Bracket to connect the folding bracket with the main body – a set of two Item no. T -8		Mild steel flat bar of 20 mm X 4 mm, 0.050 kg each
9	Folding bracket for the foldable canopy – a set of two Item no. T -9		Mild steel flat bar of 20 mm X 4 mm and 16 mm diameter rod, 0.650 kg each
10	Folding hinge for the foldable canopy – a set of two, Item no. T -10		Mild steel rod of 12 mm diameter, 0.450 kg each
11	Bracket to connect Folding hinge for the foldable canopy to body – a set of two, Item no. T -11		Mild steel plate of 4 mm thickness, 0.150 kg each
12	Bracket to connect the rear mudguards with the main body – a set of two Item no. T -12		Mild steel rod of 10 mm diameter, 0.400 kg each
13	Bearing holding clamp – a set of two, Item no. T -13		Mild steel flat bar of 35mm X 3 mm, 0.200 kg each
14	Fork guard – a set of two Item no. T -14		Mild steel rod of 10 mm diameter, with aluminium sleeve, 0.500 kg each

Table 2.2 Details of the parts procured from bicycle and tricycle industry
(Price as on 01.05.2004 in Guwahati)

Sl No.	Description	Quantity	Rate Rs.	Amount Rs.
1	10 Gauge Rim, size 28" x 1 ½ "	3 Pieces	103.00	309.00
2	B/Bull Heavy Duty Tyre size 28" x 1 ½ "	3 Pieces	125.00	375.00
3	Ralson Ml Tube	3 Pieces	26.00	78.00
4	10 Gauge Spokes	1 Packet	162.00	162.00
5	Nipple & oval washer	1 Packet	36.00	36.00
6	10 Gauge Rear Hub	1 Pair	34.00	68.00
7	10 Gauge Front Hub	1 Piece	28.00	28.00
8	Front axle	1 Piece	40.00	40.00
9	1 Front & 2 rear wheel mudguard	1 set	135.00	135.00
10	Main Axle	1 Piece	140.00	140.00
11	06 Socket	2 Piece	17.50	35.00
12	06 Bearing	1 Pair	48.00	96.00
13	06 Bearing Cover	1 Set	70.00	140.00
14	KW Fork	1 Piece	97.00	97.00
15	Sl Racer	2 Pieces	19.00	38.00
16	Ball Racer	1 Set	10.00	10.00
17	KW type Handle with brake lever	1 Piece	130.00	130.00
18	KW type Brake Set	1 Set	95.00	95.00
19	Frame Socket	4 Pieces	5.00	20.00
20	Seat Pillar Socket	1 Piece	8.00	8.00
21	Bottom Body (BB) Socket	1 Piece	20.00	20.00
22	Bottom Bracket Cup Bush	1 Set	17.00	17.00
23	Heavy Duty Frame Cup	1 Set	5.00	5.00
24	Body Bracket	1 Piece	17.00	17.00
25	10" Seat Pillar	1 Piece	5.00	5.00
26	Seat Complete	1 Piece	100.00	100.00
27	KW Gear Crank 48 Teeth	1 Set	95.00	95.00
28	KW Pedal	1 Pair	45.00	45.00
29	Cotter Pin	2 Pieces	1.50	3.00
30	Freewheel 22 Tooth	1 Piece	28.00	28.00
31	Freewheel Plate 27 Tooth	1 Piece	10.00	10.00
32	Freewheel Socket	1 Piece	17.00	17.00
33	Rolon Heavy Duty Chain	1 Piece	62.00	62.00
34	Bell	1 Pieces	16.00	16.00
35	Handle Mirror	2 Pieces	15.00	30.00
36	Lock	1 Piece	20.00	20.00
37	¼ "Ball Apollo brand	1 Packet	15.00	15.00
38	5/4 Ball Center	1 Packet	10.00	10.00
		Grand Total:		2,555.00

3. Various outsourced items mentioned in Table 2.2 are assembled at this workshop itself. These are assembly of wheel rim, axle hub, spokes and nipple into a wheel and then fitting the same with tires and tubes. Similarly diamond frame is assembled with pedal, sprocket, handle, brake etc. into a complete assembly.

4. On this complete assembled sub-frame, the elements locally fabricated are assembled, specifically parts mentioned in the Table 2.1 (p 49), these are items 1 to 14.

5. On the metal frame chassis, the wooden body is fixed.

6. Canopy made of bamboo that is presently procured from rural areas and covered with Canvas or synthetic material is stitched at the tailoring facility shown at Fig. 2.36 and fitted on the wooden frame and the rickshaw is completed. Normally canopy is of folding type, foldability imparted by a bracket fabricated by the blacksmith. Ornamentation as per the liking of the rickshaw pullers such as photographs of film hero and heroine as well as scenery is used.


Fig. 2.31 Black smithy facility


Fig. 2.32 Carpentry facility


Fig. 2.33 Wooden main body


Fig. 2.34 Integral Seat back


Fig. 2.35 Spring fitted passenger seat


Fig. 2.36 Tailoring facility

2.1.5.3 Perception about tricycle rickshaw

Common people's perception regarding the existing varieties of traditional tricycle rickshaw is of poor quality, aesthetics, ergonomics as well as safety from the point of view of passenger (Wheeler, 1998) and rider i.e. rickshaw puller. To find out probable reasons behind this perception, direct observation method, personal interviews while meeting with group and individuals and secondary data were used. In case of direct observation method, both participatory and non-participatory methods were used. In case of non-participatory observation method, author observed usage of tricycles by the persons in general and specially regarding mode of overhead protection used by the user (pullers) to protect themselves from elements of nature, carrying of goods etc. Also users in particular were observed regarding their outlook and belonging to a class say high, medium or lower income group. In case of personal interviews, users were asked about various factors for which they are not keen to use the rickshaw, what is their perception about rickshaw being used at present and reasons for their perception, and why they feel use of the tricycle rickshaw is advantages or disadvantages etc.
For data out of reach due to geographical location, secondary sources were also used.

The followings are the probable reasons for common people's perception about traditional tricycle rickshaw that was deduced through this research:

i. Quality and the craftsmanship

Poor quality of traditional tricycle rickshaw can be attributed to present practice of manufacturing through assembly of factory made parts along with locally made body. Here quality of basic frame with drive train etc. is acceptable but region wise the fabrication of the seat with canopy for the passenger differs. Various materials e.g. iron, wood, aluminium etc. are used for its construction. Due to craft based fabrication technique, standardization is lacking even within the rickshaw made by same local manufacturer. This creates a perception of poor quality and finish for this product.

ii. Contemporary look

Rickshaw's existing form not being contemporary does not appeal to many. Rickshaw has evolved over the decades in India and has got a form, which is more or less similar all over the country. It has three wheels and old generation of rickshaw had foldable canopy made of cane and bamboo etc. Since tricycle rickshaw is basically an extended variations of a hand pulled rickshaw to which a front wheel and puller's seat is attached to and evolved when modern automobiles did not exist. The traditional rickshaw's form does not go along with modern day aesthetics relevant to other transportation mode. Thus this form is not appealing to many. Some also feel using rickshaw is below dignity, may be used for joyride; still a class of people are using this mode in a regular basis.

iii. Users' aspect

Ergonomic aspect- *for the puller and for passengers.* Traditional tricycle rickshaw needs to be redesigned with better ergonomic features. A traditional tricycle rickshaw does provide a reasonable comfort to the passenger. A passenger uses it for traveling a kilometer or so but the puller operates this for the whole day. The passengers are provided protection from sun and rain but the puller is exposed to the elements of nature. If the puller is not protected from harsh sunshine and rain, his efficiency will be always reduced. This can be overcome if rickshaws are designed to take care of these factors. Due to the manual work involved in adverse condition, the rickshaw pullers remain dirty and this also repels many users. Most of the rickshaw pullers are poor persons that take rickshaw as the least preferred avocation but forced under economic compulsion. Not only passengers, their luggage also needs to be accommodated with ease of access.

Traditional tricycle rickshaws being fabricated are having high seats inclined very wrongly to the front direction. One cannot seat comfortably. Footboard height too is very high and is difficult to get into as well as has inclination, which is difficult for seating purpose without losing balance on a moving rickshaw.

iv. Safety and structure

Concern for Safety is still another aspect. Safety associated with existing traditional rickshaw in present road condition where both the puller and the

passengers are fully exposed to other vehicles on road and are not protected from moving vehicles. Traditional tricycle rickshaw has very high center of gravity and being a 3 wheeler (delta configuration), get destabilized during turning at speed. Once overturned, the structure does not provide protection to the puller as well as the passengers. Thus rickshaw must be designed to protect the occupant from these hazards. A rolling cage in case of over turn is to be provided to protect the user. During operation on the road it should protect the user from accidents resulting out of crashes by other vehicles on the road to the extent possible by providing an enclosure where no other vehicle will directly hit the user of the tricycle. The design of traditional rickshaw makes the passengers susceptible to accidents, because the front wheel being single and connected to the passenger carrying body joined by a frame, it leaves this body directly exposed to traffic from opposite direction.

One more important aspect is attitude of a society. This attitude is regarding usage of vehicles by individual persons. There are two reasons for use of personal vehicles at present in a country like India.

A. Inefficient public transport system and related inconvenience specifically in developing countries.

B. Status associated with owning a vehicle. This is very relevant in Indian context. A vehicle in developed countries is primarily a mode of transport for the most of the population, but in developing countries like India, it is a status symbol depicting material possession & wealth of the owner. Where as lower middle income and lower income group people are compelled to buy scooter, motorcycle etc. as low cost transportation mode, because of inefficient & inadequate public transport with its associated inconvenience, higher middle income group not only combine this with convenience but to their material wealth.

2.1.6 Need for a contextual design development of a tricycle rickshaw

It is observed that in spite of so much advantage, this mode of transport is not popular or rather popularized and this is already answered through the findings regarding the shortcomings associated with the existing tricycle rickshaw in the preceding points.

To change the situation, there is a need for design and development of a tricycle rickshaw to change the people's perception as well as initiate philosophical change in society's attitude.

Literature, product survey and direct observation and interaction with the users of tricycle rickshaw, both the pullers and the passengers led to formulation of the following findings to establish the primitive need to initiate a design development process in the selected area. Photographs illustrate few of the observations and Excerpts from a few published papers justifies the rest.

i. There is no protection from the elements of nature in an inclement weather for the puller and it is not sufficient even for the passengers.
ii. The tricycle rickshaw is not comfortable for the passengers due to variety of reasons, some region based, such as narrow seat, excessively tilted seat, double row seat etc.
iii. 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 these were designed primarily for the basic functional use for moving on road almost one and a 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.
iv. Getting on and off the tricycle rickshaw is difficult due to the height of the footboard. It is much difficult for older persons and children.
v. The tricycle rickshaw is heavy in weight.
vi. The stability of a tricycle rickshaw is a concern due to high Center of Gravity (CG).
vii. Tricycle rickshaws available in India are with insufficient space for carrying luggage by the passengers or after a marketing trip for which these are extensively used. In-sufficient space for carrying luggage leads to difficulty in traveling with luggage in the tricycle.

Thus there exists a primitive need justified by the above findings and can be defined as:

"A manually propelled eco-friendly tricycle rickshaw that serves the purpose of protecting the driver and the passengers from the adverse elements of the weather in a better way, ergonomic, safe on road in changing transportation scenarios, provides for convenient luggage space, economically viable, mass manufactured and assists in income and employment generation in a developing country."

2.2 Design of a tricycle: An experiment

2.2.1 Contemporary design attempts

In addition to the attempts mentioned in 1st Chapter under subtitle 1.4 for design of a tricycle rickshaw and tricycle for disabled person, there are few initiatives undertaken as a part of the academic activity by students of engineering colleges across the country. In most of the cases these were aimed at improving the functionality of the propulsion system etc. and integrated design development did not take place and hence were not taken to the regular production stage.

2.2.2 Institution associated in tricycle design in India

In addition to the Institute for Transportation and Development Policy (ITDP) initiated cycle rickshaw design mentioned in Chapter 1 under section 1.4, p 17 there are other institutions associated in tricycle design and manufacturing.

The following are few of them.

i. **Nimbkar Agricultural Research Institute (NARI)**, at Phaltan, Maharashtra, India is another organization associated with the development of tricycle rickshaw in India. Their mission and activities are given below as an excerpts from their website. NARI have developed three types of rickshaws:

a) Improved pedal cycle rickshaw (IMPRA), Fig. 2.37

b) Motor assisted pedal rickshaw (MAPRA) and

c) A completely battery driven rickshaw called ELECSHA^{TM} and an electric bicycle.

The tricycles designed under their projects are shown in Fig. 2.38

Details of the products (for human powered one) is given below as an excerpts.

Improved pedal cycle rickshaw named *IMPRA is a* new design of a pedal rickshaw and has 3 speed gears, reduction in length of long chain drives compared to the existing rickshaws, back wheel braking, better suspension and less aerodynamic drag than the existing ones. Fig. 2.37 shows the improved NARI rickshaw. It is claimed that tests done at their Institute have also shown that it enables a rickshaw puller to take 2 passengers on a 6-10% slope quite easily and without getting down from his seat. This rickshaw is made of mild steel angles, is light in weight and is sturdy. The weight of the rickshaw is 65 Kg. Its life is estimated to be between 7-10 years.

Fig. 2.37 NARI designed IMPRA

Fig. 2.38 NARI designed rickshaws together IMPRA, MAPRA and ELECSHA

NARI (www.nariphaltan.org, http://nariphaltan.virtualave.net, Dec, 2006) published (basis-January, 2002) data on urban towns of India has shown that lots of rickshaw pullers are migrant laborers from villages and have sometimes only rickshaw as their sole possession. Hence at night when they sleep, they sometimes do so on the cramped seat of the rickshaw for the fear of it being stolen. Their new design allows the seats to be arranged in such a way that a long bed results which allows a rickshaw puller to sleep properly without the fear of his rickshaw being stolen at night. The cost of this rickshaw is estimated to be Rs. 7000/- in mass production and compares very well with Rs. 4000-5000/- which is the cost of existing regular rickshaws. Presently for small batch production the cost is Rs.12,000.00

Economic issues as addressed by NARI:

NARI states that, discussions with rickshaw puller in various cities reveal that they ply the rickshaws to a maximum of 25-30 km/day. During hot season (which is majority time of the year) they can only go up to 15-20 km/day. On an average they charge Rs. 3-5/km. Hence they can make between Rs. 75--125/day. After paying Rs. 15/day as rickshaw hiring charges they can earn about Rs. 60-110/day. NARI claimed that based

on data on rickshaw developed by them, with IMPRA, the rickshaw puller can easily go about 30-40 km/day due to the gears. This can easily increase his earnings substantially.

Policy issues as mentioned by NARI:
NARI claimed that, in developing countries most of the cities are very congested with narrow roads. Because of historical reasons these roads cannot be broadened. For such roads non-polluting vehicles like IMPRA, MAPRA etc. can provide a very attractive transport system. With enlightened Government policies of allowing only such vehicles in these areas, the cities of developing countries can become pollution free and livable. Besides such vehicles can also be a boon for small towns which have started introducing polluting vehicles like the existing autorickshaws.

There is a need for a policy decision on part of developing countries' governments to permit only improved cycle rickshaws in congested areas of inner cities. This will help in reducing pollution; provide a clean sustainable transport system and employment. Already courts have banned three wheeled diesel tempos from certain parts of Lucknow. Improved rickshaws can provide an attractive alternative to help this order.

There is also a need for the Government to enact legislation such that banks can provide lower interest loans to the rickshaw owners. Since this is a renewable energy system, hence it should get all the benefits presently available to these systems.

NARI's tricycle rickshaw was funded by financial grants from E & Co, New Jersey and Ministry of Non- conventional Energy Sources, New Delhi.

ii. **Super Trikes of India**, Delhi is one commercial organization associated with the development of tricycle rickshaw in India and branded their products as 'Eco-Trike'
It has developed several application-based models for future production based on tricycles in addition to passenger rickshaws (Fig. 2.39- 2.41). These are:
School-children/joy-ride, delivery/shop-on-wheels - vegetables/ fruits vending (Fig. 2.42, p 57), ice cream vending (Fig. 2.43, p 57) garbage-collection (Fig. 2.44, p 57), pick-up and tailor-made designs for specific applications.

Fig. 2.39 Eco-Trike passenger rickshaw

Fig. 2.40 Eco-Trike passenger rickshaw with shocker fork

Fig. 2.41 Eco-Trike passenger rickshaw with 18-gears

Fig. 2.42 Eco-Trike vegetable vending van

Fig. 2.43 Eco-Trike ice-cream vending van

Fig. 2.44 Eco-Trike garbage-collection van

Product specifications of their models are given below as an excerpts from their website. Super Trikes of India claims that, development of the 'Eco-Trike' design has involved basic re-engineering of the Cycle Rickshaw. The technology developed utilizes state-of-the-art in bicycle technology such as the use of oversized pipes and advanced welding techniques, uses all-steel structure- disposing older and inappropriate materials such as wood. Its engineering-optimizes various design aspects such as layout, transmission, aerodynamics, ergonomics for both the puller and passengers, safety and stability, utility attributed by user-value and so on. Redundant parts have been eliminated and the number of parts used minimized, leading to lower maintenance requirements. Use of monocoque structure leads to minimal vehicle dead-weight. The use of sturdy moped type fork design eliminates the problems associated with frequent fork failure in conventional rickshaws.

Space occupied on the road by Eco-Trikes is considerably less due to slick designing that manufacturer claims to be a boon for Indian overcrowded towns. To facilitate exports, a detachable canopy has been fabricated as a result of which more 'Eco-Trikes' can be accommodated in a 20' container. Also a small turning circle, ease of parking on its back, shorter and more efficient chain drive that does not come off while operating, use of coiled springs above the bearing mounts (in conventional clips with ball bearings or in plummer blocks with self-aligning bearings) reduces vibration and shock and a shocker type front-fork is also possible, are amongst other benefits claimed by the manufacturer for Eco-Trikes.

Smaller wheels (with the overall drive ratio being adjusted by change in the freewheel size) with 24" 'balloon' tyre in the front and 20" diameter or heavy-duty 21" diameter moped tyres in the rear reduces the height the centre of gravity thereby reducing the vehicle tendency to topple off- the primary defect of the conventional rickshaw. Due to the low floor height, the passengers- especially the elderly and the children, can now enter and exit from the vehicle with ease.

Super Trikes claims that introduction of a simple rear-axle mounted hydraulic disk-brake developed by them improves braking efficiency. It can also be fitted individually on the rear wheels or on all the three wheels. For the front wheel brake, choices range from simple but effective Philip type brakes, Cantilever brakes to hydraulic disk-brakes. Option of band type drum brakes are also available in the rear. Gears can be accommodated with ease to reduce effort while starting-up the vehicle or climbing slopes. 3-speed gears are standard, but up to 18-speed gears can be provided. Reflectors for safety at night can be included.

Super Trikes also claims that the passenger seat has been developed in an optional 'folding' mode, thereby combining the passenger and load carrier rickshaws in one to enable the puller to earn more flexibly. Seats use webbing, are ergonomic and comfortable, although other possibilities also exist. The puller seat and handlebar is designed for adjustment for variation in puller's physique. The canopy has a fixed structure to protect passengers and goods constantly and is aerodynamic. The waterproof covering cloth is fitted with velcro for ease of affixing and removal when required. Rain-covers on three sides are provided.

Super Trikes claims that the vehicle scores very high on aesthetics and cities will wear a new look with 'Eco-Trike'.

iii. In addition to the above organisations, some departments of IITs such as Industrial Design Centre, IIT Bombay and different Regional Engineering Colleges (presently National Institutes of Technology) as well as many other relevant institutions including Occupational Health Research Centre, Kolkata worked on design development and occupational issues of tricycle rickshaws in India. Except the tricycle developed by IIT Delhi (mentioned in Chapter 1 under section 1.4, p 18), none of the tricycle rickshaws developed by the above institutions saw successful commercial implementation anywhere in India including North Eastern Region and can not be seen plying on road in spite of designed some years back.

However keeping the research interest in mind, the various problems that were identified by NARI for design development of IMPRA and other models by other institutions in India were studied and were found that many vital aspects were not at all covered including safety of the passengers and the pullers. There are several such issues and it was found that these models do not provide sufficient ground against which Dipbahan is to be benchmarked at all. However after the Dipbahan was completed, it was compared with features from some of these models including IMPRA and found to be superior.

In abroad, specially in the western developed countries, it is the individual manufacturer that are carrying on the task of development of tricycle rickshaw as well as a whole category of products classified as Human Powered Vehicles. These are scattered both in Europe and in America.

DESIGN DEVELOPMENT OF AN INDIGENOUS TRICYCLE RICKSHAW

Chapter 3

A Conceptual Design of a New Tricycle Rickshaw

- A single seater trike
- A passenger rickshaw

3.1 Preliminary design attempts-design development of a trike- a HPV

Prior to the design and development of a tricycle rickshaw, an attempt was made to design and develop a tricycle suitable for self ride specifically to facilitate movement in a campus type locality or inside a residential complex to study various factors associated with a tricycle and their effect. The tricycle will have a new identity of its own. The features would be modifiable for disable (handicapped) person. In this attempt, few assumptions were made. These are regarding feasibility of a new tricycle design for disable persons. It was assumed that based on the annual volume of tricycle for disable being distributed by the governmental agencies, there exists an economically feasible opportunity for another manufacturer to launch a new model with better features in the market. In this design attempt, the meaning of handicapped should be understood as given below: -

He/She is the person who is without the capability to use of either one or both the lower limbs but is able to propel the tricycle with both hands, sitting in it.

Assumptions:

1. It is assumed that if a new look space frame structure based tricycle having sufficient safety with full overhead cover suitable for both able and lower limb disabled users is designed, there is sufficient demand for it to be manufactured commercially.
2. Another consideration is that, if the features of the tricycle meet the requirement of disabled users, it would be compatible with all able bodied users.
3. The form and shape developed for the self propelled tricycle for singular use purpose in this pilot project is extended to the passenger carrier tricycle rickshaw.

3.1.1 Designing of a tricycle for disabled

In normal situation the normal human beings can enjoy most of the transportation facilities mentioned in Chapter 1 including manually propelled (pedaled) bicycle and tricycle. Every disable person also has the right to use all these facilities to move around independently and to compete with the fast moving world. But due to his disability and type of disability, present situation does not always facilitate his movement. Thus he is dependant on special versions made available to him to be used with his remaining capability in spite of his disability.

3.1.2 Study of commercially available tricycles for disable persons

For disable persons with only lower limb disability, various manually (hand) propelled tricycles are now days commonly available. At present, there are three variations are seen in use in the Indian market.

These are:

i). Front wheel driven with sprocket and chain, centrally placed pedals - Fig. 3.1
ii). Rear wheel driven with sprocket and chain, pedals at the side Fig. 3.2 and
iii). Rear wheel driven with crank mechanism, handle at the side Fig. 3.3.

Fig. 3.1 Front wheel driven driven with sprocket and chain

Fig. 3.2 Rear wheel driven with sprocket and chain

Fig. 3.3 Rear wheel with crank mechanism

In a front wheel driven tricycle, the power is transferred to front wheel by chain and sprocket arrangement using hand operated crank handle. Another handle is fitted to the same wheel and is used for steering. For a rear wheel driven ones using sprocket and chain mechanism, the power is transferred to one or both the rear wheels by chain and sprocket arrangement. For steering purpose, a handle is fitted to the front wheel similar to the front wheel driven ones. In both the above cases, free wheeling mechanism is not used, so that the handles while rotating in opposite direction can reverse the tricycle. In case of the third version of tricycle that is rear wheel driven ones using crank mechanism, power is transferred to rear shaft having a crank for moving the tricycle. Steering is same as that for the other two versions. In all the three versions, braking is provided at the front wheel only. The steering handle if lowered will engage the brake and stop the tricycle.

In India, there are few organisations that manufacture tricycles for lower limb disable persons. Artificial Limb Manufacturing Corporation of India (ALIMCO) is one such organisation and manufactures few models, Fig. 3.4, Fig. 3.5 and Fig. 3.6 specifications of which are presented in Table 3.1, 62.

Fig. 3.4 ALIMCO- STUTI

Fig. 3.5 ALIMCO- HAMRAHI

Fig. 3.6 ALIMCO- SACHIN

Table 3.1 ALIMCO manufactured Tricycle for lower limb disable person with specification (Information based on product catalogues of ALIMCO)

Features	Model name and product code		
	STUTI TD 2 C 95 or TD 2 C 96 Being compact in size.	**HAMRAHI** TD 2 C 98 A convenient, rugged and comfortable tricycle for outdoor use. Ideal for village.	**SACHIN** TD 2 C 94 Sleek look, robust, excellent maneuverability, seating & driving comfort for out door mobility. Facilitates indoor parking.
Overall Length	1815 mm	2000 mm	Not available
Overall Width :	750 mm	860 mm	Not available
Overall Height	Not available	1000 mm	Not available
Weight	26 kgs.	42 kgs.	Not available
Main Frame	Special quality Cold Drawn Bright annealed tubes of dia 25.4 x 1.25 mm wall thickness conforming of IS : 2039 used for fabricating the main frame makes it sturdy to withstand stresses caused by rough terrain. Neatly welded joints add further to the strength of main frame.		
Seat & Back Rest	Made from Cold Rolled Annealed Mild Steel Sheet provides sturdiness to the frame and stability to the user.	Cushioned seat and back rest provide desired comfort to the user. Can accommodate two persons in emergency	
Facility for Right/Left Hand Drive	Both the options are provided. The user can choose Right Hand Drive or Left Hand Drive to suit his/her convenience and when one hand is tired, the other hand can be used for cranking.		
Driving Mechanism	Driven by standard chain and sprocket mechanism. The gear ratio ensures max. mechanical advantage using minimum effort.		
Steering Mechanism	The steering rod serves dual function of directional control and braking.		
	Hand grip on steering rod is made of special quality PVC, designed for longer life.	Hand grip on the steering rod is specially made of non-marking type rubber and designed for longer life.	
Side Guards	Carefully designed to prevent entry and exist from right side in conformity with traffic rules in India.		
Rear Box	Specially designed box made from G.I. Sheet is provided at the back to carry necessary tools, belongings.		Specially designed box made from G. I. Sheet is provided at the back to carry necessary tools and belongings.
Foot Rest	Made from cold rolled annealed M.S Sheet.		Made from Cold Rolled annealed M.S. Sheet with special non-skidding rubber cushioning.
Materials and Bought outs	The raw materials and bought-outs are of tested quality conforming to relevant specifications laid down by B.I.S.		
Finish	Self drying paints impart excellent overall finish.	Self drying paints impart excellent overall finish.	Epoxy powder coating in colours imparts excellent overall finish and durability.
Quality Control	ALIMCO, observes strict quality control measures at every stage of production and assembly of the tricycle to ensure a reliable product to every needy disabled.		
Repair & Maintenance	Requires only routine maintenance. Use of standard bicycle components ensures easy repairs and replacement of parts in the local markets.		
Turning Space	Requires turning radius of 1.15 meters		
Optional Accessories		Hood for protection from heat and rain. A container at rear side to keep necessary items and belongings. Bell, Head Light.	A Box at rear side serves as goods storage for road-side vending by disabled. Caution Bell Rear view mirror

As seen above, most of the tricycles for lower limb disabled users, available in India are generally hand pedaled, requires simultaneous operations of various levers at the same time, which prevents it from easy handling, and this hinders the operation of tricycles.

Specific observations made while users were using the above models are given below:

- There is no protection from the elements of weather, Fig. 3.7, neither have any safety enclosure to protect the user in case of accident and overturn.
- Most of the tricycles available in India are with insufficient space and this leads to difficulty in getting in and out of the tricycle, Fig 3.8, 3.9, 3.10.
- Simultaneous handling by the cyclist is required due to presence of different levers for propulsion and steering.
- Rear view mirrors are not provided as standard fitment and observing vehicles coming from back side is tedious for the user, Fig. 3.11.
- The existing tricycles are not provided with standard fitment for carrying personal items with the users that are essential to carry with him.
- The tricycle is heavy in weight.
- Thus it is found that the designs of the existing tricycles are not user friendly.

Fig 3.7 A tricycle without provision of protection from elements of nature

Fig 3. 8 Access to a tricycle is difficult due to constraint space & design

Fig. 3.9 Access to a disable tricycle

Fig 3.10 Exit is equally difficult

Fig 3. 11 Rear viewing is difficult without rear view mirror

Fig 3.12 Self made weather protection measures by a disable person

The above shortcomings are due to the fact that these tricycles are designed primarily for the basic functional use of movement on road. Various important aspect of safety, comfort, human factors, aesthetics etc. are not duly considered. It induces inferiority complex to the user of being disabled due to the designs of these otherwise special mode of transport. The form must be elegant to impart self reliance and not just aiding to overcome the disability.

3.1.3 User survey

Methodology used:

Direct observation method, personal interview and secondary data were used. In case of direct observation method, both participatory and non-participatory methods were used. In case of non-participatory observation method, author observed usage of tricycles by the disabled persons in general and specially regarding mode of overhead protection used by the user to protect themselves from elements of nature, carrying of their items etc. In case of participatory observation method, selected disable persons were requested to perform few tasks related to their existing tricycles for disabled. Photography was used to document various aspects like getting on and off to the tricycle, rear viewing etc.

In personal interviews with the users, they were asked about various uses of the tricycle, advantages and disadvantages, ease of operations etc. and the features they desire in a new design. A through interaction was made with 10 disabled persons and emphasis was given to the problems faced by them and to understand their requirement. The findings were compared with the direct observation results for validation. It was found that there is direct co-relation between the direct observation results and the findings from the user survey. These findings can be summarised under different sub-head as:

- ***Need***

  Disable persons need to have independent moveability in outdoors.

- ***Human Factors***
  - Users do not like the driving mechanism that uses crank and shaft and rear wheel drive, since effort required is very high.
  - Some disable persons can't handle the different lever synchronously for movement and steering.
  - Some disable persons restrict themselves from using a tricycle due to the insufficient space available that leads to difficulty in access and exit.
  - In absence of rear view mirrors, users expressed difficulty in observing vehicles coming from back side and it is tedious and risky for the user for taking turn on road.
  - All the users need protection from the elements of nature in an inclement weather. Use of self innovation like make shift polythene cover on top is also seen during field surveys, Fig. 3.12, p 63.

- ***Aesthetics and psychological factors***

Physical disability may lead to inferiority complex as a result of necessity to use specialised aids or accessories that do not express a "feel happy to possess and use" feeling.

- ***Safety aspects***

It is unsafe on road due to the open structure of the tricycle, since other fast moving vehicles move close to them.

Discussions with disable persons using a tricycle for moving outdoor and direct observations, provides the basis for the following factors to be considered in the designing of a new tricycle for disable persons to enhance usability based on principles of Human Centered Design.

1. Human factors should be considered to provide better comfort to the user including accessibility, establishing users' body dimensions (static and dynamic while using the tricycle) and product geometry match ensuring users' behaviour match with design features.
2. Reduction in required driving force through improved driving mechanism so that effort required for operating the tricycle is less.
3. Sufficient space should be available for the user for ease of access and provision for carrying at least minimum items along with him required by him.
4. Protection against the elements of nature/environmental hazards.
5. Aesthetics and visual identity to take care of psychological factors.
6. Better safety features with better maneuverability of the tricycle.

3.1.4 Design development brief for the trike

To incorporate the above features in the design, the following product brief was drawn.

- It should be ergonomically designed to meet ergonomics/anthropometrics requirements and various other human factors.
- It should be easy to operate.
- It should have proper space for the user.
- It should provide protection from the elements of nature-sunshine, rain, wind etc.
- It should provide a positive feeling to the user that enhances his confidence to overcome his inferiority complex that may have formed due to his disability and can use the trike with dignity.
- It should be light in weight and should impart the feeling of lightness visually.
- Visual identity should be contemporary, sophisticated, sporty and dynamic.
- It should be easy to manufacture and modular in design to possibly tend to other uses so that economic lot of production can be achieved.
- It should be easy to repair and maintain.

Work was initiated to provide an appropriate and aesthetically appealing form that does not make the person feel about his disability and use the tricycle with dignity.

It was also undertaken to

i. fulfill the relevant ergonomics aspects and strive for improving upon them.
ii. improve upon the conventional way of riding the tricycle by pedaling and steering with the hands.
iii. provide access so that the disable user can get in and out of the tricycle easily.
iv. provide easy maneuverability, keeping up to the present day transportation needs. The tricycle designed is to be able to take quick turns and acquire lesser space on road.
v. protect the user from the elements of nature by providing a overhead structure without increasing the weight of the tricycle excessively which will affect the manual maneuverability.
vi. provide protection to the user from accidents resulting out of crashes by other vehicles during operation on the road to the extent possible by providing an enclosure so that no other vehicle will directly hit the user of the tricycle. A rolling cage is to be provided to protect the user in case of over turn. This is to be integrated with overhead structure to be provided for protecting the user from the elements of nature.
vii. design a tricycle that can be manufactured by using the modern technologies and materials through small enterprises incorporating various customized features.

The above initiates a concept that can be tested initially for its feasibility. If a common form and shape of a trike is designed, by changing the driving mechanism from foot pedaling similar to normal bicycles for able bodied users for self travel and hand operated for lower limb disability can also be made. The present trial was to make a specific form to travel self that in turn may be extended to passenger carrier version for general use. This thesis work seeks to impart an identity to the Human Powered Vehicle for self as well as for transporting passengers with a new look amongst the existing products prevailing in the market.

3.1.5 Conceptualization

Based on the product brief and existing design of a tricycle for a disable person, concept was generated to utilise a space frame to provide necessary strength to the structure and protection to the user without increasing the weight un-necessarily. The other major constraints considered for design of the Trike concept was as under:

1. Components already available from commercial bicycle industry is to be used to minimize capital investment required for setting up of a commercial manufacturing facility for the trike and its repairing by local cycle repairing shops.
2. Components and subsystems from existing bicycle industry will be out sourced also to facilitate easy maintenance and availability of spare parts.
3. The trike will have bucket type of seat to conveniently sit the disabled user.

A concept for able bodied single user with foot pedaling is developed and initial sketches are shown in Fig. 3.13

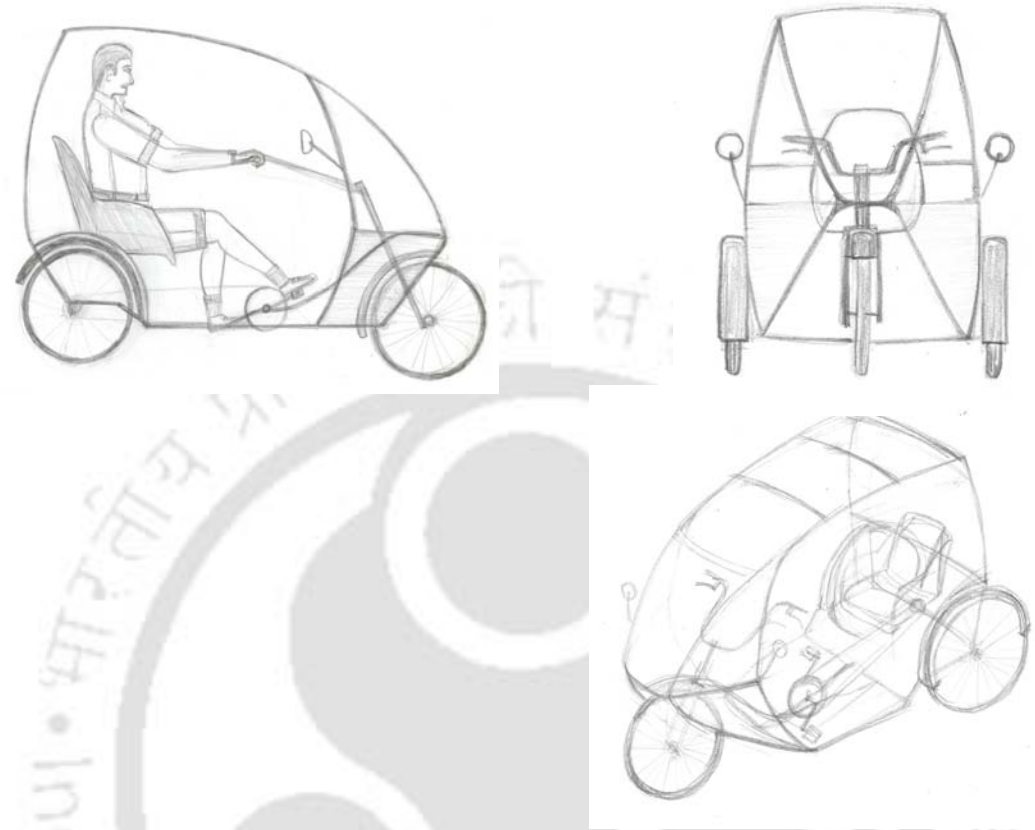


Fig. 3.13 The sketches of the trike concept using foot pedal mechanism

3.1.6 Virtual design of the trike using AutoCAD software

Once the physical sketch was ready, Fig. 3.13, to reduce time and to built in scale into the concept, next step followed was to resort to CAD. Virtual design of the Trike using a space frame was carried out through CAD using AutoCAD software. Various screen shots of the design are shown in Fig. 3. 14- 19, p 68.

The major difficulty encountered in CAD based virtual design was introduction of feeling of scale in CAD design for the Trike that is much bigger than the Computer display screen. Since computer display never conveyed the actual feeling of scale, it was found essential to actually carry out full scale tape drawing of the design. Designers in the automobile industry traditionally create concept sketches on large scale upright surfaces (walls) that preserve a 1-1 or full-size scale factor between the sketch and the final physical car. The main reason attributed for these full-size upright sketches by the designers and managers is to determine and evaluate the principle curves of a design as early in the design process as possible. To avoid the unpleasant 'surprises' that might otherwise occur if work were done at a reduced scale or on a conventional CAD system monitor, working at 1-1 scale is critical to this (Buxton, Kurtenbach, Fitzmaurice and Balakrishnan, 1999). However a 95 percentile human being was roughly created in CAD

and integration was carried out to get a comparative idea of scale and proportion. The various screen shots are shown in Fig. 3.20 – 3.25, pp 68-69.

Fig. 3.14 CAD model in front 3 quarter view

Fig. 3. 15 CAD model in rear 3 quarter view

Fig. 3. 16 CAD model in front view

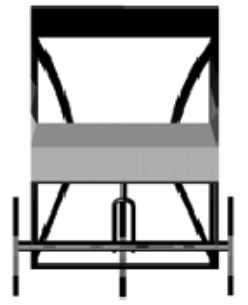


Fig. 3. 17 CAD model in rear view

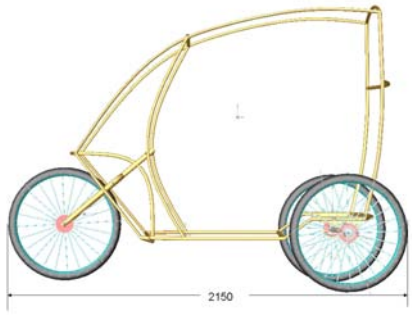


Fig. 3.18 CAD model (silhouette in side view)

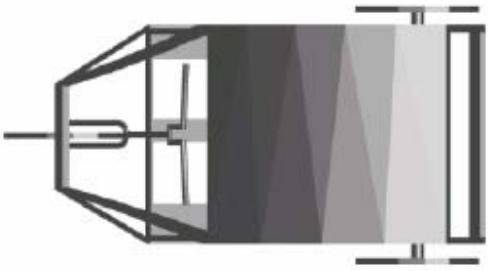


Fig. 3.19 CAD model in top view

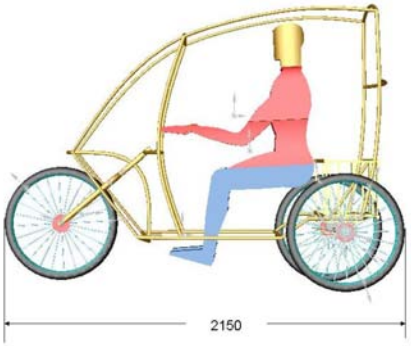


Fig. 3.20 Side view with mannequin in CAD

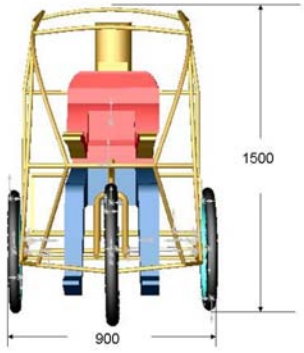


Fig. 3.21 Front view with mannequin in CAD

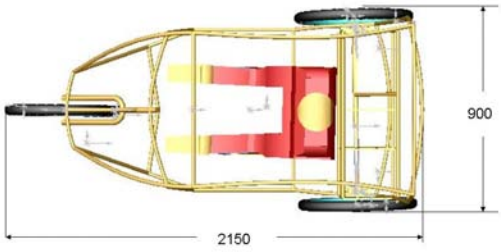


Fig. 3.22 Top view with mannequin in CAD

Fig. 3.23 Rear view with mannequin in CAD

Fig. 3.24 Three quarter front view of trike

Fig. 3.25 Three quarter rear view of trike

3.1.7 Prototyping of the trike

Next work involved making a scaled wire frame model of the concept. Physical model made is shown in Fig. 3.26 and 3.27. This helped in better visualization of the design.

Fig. 3.26 Wire frame scaled model, side view

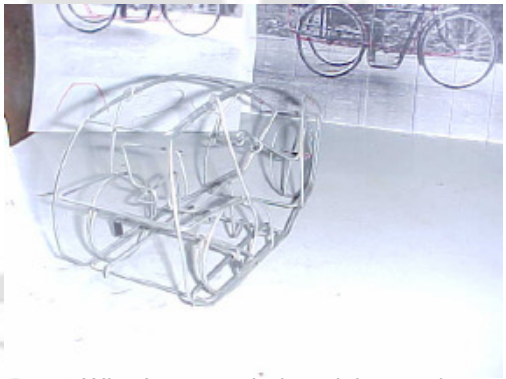


Fig. 3.27 Wire frame scaled model, rear view

Next stage was prototyping of the concept in a full scale functional model. The major constraint considered at this stage is to initially prototype a functional model for able bodied person. This model would be foot pedal operated so that before putting the concept model to actual testing by the disable person, this can be tested by able bodied person for various factors like appropriateness of the design, stability of the trike during operation on road, integrity of the structure, response of other persons regarding the trike and its form, its aesthetic appeal etc. The other constraints considered for prototyping was the selection of parts from existing bicycle and tricycle rickshaw, Table 3.2, p 71.

Material used for fabrication of the prototype is shown in Table 3.3, p 71. For facilitating prototyping process, full scale tape drawing was carried out to check various factors such as form, height, width and proportion. After ascertaining these data, the actual fabrication of the frame was completed through a small workshop in Guwahati (Fig. 3.28-3.31) specialising in tubular fabrication. Outside the Department of Design, IIT Guwahati workshop facility was utilized, since all the required facilities were not immediately available in the department at that time specifically 3 roller type pipe bending machine. Rest of the prototyping work including fitting of the sub-systems and components was carried out in the department. Total fabrication cost comes to Rs. 6,909.00 of which details are shown in Tables below.

Table 3.2, p 71 enlists the parts procured from the available components in the market.

Table 3.3, p 71 enlists various materials procured from multiple sources.

Table 3.4, p 72 enlists Labour charges for fabrication of a newly designed Trike for disable persons on job work basis.

The Tables 3.2 to 3.4 provides a comprehensive idea about the possibility of implementing the design commercially with ease, since it conveys a clear information about the components required and its availability locally.

Fig. 3.28 Prototyping of the Trike

Fig. 3.29 Prototyping of the Trike in progress

Fig. 3.30 Prototyped Body shell of the Trike
Side view

Fig. 3.31 Prototyped Body shell of the Trike
3 quarter front view

In mass production, with setting up of proper manufacturing facilities, the cost is expected to come down to a considerable amount. Local enterprises may take up this exercise, an aspect that is discussed in Chapters 6 and 7.

Table 3.2 Standard items bought out from existing bicycle and tricycle industry
(Price as on 1.1.2004 in Guwahati)

Sl. no.	Description of materials	Rate per unit Rs.	Quantity	Amount Rs.
1	Mountain bike rim10 gauge 26" dia	130.00 each	3 nos.	390.00
2	10 gauge spokes 36 nos. x 3	180.00 per gross	108 nos.	135.00
3	10 gauge front hub 36 spokes	30.00 each	1 no.	30.00
4	10 gauge back hub 36 spokes	35.00 each	1 pair	70.00
5	B/bull heavy duty tyre 26"X 1.75"	125.00 each	3 nos.	375.00
6	Ralson ml tube 26"X 1.75"	30.00 each	3 nos.	90.00
7	Front mud guard	45.00 each	1 no.	45.00
8	Rear mud guard	45.00 each	2 nos.	90.00
9	Fork	150.00 each	1 no.	150.00
10	Screw racer	10.00 per set of 2	1 set	10.00
11	Ball racer	10.00 per set of 2	1 set	10.00
12	¼ ball Apollo	15.00 per packet	1 packet	15.00
13	Handle	150.00 each	1 no.	150.00
14	Rickshaw frame brake set	35.00 per set	1 set	35.00
15	Bell	20.00 each	1 no.	20.00
16	Handle fitted Rear view mirror	20.00 each	2 nos.	40.00
17	Rear Axle with Freewheel socket (Specially fabricated)	300.00 each	1 set	300.00
18	Brake set from mountain bike	100.00 per set	2 sets	200.00
19	BB socket	20.00 each	1 no.	20.00
20	BB axle Black	20.00 each	1 no.	20.00
21	BB cup Black	20.00 per set	1 set	20.00
22	Gear crank -48 T	95.00 per set	1 set	95.00
23	Pedal	45.00 per pair	1 pair	45.00
24	Cotter pin	2.50 each	2 nos.	5.00
25	5/4 ball center	10.00 per packet	1 packet	10.00
26	22 teeth freewheel	30.00 each	1 no.	30.00
27	Freewheel plate 27 teeth	10.00 per set	1 set	10.00
28	Heavy duty bicycle chain	65.00 each	1 no.	65.00
29	Heavy duty frame cup	5.00 per set	1 set	5.00
30	Frame socket	5.00 each	4 nos.	20.00
31	Head pipe	10.00 each	1 no.	10.00
32	Lock	20.00 each	1 no.	20.00
33	Rear end reflector	5.00 each	2 nos.	10.00
34	Shell type Seat complete	100.00 each	1 no.	100.00
			Total: A	2,640.00

Table 3.3 Items procured from various sources

Sl no.	Description	Rate Rs.	Quantity	Amount Rs.
1	MS tubes 19.0 mm dia, 170 gms/RFt	40.00/kg	90 RFt-15.3 kg	612.00
2	MS tubes 25.4 mm dia, 350 gms/RFt	40.00/kg	3 RFt- 1.0 kg	40.00
3	MS flat 25.4 X 4 mm, 180 gms/RFt	40.00/kg	10 RFt- 1.8 kg	72.00
4	MS tube 50.0 mm outer dia	50.00/kg	2 RFt- 2 kg	100.00
5	MS perforated sheet 20 Gauge	450.00/sq.mt	0.5 sq.mt	225.00
6	Aluminium sheet for floor	450.00/sq.mt	0.6 sq.mt	270.00
7	Acrylic sheet for the front end 3' X 4'	500.00/sq.mt	1.1 sq.mt	550.00
8	Canvas for hood, rain guard flap etc.	100.00/m	4 meters	400.00
9	Welding rods	100.00/pkt	1 packet	100.00
10	Assorted Nuts and bolts etc.	100.00/kg	1 Kg	100.00
11	Duco automotive putty	200.00/kg	0.250 Kg	50.00
12	Duco primer & surfacer	150.00/ltr	1.0 litre	150.00
13	Duco paints	300.00/ltr	1.0 litre	300.00
14	Duco thinner	200.00/ltr	1.5 litre	300.00
			Total: B	3,219 .00

Table 3.4 Labour charges for fabrication of a newly designed Trike for disable person (on job work basis)

Sl. No	Description	Rate Rs.	Quantity	Amount Rs.
1	Bending	50.00	Per Trike	50.00
2	Cutting & grinding	200.00	Per Trike	200.00
3	Welding & grinding	300.00	Per Trike	300.00
4	Painting	200.00	Per Trike	200.00
5	Fitting of wheels with spokes, balancing	50.00	Per Trike	50.00
6	Fitting of gears, axles, chains, handles, fork	100.00	Per Trike	100.00
7	Stitching of hood	100.00	Per Trike	100.00
8	Fitting Seats, front wind shield etc.	50.00	Per Trike	50.00
			Total: C	1,050.00
			Total (A+B+C)	6,909.00

3.1.8 Trials of the trike and findings

Once the functional prototype was ready, it was extensively tested for its performance, stability, convenience, comfort etc. (Fig. 3.32), which was also been tested with children (Fig. 3.33) to see with less physical strength and body size, if the trike suits them, then the shape, assumed to fit the disable users.

Fig. 3.32 Trike under Trial

Fig. 3.33 Trike ridden by kids

Fig. 3.34 Trike in side view

Fig. 3.35 Trike in three quarter front view

Fig. 3.36 Trike in top view

Fig. 3.37 Trike in front view

Fig. 3.38 Trike in rear view

The findings are as under:

- The operation of the trike was found to be very easy and comfortable by adults as well as children. This was very much evident from the fact that during its testing, many children from the campus rode this trike with ease (Fig. 3.33, p 72) not only alone but with hordes of them at the same time.
- In terms of aesthetics, common view from the persons who experienced by riding and many others who opined on the new trike liked it due to its form. The trike looks best at its side view (Fig. 3.34, p 72) and 3 quarter views (Fig. 3.35, p 72). In these views, the trike achieved the desired visual identity of being contemporary, sophisticated, sporty and dynamic. It was felt that its top (Fig. 3.36), front (Fig. 3.37) and rear (Fig. 3.38) views appeared to be static. This could be attributed to its prototyping process and skill available with the local workshop. Fabricating a 3 dimensional curved frame was found to be difficult for the persons available in the workshop. Refinement in achieving the smoothness may be taken care in due course of further development for manufacturing. Till this level, the concept's acceptability is tested.
- From the point of view of Human Factors and ergonomics criteria and strive for improving upon them, the result could be best described as mixed. This can be attributed to the design of the trike that was towards recumbent bike but required to ride conventional way by pedaling with foot and steering with the hands.
- The trike provided easy access to the able bodied user but for ease of access by the disable user to get in and out of the tricycle, swivel seat that can turns to the side needs to be incorporated.
- The trike provides easy maneuverability, keeping up to the present day transportation needs. The tricycle designed was able to take quick turns and acquires lesser space on road. However its wheel track was found to be less and there was a tendency at higher speed to get destabilized during sharp turning. Wheel track needed to be increased.

The safety enclosure and the overhead structure were integrated and acts like a rolling cage to provide protection to the user in case of over turn. It provided protection to the user from the elements of nature without increasing the weight of the tricycle excessively. It also provided protection to the user from accidents resulting out of crashes by other vehicles during operation on the road to some extent through the enclosure so that no other vehicle will directly hit the user of the tricycle.

Tricycle design was carried out to use high strength thin profile Mild Steel tubes welded through arc welding. As an anti corrosion measures, this was treated with anti corrosion treatment and in the first functional prototyping, coated with automotive paint through spray painting process. However it was designed for powder coating either in epoxy or polyester based material or even dip coated in these materials. Trike can also be made in stainless steel, aluminium or similar materials to reduce its weight. If desired, the materials can be precisely cut through laser cutting machine and assembled through robotic assembly lines and thus the trike can be manufactured by using local expertise as well as the modern technologies and materials.

It was found that during trial of the trike, many people wanted to know the availability of the trike, its cost and expressed keen desire to purchase it even by paying in advance. As this work is still in developmental stage, a concept further detailing and looking for appropriate arrangement for its manufacturing and marketing was not carried out. The process for modification of the trike to a disable person's tricycle is being continued as well as conversion in combination with other power sources and experiments as a solar powered electric tricycle is being taken up as a separate project attempt. The experience gained here in led to the designing of a tricycle rickshaw for passengers, which is the main emphasis of this thesis work.

Designing of a Tricycle Rickshaw for Passengers

For a citizen living in South East Asia, a tricycle rickshaw is an existing product. Therefore designing a tricycle rickshaw may be thought as a redesign exercise. Thus extreme caution is to be taken for its design under this research work so that context for its design is not lost. In this case although existing tricycle rickshaw was studied, except the concept of a tricycle the design work initiated was fresh and started from scratch. The only similarity between the traditional rickshaw and the newly designed tricycle rickshaw is that it is also a tricycle.

3.2 Concept of a new tricycle rickshaw

The experience gained during the design and prototyping of the Trike provided with invaluable insights to the main research and design work to be carried out under the thesis. The major aspects being the consideration for tie up with future manufacturer and marketing channel for the tricycle rickshaw designed and study of socio-economic aspects prevailing in the area of rickshaw pullers and allied sector. During the research work it was very much evident that-

The designing of a tricycle rickshaw will be a much easier task than changing a society's philosophical attitude for its acceptance. It is a much difficult and time consuming process and may need to consider others aspects such as training, awareness, motivation etc. as well as to make the ownership of these rickshaws easier by the pullers. Transferring the design and technology to the small enterprise for its manufacture in an effective manner is another challenge to be met. Thus this aspect has to be kept in mind during design development stage itself.

3.3 Primitive need and formulation of product development brief

Initially the primitive need for designing a tricycle rickshaw was felt by the researcher based on experience of using one in day to day life. Based on various shortcomings of a traditional tricycle rickshaw as described in Chapter 2 under section 2.1.5, p 47 the essential design considerations for a tricycle rickshaw for passengers, the detailed design brief for the tricycle rickshaw was formulated under different sub-division.

<u>Design and Human Factors considerations</u>

i. Features of the new tricycle rickshaw should go along with relevant ergonomics criteria and strive for meeting various context specific requirements. Easy access is to be provided so that both the puller and the passengers can get in and out of the tricycle easily. During movement, sitting should be comfortable.
ii. It should provide protection to both the puller and the passengers from the elements of nature in an inclement weather without increasing the weight of the tricycle excessively which will affect the maneuverability manually.

iii. To the extent possible, the effort required to operate the new tricycle rickshaw should be less and comparable with other benefits available in the existing ones.
iv. Keeping up to the present day transportation needs the new tricycle rickshaw should be able to take quick turns and acquire lesser space on road.
v. It should provide proper space for the user to carry luggage.
vi. It should provide feeling to the user, which enhances his desire to use a tricycle rickshaw.
vii. It should be light in weight and also as well as visually light yet stronger and rugged.
viii. It should have a contemporary visual identity of sophisticated, sporty and dynamic.

Safety

The new tricycle rickshaw should protect the user from injuries and accidents resulting out of aberrations while passing other vehicles and hit and crashes by other vehicles during operation on the road to the maximum extent possible by providing an enclosure where no other vehicle will directly hit the user. A rolling cage in case of over turn is to be provided to protect the user and integrated with the structure provided to achieve this.

Manufacturing process considered

i. The new tricycle rickshaw design should be able to use the modern technologies for manufacturing and material.
ii. The new tricycle rickshaw should be easy to manufacture and modular in design to probably tend to other uses to achieve economic lot of production.
iii. The new tricycle rickshaw should be possible to be manufactured by local Small Enterprise without much capital intensive process and with low volume of production.
iv. The process of manufacture of the new tricycle rickshaw should be eco-friendly.

Maintenance

The new tricycle rickshaw should be easy to maintain and may be repaired using commonly found facilities in local cycle and rickshaw repairing shops.

Cost

The new tricycle rickshaw should be economic to own and operate and should have cost comparable to existing one as far as possible. To achieve this, components were selected as far as possible from the existing components available in the market.

Branding

The new tricycle rickshaw should be branded to provide it with easy recognition. *'Dipbahan'* is suggested as a brand name for these ranges of newly developed tricycle rickshaw.

The essence of the above product brief can be summarised in a single sentence as:
A manually propelled eco-friendly tricycle rickshaw that serves the purpose of protecting the driver and the passengers from the adverse elements of the weather in a better way, ergonomic, safe on road in changing transportation scenarios, provides for convenient luggage space, economically viable, mass manufactured and assists in income and employment generation in small localised operational area in India, a developing country.

3.4 Aim and objectives

The present design exercise is aimed at design development of an indigenous tricycle rickshaw with contemporary aesthetics suitable for Indian conditions, its prototyping and manufacturing system management with the participation from Small Enterprises.

Objectives

The specific objectives are to:

i. Study the **existing design** and **manufacturing technology** of **traditional tricycle rickshaw** in **Indian context** for **localized transportation** of passengers.

ii. Design a new tricycle rickshaw using **appropriate technology** for its **manufacture** and to **demonstrate** the **design methods** and **technological details** through **this process** to the **target manufacturer**.

iii. Explore the possibility of this tricycle model for **multiple uses** such as school van, delivery van, garbage disposal van, vending van. etc.

3.5 Materials and methods

In tune with the above objectives, design development of a tricycle rickshaw for passengers in the Indian context was considered along with its prototyping and manufacturing system management.

The followings are the key areas (shown in bold type face) and are explored further to gain a better understanding of the situation under which the research work was initiated.

Study the **existing design** (for its limitations and Indian context):
It is essential to study the limitations of existing design of a traditional tricycle rickshaw in present context to arrive at context specific feature and aesthetics for the tricycle rickshaw and these are mentioned in sub-section 2.1.6, pp 53-54 in details.

Study the **manufacturing technology** of **traditional tricycle rickshaw** (for its limitations and in Indian context):
Manufacturing process and technology of a traditional tricycle rickshaw is to be studied to see its applicability since many new technologies has become common even in rural areas and others that were prevalent at earlier time became obsolete. Similarly new materials have replaced traditional natural materials due to the non-availability of

traditional natural material in abundance. We can cite the example of black smithy and arc welding. Earlier black smithy was prevalent in any rural areas and arc welding was not heard of. However, black smithy has become an obsolete practice in rural areas but one can find a fabrication unit equipped with arc welding and drilling. Manufacturing technology of traditional rickshaw was studied from this point of view to see whether these can be replaced with currently available technology for ease of manufacture and maintenance in a decentralized situation that is favourable with Indian SME's distributed manufacturing sector. Details are provided in Chapter 2 under section 2.1.5.2, pp 48-51.

Indian Context:

There is a need to go back to the origins of Indian value system to understand the common and comprehensive way of living and this can provide clue to Indianness and Indian context, (Nadkarni, 1995). For a design to be successful, it must meet the actual need of the population that reflects the Indian culture and tradition and their lifestyle. Indians has many faiths and also believes in myths, even though they may be scientifically educated, these beliefs are handed down the generations without being questioned. Although there is change in lifestyle with advent of technology, there are still these roots visible. One example cited is the photographs of gods and goddesses that are auspiciously placed in a home and oil lamp lighted each day before these deities. With the availability of electricity, these oil lamps have been replaced with electric lamps and unlike these being located in main hall as used to be in the old times, these have been moved to the kitchen. However the tradition continues in some form or the other.

Thus in design context, when designing for the Indian population, a design will be in right context (Indian context) and will meet the need of Indian population in their context only when this culture, tradition and way of living is addressed. Imposition of outside influence will not meet the true need but will be only meeting the aspirations at the most.

Based on the above understanding prior to starting of design development of the tricycle rickshaw, way the common Indians travel, the types of ownership of the tricycle rickshaws, its manufacturing set up, ornamentation of the tricycle rickshaw that provide identity to the rickshaws etc. were observed. Some of the findings are given below:

- Regarding transportation, Indians prefer to travel with families for festivities etc. and family being large with more number of offspring, not to mention joint families in rural and semi-urban areas, more persons travel together. This also results in crowded traveling since there is always a shortage of sufficient numbers of vehicles.
- People also carry significant amount of luggage with them during traveling including eatables. Therefore space for luggage becomes imperative for any transport vehicles.
- India being a vast country, it also has very diverse climatic conditions. In summer people prefer to travel in semi-open vehicles due to high temperature and in

winter, people need protection from extreme cold in north India. Thus designed vehicles should take care of these aspects.

- Indians has a habit of using any product in many different ways in different context. A tricycle rickshaw is used for transporting people to places, school children to school and back, transport luggage, industrial goods, food items, vegetables and fruits, vending and in a few cases even patients to hospitals. One needs to consider all these.
- In India, tricycle rickshaws are made locally by unorganized units in various dimensions and forms.
- Owners and drivers of the vehicles also prefer to decorate their vehicles in a very colourful way through painting natural sceneries, portrait of god and goddesses, film hero and heroines etc. and also fixing various decorative and ornamental pieces onto their vehicles. Providing scopes to do that may evoke their interest and providing a scope for them to create an identity for their rickshaw through this type of customization.
- Most of the rickshaw pullers in Indian context do not own the rickshaw of their own due to their deplorable economic conditions and non-availability of funds from financial institutions. Therefore rickshaw pullers hire a rickshaw on daily basis and they can not improve their economic status due to this. When majority of the rickshaw pullers live a deplorable life, this avocation remains undignified for the unemployed youth. To make this work dignified, rickshaw pullers have to be empowered by providing them ownership, so that after initial repayment for owning the rickshaw, they are no more required to pay a significant portion of their daily earning as hiring charges. This will improve their economic situation. Thus a mechanism will be required to achieve this and this can be micro-finance.
- People in India reuse lots of product after its primary use is met and recycle almost everything in various way and common people live a life of austerity even now. Thus design may require consideration from this point of view. This is specially true regarding the components to be used in the rickshaws. If there is better use of any of these components, these may end up with that use, and this is specially useful after the useful service life of the product is over and product is to be retired and recycle is easier in this case.
- Many a time, rickshaw pullers in a region has beliefs that are not based on scientific principles but still they adhere to it. One example that can be cited is regarding inclination of the seat of the passenger in NE region mentioned in Chapter 6 in p 198.

Old and modern goes hand in hand in India. Thus integration with existing habit of the population is essential.

Localised transportation:

Study to understand various ways that are currently adopted by common people in the context of North Eastern Region of India is essential for design development of a new tricycle rickshaw. These are mentioned in Chapter 1 under section 1.3 in pp 13-14.

Appropriate technology for **manufacture** (of the tricycle rickshaw to be newly designed in present context in NER of India):

Traditional rickshaws use various skills that were common at the period of time when it evolved, like black smithy, carpentry, tailoring etc. Currently these are becoming scarce in towns and cities and also materials like wood used for fabricating rickshaw body locally are becoming scarce and expensive specifically after tree felling has been banned in NER for more than a decade to preserve the eco-system of its fragile eco-system.

Against this back drop, many new technologies have become common even in rural areas and others that were prevalent at that time became obsolete. Example of black smithy and fabrication workshop equipped with arc welding, drilling and cutting can be cited here. Earlier black smithy was prevalent in any rural and urban areas and arc welding was not heard of. However, black smithy has become an obsolete practice in urban and semi rural areas but one can find a fabrication unit equipped with arc welding, drilling and cutting mild steel even in any rural area that is electrified. Similarly new materials like plastics have replaced traditional natural materials due to the non-availability of traditional natural material in abundance.

Thus manufacturing technology and materials of traditional rickshaw can be replaced with currently available appropriate manufacturing technology and materials such as plastics (FRP in this case) for newly designed tricycle rickshaw for ease of manufacture and maintenance in a decentralized situation that is favourable with Indian SME's distributed manufacturing sector. These are suitable and appropriate at present context.

Demonstrate the **design methods** and **technological details** (through product design **process, prototyping and testing):**

A product design methodology is to be practically demonstrated to the target manufacturer, in this case Small and Medium Enterprises (SMEs) in North Eastern Region of India. Design methodology to be adopted for this purpose should be simple to understand even by a layman while transferring design and technology and thus helps in subsequent design process by the target manufacturer in a conventional way. Method adopted is Morris Asimow propagated design method mentioned in Chapter 1 under section 1.7, p 30 and discussed in this chapter in detail under section 3.5.1, pp 83-85

Technological details in terms of the technology to be used for the manufacture of the tricycle rickshaw to be newly designed and the process of design development, prototyping, testing and manufacturing are to be appropriately demonstrated to the target manufacturers so that they can adopt these within their constraint resources such as infrastructure for the design to be successfully implemented.

Target manufacturer:

The focus was on small and medium enterprises, in many cases tiny enterprise for manufacturing of the tricycle rickshaw to be newly designed in the context of North Eastern Region of India as the target manufacturer. These are decentralized, Small and Medium Enterprises specifically in North Eastern Region of India who are interested in undertaking manufacture of the design. No patents should be attempted so that anybody interested can improve or modify the design as per their contextual requirement.

Multiple uses:

Tricycle rickshaw and its derivatives are used for various localized transportation needs currently in North Eastern Region of India. Thus in addition to transporting passengers, it is also used to transport school children inappropriately (Fig. 2.22, p 42). Similarly garbage disposal from narrow roads and lanes, use of tricycle based derivatives extensively (Fig. 2.24, p 42) is a need of the society today. Thus these areas provides for immediate scope and action for design. While designing a tricycle rickshaw from the beginning, keeping in view modularity (Otto and Wood, 2001) for designing derivatives will help in the long run and reduce cost of design development. This also provides for capacity planning for the manufacturing so that facility can be economically feasible. Thus design development of tricycle rickshaw modifiable for multiple use such as School van, delivery van, garbage van etc. were included.

The area of work was considered as a part of system design approach of transportation design for the fact that this is the first level for any transportation aspect and at best can be useful for meeting localized transportation needs as given below:

Environment friendly manually propelled tricycle

- Trikes for single user–modifiable for lower limb disable person- *done experimentally as presented in the previous section of this chapter.*
- Tricycle rickshaw for multiple use
  - Passenger version - *considered initially based on the basic form of the single user version.*
  - School van - *considered based on the passenger version*
  - Garbage disposal van- *considered based on the passenger version*
  - Delivery van - *considered based on the passenger version*
  - Vending cart etc. - *considered based on the passenger version.*

The basis of research considers:

- A **tricycle** (often abbreviated to **trike**) - a three-wheel (thin rim) vehicle.

In India, most commonly seen tricycle is a passenger tricycle rickshaw. In addition to passenger tricycle rickshaws, there are tricycles used as delivery vans with boxy storage compartments, goods carrier, school children van etc. in Indian context.

The research also considers:

• **Product design**:

In product design, the following steps were followed-

i. Need identification/ creation and conceptualization to satisfy the context specific requirement of the period of time and prediction regarding scope of the need for near future.

ii. Prototyping

: mock up model to assist visualization, form study, ergonomics etc.;

: functional prototypes- alpha model, beta model to assess functionality and target users trial for feedback for design refinement.

iii. Production and

iv Marketing and use; and feed back and modifications.

In the preceding chapter titled Tricycle Rickshaw Development: Issues and Contextual relevance, it is found justified to undertake the research work.

Branding exercise is to be carried out to differentiate the tricycle rickshaw designed under the research work in the market place as a strategy. Appropriate promotional materials are to be prepared to establish this brand in the market.

3.5.1 Design process

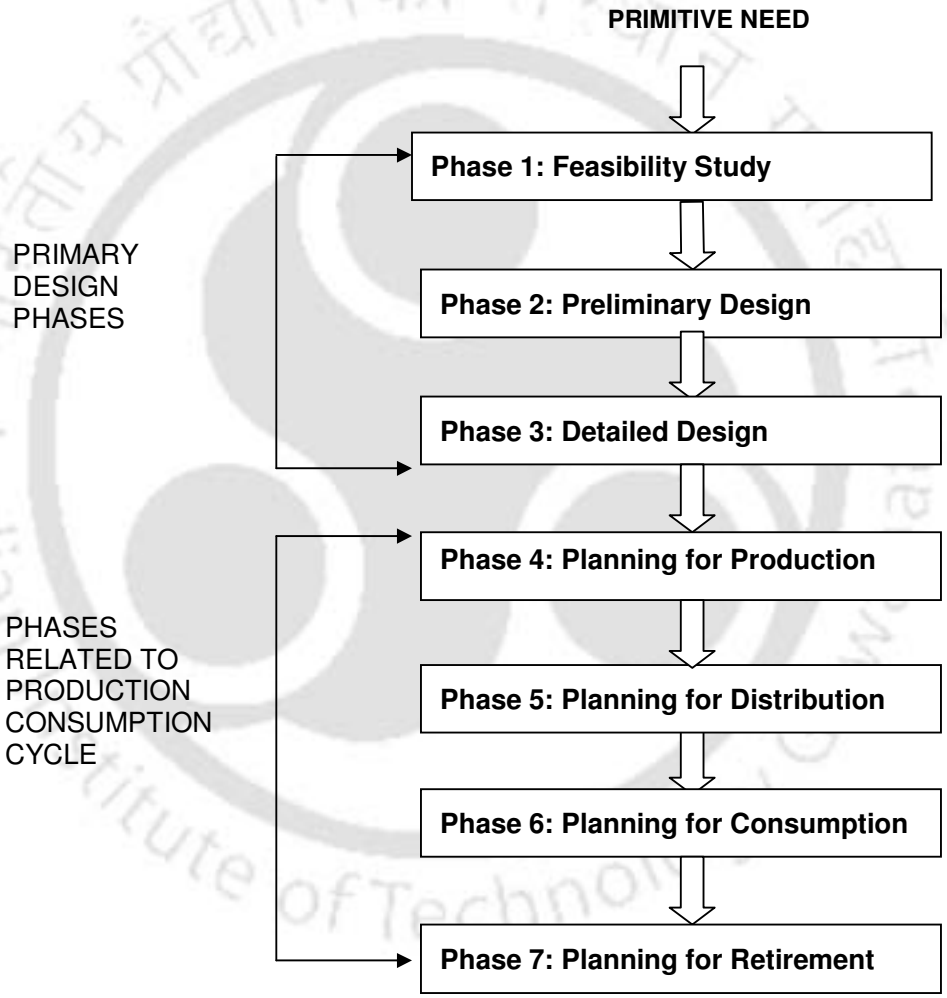
Design in the most simplest form is defined as initiation of change in man-made things (Christopher, 1992). Product design deals with conversion of ideas into reality (tangible products) and, as in other forms of human activity, aims at fulfilling human needs.

A designer designing products/systems is also many a times referred as an Industrial Designer, being identified such because he is to design products/systems which can be mass produced using industrial production/manufacturing lines.

In a mass production set up, an industrial designer does not usually produce the products or services that satisfy consumer's needs immediately. Rather, he facilitates the production of the prototype which is used as a sample for reproducing the particular products or services as many times as required.

Whenever an existing or a prospective manufacturer is confident that a sufficient number of customers will be satisfied by the product, then mass production of the item or service may be initiated by the production department in an existing industry or a set up for producing the product or services is brought into existence. During the course of production, an error due to the producer in manufacturing an item may lead to its rejection for not meeting the specification in terms of quality etc. but an error in design of a product or services will be repeated in all products, and may lead to an economic misadventure of enormous proportions or even legal implications. Therefore the designer's responsibility is stupendous.

Design development of any product is a systematic science. This is basically carried out in seven phases and their constituent steps (Chitale and Gupta, 1999). This process is also called as morphology of design. Of the seven phases (Flow Chart 3.1), the initial three phases Feasibility Study, Preliminary Design and Detailed Design proposed by Asimow (Asimow, 1962), belong to design, and the remaining four phases belong to production, distribution, consumption and retirement (or recovery or disposal) and also called as the production-consumption cycle (Chitale and Gupta, 1999). It is one of the main features of the socio-ecological systems. The Flow Chart 3.1 shows the various phases in morphology of design and the production-consumption cycle is illustrated in Fig. 3.39, p 85.



Flow Chart 3.1 Morphology of design process

Each phase shown in above has several steps. These are given below:

Phase 1: Feasibility study

Step 1: The need-Establishing its economic existence

Step 2: The design problem – Identification and formulation

Step 3: The synthesis of possible solutions

Step 4: Physical realisability
Step 5: Economic worthwhileness
Step 6: Financial feasibility

Phase 2: Preliminary design

Step 1: Selection of the design concept
Step 2: Formulation of mathematical model
Step 3: Sensitivity analysis
Step 4: Compatibility analysis
Step 5: Stability analysis
Step 6: Formal optimization
Step 7: Projections into the future
Step 8: Prediction of system behaviour
Step 9: Testing the design concept
Step 10: Simplification of design

Phase 3: Detailed design

Step 1: Preparation for design
Step 2: Overall design of subsystems
Step 3: Overall design of components
Step 4: Detailed design of parts
Step 5: Preparation of assembly drawings
Step 6: Experimental construction
Step 7: Product test program
Step 8: Analysis and prediction
Step 9: Redesign

Phase 4: Planning for production

Step 1: Detailed process planning for every part, subassembly and the final assembly
Step 2: Design of tools and fixtures
Step 3: Planning, specifying or designing new production and plant facilities
Step 4: Planning the quality control system
Step 5: Planning for production personnel
Step 6: Planning for production control
Step 7: Planning the information-flow system
Step 8: Financial planning

Phase 5: Planning for distribution

Step 1: Designing the packaging of the product
Step 2: Planning the warehousing systems
Step 3: Planning the promotional activity
Step 4: Designing the product for conditions arising in distribution

Phase 6: Planning for consumption

Step 1: Design for maintenance

Step 2: Design for reliability

Step 3: Design for safety

Step 4: Design for convenience in use (taking into account human factors)

Step 5: Design for aesthetic features

Step 6: Design for operational economy

Step 7: Design for adequate duration of services

Step 8: Obtain service data that can provide a basis for product improvement, for next-generation designs, and for the design of different, but related products

Phase 7: Planning for retirement

Step 1: Designing to reduce the rate of obsolescence by taking into account the anticipated effects of technical developments

Step 2: Designing physical life to match anticipated service life

Step 3: Designing for several levels of use so that the product can be used in a less demanding level after service life at higher level of use is terminated,

Step 4: Designing the product to recover the reusable materials and components

Step 5: Modularity in design can be contemplated, instead of integrated designs

Step 6: Examining and testing of service-terminated products in the laboratory to obtain useful design information

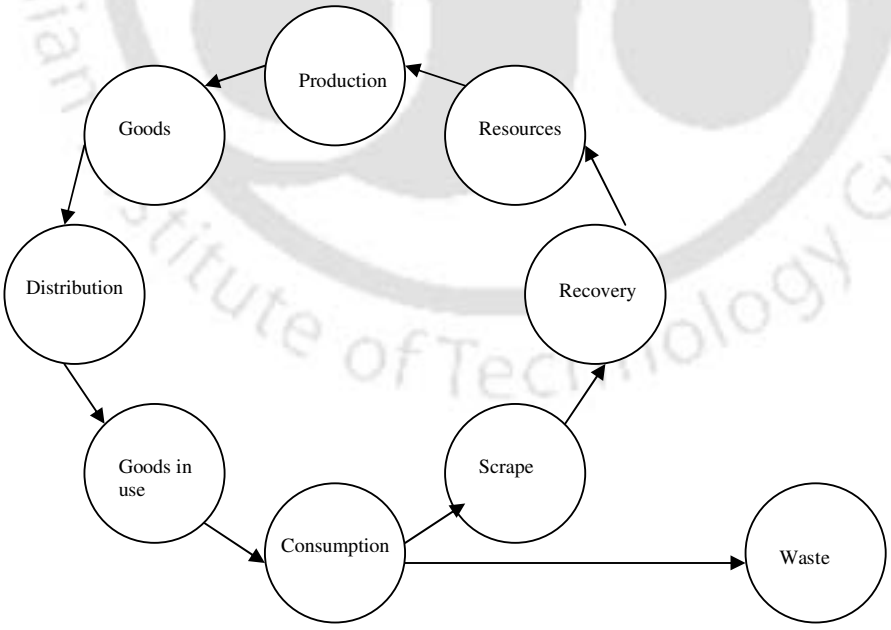


Fig. 3.39 Production-consumption cycle

The actual 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 of the research work smoothly and appropriately.

The entire process is mapped as under:

As mentioned in the Flow Chart 3.1, in p 83, Morphology of Design Process propagated by Morris Asimow, there must be a Primitive need to start a design process and it started with a primitive need as mentioned in p 54.

In the first phase, Feasibility study, actual feasibility of design development of a tricycle rickshaw was carried out. These are discussed in pp 88-89 and 94-99.

After Feasibility study, the second phase, Preliminary design was initiated and these are discussed in pp 89-93, pp 89-93 and pp 99-110 and also involved conceptualization of the design.

The third phase, Detail design was initiated after the preliminary design and is covered in Chapter 4 - *Detail Design of a new Tricycle Rickshaw Dipbahan* from pp112-113, pp 127-143 and in Chapter 5 – Prototyping and Testing of Dipbahan, pp 145-174.

The fourth phase, Planning for Production was initiated after the Detail Design phase and covered in Chapter 7 – Participatory Approach in Dipbahan+ Development and Transfer of Technology to Small Enterprise and discussed in pp 200-216.

The fifth phase, Planning for Distribution although listed after 4 phase mentioned above, actually this is partly a concurrent activity and was initiated during the Detail Design phase and covered in Chapter 7 – Participatory Approach in Dipbahan+ Development and Transfer of Technology to Small Enterprise and discussed in pp 216-223.

The sixth phase, Planning for Consumption listed after 5 phase of Morphology of Design mentioned above, actually this is also partly a concurrent activity and was initiated during the Detail Design phase and covered in Chapter 4 – *Detail Design of a new Tricycle Rickshaw Dipbahan* and discussed in pp 113-122.

The seventh phase, Planning for Retirement although listed after 6 phase of Morphology of Design mentioned above, similarly a concurrent during design activity and was initiated during the Detail Design phase and covered in Chapter 4 – *Detail Design of a new Tricycle Rickshaw Dipbahan* and discussed in pp 122-127.

As given at section 3.3, pp 75-77 of this chapter, it was found that there exists a valid Primitive need. Once primitive need was established, a design project was initiated. This started with the feasibility study; the purpose was to achieve a set of useful solutions to the identified design problem. Feasibility study itself is broken down into six separate and distinctive steps.

3.6 Feasibility study.

Feasibility study was conducted in Guwahati and different localities of North Eastern region of India. This was presuming that the original need does indeed have current existence or strong evidence of latent existence, the first step in the feasibility study

demonstrated this need to be valid. In the second step the 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 solutions to the problem were sought. In the fourth step, the potentially useful solutions were sorted out from the feasible set in three steps on the basis of physical realisability, economic worthwhileness, and financial feasibility.

The completed feasibility study finally indicated that a current and a potential need exists. It also helped to formulate the design problem and possibility that of useful solutions can be found. Thus this study fully investigates the feasibility of the proposed research project for its practical implementation. For generating alternative designs from which the best can be selected, computer aided modeling is found to be very useful.

3.6.1 Establishing economic existence of the identified need

First step in feasibility study is establishing 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 scene. It was worded in the form of a primitive need statement as given above at section 3.3 of this chapter and was elaborated into a sophisticated and authenticated statement based on market and consumer studies. The need existed during the initiation of the project, and there was evidence that it is latent, and that it may arise when economic means for its satisfaction through design intervention become available.

Licenses for tricycle rickshaws are issued by the municipal council/corporation in various towns and cities in India. Thus source for registered tricycle rickshaws are the offices of these councils/ corporations of various cities and towns in North Eastern India. It was found that there are more than 200,000 numbers of tricycle rickshaws registered under various municipal corporations and committees in Assam, Tripura and Manipur etc. and even a 10% replacement of this number will provide an avenue for manufacturing 20,000 numbers of tricycle rickshaw per annum. Registering authorities provided the information based on their license issued each year that they issue maximum of 10% new licenses for every year against the existing rickshaws registered with them in the previous year. Also as per their record, renewal of license per year hovers around 85 to 90% of the existing rickshaws in the previous year. As per them, the non-renewal rickshaws are scraped by the owner due to physical deterioration. In case, new licenses issued in a year exceed 10% of the total registered rickshaws in the previous year, any fresh licenses are used for new rickshaws only against license of old rickshaws that are scraped. Thus 10% replacement value was established. However it was informed unofficially that some rickshaws in interior places are also used without valid licenses and this number was not available.

The need was also suggested by an innovative micro-credit strategy for empowering the rickshaw pullers who are non-owners but hire a rickshaw to earn a livelihood and this

motivates its exploitation through a product like tricycle rickshaw for social good. The way the need had been perceived, its economic existence, latent and current was established with sufficient confidence to justify the commitment of the funds necessary to explore the feasibility of developing a means for satisfying it.
Economic existence of the need means that individuals (rickshaw pullers), institutions (Funding agency for design development of the new tricycle rickshaw - North Eastern Development Finance Corporation, Indian Jute Industries Research Association, M/s Tim Steel Innovative; NGO-Centre for Rural Development; corporate funding the Rickshaw Bank Project; Municipal corporation, local government etc.) and society recognized the need and paid the price of the new tricycle rickshaw that satisfied the need.

As a result of this confidence, it was possible to make the new tricycle rickshaw available in the market for a purchase price under the Rickshaw Bank Project scheme and also directly to the buyers. There are 2 numbers of agencies (Centre for Rural Development, Guwahati and M/s Tim Steel Innovative, Guwahati) currently manufacturing and supplying the product.

The importance of establishing the need can hardly be overestimated. Primitive need statement contains a vague description of requirement and does not point out the way a design should be made. It may only state the sponsor's need in a general statement. An organization going for a project by developing a base on an assumed need that was imaginary and disappeared in the light of reality may end up in financial failure. Primitive statements enable the generation of more ideas than specific statements.

Intuitive knowledge about people in the target area, specifically North Eastern Region of India, their habits and lifestyles and their behaviour in the socio-economic system, was combined with specific information obtained by market research. This provided the information necessary for making a need analysis. After performing the need analysis, a decision was made about the validity of the economic worthwhileness of the need. It was found to be favourable and the results of this step are summarized as given below in a set of specifications of desired outputs the Tricycle Rickshaw as a product must be capable of producing in order to satisfy the need. As mentioned earlier, the need statement practically or theoretically did not immediately converge to suggest a single design. It was primitive and general and encouraged multiple solutions and ideation.

The present sort of tricycle rickshaw available in the market costs around five thousand five hundred to six thousand. Thus the price of an existing traditional rickshaw constituted a major cost constraint and this is to be fulfilled within an increase of 10% of this cost. Therefore the new design of the tricycle rickshaw with whatever improvement and attachment to be considered, as specification summarised in Table 3.5, p 89 should not increase the cost more than Rupees five hundred to six hundred.

Keeping the additional features into consideration the tricycle rickshaw seems to be economically feasible for the starting of the design stage.

Table 3.5 Summary of a set of specifications for passenger carrier tricycle rickshaw.

Specifications ⇓ Type⇒	Present tricycle rickshaw	New design tricycle rickshaw code named-Dipbahan
Economic viability/Cost	Available at approximately Rs. 5,500 –6,000/-	To be made available at approximately Rs. 6,000-6,500/-
Protection of the puller and the passengers from the element of nature	Protection is available only for the passengers, that too partially	Protection to be provided to both the pullers and the passengers
Ergonomic issues	Due to inclined seat and foot board, awkward access and exit from the rickshaw, it is not ergonomic	Should address the ergonomic issues
Safety	Not safe form accidents due to the open structure	Should protect the puller and the passenger in case of accidents
Provision of luggage space	Not available	Suitable provision for luggage space must be provided
Environment friendly	Operation wise yes; from the point of view of material used for its fabrication, it is not, it uses wood to the maximum and timber felling is banned in North East region	It should be environment friendly both from operation and manufacturing point of view
Mass manufacturability	Craft based manufacturing process is used , it is not suitable for mass manufacture	Should be suitable for mass manufacturing specifically by small enterprises
Use of modern technology	Not conducive for using modern manufacturing technology	Should be using modern manufacturing technology

3.6.2 Identification and formulation of the design problem

Second step in feasibility study is the identification and formulation of the design problem. The information required for this step is derived from the results of the preceding step, particularly the specifications of desired output and relevant technical knowledge about environments, resources and the general engineering principle. An activity analysis is performed with this information as the basis to provide a technical formulation to the design problem. Before considering this step to be complete, it was ensured that the resulting engineering statement of the design development of a tricycle rickshaw is sufficiently relevant and adequate to commit the ensuing steps to the design. More and more new information was constantly developed by the design work itself. Previously these were either overlooked or unknown. This new information changes the confidence levels on which prior decisions were made.

The following factors were identified and design problem was formulated in the preliminary design of the tricycle:

- Being a 3-wheeler, stability of the proposed design is to be ascertained.
- Fabrication process for the new rickshaw to facilitate use of commonly used modern materials and manufacturing processes such as mass manufacturing through assembly process.
- Possibility of outsourcing parts and components for the rickshaw from the readily available standard parts / components bins from existing bicycle and tricycle industries. This can facilitate in reduction in capital cost of the project for manufacturing in addition to ease of maintenance of the new rickshaw.
- Protection of the puller and the passengers from the elements of adverse weather requires a canopy on the top and need to explore the possibility of providing supports for the canopy in the design as an integrated aspect.
- Provision of proper space for carrying the luggage.
- Ergonomic seating arrangement.
- Ample legroom for the passenger.
- Effective mudguard.
- Protection of the occupants from direct impact from heavier vehicles.
- Possibility of incorporating advertising space to facilitate acknowledging the sponsorship for economic contribution by the sponsors or as a way of earning revenue through provision of advertisement space.

Preliminary Design Concepts:

After detailed study of the existing tricycles used for transporting passengers all over the world, new concepts were generated in the context of the local situation. Before conceptualization, a list of constraints were identified for the sake of practicality. These are:

- As far as possible cost of the tricycle rickshaw must be within the targeted amount of Rs. 6,500.00 as decided in a meeting with the likely implementing agency, Centre for Rural Development (CRD), Guwahati. This is the retail price. Therefore one must consider the profit margin also within it.

- To achieve the above constraint, design must outsource maximum parts and components from the available parts bins of existing bicycle and tricycle rickshaw. This will reduce capital cost of the manufacturing unit and thus will require lower amount as return on capital.

- The stability of the existing tricycle rickshaw in Guwahati specifically, was found acceptable with the existing foot prints of the 3 wheels. The wheel base of rickshaws in Guwahati city was found to be maximum compared to other places in the North Eastern Region of India and it has continued traditionally over the years. May be it is because of the fact that Guwahati is the biggest and oldest city in the North Eastern Region of India and has best road infrastructure in terms of surface quality , width of the roads, straight roads etc. and hence the longer rickshaws are not a hindrance. Compared to this, roads in various towns are

narrow, with sharp turns etc and rickshaw pullers prefer shorter rickshaws. The wheel base of a rickshaw is not governed or prescribed by any law/ government regulations. It is entirely dependant on the local decentralised fabricators of the rickshaw in various locations. Thus it was decided that the existing foot prints of the tricycle will be retained. This means the track and wheel base will be unaltered. Stability of the rickshaw can be still enhanced if Centre of Gravity can be lowered. This is possible if the passengers' seat can be lowered in the new design. Dipbahan based on longer wheelbase as that prevailing in Guwahati provided ample space to the passengers including luggage space. This was welcomed by the passengers all over the country as found later, but rickshaw pullers in Imphal in Manipur, Silchar in Assam and Agartala in Tripura were not that happy since with good luggage space, passengers were seen to be taking advantage of this feature that made rickshaw pullers toil more. However passengers paid more for this features and except for few rickshaw pullers, this design decision was otherwise welcomed by all.

- Materials used for fabrication was one of the critical parameter in this design. Existing rickshaw uses multiple materials as evident from the analysis of these rickshaws for materials and processes used. In the new design, emphasis was laid on reducing the types of materials to a few. Thus mild steel (MS) was identified as the predominant one, since most of the other items used in the existing tricycle were available in mild steel/steel and will be easier to join with each other. It is also convenient that MS is widely used nowadays for fabrication of various items ranging from grills, gate and truss of house to various furniture items like storage cupboard, storage racks, display cabinets etc. even in small town and villages. This will ensure easy maintenance of the rickshaw.

Based on the above criteria a few concepts were conceptualized; these are:

Concept 1

Fig. 3.40, p 93. A tricycle with existing foot prints but with extended roof fulcrumed permanently over the passengers and the pullers with identical configuration of existing rickshaw (Delta configuration)

Concept 2

Fig. 3.41, p 93. A tricycle with two wheels at the front and single wheel at the rear with extended roof fulcrumed permanently over the passengers and the pullers**.** (Tadpole configuration)

Concept 3

Fig. 3.42, p 93. A tricycle with existing foot prints and with extended roof fulcrumed permanently over the passengers and the pullers with identical configuration of existing rickshaw, but replacing the structure completely with MS structure.

Concept 4

Fig. 3.43, p 93. A tricycle rickshaw with existing foot prints with a space structure/monocoque body made in tubular material in MS similar to that of the trike designed earlier with recumbent style pedaling.

Concept 5

Fig. 3.44, p 93. A tricycle rickshaw based on a bicycle with a side car as available in South East Asia but with integral canopy to protect both the passengers and the pullers with a space structure/ monocoque body made in tubular material in MS.

Concept 6

Fig. 3.45, p 93. A tricycle in the form created for the disable person in the first part of this thesis/ research work but puller pedals it like a normal (upright style of pedaling) rickshaw.

For all these concepts, wherever required, a full scale tape drawing was initiated to study the overall form, scale and proportion.

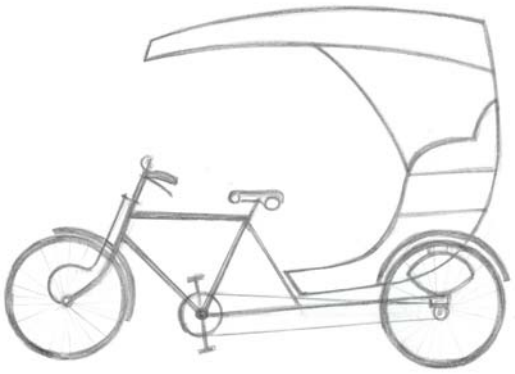


Fig. 3.40 Concept 1-delta configuration rickshaw with extended canopy

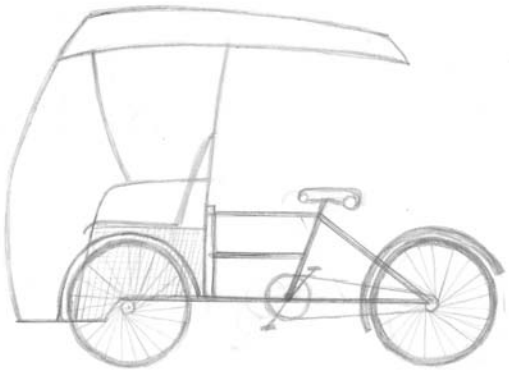


Fig. 3.41 Concept 2 –tadpole configuration rickshaw with extended canopy

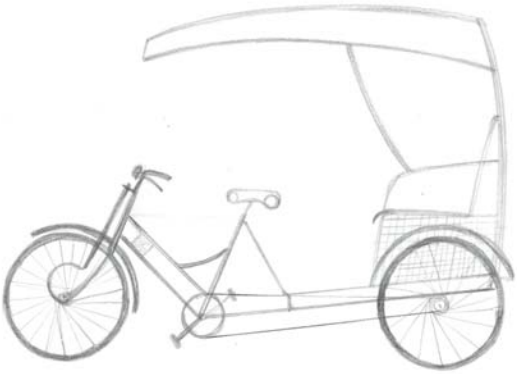


Fig. 3.42 Concept 3 -delta configuration rickshaw in mild steel structure with extended canopy

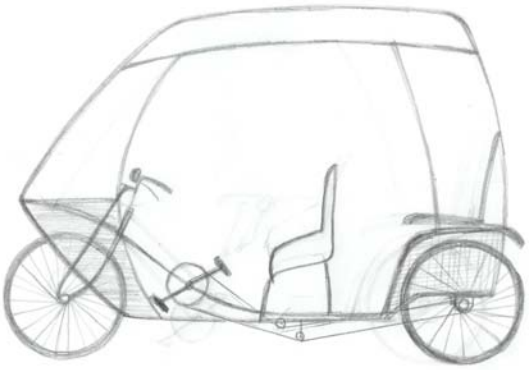


Fig. 3.43 Concept 4- rickshaw based on trike designed earlier with recumbent style pedaling

Fig. 3.44 Concept 5 -rickshaw based on a bicycle and a side car in mild steel structure with extended canopy

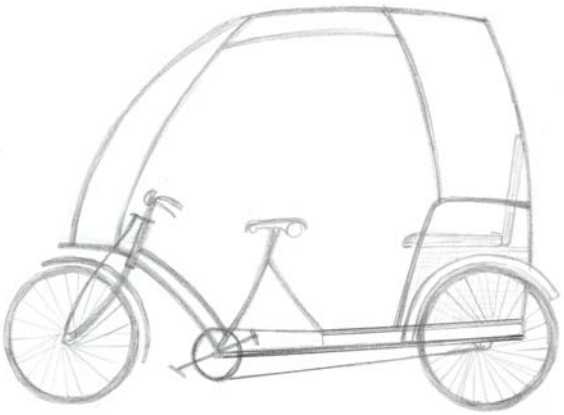


Fig. 3.45 Concept 6- rickshaw based on trike designed earlier with upright style pedaling

3.6.3 Synthesis of possible solutions

Third step in feasibility study is the Synthesis of possible solutions. Synthesis in design vocabulary implies combining or bringing different ideas to produce an integrated whole. In this step, the project as a design undertaking is characterized. This activity requires innovative and creative effort, creativity being an essential ingredient for product design. Creativity in design context can be defined as "A talent for discovering a combination of principles, materials or components, which are especially suitable as solutions to the problem in hand" (Chitale and Gupta,1999). The following possible solutions of the previously identified problems were arrived at through the preliminary design and generated concepts:

- Aerodynamic orientations of the proposed design to provide contemporary aesthetics, dynamic form etc. from concept 4
- Reinforcing the platform for enabling it to support the structure for canopy and luggage etc. for concept 4
- Optimizing the available space below the passengers' seat in concept 4
- Possible structure enveloping the driver and passengers as in concept 6

Any product designed in a particular context (in this case North Eastern Region of India) has to be possible to be realized physically having enough economic worth to be accepted by the target population and should be financially feasible to be undertaken by any business houses to manufacture and deliver to the end users. If the product does not meet any of these criteria, then it is not worth the effort to consider it for any further development. Thus these criteria were chosen for evaluation as provided in Table 3.6 in p 97. These are also the prime criteria mentioned in the Morphology of Design propagated by Morris Asimow, that was followed in this research activity.

Similarly other parameters used in Table 3.7, p. 101 were derived from the design briefs mentioned in the thesis and are basically related to the design brief.

3.6.4 Physical realisability of the concepts

Fourth step in feasibility study is the Physical realizability of the concepts. The challenge was to evaluate the possibility to accomplish such a practical physical embodiment, as is conceptualized. The elements and results of a new concept were visualized. It was found that the concept of the tricycle rickshaw can be realized physically. This is possible, through outsourcing of existing components and MS fabrications. Finishing in automotive paints are easy and concept makes it possible to fabricate these through mass manufacturing process using assembly lines. Manpower required is readily available. Setting up of a facility for manufacturing the rickshaw is possible within Rs. 1.00 Million.

3.6.5 Economic worthwhileness of the concept

Fifth step in feasibility study is the Economic worthwhileness of the concept. Unless the concept of the tricycle rickshaw is able to pass the test of economic worthwhileness, it is not going to be considered as a proper subject of product design. Literally translated, this means that the tricycle rickshaw must be "… of sufficient value to repay off effort" (Chitale and Gupta,1999). Regarding value as given above, its meaning depends on the evaluator of the concept, his viewpoint, and the prevailing circumstances and context. Thus it is singularly personal. Value can only attain objective measure in the market place. Applying this instrument of measure, the results can be quantitatively expressed in monetary terms. Many a times highly sophisticated and difficult to apply indirect tools must be used for their measure.

For tricycle rickshaw, utility is a good measure of economic worthwhileness. On a comparative basis, a rickshaw costing Rs. 6,500.00 with 4 years of useful life has a higher utility than a rickshaw with costing Rs. 6,000.00 with 3 years of useful life. Also when the rickshaw puller with the new design can earn Rs. 100.00 per day and pays Rs. 25.00 per day compared to existing rickshaw puller earning Rs. 80.00 per day paying Rs. 20.00 per day as hiring charge the utility of the new rickshaw is higher. This additional earning can be ensured through ease of operation due to less fatigues resulting out of protection from the adverse element of nature, better alignment of the rickshaw, attraction created to the user due to better ergonomics, actual and perceived safety etc.

A producer and a consumer attach different values set to a product. From the point of view of the producer, who must acquire the requisite resources of raw materials, energy, capital and manpower from the open market, their value of acquisition can be determined objectively. The final product by transforming the input resources and after its completion is returned to the market place. Thus the value can be determined and comparison of the input-output values is possible. Once the input value of the material taken through the production process has increased the output value sufficiently to continue it, the production process is considered to be economically worthwhile. This can be extended to the distributor in the same manner. However against the above logic, a consumer attaches value to product only if it meets some of his needs.

Considering both the producer and the customer, the tricycle rickshaw concept was found economically worthwhile. A producer can manufacture the tricycle rickshaw to add value and generate wealth and a customer - in this case a puller can use the tricycle rickshaw to enhance his earning and still be comfortable. From the point of view of a passenger, he can have better comfort, safety and convenience during his travel which he deserves after paying the fare compared to the existing rickshaw.

3.6.6 Financial feasibility

Sixth step in feasibility study is the financial feasibility. A project cannot be realised if it is difficult to mobilize resources for its implementation in spite of being a meritorious one from every point of view and having great economic worth. Therefore it is essential to evaluate the tricycle rickshaw design project from this aspect. On actual scouting, the developmental expenditure was sponsored by North Eastern Development Finance Corporation (NEDFi). Once the tricycle rickshaw design was ready and functional prototype was tested, an NGO came forward to manufacture under Rickshaw Bank and this effort itself was funded by various corporations. Thus the concept proved economically worthwhile and financially feasible.

The last three steps, Physical realisability, Economic worthwhileness and Financial feasibility of the concepts worked like sieves. Physically realizable solutions passed through the first sieve; solutions possessing economic worthwhileness for producer/ manufacturer, distributor and consumer passed through the second sieve and financially feasible solutions passed through the third sieve. The solutions passing successfully through each of the three sieves was the useful set of solutions. In case of this research work, the conceptualization itself was constrained such that concepts created were physically realizable.

For evaluation of the concepts, a mixed group of 30 subjects comprising of 15 students, 10 staffs and 5 faculty members currently using traditional rickshaws as local transportation medium were selected randomly from the IIT Guwahati community. They were briefed about features of various concepts. Based on their expertise, they were requested to evaluate the concepts. They were also provided with cost structure of each concepts calculated beforehand. Rickshaw pullers currently using traditional rickshaws were also randomly selected from areas near IIT Guwahati and near the office of Centre for Rural Development, Guwahati and interviewed to know how much amount they will be able to return per day and their preferable repayment period. From the financial institutions, it was found out what will be the rate of interest on loans to be provided to the rickshaw pullers. These steps provided with sufficient data for finding out the economic worthwhileness and financial feasibility easily.

A Preferential Matrix was created with the concepts and their physical realisability, economic worthwhileness and financial feasibility (Chandra, 2004). Comparative grading of the concepts were carried out based on their physical realizability, economic worthwhileness and financial feasibility. Since there are 6 concepts, grading values were from 1-6; 1 being lowest and 6 being highest. In case of physical realizability, the lowest grade was given to the concept that can be realized with highest difficulty and highest grade to the concept with least difficulty.

For economic worthwhileness, the lowest grade was given to the concept that can be least economic worthwhile due to the factor that the concept being unfamiliar in Indian context may not pick up or chosen by the manufacturer and customer and highest grade

to the concept that are novel but with familiarity and can be conveniently manufactured and priced competitively.

For financial feasibility, the lowest grade was given to the concept that will require maximum in terms of capital investment and resources such as marketing effort and hence can be least feasible financially and highest grade to the concept that are novel but with familiarity and can use maximum materials and components from existing tricycle industry and hence can be conveniently manufactured and priced competitively. With the above criteria, a preferential matrix was tabulated and is given in Table 3.6

Table 3.6 Preferential Matrix based on Physical realizability, Economic worthwhileness and Financial feasibility (Summary based on IIT Guwahati students, faculty and staff numbering 30, value given here is the average ones)

Concepts⇨	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5	Concept 6
Physical realizability	6	1	4	3	2	5
Economic worthwhileness	3	1	4	5	2	6
Financial feasibility	3	1	4	5	2	6
	12	3	12	13	6	17

Discussion regarding tricycle rickshaw concepts:

Amongst the tricycle rickshaw concepts, the concept 1 can be easily realized physically. However addition of extended roof permanently over the passengers and puller solve the existing problem partially and it is being done in a very cheap and localized manner. It alone does not make this an economically worthwhile project for investment competing with the existing decentralized manufacturer. Regarding financial feasibility, the decentralized manufacturing units fabricates rickshaws with minimum or negligible overheads. The owner themselves works as workers and hence works without additional hired person. Thus earning their livelihood is the main return from their business. These manufacturers also fabricates only a few rickshaws at a time based on demand and after selling these starts the fabrication for more and extensively uses mild steel components made by blacksmiths out of scrap materials that contributes to lower cost. This keeps their working capital low. Thus manufacturing the new rickshaws as per concept 1 will be financially unviable because of cost of manufacture will be higher and competing with the existing decentralized manufacturer will be difficult with marginal changes in features, since form wise it will be very similar to the existing rickshaws.

Concept 2 is radical in Indian context. It will be also most difficult to realize physically with existing level of skill of the rickshaw fabricators or small enterprises due to unfamiliarity with this type of passenger rickshaw configuration. Braking and efficient steering is an issue with this concept. Thus its physical realization is linked to complex fabrication compared to traditional rickshaw. The unfamiliar design along with additional

mechanism to be made specifically for this concept will require enhanced cost inputs and its economic worthwhileness compared to traditional rickshaw is much lower, since it can not be ascertained whether it will be easily acceptable or not to the users, both passengers and the pullers. In absence of clear indications of economic worthwhileness, it is difficult to ascertain its financial feasibility. However creating awareness and changing mindsets of users will involve huge financial outlay. Thus financially, it is not feasible immediately.

Concept 3 is physically easily realizable although it does not meet all the design parameters. Process and design being simple, it can be manufactured in a financially feasible manner and it is economically worthwhile.
In fact most of the imitation of the newly designed tricycle rickshaw is in this configuration. (Fig. 7.29, 7.30, 7.34 and 7.35 pp 227-228). In the preferential matrix, Table 3.6, p 97, this concept earned the third highest total points.

The concept 4 can be realized physically but with comparable difficulty. Only advantage is that, a physical model in terms of the trike was available for its execution. Due to its novel features and configuration, it can be economically worthwhile since its pricing will not be directly depends on the common tricycle rickshaw and its manufacturing will be financially feasible, considering the available scopes for new rickshaws.

Concept 5 although appears to be simple has many difficulty in its physical realisability. First a bicycle if taken as it is has shorter wheel base compared to a tricycle rickshaw to accommodate another row of seat for passengers. If a side attachment is used with an integrated roof makes it unstable and unbalanced specifically for two passengers. Also with existing bicycle, additional carrier to be manufactured with roof / canopy will not be economically worthwhile, because it can be sold only as an accessory. Thus financial feasibility is also low.

Amongst the tricycle rickshaw concepts, the concept 6 can be comparatively easy to realize physically with existing level of skill of the rickshaw fabricators and small enterprises engaged in fabrication of mild steel items such as furniture and equipments due to familiarity with this type fabrication and also familiarity with the passenger rickshaw configuration in spite of using a space frame or monocoque frame. Integration of extended roof permanently over the passengers and puller solve the existing problem and it is being done in a very competitively and localized manner. This concept meets most of the terms of design consideration for the design of the tricycle rickshaw. This makes the concept an economically worthwhile project for investment competing with the existing decentralized manufacturer. Regarding financial feasibility, in this concept, almost everything including the mainframe are fabricated in house and makes this more cost effective compared to the decentralized manufacturing units that fabricates rickshaws in spite of their minimum or negligible overheads, since this lower overhead expenses is balanced through lower cost of off the shelf components for fabrication of the rickshaw. Also the new rickshaw will be more durable and variety of materials and

types of skill required is reduced. Thus manufacturing the new rickshaws as per concept 6 will be financially feasible although the cost of manufacture may be marginally higher. Competing with the existing decentralized manufacturer will not be difficult with considerable changes in features in spite of form wise it will be somewhat similar to the existing rickshaws.

Based on the above Concept 6 qualified through the three parameters of physical realizability, economic worthwhileness and Financial feasibility and considered for detailed design of the tricycle rickshaw.

3.7 The Preliminary design

The preliminary design of the tricycle rickshaw was intended to establish an overall concept for the project and served as a guideline for the detailed design. Decision for commitments for the next phase was based on a comprehensive evaluation of the design concept carried forward the main objective being optimization in all aspects.

3.7.1 Selection of the design concept : Preferential Matrix

First step in Preliminary design is selection of the design concept. The most promising design concept out of the set of useful solutions developed in the feasibility study was identified on the basis of utility (Gupta and Murthy, 1980). In Oxford Dictionary, Utility is defined as usefulness, useful thing. In design the concept of utility is used. A customer evaluates a product on a number of diverse attributes, such as cost, safety, ease of use, etc. For a customer to be able to make a rational choice of a product, these evaluations on different attributes are required to be combined to provide a composite index. To achieve this, it is essential that a common scale of measurement need to be evolved. One example is utility scale. This scale is based on the personal preference of the evaluator and therefore very subjective. The overall utility of a product supposedly measures the usefulness of that product in the view of the evaluator. Thus when the evaluator assigns a higher utility to a product (say P1) compared to another product (Say P2), it indicates that the evaluator considers P1 to be more useful that P2. In other words, the evaluator prefers P1 over P2. The utility of a product on a particular quality attribute measures the usefulness of that particular characteristic of the product. The overall utility of a product is the sum of utilities of each of the quality attributes.

Regarding the concepts, these were evaluated in terms of utility. In addition to basic use of a tricycle rickshaw in carrying passengers, these are also used for various other useful work and concepts having better provision to meet these needs were considered to have better utility value. For example, in India, tricycle rickshaws are used for transporting goods, vegetables, fruits and grains, building materials such as cement, LPG cylinders(In spite of being dangerous, carrying of LPG cylinders in rickshaw is very common in North East India, since these are always in short supply and the distributors hardly deliver

these at home), hardware materials etc. List of tasks performed through a tricycle rickshaw is almost endless. Thus it is important that concepts meet these requirements.

From the point of view of the pullers, it was the cost of ownership, comfort for operating it, earning per day, maintainability etc.

From point of utility it was found that concepts 3 and 6 with flat foot board and space below passenger's seat were the best amongst the concepts.

The various other important factors such as reliability, safety, cost and user friendliness were given due consideration. The design concept with the highest point rating in the matrix emerged as the best concept. Since there were 6 concepts, grading scale was selected from 1 to 6, 1 being lowest in preference and 6 being highest. As mentioned in the last part of section 3.6.6 in p 96, the same group of 30 subjects from Department of Design, IIT Guwahati community selected earlier that evaluated the parameters mentioned in Table 3.6, p 97 along with various other persons including stake holders like tricycle rickshaw pullers: 10 numbers and passengers: 10 numbers, traditional rickshaw owners: 5 numbers, executives from NGO: 5 numbers, all of them selected randomly were involved for evaluation of the concepts on the basis of second set of parameters mentioned above.

Members of this enlarged group were engaged for evaluating and providing scores for the concepts based on their background.

For overall design and aesthetics, persons conversant with design, design professionals were involved.

For human comfort for users, pullers and passengers currently using traditional rickshaws were involved. They were briefed about features of various concepts and as and where possible jigs were made for actual physical assessment simulating the concepts, e.g. height of the foot board, handle etc.

Table 3.7, p 101 is the summarized response based on above factors and preferential ratings for the concepts. The last row in the table provides the ranking of the concepts.

Table 3.7 Preferential Matrix based on Design parameters

Concepts⇨	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5	Concept 6
Overall Design	1	4	3	5	2	6
Aesthetics	1	3	2	6	4	5
Human Comfort Factors - overall	3	1	4	6	2	5
Puller						
Access	4	2	5	3	1	6
Ease of operation	4	3	5	2	1	6
Protection from the elements of weather	1	4	3	6	2	5
Passenger						
Access	1	6	4	3	2	5
Protection from the elements of weather	1	3	4	6	2	5
Seating posture	1	3	4	6	2	5
Space for luggage	1	4	5	3	2	6
Safety	2	4	3	6	1	5
Manufacturing	4	2	6	3	1	5
Materials used	1	3	4	5	2	6
Manufacturing Process	1	3	4	5	2	6
Manufacturability by SMEs	1	2	5	4	3	6
Eco-friendly	1	3	4	5	2	6
Maintenance	1	2	5	4	3	6
Cost	6	1	4	2	5	3
Reliability	1	3	4	5	2	6
Space for Advertisement	1	4	3	6	2	5
Total points	**37**	**60**	**81**	**91**	**43**	**108**
Rank	**6th**	**4th**	**3rd**	**2nd**	**5th**	**1st**

Thus out of the various design concepts, Concept 6 with space structure, also referred as monocoque structure appeared to be most promising. The same type of structure is used in cars and other modern vehicles. This structure apart from meeting the objectives of the project also provides various utilities as envisaged. Such a structure gives optimum safety to the passenger and driver. The structure seems to be highly reliable and cost effective.

3.7.2 Formulation of mathematical model

Second step in preliminary design is formulation of mathematical model. Design proceeds from the abstract to the concrete. 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 optimized on a

computer. In case of the tricycle rickshaw design process, formulation of mathematical model was required regarding stability of the tricycle rickshaw and its relationship with respect to change in the Centre of Gravity. In the case of selection of gear ratios, simple mathematical model were formulated using existing formula. Here the constraints were known since existing gear wheels and pinions etc. from the tricycle and bicycle industry were to be used. Table 5.6 p 172 compiled in Chapter 5 illustrates the possible gear ratios with existing gears and pinions.

3.7.3 Sensitivity analysis : cost and material effect

Third step in preliminary design is sensitivity analysis. Theoretically, a system is visualized 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 the performance of the system is to the adjustment of several design parameters. Those which critically affect the performance must be carefully adjusted, whereas others which are less critical can be adapted to suit convenience. In recent years, Taguchi the Japanese pioneer of quality control has been advocating the concept of robust design (Otto and Wood, 2001). According to this philosophy, the design parameters that on changing result in a large change in undesirable output from the system should be deleted. However in case of the tricycle rickshaw, most of the physical parameters are already constrained due to choice of materials and processes available for its manufacture.

Therefore sensitivity analysis in terms of other factors that are critical in case of the tricycle rickshaw was considered. The one of the foremost critical factor is the cost of various components and sub-assemblies and their availability. This was the determining factor for the selection of technology for the manufacturing, safety, operation and maintenance. Thus selection of these items and their cost sensitivity on the total cost was more important and thrust was on this aspect to choose and eliminate parts and sub-assemblies to keep the tricycle rickshaw within the reach of its targeted users.

3.7.4 Compatibility analysis

Fourth step in preliminary design is compatibility analysis. Theoretically a system or a complicated product or a device is considered as an object consisting of a combination of objects on the next lower order of complexity. In a complex system such constituent objects are referred as sub-systems.

Straightforward considerations such as geometrical tolerance or chemical tolerance may be involved in compatibility in normal situation. Critical problems of compatibility arise when interacting co-members require matching operating characteristics. This may be due to one member is in series with another and the outputs of one are the inputs of the other. One example of this aspect of compatibility is propulsion system used in the tricycle rickshaw involving pedals, cranks, chains, sprockets, free wheels axles, bearing,

bearing block, brackets for fixing the bearing blocks to the frame of the rickshaw and finally the wheels as one subsystem and the tricycle rickshaw frame as another subsystem. To obtain optimum output from the system using human energy, each subsystem has to be compatible with each other in many points rather than straight forward considerations of geometrical tolerances.

Considering the tricycle rickshaw as a system, various sub-systems were established. The sub-systems are:

- Platform also can be called as chassis
- Steering and control such as brake, horn
- Propulsion system with pedals, chain, wheel, mudguard etc.
- Space frame enveloping the puller and the passengers
- Seating arrangement for the puller
- Seating arrangement for the passengers
- Space for carrying luggage
- Space for advertisement

Special attention was given to each subsystems and its part and components individually. For example, to ensure proper matching of the ends of two tubular elements, these were cut at a predetermined angle. The stability, strength and rigidity of the system was ensured by using rigid hollow pipes.

3.7.5 Stability analysis

Fifth step in Preliminary design is Stability Analysis. Systems and devices that designers and engineers design are often exposed to a dynamic environment. Tricycle rickshaw as mentioned earlier is a tricycle. Thus for stability analysis of a tricycle, it is important to consider different configuration of a tricycle. Based on the configuration, the stability varies. This is discussed below.

3.7.5.1 Comparison of delta and tadpole layout tricycles

Tricycles are classified as delta and tadpole configuration based on the layout of the wheels as mentioned earlier in sub-section 1.2.3.2 of Chapter 1, p 12. In the case of delta tricycles, the drive is often to just one of the rear wheels, though in some cases both wheels are driven through a differential. A double freewheel, preferably using no-backlash roller clutches, is considered superior. Tadpoles are generally rear wheel drive.

Recumbent tadpole trikes often brake one wheel with each hand, allowing the rider to brake one side. This has led to geometry (misnamed centre point steering) with a kingpin axis intersecting the ground directly ahead of the tyre contact point, producing a normal amount of trail. This arrangement, elsewhere called "zero scrub radius" is used to mitigate the effects of one-sided braking on steering. It is said to allow the rider to steer by braking. Zero scrub is generally avoided on the grounds that it reduces steering feel and increases wandering. The alternative is to use standard Ackermann steering

geometry, perhaps with both front brakes operated by the stronger hand. The KMX Kart stunt trike makes a feature of allowing the rear brake to be operated separately, allowing "handbrake turns".

Tadpoles are more stable under braking (Horwitz, 2006) and more likely to slide instead of roll; front braking hard on a delta requires the vehicle to steer almost straight to avoid tipping. The balance of friction patches and rolling resistance also means that tadpoles tend to understeer and deltas oversteer.

Both delta and tadpole type can be made low and large enough to be difficult to overturn on dry pavement, but usually the centre of gravity is high enough that tipping is possible, especially if the rider does not lean into the corners. Adults may find upright tricycles difficult to ride due to familiarity with the counter-steering required to balance a bicycle. The variation in the camber of the road is the principal difficulty to be overcome once basic tricycle handling is mastered. Recumbent trikes are less affected by camber and, depending on the riding position, capable of very fast cornering. A few trikes are designed to tilt into the corners much as a bicycle does, and this also renders them more comfortable on cambered roads. They are known as tilting three wheelers (TTW's).

A selected concept of a tricycle rickshaw based on a space structure is based on delta layout. The drive is to just one of the rear wheels. This has a major drawback of toppling at steep turn. A stand still tricycle rickshaw is apparently a stable and static structure, but when moving on road, it gains momentum and its centre of gravity changes with the movement. This can cause an accident when taking a turn and result in grievous injury to the puller and the passengers. This is very much prevalent when puller applies the brake provided in the rickshaw. One reason being that a traditional rickshaw is provided with brake only for the front wheel. This leaves the rear wheels to keep on rolling during braking action. Another reason is that the Centre of Gravity of the traditional rickshaw is high and this can be attributed to passengers' seat placed at a much higher position from ground. This also causes difficulty for access. It is essential to provide stability to the newly designed rickshaw in similar conditions of use. To achieve this, from the very beginning, effort was to lower the position the passengers' seat height to bring down the Centre of Gravity. Also effort was made during detail design phase to ensure that the center of gravity (C.G.) of the tricycle lies within its footprint even when it is dynamic.

The second aspect is to provide a brake system to control the rear wheels. Challenge was to provide a low cost effective mechanism. This was achieved and the dynamic stability was increased.

The initially proposed height of the tricycle was also reduced to lower down the C.G. since during strong wind the torque imparted by the wind could have toppled the structure. To minimize aerodynamic resistance, the two sides were kept open. Use of Sandwich platform (which has been proved to be more stable and also shock absorbing) provides inherent stability during unexpected dynamic environment.

3.7.5 Formal optimisation

Sixth step in preliminary design is formal optimization. Till this point effort was not directed to fix all the major design parameters at definite and 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 values, there is one superior to all others called as the optimum combination. The process for finding this combination is called *optimisation.* Theoretically the optimum combination satisfies all the design constraints and therefore could be expected to work. In case of the design of a tricycle rickshaw, one major constraint of design is to use the existing parts from the tricycle and bicycle industry and hence, compatible subsystems were initially identified. The scope left out was space structure and its dimension and this was optimized based on anthropometric data available to accommodate 5^{th} and 95^{th} percentile of Indian population for various parameters as applicable.

After forming a basic idea of the main structure the sub-systems were studied. The various individual parts were now provided with the dimensions. These dimensions were checked and optimization performed. In the accepted preliminary concept, for passengers' seat, all the four legs were considered. However with the help of proper optimization later, the hind legs were eliminated. The space structure was modified several times to improve upon. Cross binding bars provided on the roof in addition to its basic function of binding the structure to impart rigidity also supported the hood.

3.7.7 Projection into the future

Seventh step in preliminary design is projection into the future. Two main questions that require to be considered at this stage are:

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

Aim was to reduce the development period for the tricycle rickshaw so that by the time it comes in the market, possible competitor would not be able to launch a superior vehicle in the context of design that the project was undertaken. Actually all the existing and eager technology provider to the first user of this tricycle rickshaw in Rickshaw Bank project, Centre for Rural Development, Guwahati lost in the face of the new design.

Newer versions of the tricycle rickshaw (later branded as Dipbahan, Dipbahan + etc. were developed quite faster and also variations based on the same platform for other applications like Garbage disposal (tricycle designed was branded as *Pariskar*-Cleanliness), School van (tricycle designed was branded as *Ankur*-Germination) etc., came into existence much faster.

The other aspect of the future projections is the expected useful life of the tricycle rickshaw in expected operating environment. This was estimated at minimum 5 years with due care taken by the rickshaw puller.

A consumer may have queries related to the need of the redesign of the old model of a rickshaw. In such a case, he should appropriately question himself about the basic need of a rickshaw or "Why a rickshaw?" which on basis of socio-economic environment itself answers the question. The simplicity of the model increases its chances of greater use in future. In today's world, "ecology" seems to be the watchword. Being a pollution free product, it encourages the concept of "*Green Engineering*", which will be given great importance in the future.

Another projection is the conversion of this tricycle rickshaw to electric powered ones using photo voltaic solar panels for charging the storage battery and propelling the rickshaw through electric motor. During the design phase, these possibilities were considered and formed one of the constraints in the second layer of priority.

3.7.8 Prediction of system behaviour

Eighth step in preliminary design is prediction of system behaviour (Chitale and Gupta, 1999). The tricycle rickshaw considering as a system to be successful in the marketplace must function in an acceptable manner throughout a reasonable service life of 5 years. This minimum life expectancy for the newly designed tricycle was thought to be a reasonable expectation from the rickshaw pullers and was guided by the fact that municipal councils and corporations in North Eastern Region of India at present are renewing the licenses of rickshaws only up to 5 years based on traditional rickshaws and their view is that after 5 years, these are not safer to be used for commercial use in transporting passengers. The implication of this on the design is that, all systems and subsystems must be considered for a period more than 5 years to meet this expectation.

The desired outputs, i.e. operating as a trouble free passenger carrier with ease for the puller and the comfort for the passenger over a span of time both at the start when the system is new and when it is coming to the end of its service life. However being a mechanical system, it is subject to wears and tears but attention was paid to the fact that wear out is even and moving parts can be replaced with readily available parts from the market to provide desired output through out the life of the tricycle rickshaw. Items requiring periodical replacement are: tyres & tubes, brake pads, sprocket and chain, bearings, foot pedal pads, top covering materials like synthetic tarpaulins, rain guards and seats etc. Once replaced when worn out, the tricycle rickshaw is expected to deliver the same output.

Instruction guidelines of DFA (Design for Assembly) and DFM (Design For Manufacturing) were followed and avoided excessive use of certain processes (like welding), which increased the average life of the component tremendously. The Super Structure-Space Frame was found to be stable.

3.7.9 Testing and validating the design concept

Ninth step in preliminary design is testing the design concept. The appropriateness of the design project and the resultant tricycle rickshaw can be tested through its use. Tricycle

rickshaw designed is not a purely evolutionary design to waits for the evidence for its utility to be revealed, the new design concept was tested with a scale model and through computer simulation using AutoCAD and Rhino solid modeling CAD software. Various views of the selected concepts in CAD are shown in Fig.3. 46-3.52, pp 107-108.

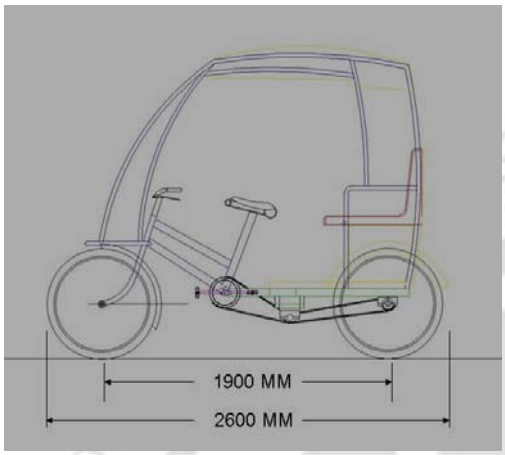


Fig. 3.46 Side view of selected concept in AutoCAD

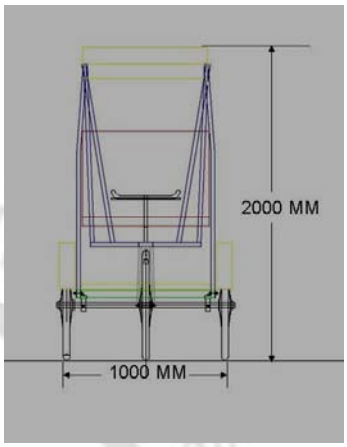


Fig. 3.47 Front view of selected concept

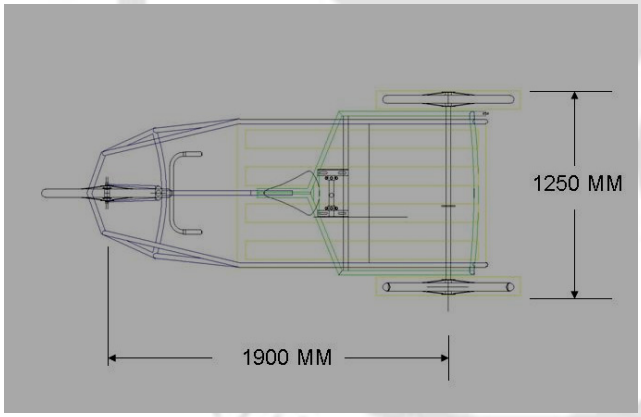


Fig. 3.48 Top view of selected concept in AutoCAD

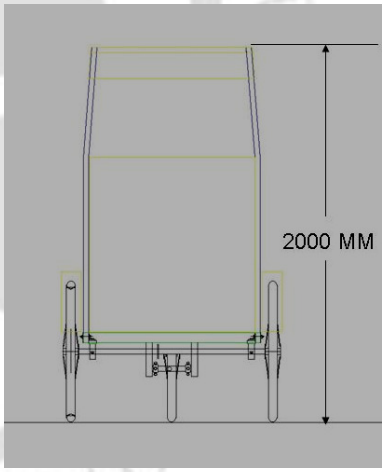


Fig. 3.49 Rear view of selected concept

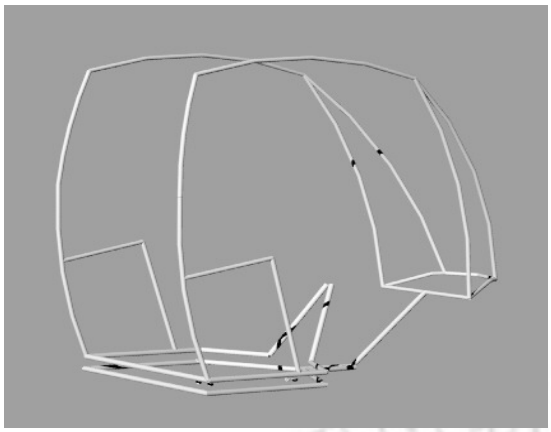


Fig. 3.50 Basic body shell in three quarter rear view in solid model of selected concept generated using Rhino CAD software

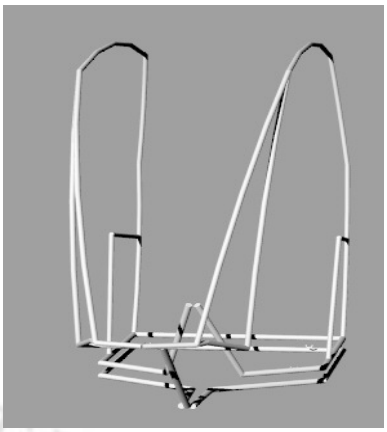


Fig. 3.51 Basic body shell in three quarter front view in solid model of selected concept generated using Rhino CAD software

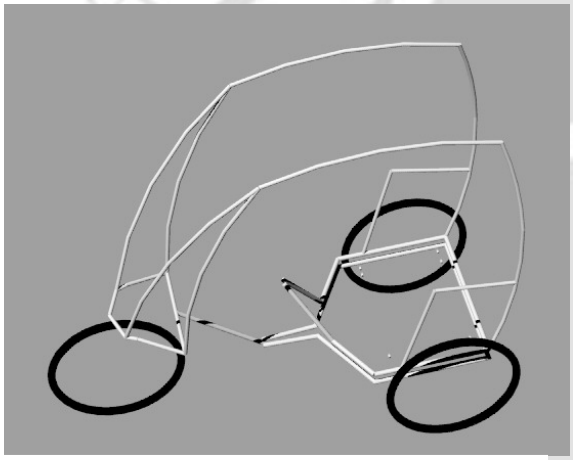


Fig. 3.52 Basic body shell with wheels in solid model of selected concept generated using Rhino CAD software

CAD was followed by construction of the prototype in materials other than the ones in which the actual production versions will be manufactured described in Chapter 5 (Fig. 5.6 – 5.10, p 149). This novel design of the tricycle rickshaw relying more on innovation required speedier implementation before it is overtaken by next wave of design and technology as well as changing socio-economic and political situations. This is very context specific and found to be very relevant in India and North Eastern Region of India in particular. It is seen that many old products remain in production till some new development takes place. Once a new product is introduced that gains market acceptance, these is a flood of products in that category that are either developed based on the new products or and blatant copies of the same product. One case in hand is electric bike. It was initially introduced in India way back in eighties. That product was not appealing and did not succeed. However at present, there are several manufacturers producing electric bike in India after the success of one product in the early 2006.

Similar is the case with Design of Dipbahan. The first commercial tricycle rickshaw was released within 3 months of fabrication of the beta model prototype in the Department of design, IIT Guwahati. As anticipated, it was found that after its successful introduction at the end of 2004, there are various organizations and persons bringing out tricycle rickshaws those are more or less copied from Dipbahan. Surprisingly many of these are in line with the initial concepts that the author did and rejected due to various shortcomings in these concepts and persons and organizations trying to bring out new models are bringing out similar products.

It was also found that after Synthetic canvas for the roof, seat etc., was introduced in the Dipbahan, this is being followed even by the normal rickshaw manufacturing units.

Coming to technology aspect, after Dipbahan^{+} version was released with gears, there are few persons that modified the conventional rickshaw in similar lines. However, since the perfection and tolerance required for the system was not easily achieved in traditional rickshaws due to the fabrication imperfections, these has not been successful so far. But in places like Bihar state, where it is very difficult to enforce Intellectual Property Right, traditional rickshaw makers are shifting to Mild Steel fabrication copying the Dipbahan in a large scale, except that even now they are making these mostly out of scrap material to meet the lower cost target for these rickshaws. Thus common technology used for fabricating rickshaw with wood, etc. are becoming obsolete.

3.7.10 Simplification of the Design

Tenth step in Preliminary design is Simplification of the Design. As the design of the tricycle rickshaw moved through various steps, the original concept became more complicated. The apparently simple and the obvious were hard to achieve. Simplification of Design depends upon various aspects.

- First, expertise available with the designer regarding the specialized area one is working with.
- Second aspect is search of existing products or similar product.
- Third is rewriting the function of the products/parts etc.
- Forth is use of Value engineering.
- Fifth is guideline for design for Manufacturing and Assembly.
- Sixth can be change of materials.

There can be more such aspects.

Out of the various possibilities as mentioned above, best possible aspect was tried out to simplify the design.

One of the most important questions mulled over again and again was whether the projected solution is the simplest and conceptualize alternative ways of simplifying the same. This yielded in innovative simple solution hitherto unthought-of solutions. One such solution is for the passengers' seat structure. Initially, the seat structure was designed and conceived as foldable. Although the concept was brilliant and could have provided an innovative feature very much desirable to facilitate transportation of goods,

this also made the monocoque structure of the tricycle rickshaw weak. This seat structure can not be load bearing any more like the one actually executed, manufactured and marketed in the newly designed tricycle rickshaw providing the much needed triangulation and rigidity. Thus the passengers' seat was kept fixed type reducing the initially planned four posts to only two through elimination of the front posts (Fig. 5.23, p 161).

The detailed design of the tricycle rickshaw discussed now onwards carries the overall design concept, developed in its preliminary stage, to its final product form. To do so, the overall concept was brought to a state of design that is clearly physically realizable. This state was achieved by finally constructing a prototype from a full set of design information, testing this prototype and making the necessary improvements in both prototype and design details until the tricycle rickshaw was satisfactory for production, distribution and consumption.

DESIGN DEVELOPMENT OF AN INDIGENOUS TRICYCLE RICKSHAW

Chapter 4

Detailed Design of a New Passenger Tricycle Rickshaw Dipbahan

4.0 Detailed Design

The concept evolved in the preliminary design, presented in previous Chapter, is the basis for the detailed design phase (Chitale and Gupta, 1999; Priest and Sanchez, 2001). It is aimed at furnishing the engineering description of a tested and producible design. Prior to the detail design phase, the design is characterised by greater flexibility. This provides for accommodating major changes in concept without greater financial burden. Concepts being exploratory in nature, flexibility are essential in seeking to reveal an adequate range of possible solutions.

4.1 Preparation for design

It is the first step in detailed design to fix the design specifically.

- Setting up priority criteria to be achieved

For any design idea to proceed further for physical manifestation needs financial support and a design team. Also relatively close estimates of time and money are essential prior to the design for final commitment. Theoretically and for practical reasons in a commercial set up, it is only the top management vested with the responsibility for the final economic success of a project (Chitale and Gupta, 1999), can make the decision to approve the necessary budgets or to suspend a project. Whereas in this tricycle rickshaw design development exercise other techniques of estimation were found to be very important which emphasises social cost benefit aspects in this socially relevant project to satisfy local transportation need and employment generation. Monetary gains to any corporate style manufacturing house was not considered, rather technology transfer to local entrepreneurs was the emphasis.

- Fixing the sale price, which determine the design features

Financial assistance to this project was provided by the North Eastern Developmental Finance Corporation, Guwahati (NEDFi) with full discretion to the Project Investigator to develop the design and the Executive Director of Centre for Rural Development, Guwahati, being the initiator for the implementation of the tricycle rickshaw in local market, set Rs. 6,500.00 (nearly the cost of the existing traditional tricycle rickshaw) as the cost target be achieved. The project timing depended on the academic schedule of the researcher and the lead time available with the implementing agency, in this case Centre for Rural Development , Guwahati, an NGO and Funding agencies. With discussion with these stake holders, project timing and duration was set. Leaving apart academic matters, actual duration of the project execution was three months to develop design concept, prototype it and make it ready for production. Design and technology transfer to be implemented in another two months.

- Optimising manufacturing facilities that can be demonstrated during technology transfer to local entrepreneur for the manufacture of the rickshaw

Physical infrastructure required for executing the concept for tricycle rickshaw design was readily available in the workshop of Department of Design, IIT Guwahati. A roller type pipe bending machine was fabricated in house (Fig. 4.1 and Fig. 4.2, p 113) and a

Fibre glass Reinforced Plastic (FRP) processing facility was established in the department. The above completed the preparation for design and initial infrastructure requirement for the tricycle rickshaw design development and prototype fabrication.

Fig. 4.1 Three quarter rear view of roller type pipe bending machine fabricated specially for the project purpose in the workshop of Department of Design

Fig. 4.2 Rear view of roller type pipe bending machine fabricated specially for the project purpose in the workshop of Department of Design

4.2 Planning for consumption

Third process in the production-consumption cycle (Chapter 3, Fig. 3.39, p 85) to be considered is consumption. Influence of consumption cycle (Chitale and Gupta, 1999) on a design is profound because it pervades all phases. Consumption as a process takes place after distribution of a product. In order to have a timely impact, in the time-pattern of the design project, most of the processes of consumption must be anticipated in the early stages of design. It is a diffused phase for the most part, mingled with and attached to the earlier phases concerned with the consumers' need and utilities. Consumer is the ultimate user of any product, so his perspective of the product should be the priority of the manufacturer. Planning for consumption is considered as a separate phase only to emphasise some of the special contributions which it makes in addition to its more general and pervading influences. The purpose of this phase is to incorporate in the design, adequate service features and to provide a rational basis for product improvement and redesign. So the influence of Consumption is profound and hence it pervades all phases. Design for consumption considered the following factors:

4.2.1 Design for Maintenance (D.F.M)

With unparalleled increase in equipment, locating repair personnel with required expertise is proving to be a major concern. Concerted efforts were being made to reduce the complexity of the maintenance function by designing for repair (Priest and Sanchez, 2001).

Reparability and Maintainability:

The meaning of reparability and maintainability are very similar and often used interchangeably.

- Reparability is concerned with the ability of product to be easily and effectively repaired at the production facility.
- Maintainability is concerned with ability of a product to be satisfactorily maintained throughout its useful lifespan.

Reparability design guidelines involves simplification, standardization, and inclusion of those features that can be of assistance to the technician. A goal is to design such that it can be operated and repaired by the least experienced technician.

The familiar Murphy's Law: "if it is possible to do wrong, someone will surely do it." is often proved right. The following considerations are must in a product with many subsystems containing various components:

- Locate maintenance controls in front of operator.
- Locate the most frequently failing parts for easy access.
- Locate assemblies such that they are easy to reach, for replacement.
- Standardise equipment (fastener sizes, threads, connectors, etc.), in order to minimize the number of tools required. In the tricycle identical nuts, bolts and screws were used to minimize the number of tool to be used.
- Use snap-in retainers, latches, spring-loaded clips, etc. to facilitate easy removal and replacement of parts.

Maintenance guidelines:

- Avoid horizontal surfaces with horizontal ledge pockets for cleaning.
- Use textured surfaces to camouflage imperfections and dirt.
- Use self-lubricating sintered or plastic bearings.
- Give continuous indication of state of wear
- Prevent assembly error.

The above set objectives were met and the followings are the features of Design for Maintenance aspects of the tricycle rickshaw.

- For ease of maintenance and replacement of worn out parts, most of the components that are readily available in the market are used for steering, transmission, wheels, tyres and tubes and brakes etc.
- It can be easily maintained through conventional rickshaw mechanics and fabrication units having welding machine.
- It was observed that there was difficulty in oiling and greasing of the rear wheel bearings by the rickshaw pullers. The bearing block used is designed to protect the bearing from dirt and dust by enclosing it. Only the axle comes out through the opening at both sides of the bearing block. Oiling and greasing require dismantling the bearing block. Normal rickshaw pullers as well as mechanics in

rickshaw repairing shop are not habituated at this. Therefore for oiling and greasing, mechanics used to charge higher amount. But with traditional tricycle rickshaw with locally fabricated bearing bracket keep the bearing exposed and this assist in frequent oiling and greasing without dismantling anything and hence becomes more convenient.

4.2.2 Design for Reliability

Reliability is a design parameter associated with the ability or inability of a product to perform as expected over a period of time (Priest, Sanchez, 2001). Design for reliability is a design discipline that uses proven design practices to improve a product's reliability. The key techniques are (Priest, Sanchez, 2001):

1. Multidiscipline, collaborative design process;
2. Technical risk reduction;
3. Commonality, simplification and standardization;
4. Part, material, software, and vendor selection and qualification;
5. Design analysis to improve reliability;
6. Developmental testing and evaluation; and
7. Production reliability.

Out of the above techniques 3, 4 and 6 were fully resorted to for design development of the Dipbahan. Various sub-assemblies were simplified such as seat structure, commonality in their manufacture was achieved and the process of their fabrication was standardised. Standard parts were selected from existing bicycle and tricycle parts manufacturers. Based on the spot survey of market feed back and testing of parts, only KW branded parts were used. Once Dipbahan was prototyped, this was extensively tested in field. To incorporate test results expeditiously, another rickshaw was immediately fabricated and tested in actual conditions of its intended use. This developmental testing helped in identify problems so that they can be corrected. The essence of this testing is failure corrective action. The reliability of a product improves through testing only when failures are corrected through changes to the actual design and manufacturing process.

In case of Dipbahan, the fracture of head pipes (Fig. 5.24, p 161) was noticed and design was modified as mentioned in Chapter 5 under section 5.4 in p 160. Similarly an element of chassis showed fracture (Fig. 5.30, p 164) and chassis design was modified as mentioned in Chapter 5 under section 5.5 in p 162.

4.2.3 Design for Safety

Objectives set for the tricycle rickshaw to be designed for the safety (Flurscheim,1983; Chitale and Gupta, 1999) aspect was as under:

The new tricycle rickshaw should protect the user from injuries and accidents resulting out of aberrations while passing other vehicles and hit and crashes by other vehicles

during operation on the road to the maximum extent possible by providing an enclosure where no other vehicle will directly hit the user. An integrated rolling cage is provided, in case of over turn it would protect the user – driver as well as passengers. This safety structure adds a new identity to the whole product.

The set objective was met and the followings are the features of safety aspects of the tricycle rickshaw.

- Bubble chamber like structure affords greater protection on the road in case of accidents.
- Prevents the occupants from receiving direct impact in accidents.
- In case of overturn the occupants are spared major injuries.
- The design of mudguard prevents passenger's hand from rubbing against the tyre.
- The greater foot platform area provides safety from slipping while climbing aboard the rickshaw.

There are also other aspects like the height of the platform for the passenger that he steps onto. Although Indian Anthropometric Dimensions for Ergonomic Design Practice written by Dr. D. Charabarti and published by National Institute of Design, 1997 was referred, the height of the stepping platform is dependent on chassis height of the tricycle rickshaw and this depends upon the diameter of the wheels used. Smaller wheel size makes the platform lower but also creates difficulty in pot-holed road for the puller. Thus with 28" wheel rim used in Dipbahan, the minimum height of the stepping platform from the ground is 14" provided that the platform is in line with the top level of the chassis. Thus this minimum dimension was taken and this is still found to be more than 6 " lower than traditional ones. Initially a stepping bracket was provided at 8" from ground level hanging from the chassis at the side of the platform for the passengers to get on, but was discarded after rickshaw pullers informed that this bracket comes on way to their legs when they are dragging the rickshaw in a slope.

Regarding the surface finish of the platform, it was fitted with chequered aluminium plate to protect against slippage by the passenger in the initial version of Dipbahan. After redesign in FRP material, the footboard in Dipbahan+ was designed with inbuilt strip on the surface and an edge bit to provide protection against slip by the passenger.

4.2.4 **Design for convenience in use** (taking into account Human Factors)

Ergonomics criteria are concerned with ways of designing machines, operations, and work environment so that they match the capabilities and limitations of human operators. Thus equal emphasis is given to human component in man-machine system.
The application of principles underlying this concept results in :

- Fitting the task to man
- Increasing safety and decreasing chances of accidents and adverse impact
- Increasing efficiency of man - machine operation

- Increasing productivity
- Increasing human comfort
- Optimising effort required to operate the machines.

In the present case there are two components in this system, the puller and the passenger. Objectives set for the tricycle rickshaw to achieve were as under:

Design and Human Factors considerations

i. Features of the new tricycle rickshaw should go along with relevant ergonomics criteria and strive for meeting various context specific requirements. Easy access is to be provided so that both the puller and the passengers can get in and out of the tricycle easily. During movement, sitting should be comfortable.
ii. It should provide protection to both the puller and the passengers from the elements of nature in an inclement weather without increasing the weight of the tricycle excessively in comparison to existing ones which will affect the manual maneuverability.
iii. To the extent possible, the effort required to operate the new tricycle rickshaw should be less and comparable with other benefits available in the existing ones.
iv. Keeping up to the present day transportation needs the new tricycle rickshaw should be able to take quick turns and acquire lesser space on road.
v. It should provide proper space for the user to carry luggage.
vi. It should provide a good feeling to the user, which enhances his desire to use a tricycle rickshaw.

The above set objectives were met and the following are the features of Design for Convenience in use aspects of the tricycle rickshaw (with respect to Ergonomics for rickshaw puller and passengers).

- The tricycle rickshaw has easy access to facilitate the user to get in and out of the tricycle rickshaw. For the puller this has been achieved by removing the top bar of the regular diamond frame made possible due to adaptation of space structure in the interim version of Dipbahan. In the modified Dipbahan^{+} version, the main frame along with chassis itself was redesigned and fabricated using 25 mm x 50 mm tubular section. For the passengers, the floor level was lowered to the chassis level and this coupled with support to hold for getting in and out of the tricycle rickshaw provided ease of access.
- The passengers should be made to feel comfortable. The angle between the seat and the backrest is maintained at around 100 degrees, which ergonomically is optimum angle for general purpose. The hand rest is given sufficient height of 19 cm from seat surface. The seats are at such a height so that passenger's legs can easily rest on the surface of the platform. It provides ample legroom for the passengers

- Proper space for carrying the luggage is provided. Reinforced platform for enabling it to support the structure and carrying of luggage is used; it optimizes the available space. Due to the flat horizontal floor and space structure with seat supported on side frames, ample space was available for carrying luggage. The space below the passenger seat is also enclosed from back by the rear panel and at the sides by side panels. These enclosures not only make luggage safe for transportation, but also protect it from soiling in rainy days from mud and muck that gets thrown by the wheels.
- Human dimension for Ergonomic seating arrangement (Chakrabarti, 1997) guided the structure.
- The overall structure protects the puller as well as passengers from the elements of nature (sunshine, rain etc.) though the weight of the tricycle remains similar to the existing ones.
- It is lighter than the traditional rickshaw by approximately 20% (Table 5.4, p 155)
- The shape of the design conforms to aerodynamic orientations with a space frame structure enveloping the puller and the passengers which smoothens manual maneuverability and also protects the occupants from direct impact by other vehicles due to accident as a result of crashes during operation on road to the maximum extent possible.
- The enclosure also acts as a rolling cage and protects the occupants in case of over turn.
- It has an aesthetically appealing form which is visually perceived light with contemporary visual identity giving it a feeling of sophistication, sporty and dynamic, and a overall new look among the existing models of tricycle rickshaws.
- A set of effective mudguards for use in rainy weather.
- Keeping up to the present day transportation needs, the tricycle is able to take quick turns and is stable with low centre of gravity due to lower passengers' seat position.
- It has been provided with a set of rear wheel brake so that it can be safely stopped by applying brake through the foot pedal. Normally, traditional rickshaws have front wheel braking only and this does not provide smoothness while slowing down the speed and sudden application of brake results in overturn during higher speed and frequent breakage of front axle.
- To facilitate insertion of advertisement for revenue generation to subsidise the cost of the rickshaw to make it affordable, the rear end has a almost flat panel.
- For the rickshaw puller clear vision is one of the most necessary requirement. The cone angle of 75 degrees in the vertical direction and 30 degrees in the horizontal direction is incorporated.
- To facilitate ease of getting on and off the rickshaw by the puller to his seat, some of the tie rods used in common tricycle rickshaws are removed and the chassis

frame is made in such a manner that the driver embark and disembark easily. The handle is also modified to incorporate easy riding.

4.2.5 Design for Aesthetic features

A product needs to be essentially aesthetic for enhanced acceptance and distribution (Chitale and Gupta, 1999). Objectives set for the tricycle rickshaw to be designed for aesthetic features are as under:

- It should have a contemporary visual identity of sophisticated, sporty and dynamic look.
- It should be light in weight and also as well as visually light yet stronger and rugged.
- Usage of curvilinear form and colour to specify identity of the product smoothes the eye while seeing and using the product (Flurscheim,1983; Chitale and Gupta, 1999).

Unlike conventional rickshaws with all linear and rounded elements, the newly designed tricycle rickshaw presents a sleek and streamlined appearance, enhancing the visual appeal of it. The outer line space structure (from the side) of the rickshaw forms a half ellipse, bubble like structure, which gives a continuous look to the structure and also improved the aesthetics of the rickshaw. The rod connecting the seat and the base of the handle bar is made curved for better look. Introduction of hood, back panel, floor panels, side panels, seat and mudguards in FRP in solid primary golden yellow colour, created an aesthetic identity of its own for Dipbahan^{+}, Fig. 5.35 and 5.36, p 168-169.

4.2.6 Design for operational economy

The newly designed tricycle rickshaw is a Human Powered Vehicle (HPV). Thus there is not many factors associated with this rickshaw in terms of operational economy. However maintenance and repair cost form one aspect for the operation of the rickshaw. Since most of the components requiring replacement due to wear out are available at the same price as that for other rickshaw, its operational economy is identical to that of the traditional rickshaw. In case of chain and sprocket system, it is better and long lasting due to the use of dual chain system. Also it was noticed that the wear and tear of tyres and tubes were less due to better alignment possible due to the accurate chassis etc. Unlike wooden, bamboo and canvas cloth used in the traditional rickshaw, the FRP components used in this design are long lasting and do not need frequent replacement. This makes the newly designed rickshaw better in terms of operational economy.

4.2.7 Design for adequate duration of services

It was observed that in case of a traditional tricycle rickshaw that is fabricated using variety of materials, the body fabricated out of wood covered with aluminium sheet, foldable canopy structure made out of bamboo and its cover stitched out of tarpaulin gets worn out fast. This requires replacement that can constitute significant percentage

compared to total cost of the rickshaw. The situation was similar to certain extent for the interim version of the Dipbahan with foot boards fabricated out of wood covered with aluminium sheet, seat and its back fabricated out of wood covered with canvas fabric over coir padding and canopy stitched in synthetic tarpaulin were used, Fig. 5.27, p 161.

To overcome this and match service life of different items, FRP components were introduced in Dipbahan^{+} (Fig. 5.35 and 5.36, pp 168-169). Thus the service life could be easily extended to at least 5 years. Normally Dipbahan^{+} fabricated in mild steel and FRP can last more than 7 years with proper care and periodic preventive maintenance like painting the mild steel structure. Usually chassis of Dipbahan^{+} is coated with rubberised anti rust, anti corrosion paint to protect it from rust and corrosion due to exposure to humid and hot condition which is specifically prevalent in North Eastern region of India as the project was undertaken primarily to suit the local condition. In this case anticipated service life of the newly designed tricycle rickshaw can be safely taken as 7 years.

4.2.8 Collection and analysis of service data to provide a basis for product improvement, for next-generation designs, and for extension of design to create differentiated, but related products.

The new concept of the tricycle rickshaw was fabricated and was put on road for trial to obtain specific feed back. Summery based on feed back and direct observation of usage of Dipbahan is given below and revealed that:

- It is used for various purposes by different category of passengers.
- Some of them use it for regular commuting.
- Some of them prefer it for marketing purpose including carrying LPG cylinders.
- Some of them use it for joy ride.
- Older generation use it for convenience of getting in and out and secured sitting.

Above findings helped in making Dipbahan^{+} more acceptable and user friendly and also revealed that, there are scopes for designing next generation of Dipbahan.

- It can be designed as a solar powered electric rickshaw, a pollution free mode of transportation and to extend its range of operation against Human Powered ones.
- An exclusive goods carrier van can be designed.
- Dipbahan to partially carry goods along with one passenger having one foldable seat to facilitate marketing activity can be designed.
- Another version of Dipbahan can be designed as tourist vehicle to facilitate visit to local tourism sites in a place.
- One more version of Dipbahan can be designed for mobile vending shop.
- Dipbahan can be designed as a mobile PCO with the existing wireless telephony.

The present attempt is focused on designing a passenger version tricycle rickshaw; next chapter of this thesis describes its prototyping and field testing.

4.2.9 Environmentally Conscious Design and Manufacturing (ECDM)

In the interim version of Dipbahan seat, seat back, hood, floor boards, mud guards, rain guards, side panels/ guards and rear panel etc. were designed using traditional skills of the persons in trade. Whereas in the Dipbahan^{+} version, most of these except the rain guards were replaced with Fibre glass Reinforced Plastic (FRP also called as GRP) components.

Fibreglass Reinforced Plastic (Das, 2007), is classified as thermoset plastic. As the generic class name indicates, items made in FRP are not formed by subjecting the monomer components of this plastic to heat and pressure. Rather it belongs to this class of plastics for the fact that, during formation of FRP, it becomes irreversible compound through cross linking of the monomers through addition of catalyst and accelerator. Unlike thermoforming plastics, FRP materials do not melt with the application of heat, but degenerates. This is similar with the other thermoset plastics like bakelite (phenolic formaldehyde), urea formaldehyde, melamine formaldehyde (used extensively to produce melmoware type of dinner wares) etc. Since FRP material can not be melted, it is not possible to recycle this waste like the thermoforming plastics. Thus after the completion of its useful life, all thermo set plastics including FRP ends up in the landfills. These are also not bio-degradable. Therefore their impact on the environment and ecology is tremendous. Waste is generated not only after the useful life is over, but also during the production stage. Thermoforming material waste generated during production are reused after it is shredded and mixed with virgin granules of the respective materials. FRP waste materials are not recycleable this way. These materials used to end up in the landfills and also adversely contribute to the cost of production.

However FRP making process is a very versatile process in terms of prototyping, limited edition production in addition to various mass produced products like helmet, automotive body components, in water and chemical industry as storage tank, boat and aquatic items etc. due to its high impact strength, chemical and corrosion resistance, etc. The process is also immensely popular due to the possibility of hand laying using cheaper moulds and patterns for small batch production. Waste generated during hand laying process is due to the removal of the edges of a product. This can be as high as 10 percent of the total production during component making.

In order to overcome the shortcoming of this versatile process and product in terms of waste generation, research work was initiated to productively reuse this waste. After appropriate study of the industry and experimentation, these process wastes were converted to valuable products that can be immediately reused as reinforcements to the existing products. This reduced the component cost by the same percentage to which the recycling of waste was carried out. In addition to this, it also made the FRP products reinforced with the recycled components much stronger with enhanced life. The process of conversion of the waste is based on the its compression moulding after impregnation with resin in desirable shape and form using moulds designed accordingly (Das, 2007).

Fig. 4.3 FRP wastes generated from components as side trimmings

Fig. 4.4 FRP wastes placed inside mould

Fig. 4.5 FRP wastes inside mould impregnated with

Fig. 4.6 FRP battens moulded by Recycling wastes

Fig. 4.7 Floor panels (shown above) and passengers' seat (not shown here) fabricated in FRP for Dipbahan+ required reinforcement. Wooden battens were used prior to FRP battens using FRP wastes was available

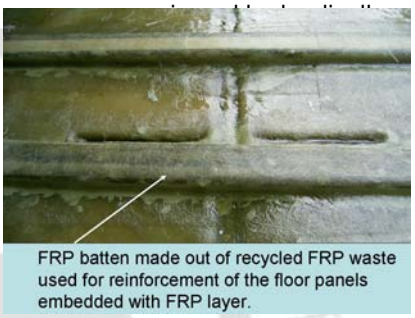


Fig. 4.8 Floor panels and passengers' seat fabricated later in FRP for Dipbahan+ are reinforced using FRP battens moulded from FRP wastes instead of wooden battens used earlier

4.3 Planning for retirement

Environmentally safe disposal of a product that has completed its useful service life is becoming mandatory both on the part of the manufacturer as well as the consumer/ user in the view of growing threat to the global environment (Otto and Wood, 2001) and became 4th phase in the production - consumption cycle of a product development. For sustainable development, recycle of various materials from a retired product is another essential factor. The forth process in the production-consumption cycle (Fig. 3.39, p 85, Chapter 3, Section 3.5.1) is essentially regarding the disposal of the retired product and also forms the seventh phase (Chapter 3, Flow Chart 3.1, p 83) in the morphology of design process (Chitale and Gupta, 1999). Any consumer item can retire because of either physical deterioration or due to technical obsolescence. Much cannot be done about technical obsolescence but efforts can be made about reducing physical deterioration. In order not to incur extra cost providing longer than useful life, the product should be designed to wear out physically at the same time that it becomes technically obsolete (Chitale and Gupta, 1999). A complete compromise between obsolescence and wear out is generally not possible, because the elements of design that contribute to a

longer life of a product are also essential to ensure adequate reliability and maintenance (Priest and Sanchez, 2001).

The question is - what determines as to when an economic commodity in use such as a tricycle rickshaw has reached a stage at which it should be retired? It can be safely assumed that when the article in use is worn to the point at which it is incapable to render adequate service any more, and then the need for replacement is clear. However, the fast pace of technology accelerates the aging process of goods in use. At present times goods in use are retired more frequently because of technical obsolescence rather than for physical deterioration.

To the product designer, the question whether to design to prevent physical deterioration or technical obsolescence is of fundamental importance. A tricycle rickshaw being a Human Powered Vehicle of mass appeal, functionally useful, with very low cost of ownership, existing for more than a century without much changes in its form and function can not be wiped off by technical obsolescence so easily. Thus, designing to overcome physical deterioration played more dominant role in design of the Dipbahan.

The impact on a new design of tricycle rickshaw is more immediate as an old structure or system must be replaced by a new one with minimum disruption of normal operations, specifically concerning the early retirement of a traditional rickshaw. The structure of traditional rickshaw is totally craft based and uses many different materials. Most of these get deteriorated over a very short period of time. Only the mild steel based components that are sourced from bicycle and tricycle component industry are of some use. Even the chassis of traditional rickshaw is normally fabricated out of scrape materials and is also a non-standardised item. Therefore it can be assumed that in the longer run, the Dipbahan range of newly designed tricycle rickshaws with long lasting and easy to replace components assembly can successfully replace the traditional version of the rickshaws in market.

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 in design. The purpose of this phase is to take into account the problems associated with retiring and disposing of a product. Designing for retirement, according to Asimow, must consider the following aspects (Chitale and Gupta, 1999):

4.3.1 Designing to reduce the rate of obsolescence by taking into account the anticipated effects of technical developments.

Tricycle rickshaw has been in existence for a long time. Due to its localised and decentralised manufacture and very low margin of profit for its manufacture associated with common people's perception of rickshaw, not much technological developments are initiated that can create obsolescence of traditional tricycle rickshaw. However, during design development of Dipbahan^{+}, due consideration was given to reduce the rate of obsolescence by taking into account the anticipated effect of technical developments in

near future. One such consideration is introduction of FRP. Since wood and other natural materials are becoming scarce and expensive, these may render traditional rickshaw design obsolete. To counter this aspect, Dipbahan+ has been furbished with FRP component extensively. Another aspect in case of Dipbahan^{+} was its new design, materials and processes that are used for its manufacture. As stated in Chapter 3, p108, design of Dipbahan require speedier implementation. This was to counterbalance the technological change. Retrospectively this was proved right by the number of efforts initiated by various persons and agencies in designing and including copying the Dipbahan versions after its tremendous success in the market. When prototype of Dipbahan was previewed by selective persons, it was commented that the design and its material and manufacturing process is excellent and this should be immediately introduced in the market to cater to the needs of the users. Also with each passing days, people who do not uses rickshaw but automobiles were trying to ban this mode of eco-friendly transport from the cities. Thus further delay in implementation could have adverse effect on the future of the project. Political situation required more and more income generation projects with lower capital costs to solve unemployment problem and it was an opportunity to introduce Dipbahan immediately to reap that benefit.

Entire structure of the Dipbahan^{+} has been designed in such way that if desired, it can be easily converted into an electric tricycle rickshaw by easily fitting it with electric motor, solar photo-voltaic panels and storage battery. The basic assumption in converting the Dipbahan^{+} to electrically operated one is that it will retain its pedaling option as it is and it will be only added electrical motor and other paraphernalia like battery pack, battery charger, controller etc. to the vehicle. Thus to convert Dipbahan+ to an electric one using motor required few considerations mentioned below:

- There should be space for housing the 2 battery pack with overall dimension of 400 mm X 200 mm X 250 mm (Length x Breadth X Depth).
- The chassis should be able to support fixtures for fitting the motor below the floor panels and also the overall weight increase of approximately 60 Kg.
- The motor controller actuator should be positioned at handle bar to be easily operated.
- Charging socket along with battery charger should be located within the frame that can be plugged to external charging system, normally 220 Volt AC or through photovoltaic solar panels.

To facilitate conversion of Dipbahan^{+} to an electrically operated vehicle, its chassis has been designed to bear additional load of battery pack, controller, charger system and motor. It is designed to facilitate electric motor to be coupled to rotate the rear shaft through pulley and V- belt with built in gear reduction. This will facilitate retaining the same wheels from the Dipbahan^{+}. Currently hub mounted electric motors are being used in electric 2 wheelers and if this is used will require change of wheels. These are also expensive. Using stand alone motors to rotate the rear axle will also simplify the design

and motor mounting can be easily located below the floor. Part of the luggage space below the passengers' seat can be used to house the battery pack, charger and motor controller by providing additional depth to the rear floor panel. Also motor controller actuator can be easily mounted on the handle bar.

Dipbahan^{+} has been designed to accommodate all these components in spite of retaining all its advantages and these features are not easily visible.

Facilitating the above in the Dipbahan^{+} did not have any significant impact its existing design. Chassis was anyway designed to take care of overloading than the normal payload. Presently entire space below the seat has been provided as luggage space and it is seen that this space is not always used by all passengers. Thus partial reduction in luggage space will not have adverse impact. There will be definite increase in weight in case of electrification, but this will only affect the rickshaw puller once he is forced to pedal it due to discharge of the battery pack. Also additional weight is maximum of 60 Kg.

Similarly, it can be fitted with a small fuel engine to convert Dipbahan^{+}. to a motorised tricycle rickshaw.

The above measures ensure that the newly designed rickshaw will have lower rate of obsolescence considering anticipated technological developments.

4.3.2 Designing physical life to match anticipated service life

As discussed in section 4.2.7 of this chapter, p 119 the newly designed tricycle rickshaw has been designed for a minimum physical life of 7 years in reality. However parts that wear out during normal operation will require replacements. These are tyres and tubes, sprockets and chains, brake pads, foot pedal rubbers etc. Dipbahan^{+} has been designed for an anticipated life of 7 years to be attractive for the rickshaw pullers to own one. Considering the capital cost of the Dipbahan+ is Rs. 13,500.00, a useful life of 5 years as considered by the licensing and insurance authorities will entail a depreciation of Rs. 2,700.00 per year @20% per year in straight line depreciation method. This comes to Rs. 9.00 per working day provided, rickshaw pullers use it for 300 days a year. If the rickshaw puller repays his loan over 2 years i.e. 600 working days @ 300 working days per year and rate of interest 12 % per annum calculated over reducing balance, his repayment installment comes to almost Rs. 25.00 per working day. Thus for the first two years, his daily outflow will be Rs. (25.00 + 9.00)= Rs. 34.00 per day, assuming rickshaw puller will set aside Rs. 9.00 per day as depreciation and also for the next 3 years, he will require to set aside Rs. 9.00 per working day so that he can buy a new Dipbahan at the end of 5 years. Here his old Dipbahan^{+} will be of zero book value. In the above calculation, interest in the set aside amount as depreciation was not considered as well as any increase in the cost price of Dipbahan^{+} after 5 years. There will be also some residual value for the old Dipbahan^{+}.

Once we consider the useful anticipated life of 7 years, and depreciation is spread uniformly over these years, annual depreciation comes approximately 15% per annum

and the set aside amount becomes Rs. 7.20 per working day. This is 20% lower that the earlier and the rickshaw puller can operate the Dipbahan^{+} for 2 more years. However, the Municipal councils and corporations have to agree to extent the license to 7 years. In this case there is a match between the physical life and anticipated service life.

It is assumed that once Dipbahan^{+} currently on road lasts more than 5 years, authorities can be convinced, since there are valid documents to convince them. These includes, license issued earlier, loan and membership document, insurance documents etc.

4.3.3 Designing for multi-levels of use to facilitate adaptability for further use with a less demanding level after the service life of the product at higher level of use is terminated

In case of a tricycle rickshaw, satisfying the above guide line is difficult if not impossible. However when the tricycle rickshaw is no more suitable for transporting passengers, by removing the passenger seat, it can be used for transporting goods, poultry products etc.

4.3.4 Designing the product to facilitate recovery of reusable materials and long-lasting components. Introduction of modularity in design instead of integrated designs.

The tricycle rickshaw designed uses various mild steel elements in chassis and various parts and components; rubber materials in tyres and tubes; glass and plastic in rear view mirrors; plastics in rain guards and fibre glass reinforced plastic components in seat, hood, floor panel, rear panel, side panel, rear mud guards. Mild steel materials specifically rear axle can be reused and design of the tricycle rickshaw facilitate its recovery for reuse. Other mild steel materials can be reused based on their condition. Otherwise these can be recovered for recycling easily. Rubber tyres are not reusable after the expiry of its service life. Fibre glass reinforced plastic components based on their condition can be reused and design facilitate their recovery. If these are not in working conditions, these are to be discarded in land fills. However, a process has been developed in house at Department of Design, IIT Guwahati to reuse the FRP components as refill in new component making (Section 4.2.9, Fig. 4.3 - 4.8, p 121).

Second aspect of tricycle rickshaw design is introduction of modularity. From the beginning of the research work, emphasis was on introduction of modularity. Thus after Dipbahan was introduced as a passenger version, two more version based on the same platform was designed and fabricated through participation of Small Enterprise. These are Dipbahan Ankur as school van and Dipbahan Pariskar as a municipality solid waste disposal vehicle for collection and disposal of garbage from individual households, where on the basic chassis frame the passenger seat component may easily be replaced with modules of specific requirement (which is detailed out in Chapter 7).

4.3.5 Examining and testing of service-terminated products to obtain useful design information

Service terminated products were collected and examined to ascertain the cause of its failure thereby shortcomings of design and materials. This provided some vital information for redesign of the newly designed tricycle rickshaw. One such case in hand was rear wheel bearing and bearing block. It was found that the rear wheel bearings used to get damaged frequently. There were also few cases of breakage of bearing block during operation of the rickshaw. The causes for these were traced to:

i. Breakage of bearing is due to lack of oiling and greasing. This itself is to be attributed to difficulty in oiling and greasing by the rickshaw pullers. The bearing block used is designed to protect the bearing from dirt and dust by enclosing it (Fig. 5.33, p165). The axle comes out through the opening at both sides of the bearing block. Therefore for oiling and greasing require dismantling the bearing block. Normal rickshaw puller as well as mechanics in rickshaw repairing shop are not habituated at this. For oiling and greasing, mechanics charge higher amount. Every time it amounts around Rs. 20.00 – 25.00. But with traditional foot pedaled tricycle rickshaw with locally fabricated bearing bracket keep the bearing exposed (Fig. 5.32, p 165) and this assist in frequent oiling and greasing without dismantling anything and hence more convenient. This prevented the damage and failure of the bearings. This has been incorporated in the new design.

ii. Second aspect of breakage of bearing block was due to absence of a rubber piece used as dampener between the bearing and the bearing block and a wooden piece between the chassis bracket and the bearing block used for mounting the bearing block to the chassis. Thus being a cast iron piece, during sudden shock on road, the bearing block used to crack. It was also found that in a few cases, bearing block itself was sub-standard. Usage of mild steel bracket in the new design increases the life of the component.

4.4 Overall design of subsystems

Overall design of subsystems is the second step in detailed design in the design development process. System development precede subsystem development. A system is an aggregation of subsystems or elements organized in some structure (usually hierarchical) to accomplish a unified system goal with many specific objectives oriented components within. System development is the total life cycle of the system being designed, up to the point at which it is released to the customer. It has three major functions;

Analysis of the design problem,
Solution of the problem, and
Testing of that solution.

The design process chosen in this research work is 'Top down' process (Bridger, 2003), where at the beginning the full projected look is visualized and then various components and links among them are developed to achieve a resultant functional goal. System development is repetitive and progressively more detailed and means that initial solutions are somewhat general and tentative, and are often refined at more detailed levels. Top down process is a time-driven process and is constrained by cost, resources, and organizational and environmental requirements.

Main concern in the preliminary design was with the overall concepts; subsystems were examined only to evaluate the integrity among them to meet the overall system concept. After the overall concept was found to be acceptable, each subsystem was considered at as an individual entity as shown in Flow Chart 4.1, p 130. The Flow chart is more of self explanatory where three levels of a system, in this case tricycle rickshaw is shown from left to right viz, complete system, various sub-systems that comprise the rickshaw and components of these subsystems. As in any system level approach, there must be compatibility between different sub-systems to yield operational system and this compatibility is achieved through the interface linkages between these sub-systems, since each subsystem also depend on the other subsystems through these link elements. Similarly in the next lower level, there must be compatibility between components to provide a working sub-system through their interface.

One simple example is the main frame of the rickshaw and the pedaling arrangement. These are two subsystem of the rickshaw. These are joined through the interface of Bottom Body (BB) socket. BB socket is welded to the main frame and also houses the axle of the pedal assembly through ball bearing and BB socket cup. Thus BB socket design and configuration should be compatible with the tubular elements used for the main frame as well as the axle used for fitting the pedals with cranks.

A full scale chart with the components marked was prepared during conceptualization. Appendix 7 is incorporated in pp 270 – 271, where various parts of Dipbahan+ has been labeled including the in house made ones and outsourced ones. Many individual components can not be seen in the assembled product, since these get hidden behind or inside the assembled product, e.g., steel ball, ball bearing, screw racer etc.

Compatibility of one subsystem with the other was also verified. One such situation dealt in this project was use of robust tyres and tubes from mountain bike. Since mountain bike tyre and tube are not compatible to the wheel rim of tricycle rickshaw, the mere change of tyre and tube necessitated the change of wheel rim. Once the wheel rim was changed from tricycle rickshaw type to mountain bike type, there was problem of braking. This is because, in case of rickshaw type rim, the braking shoe attachment system is different from that of mountain bike type wheel rim and works through rigid links against cable operated for the later type. This led to change of brake sub-system to that of cable operated ones like mountain bike. To accommodate the brake system acquired from the

mountain bike required replacement of the rigid link brake subsystem with change of handle bar and front fork to the ones used for mountain bike. Only after changing all these sub systems, the compatibility was possible. However mountain bike type handle bar as was not preferred by the rickshaw pullers as found from the feed back from the rickshaw pullers on field trials and the reasons for this has been mentioned in Chapter 5 under section 5.4, p. 159-160. Rickshaw pullers also rejected this compatible subsystem that led to change of so many other sub-systems which created a problem in maintainability in common repairing shop for traditional tricycle rickshaw. This rejection of subsystem required re-establishment of compatibility afresh. Thus in the commercial version of Dipbahan, usual tricycle rickshaw based tyre, tube and brake system was retained along with handle bar and fork and compatibility restored. For improving brake ability, separate rear wheel brake was provided that are actuated by foot.

Rickshaw puller – the prime system component

The tricycle rickshaw design was based on Human Centered Product Design. Here the central factor is the rickshaw users- pullers and the passengers. Thus all the sub-systems were designed and adapted to fit the users. Thus Human Factors considerations was given the top most priority in the designing and integrating various sub-systems. Ergonomic information (Sanders and McCormick, 1987; Pradhan, Thakur and Roy Choudhury, 2006; Hendrick and Kleiner, 2002) and considerations are taken to conceive the design dimensions. Indian Anthropometric data (Chakrabarti. D., 1997), Fig. 4.9, p 131 match with relevant dimensions of traditional tricycle rickshaw were checked and duly applied in the newly designed tricycle rickshaw. The terms used as well as recommendations in Indian context (Chakrabarti, 1997) are taken as available in this source book and hence these were not discussed. This comparative statement is given in Table 4.1, pp 132-135. Based on this dimension, during integration of various sub-systems, the overall dimensions were modified to meet the recommended specifications to the greatest extent possible. After completion of the prototyping, it was finally verified in field trials with rickshaw pullers. It is evident that the dimension of the new tricycle rickshaw meets the requirements appropriately.

Level 1	Level 2		Level 3		Link element between two subsystems
Complete System (Tricycle Rickshaw for passengers)	**Subsystems** of system	Integrated Chassis	**Components** of subsystems	Main frame, chassis and BB socket	Main frame and chassis joined through BB socket
		Propulsion system		Tyre, tube, wheel rim, spoke, wheel hub, axle, bearing socket, bearing, bearing block Free wheel socket, free wheel, chain, chain ring on crank, Pedal, BB socket assembly	Bearing block to integrated chassis with nuts, bolts, lock washer and spacer (wooden or rubber) BB socket assembly with main frame
		Steering system		Handle bar, head cup assembly, front fork assembly, front axle and hub assembly, spokes, wheel rim, tube, tyre	Head cup assembly with head pipe in main frame
		Braking system Front wheel Rear wheel		Hand operated brake lever assembly on handle bar, brake link, fork, fork bracket on front fork, brake shoe and pads Foot operated brake lever, link rod, brake shaft with brake shoe and rubber brake pad	Brake lever assembly and handle bar Brake lever with brackets welded to the mainframe and brake shaft with the chassis
		Seating for Puller Passengers		Saddle post, seat assembly with shock absorbing spring structure Seat structure, seat and back	Saddle post with main frame Seat structure with left and right side frame' welded U-brackets through nuts, bolts and locking washers
		Canopy for protection from elements of nature and as a protecting rolling cage		Tubular structure side frames and binding cross bars, FRP hood, Vinyl rain guards etc.	Tubular structure side frames with U-brackets welded on chassis and main frame through nuts, bolts and lock washers at the chassis and male female joint at the front of main frame. FRP made hood fitted to the tubular structure with screws and lock washer
		Protection from mud and muck splashing onto the users		Mudguard (for the front wheel, in mild steel), brackets Mudguard (for the rear wheels, in FRP), bracket	Mudguard for the front wheel through 2 types of bracket fixed to the front axle and front fork through nuts, bolts and locking washers Mudguard for the rear wheel with bracket fixed to the side frames and chassis through nuts, bolts and locking washers
		Advertisement space		Rear panel made in FRP	Rear panel with side frames and chassis through nuts, bolts and locking washers
		Luggage space		Floor boards in FRP, side panels in FRP, Seat bottom in FRP, lower half of rear panel used as advertising space	Various panels are fixed to the tubular seat structure, side frames and chassis
		Night visibility by the puller and by others on road		Lamp with bracket mounted on handle bar or body; Kerosene type or dry cell battery Reflectors	Bracket either on the handle bar or on the tubular structure at the front Reflectors fixed over the mudguards with nuts, bolts and lock washer
		Warning bell		Handle bar mounted manual bell or electric bell with bracket	Bracket either on the handle bar or on the tubular structure at the front
		Rear view mirror		Rear view mirror plain / convex with mounting bracket	Bracket on the handle bar or on the tubular structure side frames at the front

Shaded text indicates the linking elements in two subsystems; some components are actually a subsystem of components, like bearing, but considered as components since these are procured as build up components

Flow Chart 4.1 System compatibility chart for sub-system, components with complete system.

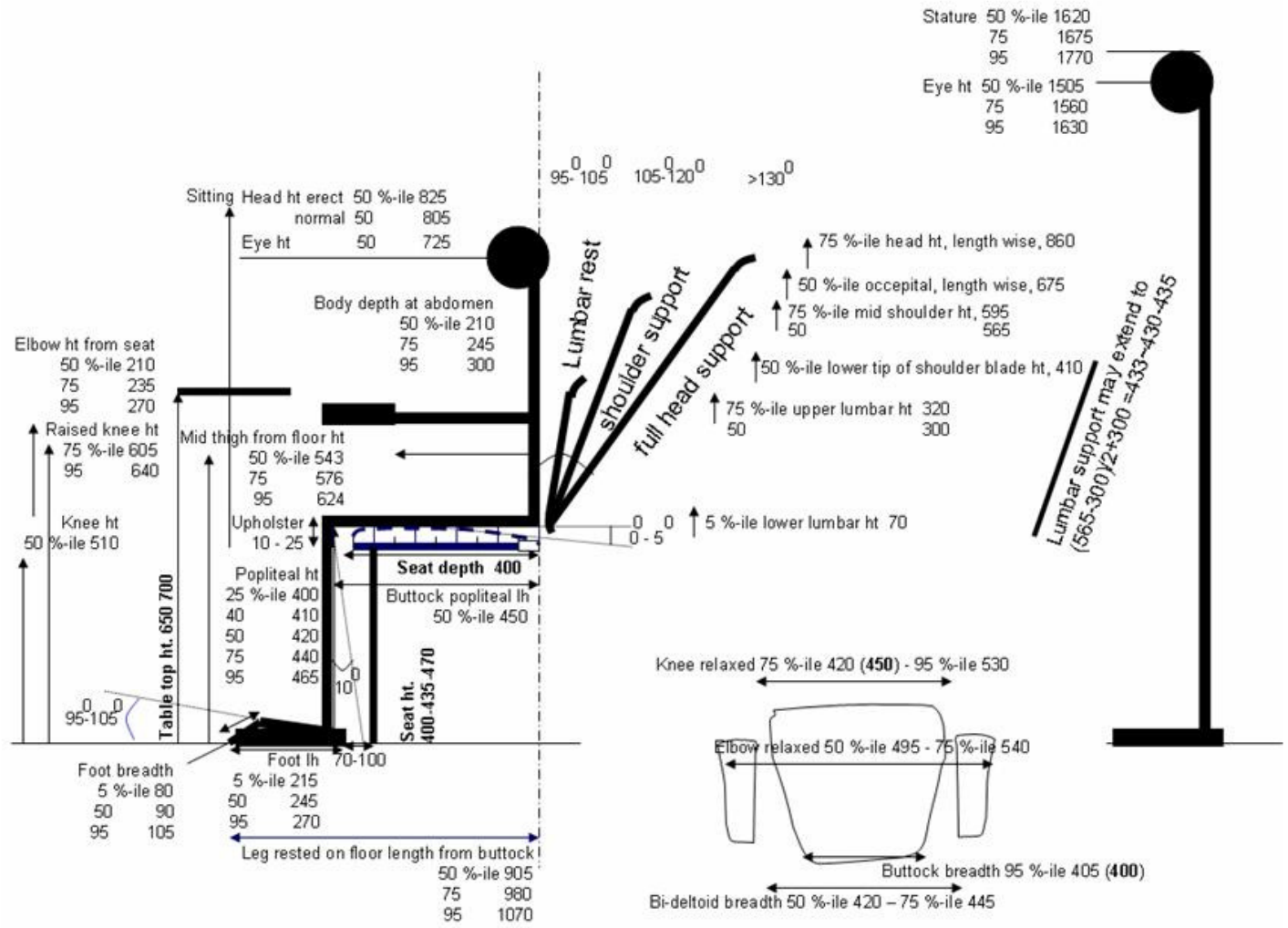


Fig. 4.9 Anthropometric dimensions (Indian male female combined) relevant to conceive seat design values in mm, rounded off to nearest 5 mm (Chakrabarti. D, 1997)

Table 4.1 Comparisons of New tricycle with traditional regarding Ergonomics (Indian Anthropometric Data: Chakrabarti. D., 1997)

Parameters	Percentiles		Preferable/ Recommended	Existing Rickshaw	New Rickshaw	Remark
	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 - 50th percentile 857 - 75th percentile	810 distance from seat to hood	990 distance from seat to hood	higher the clearance, it is better
Erect sitting- Top of the head, sitting in erect stretched posture	738	901	824- 50th percentile	810 distance from seat to hood	990 distance from seat to hood	higher the clearance, it is better
Eye- Inner corner of the eye	623	796	723 - 50th percentile	visibility at the front		
Cervical (Trunk)- Most prominent spinous process of the seventh cervical vertebra	531	667		back support		
Mid shoulder- Uppermost point on the middle level of the shoulder	499	630	566 - 50th percentile 594 - 75th percentile	300 seat back height	430 seat back height	
Acromion – Most lateral point on the superior surface of the acromion process of the scapula	475	603		300 seat back height	430 seat back height	
Upper Lumber- Uppermost point of the first lumber vertebra	246	352	298 - 50th percentile 317 - 75th percentile	300 back support	430 back support	
Lower lumber -Lower most point of the first lumber	72	159	72 - 5th percentile	300 back support	430 back support	
Tip of shoulder blade – Lower blade of shoulder blade(scapula)	350	470	411 - 50th percentile	300 back support	430 back support	
Elbow rest – Lower most part of the elbow	150	268	210 - 50th percentile 234 - 75th percentile	150 hand rest	190 hand rest	

Parameters	Percentiles		Preferable/ Recommended	Existing Rickshaw	New Rickshaw	Remark
	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	50th percentile 509			
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	25th percentile 399 40th percentile 410 50th percentile 419 75th percentile 439	380 seat height	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		support on inclined road		

Lengths						
Buttock to knee length, normal seating – Horizontal distance from the most posterior point on the uncompressed buttocks to the most anterior point on the knee (Knee at right angle)	479	613		500 Clearance between the passengers and the puller' seat	820 Clearance between the passengers and the puller' seat	
Buttock to popliteal length, normal seating – Horizontal distance from the most posterior point on the uncompressed buttocks to the back of the lower leg at the knee, i.e. the popliteal angle point (Knee at right angle).	394	509	50th percentile 451	410 seat depth	513 seat depth	

Parameters	Percentiles		Preferable/ Recommended	Existing Rickshaw	New Rickshaw	Remark
	5th Percentile Combined	95th Percentile Combined	Man and women combined			
Buttock to leg length, normal seating – Horizontal distance between the most posterior point on the uncompressed buttocks and the tip of the longest toe, when the legs are placed on the floor with the knee at an angle of 90 degrees	540	779	95th percentile	700 floor board length	855 floor board length	Spacious and comfortable compared to traditional ones
Buttock to leg length, length while raised on toe – Horizontal distance, perpendicular to the trunk, between the most posterior point on the uncompressed buttocks and the tip of the longest toe, when the legs are extended horizontally and the knee is lifted to the maximum height keeping the toes on the floor.	559	759		700 Floor board length	855 Floor board length	
Buttock to extended (rested on floor) leg comfortable length - Horizontal distance, the most posterior point on the uncompressed buttocks and the tip of the longest toe, when the legs are extended to the maximum keeping the heels and the toes on the floor.	739	1069	75th percentile 979 50th percentile	700 Floor board length	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 longest toe, when the legs are lifted from the floor, extended horizontally and stretched forward to the maximum, perpendicular to the trunk.	941	1199		700 Clearance between the passengers and the puller' seat	855	

Parameters	Percentiles		Preferable/ Recommended	Existing Rickshaw	New Rickshaw	Remark
Breadth						
	5th Percentile Combined	95th Percentile Combined	Man and women combined			
Bi-deltoid breadth– Maximum horizontal distance across the shoulders, breadth measured to the protrusions of the deltoid muscles	349	479	50th percentile 417 75th percentile 443 95th percentile	690 Double seat width	815 Double seat width	
Hip breadth – Maximum horizontal distance across the hips	269	406	95th percentile 406	690 Double seat width	815 Double seat width	
Mid thigh-to-thigh breadth, relaxed - Maximum horizontal distance across the mid thigh to mid thigh, most lateral surfaces, spreading external sideways, in relaxed position.	289	479	50th percentile	690 Double seat width	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	50th percentile 494 75th percentile 539	690 Double seat width	815 Double seat width	
Knee to knee (relaxed) - Horizontal distance across the lateral surfaces of both the knees when they are maximum relaxed position, spreading sideways.	252	529	75th percentile 419	690 Double seat width	815 Double seat width	
Foot length – Distance parallel to the long axis of the foot, from the back of the heel to the tip of the longest toe	215	271	50th percentile 244	300 Floor board length	335 Floor board length	
Foot breadth- Maximum horizontal distance, whenever found, across the foot, perpendicular to its long axis**.**	77	104	50th percentile 92	710 Floor board width	815 Floor board width	
Seat inclination			0-5º	-15 º	5º	
Leg inward			10 º	0 º	10 º	

The dimensional value for Lumber support is arrived by the following formula:
Lumber support recommended= (50^{th} percentile Mid Shoulder height- 50^{th} percentile upper lumber height)/2+ 50^{th} percentile upper lumber height
(566-298)/2 + 298 = 234 + 298 = 432 mm ≈ 430-435

As per ergonomics criteria used in this thesis, some dimensions are based to accommodate 50 percentile population for both man and woman and some of these are for 75 percentile. Based on exact criteria, some dimensions exceed or are lower. E.g. in case of seat height 50 percentile value is 419 mm and 75 percentile value is 439 mm. Thus more the seat height in this case will accommodate more percentile of population in this range. We need to accommodate at least 50 percent of the population. If we have seat height at 419 mm, 50 percent of the population will be able to seat comfortably but if it is 438 mm, 75 percent population will be able to seat comfortably. Recommendation being for minimum 50 percentile, the height has been fixed at 430, that is more than 50 percent but less that 75 percent. In this case dimension of seat height is more than recommended figure.
In case of mid shoulder, percentile value for 5^{th} percent population and 95^{th} population are 499 mm and 630 mm respectively. Therefore considering a lower back support for the passengers, it is not required to be more than 499mm nor 630 mm. Anything below 499 mm will cover all population between 5 percent to 95 percent population. In case of Dipbahan it is 430 mm. Thus it is a matter of whether it is exclusive of inclusive that determines more or less than the recommended dimension.

Other physical dimensions were considered and optimized as far as possible based on the dimension available from the Table 4.1, pp 132-135 e.g. storing a luggage was found to be dependant on two other factors since it was stored below the passenger's seat. First the height of the foot board floor from ground and height and depth of the passenger's seat from this floor. It was found that most of the common luggage that passengers carry along with them can be accommodated within the space available. Similarly there was no covering provided at the side of passenger's seat to keep the tubular structure exposed that were designed also as hand rails to get on and off.

To obtain better understanding of the ergonomic aspects for the puller, the various muscles of the human body that are activated and contribute for propelling the tricycle rickshaw through pedaling were observed and while operation difficulties and specification points / areas were also noticed and accordingly design features were fixed. This is illustrated in Fig. 4.10, p 137 (Ballantine, Grant, 1998). The rickshaw puller along with pedaling shifts his body alternatively to both sides to use optimum muscle economy. To facilitate this movement, seat height, contour and specific softness to ease the pedaling movement needs to be considered.

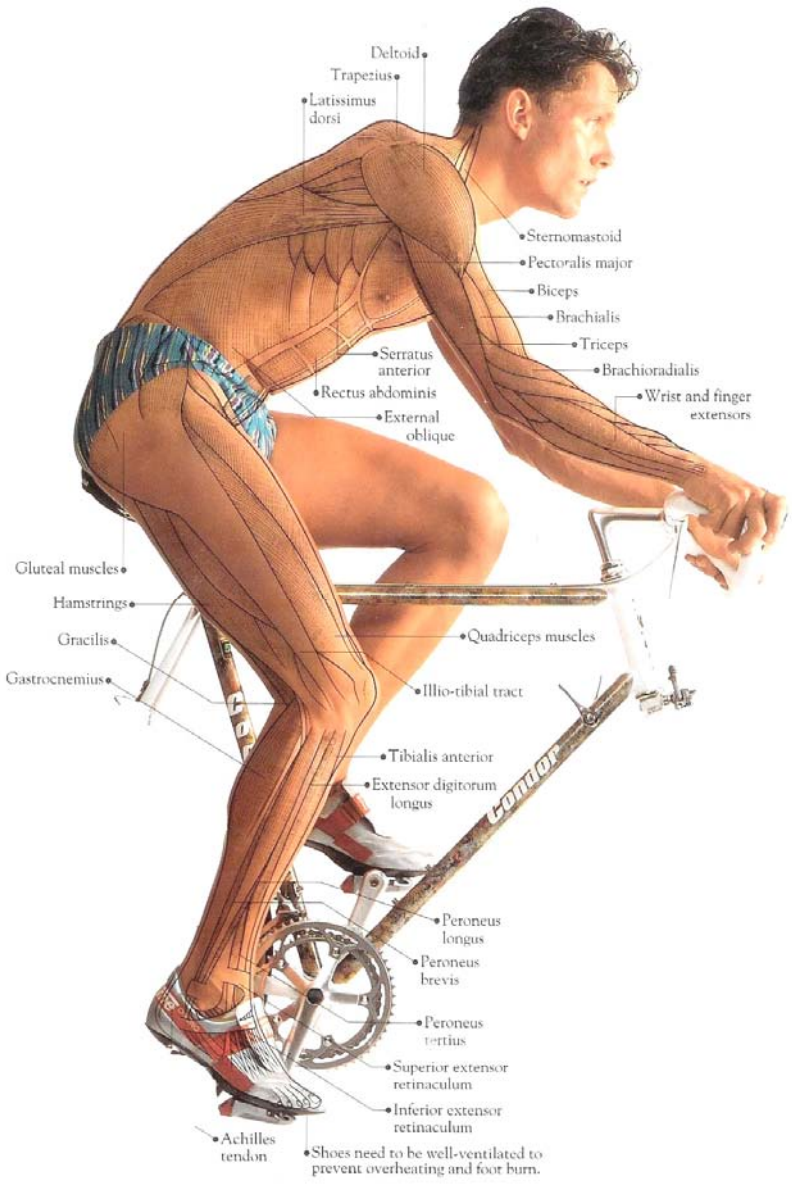


Fig. 4.10 Muscles that contribute to the cycling (Ballantine, Grant, 1998)

Arm Muscles:

Arm muscles both help to control the rickshaw and to move the body position back and forth over the handle bars. Rickshaw pullers should avoid locking their elbows straight-bending them helps to absorb any road shock.

Back muscles:

Back and stomach muscles are not directly employed in pedaling, but operate in equilibrium to keep the upper body and head positioned and chest open. Lower body muscles are not exercised.

Thigh muscles:

Cycling utilises the largest, most powerful muscles in the body. In the thigh, the quads and the hams work in harmony to drive the pedals around and the rickshaw forward. As the rider push down with the quads at the top of his thigh and extend the leg, the hams underneath contract to bring the leg back up to complete the circular pedaling motion. Strain can occur if unnecessary force is applied by having the saddle too high and outstretching the quads, or too low and over contracting the hams.

Avoiding knee strain:

In the lower leg, the gastrocnemius (calf muscle) is connected to the thigh bone behind the knee and the Achilles tendon above the ankle. Upper and lower leg muscles lever and pivot through the knee. Pedaling at an aerobic cadence of 80 rpm (revolutions per minute) bends and extends the knee 4,800 times an hour. Strain occurs if a knee is pulled out of its vertical plane or if pedal twists the foot out of its natural alignment with the knee. In reality due to the use of free wheel pedaling continuously at this rate is not done. Efficient mechanism optimizes the pedaling and pause ratio.

The whole aspects of determining the various parameters for the puller's seat is much more complicated than the passenger's seat and will require detailed ergonomic experimentation. Parameters that govern the ergonomic aspects of the puller and require consideration are:

- Height of the Bottom Body (BB) socket (used for mounting the pedals) from ground
- Puller's seat height from the Bottom Body (BB) socket
- Height of the handlebar of the front wheel (for steering) from ground
- Handlebar of the front wheel (for steering) and its distance to the puller's seat
- Handlebar of the front wheel (for steering) and its distance to the Bottom Body (BB) socket.

As most of the parameters can be considered from bicycles and tricycles, the best source was found to be the current generation of bicycles and main frames for tricycles produced by the industry. After initial observation of the existing parameters from the bicycle/tricycle industry, the above five parameters were derived from the existing main frame of a tricycle commercially manufactured in India and maintained in the Dipbahan.

In addition to the fixed dimension of the above 5 parameters, puller's seat is adjustable for height and distance from handle bar. The spindle of the seat is similar to normal bicycle and loosening the bracket for the spindle allows it to be raised and lowered. Similarly, bracket below the actual seat cushion supporting the seat allows it to move it forward and backward by limited distance. The height of the handle bar is also adjustable to certain extent.

Similarly various seats with different contour and made out of different materials such as leather, plastics and rubber were used with or without padding cushions and users tried out themselves. Based on their perception of comfort, it was integrated with the design. Since existing parameters and specifications were used along with available components and found acceptable by the users, separate ergonomic evaluation was not made.

Once the compatibility was established, a final provisional master layout was prepared for each subsystem that translates the results of the subsystem designs into drawings using AutoCAD (Fig. 3.46-3.49, p 107). All related dimensions are readily available from the AutoCAD model itself. The basis for developing the design of the components was the above mentioned master layouts.

The layout of each subsystem keeping in mind their position in respect to the main frame was drawn. Wherever the subsystem with the accepted specification did not fit properly, these dimensions were subjected to optimize accordingly.

4.5 Detailed design of parts

Detailed design of parts is the fourth step in detailed design phase in the design development process.

During the design of an individual part, its specific location and function in subsystem in relation to fit in overall system goal needs to be considered. No questions pertaining to its design should remain unanswered, and any ambiguity about its shape, its material, its surface treatment and interfere with other components it interact should be answered. At this stage from the abstract to the concrete, from the concept of the system or device to the physical embodiment, the final transition is made and the idea merges into physical reality. At present, great progress has been made in part design, particularly through sophisticated methods such as photo elasticity and the finite element methods.

It was decided during conceptualisation stage of the newly designed tricycle rickshaw (Chapter 3, Section 3.6.2 Identification and formulation of the design problem, p 89) that possibility of outsourcing standard parts and components for the rickshaw from the readily available parts / components bins from existing bicycle and tricycle industries is to be explored (Table 3.2 and 3.3, p 71), and only elements would be developed that is not readily available in market. Once these parts and components were procured, the task of the detailed design of parts gets confined to the body shell and its related parts for integrating the different sub-systems into a total system to obtain a tricycle rickshaw as designed and conceived. Other accessory parts and components were designed include seat, seat back, hood, floor boards, mud guards, rain guards, side panels/ guards and rear panel etc. In the interim version (Fig. 5.27, p 161), many of these items were designed using traditional skills of the persons in trade. However in the Dipbahan[+]

version (Fig. 5.35 and 5.36, pp 168-169), most of these except the rain guards were replaced with Fibre glass Reinforced Plastic (FRP) components (Table 4.2, p 142).

Various steps taken for fabricating the above mentioned parts are given below:

1. Pattern making using plywood, wood and galvanized sheet.

The first step in making a Fibre Glass Reinforced (FRP) component is fabrication of the pattern. Pattern is the exact replica of the component to be made in FRP for the face side, made in materials that can be easily curved. Based on the expertise available, it can be made in plaster of paris, Mild Density Fibre (MDF) board or in wood suitable for curving. Plaster of paris patterns are relatively cheaper, easier to make but not reusable. Thus when there arises a need for modification of the pattern, fresh patterns are to be made once again. Thus plaster of paris is not always preferred. Medium Hard wood used for furniture is good for this purpose. Also based on the type and size of the pattern, combinations of various other materials can be used for this purpose. Whatever be the medium of making the patterns, these are finished with automotive grade putty to cover any irregularity and obtain a smooth finish required for the final components. Surface finish that is desired in the final component is dependant on the surface finish of the pattern. Normal way of finishing the pattern is to first apply putty with spring plates, then finishing this with emery paper upon drying and then applying putty through spray painting. This is finished through wet sanding to obtain a smooth and fine finish. Finally wax based polish like waxpol is applied to obtain a fine glossy surface. The pattern must be resistant to water and one of the reasons for applying automotive grade putty is also to make this pattern water resistant. Most important point requiring attention is avoiding any under cut in the design of the components and providing appropriate draft angle for ease of removal of the components from the moulds. Normally at least 1.5° is provided as draft angle.

2. Mould making in FRP.

The second step for making FRP components is fabrication of the moulds. The mould itself is fabricated in FRP. The process of mould making starts after pattern is ready. The pattern is to be coated with releasing agent. In this case Polyvinyl Alcohol (PVA) is used as releasing agent. PVA is normally available in white crystalline granules. It is boiled in water at 1:10 solid to liquid ratio and after cooling the solution, it is applied with a brush or a sponge onto the pattern and dried in shade to obtain a fine coat of film. Usually two coats of PVA is applied.

After the pattern is coated with releasing agent, it is ready for application of FRP materials. Normally after releasing agent, a layer of gel coat is applied. Gel coat is either polyester or epoxy resins with slight difference in viscosity etc. It is called as gel coat, because, pigments for colouring the components are mixed in this type of resin and are applied before glass fibres are laid and impregnated with resins. In case the final FRP components are to be made in lighter colour, the mould is prepared in dark colour, so

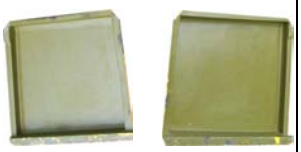
that any irregularity in application of the Gel coat for the components will be easily visible. The colours are reversed for mould and components when final components are in dark colour. In case of the tricycle rickshaw, the colour of the final components are in Post Office Red and Golden Yellow colours. Therefore, moulds were made in dark colour, actually in black colour. Gel coat for application is prepared by mixing black pigments and for setting it, catalyst and accelerator were mixed with it, their percentage being 2% by weight. Accelerator used is Cobalt Octate. For FRP 2 % solution of 2% strength solution is used. Accelerator is uniformly mixed prior to catalyst with the gel coat or resin to obtain uniform and gradual polymerization. However, polymerization starts only after mixing the gel coat or resin with catalyst. Catalyst used for FRP is Methyl Ethyl Ketone Peroxide (MEKP) 2% of 50 % solution strength is used. This gel coat mixed with accelerator and catalyst gets set very quickly and hence required to be applied fast. Gel coat is applied with a brush onto the pattern and allowed to dry. Once dried, this is ready for application of fibre glass and its impregnation with resin prepared same way as that of gel coat except mixing pigment.

The glass fibre is available in different forms. For making mould, non-woven mats with randomized direction of fibre is suitable. Glass matt of 400 Grams per Square Meter (GSM) is used for making the mould and 2 layers were applied. Once glass fibres are laid and impregnated with resin, it is allowed to dry. Once setting has completed, the mould is separated from the pattern. However, to prevent any warpage and damage to the mould during component making, the mould is reinforced further by adding wooden batten at the back side of the mould and fixing these with embedding in resin and glass fibre. The mould after separation from the pattern needs polishing before a component can be taken out. This is done by applying rubbing compound and polishing the inner side of the mould to obtain a fine and smooth polish. After the polish, a coat of wax polish is applied on to the mould.

3. Component making out of the mould.

The final step is making of the components using the moulds. This is exactly the same as making of the mould. First, a coat of release agent i.e. PVA is applied on to the surface of the mould. This is dried and Gel coat mixed with required colour of pigment is applied on the mould. Once gel coat is applied, it is dried. Care must be taken to see that whole surface is uniformly coated to avoid any unevenness in colour of the component. Once the gel coat is dried, glass fibre mat is applied and impregnated with resin. For the final component, a surface mat with smooth surface and low GSM is first laid and then based on the size and type of component, either one layer of 400 GSM mat is used or one layer of 200 GSM mat followed by another layer of 400 GSM mat is used. For superior surface finish at the reverse side of the component, a fine surface mat of low GSM can be used. Once the resin is set, which normally takes 3-4 hours with 2% each of catalyst and accelerator mixed with it, the component can be taken out and process repeated for more components.

Table 4.2 Fibre Glass Reinforced Plastic components for Dipbahan+ (Fig. 5.35, 5.36, p 168-169)

Name of Component, its dimensions and weight	Pattern	Mould	FRP Component
Hood [Length xBreadth xDepth] (L x B x D) 1,350 x 850 x 250 mm, Weight 5.500 kg			
Back Panel (LxBxD) 875 x 825 x 50 mm Weight 3.000 kg			
Combined seat (LxBxD) 830 x 550 x 530 mm weight 4.500 kg			
Floor board-front (LxBxD) 895 x 385 x 50 mm Weight 3.000 kg			
Floorboard-rear (LxBxD) 895 x 485 x 35 mm Weight 2.500 kg			
Mud guard Left & Right (LxBxD) 800 x 350 x 110 mm 2.000 kg each			
Side panel- Left and Right (LxBxD) 460 x 405 x 45 mm 1.500 kg each			
Total weight of all components 25.500 kg			

4.6 Preparation of assembly drawings

Preparation of assembly drawings is the fifth step in detailed design in the design development process. At this stage the design gets ready for prototyping, field trial testing and production. Once the constituent subsystems have been designed, the final assembly is done. The provisional layouts of the components were replaced by final assembly drawings. In preparing the assembly drawings, cases of incompatibility and oversight in compatibility analysis were revealed. The parts were suitably modified.

After the component assemblies were prepared, the corresponding assembly drawings for the subsystems were drafted. Again, incompatibilities and misfits of various kinds were revealed, and these were corrected by the usual iterative process. The final assembly for the system is similarly undertaken for integration. AutoCAD software package for Computer Aided Design and Drafting and Rhino software for solid modeling were used in this design exercise.

For example, the seat assembly was modified while executing this exercise because the number of components required was found to be too many. Hence the front post of the seat structure was removed (Fig. 5.23, p 161) with but giving the passenger the same level of comfort. Finally using Computer Aided Design and manual drafting the assembly drawing is prepared.

The sixth, seventh, eighth and ninth steps in detail design in the design development process are experimental construction, product test programmes, analysis and prediction and redesign respectively and are covered in the next chapter - Prototyping and Testing of Dipbahan.

Chapter 5

Prototyping and Testing of Dipbahan

Prototyping and testing of newly conceived design of tricycle rickshaw - Dipbahan forms a major component of the experimental work. The present chapter deals with actual prototyping of the selected concept and its components and subsystems and their testing along with explanation for various aspects of prototyping that were essential and duly considered in the design development process.

5.1 Industrial Design and Prototyping

Traditionally initial industrial design concepts are shown as renderings and drawings that show the look and feel of the product. The construction of mock up is followed after selection of a particular concept and these looks exactly like final product in true form, colour, texture etc., but without working internal components (Otto and Wood, 2001). This mock up is also known as physical model.

Physical model is defined as an object or set of objects that is fabricated from variety of materials to approximate aspects of how a product concept will perform synonymously. Physical models are also referred as physical prototypes.

In industrial design, prototypes are used to demonstrate the look and feel of the product. It may be of scale down model or life size based on category of product and purpose. Traditionally these are initially constructed out of simple materials such as foam or foam core and intended to demonstrate many options quickly.

In a broader term physical prototypes in industrial design discipline find use:

1. As alternatives for testing aesthetics and artistic impression (feel), usually embodied in early foam models,
2. For studies of semantic product statement,
3. To derive arrangement of internal components and its effect on shape,
4. New product concept and
5. Ergonomic studies to see its anticipated user – friendly features and reliability aspects of the components, subsystems and product usage as a whole.

In this present exercise, the above constituted background for development of Dipbahan.

5.1.1 Types of Prototyping

Presently 2 types of prototyping are in use in product design for modeling and simulating product's performances, and these are:

a) Virtual prototyping using analytical models, and
b) Physical prototyping making physical models

These choices are influenced by variety of reasons. In this work, concern is from the point of view of an industrial designer for Integrated Product Development using concurrent engineering approach. The benefits of Rapid Prototyping over conventional prototyping methods were studied to see whether the desired outcome can be achieved in the context of prototyping of the newly designed tricycle rickshaw. Rapid Prototyping involves virtual prototyping and provides physical models as an end product. A few items

such as hand grips for the handle of the tricycle rickshaw were carried out. In case of other items it was found to be irrelevant since prototyped components were in nylon material and could not be directly used in the tricycle rickshaw.

5.1.2 Use of Prototypes in Industrial Design

Although several types and classes of physical prototypes are generated, their planned uses across the various disciplines may be categorized rather simple way (Otto and Wood, 2001; Das, 2004). The foundational category is to minimize risk during the product development process, but specific categories and their intentions may be listed as follows:

- Communication purpose to obtain feed back from customers/users, suppliers, vendors and management.
- Demonstration purpose.
- Scheduling/milestones.
- Feasibility study.
- Parametric modeling and
- Architectural interfacing.

5.1.3 Benefits of Use of Physical Prototypes

The above uses lead to a number of benefits (Otto and Wood, 2001; Das, 2004) such as

- Greater freedom and care in allocating resources by solving many problems simultaneously with the help of physical prototypes.
- Reduction in costly iterations through insights into manufacturability and assemble ability.
- Accelerating of parallel activities by communicating to the customers, vendors and investors with the help of early product versions. Concurrent engineering practice can be easily effected through the early integration of improvements that are identified by various parties.
- More flexible product choices are possible through modeling, since a greater number of options may be explored. This results in clearer choices for shape, dimensions, material properties, processes etc.

5.1.4 Consideration required for construction of Physical Prototypes

Before deciding to construct a physical prototype, the designer needs to consider (Otto and Wood, 2001; Das, 2004):

1) Whether product design team should build a physical prototype at a certain time
2) The purpose of the prototype
3) Possible forms of the prototype in terms of scale and material
4) Simplifications that can be made independent of the prototypes' purpose Simplification and visualization while finalising design drawings with physical check of complexity. Otherwise some faults may remain unnoticed
5) Types of test that the prototype will be subjected to
6) Risks of design feature selection with constructing prototypes and concept testing vs. continuing development of the product without prototype.

Considering the above aspects from the point of view of different team members of Product Design Team can lead to increased probability of success from the physical prototyping with reduced risk of wasted resources. Otherwise it can slow down the product development process and lead to wastage of time and resources on activities that are irrelevant to the final product configuration or manufacturing.

5.1.5 Conventional classification of Prototypes

For understanding and comparison between conventional and Rapid Prototyping, the various types /classes of prototypes builds are as under (Otto and Wood, 2001):

i) *As a proof of concept models*- to answer specific questions of feasibility about a product.
ii) *Industrial design prototypes*
iii) *Design of Experiment (DoE) experimental prototypes* -are focused physical models where empirical data is sought to parameterize, lay out, or shape aspects of the product.
iv) *Alpha (same material & geometry, different manufacturing) prototype*- are limited functional prototypes
v) *Beta (final part production, special assembly) prototype*- are first full-scale functional prototype of a product.
vi) *Pre-production (pilot production, limited capacity) prototype*- is final physical models used to perform a final part production and assembly assessment using actual tooling.

The efforts of Product Development Team using Integrated Product Design principles and concurrent Engineering is to make the beta prototype be both the pre-production unit and the actual unit to eliminate any corrections needed in the beta prototype.

Since the prototypes have to serve an experimental purpose, greater freedom in revision is permissible.

5.2 Experimental construction

Experimental construction is actually the sixth step in detailed design**.** The prototype shop in an industry undertakes to build the first full-scale prototype once the detailed drawings are ready. In detail design stage, AutoCAD drawings were prepared earlier (Fig. 3.46- 3.49, p 107). Sometimes, the first prototype can also be 'the end-product'. It was decided to make a full scale physical prototype. It was realized that scaled down prototype made in foam etc. a*s a proof of concept models*- to answer specific questions of feasibility about a product could not meet many requirement for this research and full scale prototype was essential. Thus *Design of Experiment (DoE) experimental physical prototypes* focusing on empirical data to optimise layout and shape aspects of the product was fabricated.

There were multiple stake holders in the design development process of Dipbahan. When the process was underway, there were several questions raised during the stage of Design of experimental prototype due to the unfamiliarity to the process to those stake

holders. Thus they assumed that the final product will also be the same. The aim was to minimize risk during the product development process and to obtain feed back from rickshaw pullers, passengers, suppliers of components, vendors and targeted manufacturer-in this case local small enterprise. Thus the physical prototype served the purpose for communication, demonstration purpose and feasibility study.

The first full-scale prototype was preceded by full scale tape drawing based on AutoCAD drawings (Fig. 3.46 - 3.49, p 107) to facilitate its fabrication. Tape drawing is two dimensional sketch of the design in different views. Dimensional aspects were also verified prior to prototyping through trial (Fig. 5.1-5.5).

Fig. 5.1 Obtaining data using the traditional rickshaw platform; side view of layout with reduced leg space

Fig. 5.2 Obtaining data using the traditional rickshaw platform; side view of layout with enhanced leg space

Fig. 5.3 Obtaining data using the traditional rickshaw platform; rear view of layout

Fig. 5.4 Obtaining data using the traditional rickshaw platform; front view of layout

Fig. 5.5 Obtaining data using the traditional rickshaw platform; three quarter view of layout

To facilitate quick prototyping and trial, the existing tricycle platform was used. This also provides easy comparison for the stability aspect of the new design with the existing one. As the space structure was one of the main concerns in this experimental prototype metal frame structure was made on covering the upper portion of the chassis. Since the prototype was built to get the overview of the various affecting parameters such as aesthetics, ergonomics for puller and the passengers- accessibility etc. and overall safety shell of the frame was constructed using 10 mm square bars to get the desired

form and shape (Fig. 5.6- 5.10). This provided freedom for modifying the curvature and form of the design with ease compared to the targeted final material like circular tubular sections that are difficult to modify. Various welding details were neglected, as it was only a Design of Experiment prototype. The experimental model was later used for the analysis purposes and also as an important reference for the construction of the final model. Further it was kept in mind that it is not always necessary to build a prototype model if final model can be built directly.

Fig. 5.6 DoE prototype, side view

Fig. 5.7 DoE prototype, front 3 quarter view

Fig. 5.8 Rear 3 quarter view of DOE prototype

Fig. 5.9 Front view of DOE prototype

Fig. 5.10 Rear view of DOE prototype

Pre-production prototype of the Interim (first generation) version of Dipbahan

Based on the feedback received from the DoE prototype, it was decided that next prototype will be a pre-production prototype instead of an Alpha or a Beta prototype. This not only reduces the cost and time, but provides for actual and fairly accurate cost estimates of the tricycle rickshaw for the marketing stage. Thus pre-production prototype was constructed starting with the body shell (Fig. 5.11-5.15, p 150). This was made using MS sections, circular tubes, flat bars, MS sheets etc. Process of manufacture used is for normal MS work. Pipes and other MS sections are cut to size and welded using arc

welding. The welded joints were grinded to remove unevenness in the area. After fabricating the body shell, this was painted and the following process was used.

- Sanding the shell with emery papers to remove rust.
- Application of Putty to fill up and smoothen the weld joints.
- Wet sanding to smoothen the surface.
- Spray painting with Red oxide primer.
- Spray painting with automotive surfacer.
- Final spray painting with automotive paints in desired colour.

Fig. 5.11 Side view of the body shell of pre-production prototype

Fig. 5.12 Three quarter front view of the body shell of pre-production prototype

Fig. 5.13 Front view of the body shell of pre-production prototype

Fig. 5.14 Rear view of the body shell of pre-production prototype

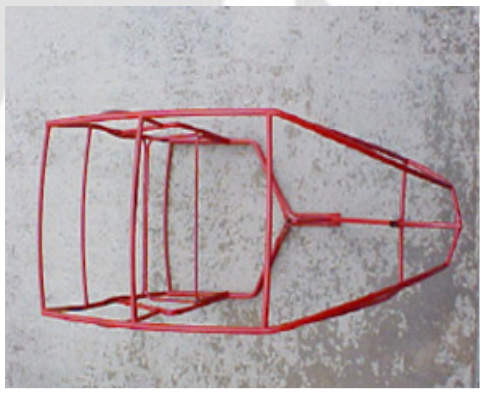


Fig. 5.15 Top view of the body shell of pre-production prototype

To reduce the total cost of the project for manufacturing the newly designed tricycle rickshaw and for the ease of maintenance locally, it was decided that the standard items as per the Table 5.1, p 152 would be directly procured from the market. Thus all these components were procured and assembled with the prototyped body shell.

Availability of components from the existing bicycle and tricycle industry for outsourcing has contributed in the design and implementation of the research in several ways. First, it made the design, prototyping and final manufacturing possible with very low initial investments. If these parts were to be made in house, the capital cost for setting up the facilities would have been prohibitive, since these items require full fledged

manufacturing facility with machine tools etc. that is used currently by bicycle manufacturer in the country mostly located in North India around Ludhiana in Punjab. This area produces the highest bicycles in India and also exports to all over the country. Also the scale of operation envisaged for Dipbahan initially is too small to go for such facilities. Being manufactured by decentralized local industries for bicycle and tricycle industry, these components are readily available at very competitive price, but of substantial quality, that may not even be possible in a centralized manufacturing set up. Second, availability of these standard quality components at very competitive price made it possible to introduce Dipbahan at an acceptable price in the market.

Third, it made the serviceability of Dipbahan a non issue, Ready availability of spares at any place that has a bicycle/tricycle garage made Dipbahan serviceable easy. Thus introduction of Dipbahan did not require setting up of spares outlet all over the places. Thus impact of outsourced components in the design of Dipbahan was very positive.

Table 5.1 Standard items outsourced from existing bicycle and tricycle industry
(Price as on 01.05.2004 in Guwahati)

Sl. no.	Description	Rate per unit Rs.	Quantity	Amount Rs.
1	K W 10 gauge rim of 28" x 1 ½" size	103.00 each	3 Nos.	309.00
2	10 gauge spokes 40 nos. x 3	162.00 per gross	120 Nos.	135.00
3	10 gauge front hub	28.00 each	1 No.	28.00
4	10 gauge back hub	34.00 per pair	1 pair	34.00
5	B/bull heavy duty tyre 28" x 1 ½" size	125.00 each	3 Nos.	375.00
6	Ralson ml tube	26.00 each	3 Nos.	78.00
7	K W front mud guard	44.00 each	1 No.	44.00
8	K W rear mud guard	44.00 each	2 Nos.	88.00
9	Fork guard	20.00 per pair	1 pair	20.00
10	K W fork	97.00 each	1 No.	97.00
11	Screw racer	10.00 per set of 2	1 set	10.00
12	Ball racer	10.00 per set of 2	1 set	10.00
13	¼ ball Apollo	15.00 per packet	1 packet	15.00
14	KW type handle	115.00 each	1 No.	115.00
15	Rickshaw brake set	35.00 per set	1 set	35.00
16	Bell	16.00 each	1 No.	16.00
17	Handle fitted Rear view mirror	15.00 each	2 nos.	30.00
18	Main axle	140.00 each	1 No.	140.00
19	06 socket	17.50 each	2 Nos.	35.00
20	06 bearing	48.00 per pair	1 pair	48.00
21	06 bearing cover	38.00 per pair	1 pair	38.00
22	BB socket	20.00 each	1 No.	20.00
23	BB axle Black	17.00 each	1 No.	17.00
24	BB cup Black	17.00 per set	1 set	17.00
25	KW gear crank -48 T	95.00 per set	1 set	95.00
26	KW pedal	45.00 per pair	1 pair	45.00
27	Cotter pin	1.50 each	2 Nos.	3.00
28	5/4 ball center	10.00 per packet	1 packet	10.00
29	22 teeth freewheel	28.00 each	1 No.	28.00
30	Freewheel plate 29 teeth	10.00 per set	1 set	10.00
31	Freewheel socket	17.00 each	1 No.	17.00
32	Heavy duty chain	62.00 each	1 No.	62.00
33	10" seat pillar	8.00 each	1 No.	8.00
34	Seat pillar socket	5.00 each	1 No.	5.00
35	Seat complete	100.00 each	1 No.	100.00
36	Heavy duty frame cup	5.00 per set	1 set	5.00
37	Frame socket	5.00 each	4 Nos.	20.00
38	Head pipe	8.00 each	1 No.	8.00
39	Lock	20.00 each	1 No.	20.00
40	Rear end reflector	5.00 each	2 Nos.	10.00
			Total: A	2,200.00

All other items such as passengers' seat, seat back and floor panels etc. were made using the traditional process and skill already available with the existing rickshaw maker. Floor panels were made using wood covered with aluminum sheet. Seat and seat back were made using wood, springs, foam, coir fibre, springs and covered with synthetic foam leather or rexin. This was done with an objective to reduce need for training/retraining of existing skilled manpower as well as not to dislodge these people from their vocation and for the ease of maintenance. There were no side panels and left and right side near rear wheels were covered with wire net. Back panel was in Mild steel sheet and lower part of back side was in wire net. This enclosure below passengers' seat

provided the convenient luggage space. Hood, rear and side rain guards were in synthetic foam leather / Vinyl / Reskin. In the prototype, initially trial was taken with a Fibre Glass Reinforced (FRP) hood (Fig. 5.16-5.20). Later hood and rain guards were made in synthetic tarpaulin (Fig. 5.21, p 157).

Fig. 5.16 Side view of pre-production prototype

Fig. 5.17 Three quarter front view of pre-production prototype

Fig. 5.18 Three quarter rear view of pre-production prototype

Fig. 5.19 Front view of pre-production prototype

Fig. 5.20 Rear view of pre-production prototype

Details of other materials used with their contribution to total cost of fabrication is provided in Table 5.2, p 154. The labour cost for fabrication of one new design tricycle rickshaw on job work basis is shown in Table 5.3, p 154.

Table 5.2 Items procured from various sources: (Price as on 01.05.2004 in Guwahati)

Sl no.	Description of materials	Rate Rs.	Quantity	Amount Rs.
1	MS tubes 25.4 mm dia, 350 Gms/RFt	40.00/Kg	100 RFt-35 Kg	1,400.00
2	MS flat 40.0 x 6 mm, 400 Gms/RFt	40.00/Kg	15 RFt- 6 Kg	240.00
3	MS flat 50.0 x 4 mm, 700 Gms/RFt	40.00/Kg	1.4 RFt- 1 Kg	40.00
4	MS angle 40 x 40 X 5 mm, 660 Gms/Rft	40.00/Kg	1.1 RFt/ 0.725 Kg	29.00
5	MS flat 25.4 x 4 mm, 180 Gms/RFt	40.00/Kg	1.1 RFt/0.2 kg	8.00
6	Welding rods	100.00/Pkt	1 packet	100.00
7	Vinyl fabric for hood, seat, rain guard flap	100.00/m	4 meters	400.00
8	Wood for seat and floor 12"X 1" X 18"	200.00/ Cft	1.5 Cft	300.00
9	Sponge for seat & backrest	35.00	6 Sqft	210.00
10	Aluminium sheet for floor	40.00/Sqft	6 Sqft	210.00
11	Wire mesh for luggage space	20.00/Sqft	6 Sqft	120.00
12	MS sheet for back panel 20 Gauge	40.00/Sqft	5 Sqft	200.00
13	Nuts and bolts etc.		1 Kg	48.00
14	Duco automotive putty	160.00/Kg	0.250 Kg	40.00
15	Duco primer & surfacer	150.00/Ltr	1.0 litre	150.00
16	Duco paints	160.00/Ltr	1.0 litre	160.00
17	Duco thinner	110.00/Ltr	1.5 litre	165.00
			Total: B	3,820.00

Table 5.3 Labour charges for fabrication of designed tricycle rickshaw on job work basis

Sl. No	Description	Rate Rs. per rickshaw	Amount Rs.
1	Bending	20.00	20.00
2	Cutting & grinding	200.00	200.00
3	Welding & grinding	400.00	400.00
4	Painting	200.00	200.00
5	Fitting of wheels with spokes, balancing	30.00	30.00
6	Fitting of gears, axles, chains, handles, fork	70.00	70.00
7	Stitching & fitting of hood, rain flap, back cover etc.	250.00	250.00
8	Carpentry work for making the seats, floor	100.00	100.00
9	Fitting Seats etc.	30.00	30.00
		Total: C	1,300.00
		Total (A+B+C)	7,320.00

An overhead of 10% is required over the above amount to cover indirect cost of supervision etc. Profit is not considered at this stage, since it is to be manufactured by an NGO under a scheme.

	D	732.00
	Grand Total(A+B+C+D)	**8,052.00**

Cost of Standard items from existing rickshaw industry as percentage of total cost : 30%

Cost of other items bought out from various sources as percentage of total cost : 52 %

Labour cost as percentage of total cost : 18 %

The various category of cost as percentage of total cost indicated in the above cost calculation provides vital clues about a process, working capital requirement and capital investment required in addition to dependence on outside vendors for the success of the product. It also provides an indication of flexibility of the process and area where cost cutting measures are to be initiated. In case of Dipbahan it is seen that, standard items outsourced from existing rickshaw industry is 30% of the total cost; cost of other items bought out from various sources is 52 % of total cost and these items are actual input to

the process as raw materials such as steel section, fittings, reskin etc that are processed in the factory; and labour cost is 18% of the total cost.

To reduce the total cost, the highest effort must be in the second category comprising 52% of this cost. A reduction of approximately 2% in this category will lead to reduction of 1% in total cost. Similarly labour cost is anyway way below the other cost component and thus effort in reduction in labour cost may not provide much reduction in total price. Sometime, expenses incurred in effort to reduce this cost may out weigh the benefit.

Costs breakup provided in percentage for different category conveys very substantial information for evaluating or formulating a project proposal from the point of view of cost accountancy and manufacturing.

5.3 Product test program

After prototype is fabricated, it requires extensive test to validate various design features and to obtain feedback from the potential users. This is actually the seventh step in detailed design and is denoted as product test program. This is a very significant step. To avoid forwarding the tricycle with an unforeseen problem for bulk manufacturing that may need expensive correction process, the prototype requires proper scrutiny. This is to be achieved through product test programme.

The newly designed rickshaw was initially tested in the workshop of Department of Design at IIT Guwahati. Its weight was 80 Kgs and is lower by 20Kgs (20%) compared to conventional rickshaw weighing 100 Kgs (Fig. 6.2 in p 198).

The rickshaw was dragged with a spring balance under various loading conditions and the results are compiled below in Table 5.4. The table also provides the comparative results recorded for a traditional tricycle rickshaw.

Table 5.4 Comparative Pulling Force required to move the New tricycle Rickshaw measured using Spring balance

	New Rickshaw	Traditional Rickshaw
Weight of rickshaw	80 Kg	100 Kg
Spring balance reading for dragging the empty rickshaw	1.0 Kg	1.5 Kg
Spring balance reading for dragging the rickshaw with the puller weighing 70 Kg	4.0 Kg	4.5 Kg
Spring balance reading for dragging the rickshaw with the puller (weighing 70 Kg) and one passenger weighing 65 Kg	5.6 Kg	6.0 Kg
Spring balance reading for dragging the rickshaw with the puller (weighing 70 Kg) and two passengers weighing 130 Kg	8.5 Kg	10.0 Kg

The above results show that the newly designed rickshaw is easier to propel.

To obtain other useful information, exhaustive and proper testing of the tricycle rickshaw in real life operating environment was done. The tricycle was subjected to various tests in actual working environment e.g. driven in bumpy roads to expose it to the extreme conditions. It was subjected to overload up to 350 kgs (5 persons) and allowed to ply on road. To obtain comprehensive feedback from the rickshaw pullers, it was plied on road for a distance of 25 KM at a stretch.

Prior to this trial, the newly designed tricycle rickshaw was given different colours to various parts to impart a product identity even through colour and product graphics (Fig. 5.18, p 153 and Fig. 5.20, p 157) and to differentiate from other traditional existing rickshaws on road. The tubular frame was painted in post office red with the rear panel painted in golden yellow. Scientifically, these colours are easily noticed and these are considered very auspicious colours by the citizens in North Eastern region of India. This is due to influence of two religions, both Hinduism and Buddhism. For both these religion, these colours are auspicious and the newly designed tricycle rickshaw painted in these colours imparts a sober look in addition to making them easily recognizable and acceptable by the users, both the pullers and the passengers.

The rickshaw was branded as *Dipbahan.*

In developing a market strategy for individual products, the seller has to confront the issue of branding (Kotler Philip and Armstrong Gary). Branding can add value to a product and is therefore an intimate aspect of product strategy.

Some of key definitions of branding are:

Brand: a name, term, sign, symbol, or design, or a combination of them which is intended to identify the goods or services of one seller or group of sellers and to differentiate them from those of competitors.

Brand name: that part of the brand which can be vocalized-utterable. Examples are Avon, Chevrolet, Disneyland, American Express, and Dipbahan.

Brand mark: that part of the brand which can be recognized but not utterable, such as a symbol, design, or distinctive colour or lettering. Examples are Playboy bunny and the Metro-Goldwyn-Mayor lion.

Branding poses a number of challenging decisions to the marketer.

Brand name for the newly designed tricycle rickshaw was coined by combining two Assamese words- *Dip* meaning lamp/light and *Bahan* meaning vehicle. Thus literary Dipbahan means a lamp vehicle but combined word Dipbahan means enlightened vehicle or rather a vehicle derived out of knowledge that is advanced, since a lamp signifies knowledge in Hindu mythology.

From the point of view of brand name, it is easily vocalized-utterable, recognizable and easy to remember.

Another crucial aspect for providing a brand name Dipbahan to the newly designed rickshaw is that when several rickshaws are placed in a rickshaw stand, many a time, these are not in a queue. Thus when a passengers calls for a rickshaw by uttering 'hey rickshaw', even though the passenger want a newly designed rickshaw, other rickshaw pullers too respond and there starts the argument between the pullers of traditional rickshaw and new ones. Once the newly designed rickshaw was named as Dipbahan, passengers were calling these as Dipbahan and there was no chance to create

confusion on part of the puller with a traditional rickshaw. Thus branding of the new tricycle rickshaw with a brand name was a well thought of process as a part of product launch strategy.

This was noticed that after CRD launched this design in the market, passengers identified and called these rickshaws as Dipbahan providing it a distinct identity.

To expedite the field trial, another rickshaw was fabricated. Thus instead of single rickshaw, two rickshaws were provided to two different pullers every day in different locations (Fig. 5.22) and feedback from the pullers as well as passengers were obtained. NGO interviewed more than 500 rickshaw pullers and 2,000 rickshaw passengers over a period of 1 month using 2 Dipbahans. That comes to almost 20 rickshaw pullers per day, 10 for each Dipbahan and 80 passengers each day, 40 for each Dipbahan.

Rickshaw pullers were the tentative members of Rickshaw Bank and passengers are regular rickshaw users in different parts of the Guwahati city.

Fig. 5.21 Pre-production model

Fig. 5.22 Pre-production models in field trial

CRD provided supervisors at various points where rickshaw was placed for trial and for obtaining feed back from rickshaw pullers and passengers. It was observed that when asked a list of questions, the persons were not keen on answering all the questions. Thus after the first day's observation, only selective questions were asked based on keenness of the users to answer these questions. Also a remark book was provided so that any one can write why he or she liked the rickshaw and its merits and demerits.

Pullers were asked to identify the advantages and disadvantages of the model in their own term. When they did not cover few expected aspects like whether lowering of the top bar as existed in the diamond type frame compared to the new ones has any advantage, they were asked to answer this. Similarly they were asked whether it is comfortable to ride this rickshaw compared to the traditional ones or not and whether hood over their head is a desired one or not etc.

Passengers were asked a separate set of questions like, what was the seating comfort? Whether is it easier to get onto the rickshaw or not, whether luggage space is suitable for them? Whether protection from elements of natural is sufficient or not, whether the

support in terms of handle incorporated in the frame was suitable and if there is any specific shortcomings from their point of view.

Whereas pullers provided feed back relevant and concerning their aspects, passengers' feed back regarding their comfort was very encouraging. The ease of access as well as the low floor height was appreciated by all. Seating comfort and ample space, good floor space was found to be the forte as per their general opinion.

Thus the experimental construction and the test program provided various important feedback and the tricycle rickshaw required certain minor revisions to incorporate these. Sometimes modifications were also done using 'Trial and error removal method'.

5.4 Analysis and prediction

Product Test programmes provided with data and this data is required to be analysed and based on this analysis, predictions are made. Thus, eighth step in detailed design is Analysis and prediction. With the notes and records of the experimental construction and the data and other general observations of the test program, preparation for revision and redesign was started wherever found necessary. Data from the field trial was recorded in a log book as mentioned in section 5.3 and analysed from the point of view of their usefulness for implementing as a design specification. Thus qualitative data was required to be translated to quantifiable ones. Luggage space can be cited as an example. Passengers stated that the space should accommodate a suitcase and common size of suitcase was found to be of 45 cm x 35 cm x 15 cm in length, breadth and depth. It was found that this is easily accommodated in the space. Similarly other users expressed that their daily marketing items are required to be accommodated and to verify this, persons coming out of market were requested to keep their items in the space and to comment whether the space was sufficient. In more than 95 percent of the cases, the spaces were found to be adequate.

Thus every aspect was analysed contextually and there was no statistical method that can be appropriately used in this type of situation without creating more complexicy. Also main aim was that the NGO/SME should also be able to use the process in future to develop more products. Approach used in this case was found to be useful by them.

The following modifications were done based upon the feedback from various quarters including the rickshaw pullers themselves, who were also the end users and maintenance of the rickshaw is their concern:

- Pullers with above average body built provided the feedback that the height of the hood at the puller's end (Front) was to be increased. It was noticed that when road condition is not good and load is more, the rickshaw pullers have a tendency to put more force on the pedal by standing on it. This transfers entire body weight of the person on the pedal. Thus this facilitate running of the rickshaw. In traditional rickshaw this was not a hindrance since there was no overhead cover

on the rickshaw puller. In case of Dipbahan, hood height over the rickshaw puller was initially based on the puller seating on the seat and required clearance for him to see properly at the front. This height was not sufficient for him to stand on the pedal. Rickshaw pullers wanted the hood height to be increased.

This was implemented by increasing the front end height by 7.5 cm without disturbing the overall design of the tricycle rickshaw.

- Another feed back available after experimental construction and trial was that the curved rear panel caused difficulty in writing of sponsor's messages and details at the rear panel through stenciling. The rear end of the newly designed tricycle rickshaw had three dimensional curvatures including the rear panel earmarked for insertion of advertisement. This curvature also made fabrication and assembly of the rear panel difficult in sheet metal. The curvature of the horizontal binding bars was reduced. These were modified on the same design without much difficulty.
- Similarly, initial prototype had separate structure for the seat and seat back aimed at its fold ability (Fig. 5.23, p 161) so that in case of carrying only goods, better space utilization is possible. The part bearing the passengers' load in this seat arrangement failed because of being a suspended beam. Later it was changed to column type arrangement, which on testing was found to be very stable. Folding type of seat arrangement was discarded in commercial production version, Dipbahan to reduce cost of production and facilitate ease of maintainability. Also responses from passengers on this version were excellent compared to provision of using the tricycle rickshaw for goods carriage. It was decided that a separate version can be built later only for goods carriage purpose.
- Absence of rear wheel brake is a shortcoming in traditional rickshaw design existing in the North East India. Mountain bike handles were selected to provide brakes at both the front and rear wheels to be actuated by hand. Initial handle outsourced from mountain bike parts bin was straight type. The handle was changed back to traditional ones that is normally used in traditional rickshaw for better operating results. As mentioned above, the rickshaw pullers have a tendency to put more force on the pedal by standing on it. Rickshaw pullers expressed that, in doing that the traditional rickshaw handles with brake lever below the hand grip was more convenient. Also, traditional handles were provided with solid links compared to cables in mountain bikes and are preferred by the. Traditional handle also provide combined braking with single front brake to the front wheel from both left hand and right hand and this helps them in maneuvering in crowded place. Another reason cited by them is that the traditional rickshaw handle orientation is better for them to easily maneuver the tricycle and to get better control when pulling the rickshaw by standing on foot on ground with passengers sitting in the vehicle, since handle grips are in line with

the body of the rickshaw compared to across the body for mountain bike. Later in the Dipbahan+, a rear brake was provided and was actuated by foot.

- During the design of Dipbahan, initially a tricycle rickshaw was analysed for various sub-systems such as puller's seat. After this analysis, various available alternatives for each of these sub-systems were studied for their appropriateness, comparative advantages and disadvantages. The mountain bike's seat, during static study and feedback from bicycle riders and rickshaw puller's emerged as the best one. Rickshaw pullers were also informed about the cost of each type of seat. Based on this, in spite of the higher cost of a mountain bike's seat, the puller's seat was taken from mountain bike parts bin and incorporated in the Dipbahan design assuming that this will provide better comfort to the rickshaw pullers. However it was after the actual field test that a different picture emerged. Thus this particular aspect could not be identified in the beginning. This was not found to be favourable during trial. Therefore traditional rickshaw seat system with leather seat was incorporated. This was also not preferred by the rickshaw puller in Guwahati. Finally it was replaced it with cheaper rubber seat made out of disposed car tyre moulded to the shape of the seat. This was encouraged since this can be a good environmental measures for recycling disposed car tyres in a reusable manner. A good design out of this drew attention for further development. Also, it was observed later that based on the socio-economic background of the puller, there is different choice for the materials of the seat. Native people from NE Region of India seem to prefer leather seat in spite of its high cost and immigrant Bangladeshi puller prefer low cost rubberized seat.
- Fracture and failure of welded joints at the front end connecting the space structure with the head pipe was noticed in the newly designed tricycle rickshaw as shown in Fig. 5.24, p 161. This was traced to excessive vibration and shock transmitted to this point through the front fork as well as hood structure due to poor road condition added with poor quality body frame socket and welding rod. The bought out socket due to substandard quality used to fail and this was also the part that was difficult to procure due to non availability. Modification was done as shown in Fig 5.25, p 161. A MS plate of 3 mm thickness was fixed in between the pipe as shown in the figure and the front end was joined at this plate.

  The failure of the joint was also due to the failure to provide a vital member at the hood area. In its absence, the hood used to behave as a fulcrum. The structure was modified by adding a binder as shown in Fig. 5.26, p 161. It was specified that quality body sockets are used along with standard welding rods like ESAB brand due to its consistency in welding thin mild steel tubular structure.

Fig. 5.23 Foldable seat structure

Fig. 5.24 Point of fracture

Fig. 5.25 Modified front end joint

Fig. 5.26 Additional binding bar

After successful testing of the pre-production prototypes through product test programme and analysis of the data, the commercial production of the newly designed tricycle rickshaw with due modification were started. 100 interim version Dipbahan was introduced in the market (Fig. 5.27) under the Rickshaw Bank Project (Appendix 1) by an NGO, Center for Rural Development, Guwahati. After initial training of the manpower engaged by the NGO at IIT Guwahati, manufacturing was left to the NGO. Rickshaw of first generation is shown in Fig. 5.28, 5.29, p 162 in different color to give a choice regarding the colour to the pullers that helps to identify their rickshaw easily.

Fig. 5.27 Interim version of Dipbahan, inaugurated at Kalakhetra in Guwahati under Rickshaw Bank project being flagged off after distribution to the rickshaw bank members

Fig. 5.28 Interim version of Dipbahan, in three quarter front view, parked for distribution to the rickshaw bank members during inauguration

Fig. 5.29 Interim version of Dipbahan, in rear view, parked for distribution to the rickshaw bank members during inauguration in front of Kalakhetra. Centre for Rural Development, Guwahati implemented the Rickshaw Bank project

5.5 Design up-gradation

Any product after production and detailed test undergoes improvements to make it better in terms of comfort to the user, functional reliability and error elimination, to reduce cost of manufacturing, to enhance maintainability and finally enhance the life of the product. Thus product up-gradation and redesign should be a regular feature for successful products while in operation. In the morphological process of design, Redesign is ninth step in detailed design**.** The analysis and predictions of performance are the prelude to redesign. The experimental construction and the test program have found the design of the tricycle rickshaw adequate and the work of redesign is just that of minor revision.

The Interim version of 1st generation of Dipbahan had the following as specific objective, for its manufacture and maintenance:

- A tricycle rickshaw to be economically competitive enough with existing rickshaw,
- But using less complex technology with existing skill of manufacturing and repairing
- Conceptually different from existing rickshaw.

The comparison of Interim version of Dipbahan against traditional rickshaw is shown in Table 5.5, p 163. Cost wise interim version of Dipbahan was quite competitive compared with traditional rickshaw. Objectives as given in the product brief at section 3.4 in Chapter 3, p 77 were achieved. It also incorporated the requirement of an advertisement space.

Table 5.5 Comparison between Interim version of Dipbahan and Traditional rickshaw.

	Dipbahan interim version	Traditional rickshaw	Remark
Cost	Rs. 8,052.00	Rs. 6,500.00	Cost of Dipbahan is 24 % higher than traditional rickshaw
Weight	80 Kg	105 Kg	Dipbahan is 24 % lighter in weight than traditional rickshaw
Materials used for fabrication	Category A.		
	Standard bought out component made by bicycle Industry	Standard bought out component made by bicycle Industry	These are same for both Dipbahan and Traditional rickshaw
	Category B.		
	Main frame, fabricated	Main frame made by bicycle Industry	Dipbahan do not require diamond frame due to the space structure employed and it is easier for the puller to get on and off the seat in absence of top cross bars.
	Category C.		
	Chassis is also made from tubular sections using arc welding	Various parts for chassis is fabricated by blacksmiths and procured from him	In Dipbahan, mainframe and chassis is integrated using a space frame structure. Process of manufacture of this structure was not used for fabrication of traditional rickshaw in the local context.
	Category D.		
	Passengers' seat, seat back and floor panels are made in wood using carpenters and fitted to the tubular body shell. Floor panels are covered with aluminium sheet; seat and seat back are covered with foam, coir fibre and vinyl fabric. Back panel is made out of mild steel sheet.	The body is fabricated in wood using carpenter is integral with the passengers' seat back and floor panels. Foot board and outer side of the wooden body is covered with aluminium sheet. Seat is made separately in wood, fitted with spring and covered with coir fibre and reskin and is removable.	In the interim version, the process of fabrication of seat, seat back, floor panel etc. are similar to traditional rickshaw to utilise the readily available large pool of skilled worker in this area.
	Category E.		
	Hood cover and rain guards are made in vinyl fabrics and fixed to the tubular frame. Rain guards are foldable	Foldable canopy is made in bamboo and covered with tarpaulin and fixed to the canopy and wooden body.	Usually no rain guards are provided in traditional rickshaw.

Based on the success and feedback on interim version (1st generation) of Dipbahan the work of 2nd generation Dipbahan was started. The strategy adopted for designing 2nd generation Dipbahan was value engineering. Every aspect of the design and component was analysed. Idea was to reduce bought out parts, number of materials and processes. The analysis in brief is given below:

Analysis of the main frame:
In order to reduce the inventory through reduction in variety of sections in mild steel and to utilize the currently used materials and processes in rickshaw industry for ease of manufacture and maintenance through available skill in this industry, the process of manufacture of Dipbahan became an amalgamation of old and new. Observations are:

- The entire body shell was made in 25 mm outer diameter MS tubes and 40 X 5 mm MS flat along with bought out items like BB socket, body and frame socket etc. The main chassis was of sandwich type, one 40 X 5 mm MS flat welded with two tubes as seen in Fig. 5.30. Making of the frame was difficult, since the flat is to be welded to pipe of circular shape as well as both being of different thickness welding was not easy. Pipe of appropriate dimension to fit the readily available body socket was not readily available in local market.
- The frame at platform level was fracture prone as shown in Fig 5.30. Failure at the platform level was due to 3 dimensional bending of this element. Normally during bending of pipe with seam joint, the bending must be done in a way such that the seam is not stressed. However in a bend like at point X1, X2, this is not possible and failure was noticed at this point. Another reason for this failure was poor quality of pipe; due to low malleability, it used to deform during bending.
- Analysis of the process showed that the making of the chassis used to contribute heavily towards cost of fabrication, because it was based on sandwich design i,e, a 40mmx5mm flat bar fixed between two circular sections to strengthen the chassis in interim version of Dipbahan. This was to reduce the variety of MS section materials to keep a low inventory. Also joining of the two circular tube was labor intensive. Thus welding used to consume more time and money.

Fig. 5.30. Chassis of interim version

Fig. 5.31. Chassis modified by CRD

Based on the failure of the frame, the NGO, Centre for Rural Development changed the process of manufacture by using a ready made diamond frame (Fig. 5.31, p164) to get rid of the problem that were not perceived by them as due to lack of quality consciousness in spite of guidance provided to them and the fact that jigs and fixtures are required to obtain better quality and input material must be checked for its quality before it is used for fabrication and once quality is degraded, it is difficult to solve teething problem through remedial measure and also adds to cost. NGO changed the chassis to solid square bar of 25mm (Fig. 5.31, p 164) and used angle of 20x20x4mm for making the platform. CRD also removed the bearing blocks (Fig. 5.32) against the specified design (Fig. 5.33)

Fig. 5.32 Rear axle without bearing block

Fig. 5.33 Bearing block as per specification

CRD manufactured rickshaw also had orientation altered for the front member compared to specified ones for it. Also frame structure was fabricated with defects (Fig. 5.34).

Fig. 5.34 Pipe fractured during bending

In case of seat, seat back, floor panels, wire mesh guard for luggage space and rear panel, it was observed that NGO was rampantly compromising on quality.

CRD did not wait and neither initiated the redesign of the interim version of Dipbahan to evolve next generation of it and resorted to short term measures as described above to solve the problem faced in the market, solely based on advise and feed back from users without appropriate analysis. This led to compromise on quality and design. Thus it was essential that next generation of Dipbahan must be designed to make it as fool proof as

possible so that a minimum standard and quality can be maintained. Concurrent design development of jigs and fixtures are identified as essential ingredient in this endeavour.

To start design development of next generation of Dipbahan, analysis of the process of manufacture of interim version of Dipbahan was resorted to.

Regarding the process of manufacture of interim version of Dipbahan, there are several types of processes involved along with different types of skills required even for the new design compared with traditional rickshaw manufacturing.
These are:

- Cutting mild steel sections, welding and grinding the body shell.
- Cutting of mild steel wire mesh, fabricating luggage guard at the rear and sides below the seat for luggage and fixing these to the body shell.
- Painting the body shell along with the back panel made in mild steel sheet.
- Carpentry work for seat, seat back and floor panels.
- Tailoring work for hood cover, seat cover and rain guards
- Fitting work for assembly of the bought out components, seat, seat back, floor panels, rain guards etc. to the body shell.

Thus it was essential that reduction in type of processes and variety of materials is to be achieved and requires analysis of the entire process of its fabrication. Also it is essential to improve the design based on feed back available from the field mentioned earlier.

Description of 2nd Generation Dipbahan: Dipbahan+ (Fig. 5.35 and 5.36, pp 168-169)
Value analysis (Christopher, 1992; Chitale and Gupta, 1999) is a preplanned branching strategy for the designing of a product to reduce cost by finding the cheapest possible means of performing each essential function. Value analysis is also known as Value engineering. Its effect is to hasten and extend the exchange of thoughts between all persons who are in a position to discover the costs and to see ways of reducing them. The stages involved in value analysis are:

(a) identification of elements, functions, costs, and values
(b) search for alternatives at lower cost
(c) selection of functionally acceptable lower cost elements
(d) presentation of selected redesign

Value engineering was used to arrived at redesigned Dipbahan+ version of the tricycle rickshaw. It was through various stages involved in value analysis that led to replacements of various components with newer alternative material components including fibre glass reinforced plastics for floor panels, side panels, rear panels etc. It also led to reduction in components for the Dipbahan+ version fabrication. Based on the Value engineering and feed back, the mainframe and chassis was made out of 50x25mm rectangular tubular mild steel sections (Fig. 5.37, p170). This could overcome all the draw backs of earlier design as well as reduced inventory and number of different

material. All bought out body, frame and seat sockets were no more required. For the entire body shell bought out part was only the BB socket.

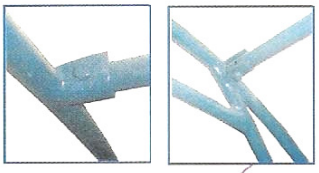
In terms of varieties and numbers of processes involved, value analysis and resultant redesign led to increased productivity through reduction in amount of welding required for fabrication compared to interim version since sandwich type platform was no more required and parts orientation was easier compared to circular tubular section when these sections were replaced with rectangular tubular sections. Also grinding process for round tubular section could be eliminated once rectangular section was adapted. This led to lower cost of production. For the entire Dipbahan body, it was broken into sub frames. These are mainframe and chassis, seat structure, right side frame, left side frame and three numbers of cross binding members. Once all sub frames are ready, these are welded together using fixtures to fabricate the main shell of the Dipbahan (Fig. 5.38, p 170). This ensures accuracy of dimension. After the shell is ready, it is sent for spray painting using automotive paints and the process is same as in case of the interim version of Dipbahan.

For the body shell, all other aspects of design were kept similar to the interim version of Dipbahan except the radius of the rear elements were changed to reduce the curvature to accommodate advertisement space that is planner and can be screen printed.

Dimensions
Wheel base : 1900 mm
Track : 1000 mm
Weight : 85 Kgs

Fig. 5.36 Rear three quarter view of Dipbahan*

Appropriate and aesthetically appealing form, visually light with contemporary visual identity giving it a feeling of sophistication, sporty and dynamic.



Details of joint for Knock down ability of the structure to facilitate transportation

Hood protecting puller and the passenger from elements of nature #

Rain guards made of Synthetic vinyl material for side and rear

Enveloping tubular structure of 25mm dia MS tube, spray painted with Duco paint protects the occupants

Ergonomic Seat at lower height brings down the Centre of Gravity #

Side panels #

Effective Mudguard #

Low height Floor for ease of access #

Ample leg room

Reduction Gear

Space for passenger's luggage

Chassis -strong tubular structure of 25mm x 50 mm rectangular MS tube

Hand molded Jute composite

Chassis, Left and right frames are stackable for transportation. Similarly, hood and seat are stackable.

Readily available components from market are outsourced and used for ease of maintenance at local rickshaw workshop

Dimensions

Overall Length	: 2600 mm
Overall Width	: 1250 mm
Height	: 2000 mm

Fig. 5.35 Front three quarter view of Dipbahan+

Fig. 5.37 Mainframe and chassis

Fig. 5.38 Assembly of body from sub frames

The second important achievement in the second generation Dipbahan design was concurrent design of jigs and fixtures for fabrication of the Dipbahan. Details of design and development of jigs and fixtures are provided in Chapter 7 under section 7.1.2,p207.

The third important features of 2nd generation Dipbahan is introduction of Bio composites based on Jute fibre (Fig. 5.39, p 171) and Fibre glass Reinforced Plastics components. This led to elimination of seat and seat back earlier fabricated using wood, foam, coir and covered with synthetic foam leather or rexin and floor boards fabricated using wood and covered with aluminum sheet. The rear panel and rear mudguards earlier fabricated in mild steel sheet were eliminated. Initial set of mild steel mudguards used in 1st version of the Dipbahan shown in Fig. 5.28 and 5.29 (p162) were out sourced from the parts available from tricycle and bicycle industry. In conventional rickshaws the rear mudguards due to its narrow width and position for fixing with body and details for the same were not suitable and used to throw mud and muck on the users. In case of 1st version of Dipbahan, mudguards were retained but their effectiveness increased through proper fixing and location. However due to small width these were found to be still impractical. Redesign of 1st version of Dipbahan provided the scope for entirely designing these to go with FRP based items and also to provide really effective set of mudguards in the rear. These are wider and non-rusting and hence fully met the objectives. These mudguard clad Dipbahan+ is shown in Fig. 5.35, 5.36, pp168-169.

Sides below the seat and lower part of the rear panel below the mild steel sheet fabricated out of wire mesh was also replaced with closed side covers and a larger rear panel. The wire mesh cover was ineffective in terms of protecting the luggage space from mud and slush getting spread by the rear wheels. Hood in the interim version was in synthetic foam leather / vinyl / rexin. All the above items were replaced with new and appropriately designed Jute based bio-composites. These are 10 in numbers 1 for seat, 1 for the seat back (Fig. 5.40, p 171), floor panels in two parts, side panels 2 numbers- for left and right, mud guards – 2 numbers for left and right, rear panel and the hood (Chapter 4, Table 4.2, p 142). All these were introduced after value engineering. Seat and seat back were integrated later to a single piece (Fig. 5.41, p 171).

Fig. 5.39 Jute based Bio-composite

Fig. 5.40 Seat in two piece

Fig.5.41 Integrated single seat

The design development of the 2nd generation of Dipbahan was sponsored by M/s. Tim Steel Innovatives, Guwahati a SME specializing in fabrication business using iron, steel etc. Another SME, M/s. National Associates, Guwahati, a manufacturer of FRP products associated in development of composite components for the Dipbahan+. In addition Indian Jute Industries' Research Association (IJIRA), Kolkata, under Ministry of Textiles, Government of India sponsored the design development of Jute Composite based components used in the Dipbahan+.

Thus the initial version of the Dipbahan continued to be manufactured by NGO, Centre for Rural Development, Guwahati and manufacturing of 2nd generation Dipbahan+ was started by M/s Timsteel Innovatives, Guwahati. This manufacturer tied up with M/s. National Associates, Guwahati, for regular supply of FRP components to the former. Thus there was no impact on manufacturability due to the introduction of FRP components for local producers except creating avenues for more business in their own area of specialization.

Since, the appropriate work was allotted to relevant concerns with their expertise, there was no fresh capital outlay required in order to produce these specific components and nobody had to learn new skills.

The fourth important feature is introduction of reduced gear ratio. One important observation during initial study of tricycle rickshaw was that, the gear ratio of the drive train is very high for the rickshaw to go up an inclination like a culvert that are very common in city like Guwahati. This compelled the rickshaw puller to get down from his seat and drag the rickshaw and this is very dehumanizing. Also due to longer length of the chain, it used to come off the sprocket frequently after some use. In the interim version of Dipbahan, this issue of gear system was not attended to due to the constraint of meeting targeted simplicity desired for ease of maintenance in commonly available rickshaw and cycle repairing shop and cost of manufacturing. This issue was addressed in the next version of the Dipbahan as a redesign exercise. One option was to fit the rickshaw with commercially available derailleur gear mechanism. However, these are not manufactured to take heavier load as required for rickshaw and also difficult to maintain. Thus simple mechanism to reduce the gear ratio was attempted. Thus gear ratio was reduced with introduction of an intermediate shaft and two additional sprockets. The Table 5.6, p 172 and Fig. 5.42, p 172 provides the details of the same.

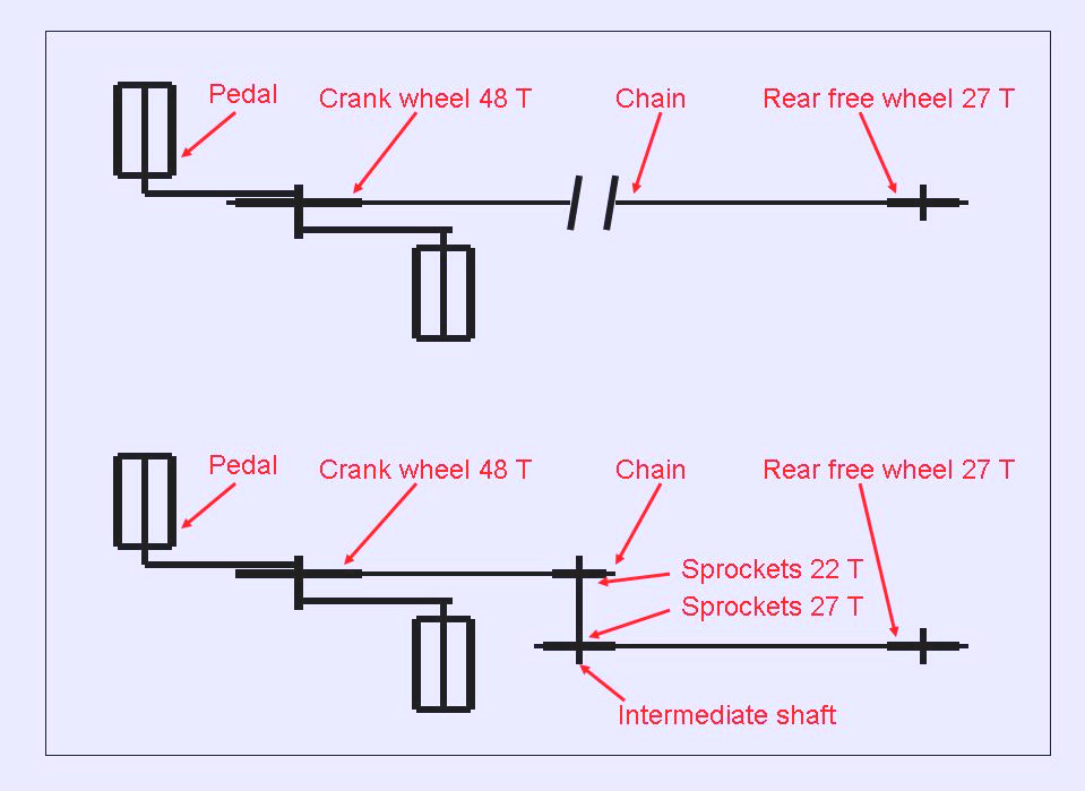


Fig. 5.42 Schematic diagram of layout of gears and pinions for gear reduction

Table 5.6 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 meters	Pedaling per minute to cover 1 Km	Pedaling per minute at 10 Km per hour
			Teeth on driver wheel	Teeth on driven wheel				
1	48	18	-	-	2.667	5.96	168	28
1	48	20	-	-	2.4	5.36	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~~

Strikes through figures are the same ones possible through intermediate shaft but are directly available even without the intermediate shaft.

As seen in the above table, commonly used gear ratio in a traditional rickshaw is **1.777** However a higher gear ratio of 2.182 is also found in some cases.

To lower effort at starting, *Dipbahan*[+] uses a still lower gear ratio of 1.45 possible through introduction of an intermediate shaft.

Information in Table 5.6 is based on following calculations.

Calculations:

For single stage gear reduction

Number of revolution of crank wheel given by n_1

Number of revolution of sprocket wheel fixed to rear axle given by n_2

Number of teeth of crank wheel given by $T_1 = 48T$

Number of teeth of sprocket wheel at rear axle given by $T_2 = 22T$

Then $n_1/ n_2= T_2/ T_1$

Since n_1 is 1, $n_2= T_1/ T_2 = 48/22 = 2.18$ i.e. for every rotation of the pedal by the rider, the rear wheel will rotate by 2.18 turns. Here gear ratio is $T_1/ T_2 = 48/22 = 2.18$

Considering the diameter (d) of the rear wheel as 71 cm (28"), in one pedaling, the tricycle will travel a distance of $n_2 \pi d = 2.18 \times 3.14 \times 71 = 487$ cm (rounded off) or 4.87 meters.

To travel one Kilometer, numbers of pedaling required will be = 1000/4.87 = 205 times.

Considering a speed of 10 Km per hour, number of pedaling per minute (ppm) to cover 1 km will be 205/6 = 34 ppm

For two stage gear reduction through introduction of intermediate shaft

Number of revolution of crank wheel given by n_1

Number of revolution of sprocket wheel fixed to intermediate shaft given by n_2

Number of teeth of crank wheel given by $T_1 = 48T$

Number of teeth of driven sprocket wheel at intermediate shaft given by $T_2 = 27T$

Number of teeth of driver sprocket wheel at intermediate shaft given by $T_3 = 22T$

Number of revolution of sprocket wheel fixed to rear axle given by n_3

Number of teeth of sprocket wheel at rear axle given by $T_4 = 27T$

Then $n_1/ n_2= T_2/ T_1$

Since n_1 is 1, $n_2= T_1/ T_2 = 48/27 = 1.78$ (rounded off two 2 decimal point)

Again,

$n_2/n_3= T_4/ T_3$ or $n_3 = n_2 \times T_3/ T_4 = n_3= T_1/ T_2 \times T_3/ T_4$ (replacing n_2 with T_1/ T_2)

$n_3 = 48/27 \times 22/27 = 1.45$ (rounded off two 2 decimal point)

For every rotation of the pedal by the rider, the rear wheel will rotate by 1.45 turns. Here gear ratio is $T_1/ T_2 \times T_3/ T_4 = 48/27 \times 22/27 = 1.45$

Considering the diameter (d) of the rear wheel as 71 cm (28"), in one pedaling, the tricycle will travel a distance of $n_2 \pi d = 1.45 \times 3.14 \times 71 = 323$ cm (rounded off) or 3.23 metres.

To travel one Kilometre, numbers of pedaling required will be = 1000/3.23 = 310 times.

Considering a speed of 10 Km per hour, number of pedaling per minute (ppm) to cover 1 km will be 310/6 = 52 ppm (rounded off to nearest integer)

Thus it is seen that for traveling same distance with higher gear ratio will require more less number of pedaling per minute against lower gear ratio requiring more numbers of pedaling per minute.

However considering torque applied by the human being as same, he will required to apply less torque per pedaling with a low gear ratio compared to higher gear ratio. Thus there is a trade off between the two. High gear ratio is advantages for continuous operation in speed and lower gear ratio is advantageous in interrupted operation like in congested city, where stopping and starting is frequent.

The introduction of the reduced gear ratio made the rickshaw riding easier even with higher load and going up a slope, but it reduced the speed and distance covered by the rickshaw for a fixed number of pedaling by the rickshaw puller. On busy roads, it was not evident but in an empty road, this was not preferred by the rickshaw pullers and a shifting gear mechanism was designed for the Dipbahan^{+}. The final design of Dipbahan+ is presented in Fig. 5.35 and 5.36 in pp 168-169.

Impact of incorporating the gear mechanism in the 2nd generation Dipbahan+ on overall design was:

Weight of the geared tricycle rickshaw increased by 8 Kgs compared to ungeared one.

Performance of the rickshaw improved during initial start up i.e. starting from stand still required less effort compared to ones without gear mechanism. However on long run, where the rickshaw can go faster, it suffered since lower gear reduced its speed and less effort to run the rickshaw did not compensate for speed reduction, since rickshaw pullers wanted to go faster too, after initial effortless start.

In terms of price, it increased the cost of the rickshaw by Rs. 750.00 due to incorporation of the additional components and processes during manufacturing.

DESIGN DEVELOPMENT OF AN INDIGENOUS TRICYCLE RICKSHAW

Chapter 6

Technology Transfer:

State of the Art from the Point of View of Design Development Awareness and Context

6.1 Economic development in India and role of design

India is one of the fastest growing economies in the world. Even then it is considered as a developing country. India has completed 59 years of Independence. Based on its emphasis in Science and Technology, it stands self reliant in these areas. However, India does not have a policy either for design education or design industry until now and in its absence, benefits of science and technology have not been translated in terms of improved standards of life, in absence of better products and services.

The following facts are the indicators of the ways and means of appropriate context specific design development of tricycle rickshaw and its manufacturing to reach to the society for its use.

6.1.1 Measures of development

Gross Domestic Product (GDP) and per capita income are often flaunted as the measuring sticks for development and prosperity of a country. Similarly energy consumption per capita is cited as a measuring stick for progress of a society. However these should not be applied uniformly all across the world. This is because in case of a country like India, the GDP and per capita income does not take into account the non monetary wealth generation by the women folk constituting 50 percent of the population.

Similarly in western countries power consumption in Kilowatt of electricity is considered as a yardstick of progress of a society. However in case of Indian context, many part of it is still not even properly electrified. Energy need is met through petroleum product to run prime movers for many applications that can be otherwise operated using electric motors if electricity were readily available. Energy requirement is also not uniform in all parts of the country and also widely varies among different strata of the society. Being a semi tropical country, most part of the country except trans Himalayan region do not need heating in the winter and thus energy requirement is low. Only in the summer, one needs air conditioner to escape the heat. Majority uses electric fans in the semi- urban and urban areas.

In the rural areas traditional housing using building materials such as mud block keeps the heat off. Air coolers using cooling power due to evaporation of water in low humidity condition has been used from time immemorial and at present efficiency has been enhanced through the use of electric fans and pumps to circulate air and water. Small scale industries initially catered to this sector but medium scale industries too stepped in recent times.

It clearly indicates that, measures of development where large populations' lifestyle can not be equated with others, well being within indigenous resources would be appropriate. A scale of satisfaction may be a yard stick, and it could be achieved through indigenous development to suit Indians in its specific contextual requirement.

6.1.2 Science and technology in India

India has the distinction of having the largest technical and scientific manpower in the world. Indian engineering and technical education system is recognized globally as one of the best. India also has a well established engineering industry as well as consumer durable industry and industrial growth is commendable. Against this background of industrial growth, these achievements failed to improve the living standards of people within the country. This can be related directly to its effort for building its industrial structure rapidly since its independence. Import of technical know how is imperative to catch up with the latest advancements in Science and Technology. The technological transfer to India from abroad has led to design transfer as well, resulting in low indigenous development in design abilities. This 'design dependency' has made Indian products less competitive in the world market and has adversely influenced the export performance. Due to its failure to develop indigenous design & development capabilities (Munshi, 1985), Indian market continues to be flooded with foreign products that in many cases meet consumer aspirations but not their needs and self reliance. There is a gradual change, however even now a majority of the products introduced in India are designed abroad and these are either manufactured in India due to cheaper cost of production and transportation or to obtain tax benefit claiming it to be locally manufactured product. It is the automotive sector that a few successful products are designed and manufactured in India.

In Product Design Engineering India appears to be better compared to product design.

To ensure industrial growth, along with improvement in the living standards of its citizens, it is important that we choose the priorities properly. Industrial Design in particular can play a significant role in this growth and economic development (Bonsiepe, 1973), employment generation and exports in future (IDC, 1997). Academic intervention and research in industrial design is taking a preferential shape.

6.1.3 Design education in India

Compared to industrial development, formal industrial design education activity started quite late in India. It is only in early sixties that design education programme started with establishment of National Institute of Design (NID) in Ahmedabad and later in the same decade with the establishment of Industrial Design Centre (IDC) in Indian Institute of Technology Bombay (IITB) in Mumbai. NID offered diploma level programmes initially and then started offering post graduate programmes with specialization specific to various applications. IDC being part of an IIT system of technical education catered to the post graduate levels and that too in industrial design and visual communication only. Till 1994 India had only these two institutes offering design education. Situation has changed in the last decade with few other institutes offering design courses in master level stressing product design.

With disparity in income level in the country, large rural population, poor infrastructure and fast degrading environment, depleting natural resources, philosophies of designing for the masses form an integral part of this new design education with responsibility of preserving India's diverse culture, crafts and environment. Philosophy of Design should consider functionality as well as to build an identity for Indian design itself. These aspects is ideal not only for India but for any other developing countries. Starting in the nineties, Centre for Electronics Design and Technology (CEDT) in Indian Institute of Science, Bangalore (IISc) and Instrument Design and Development Centre (IDDC) in Indian Institute of Technology Delhi (IITD) as well as 'Design Programme' in Indian Institute of Technology Kanpur (IITK) followed suit at different times.

In late nineties, Department of Design (DoD) in 1997 was established in Indian Institute of Technology Guwahati (IITG) to offer undergraduate level programme leading to B.Des (Bachelor of Design) in Product design and Communication design. This is the first bachelor degree offered in design in India and is starting Master programme in July 2007 aiming to cultivate need specific specialisation. Indian industry wants designer with strong engineering background. Thus a designer must be able to design as well as detail out the product completely to take it up for production. Gradually Indian design education is taking shape towards achieving this goal and many private institutions are also sharing this responsibility in building design reliance in India.

6.1.4 Philosophy of design education in Indian context

At a philosophical level, design commits to improve quality of life. There is a pre-occupation in developed market driven economy of western countries to concentrate all the efforts of design to design and redesign most of the well functioning consumer product with a view to create obsolescence to earlier products and create new demand essential for the survival of their materialistic economy. But restricting the design inputs to products from engineering industry would not be adequate in a developing country like India. Ideas of 'product' and 'industry' have changed to include new areas that were mainly left to Art earlier. In the context of developing nation, the philosophy of Design Education (Das, 2005; Ramachandran, 2005) should be to achieve the following:

6.1.4.1 Preservation of diverse culture within India

India has a rich tradition and culture. Continuous transfer of 'western' design has brought into the country Western habits and value systems, creating a crisis in our cultural identity. These cultural identity needs to be preserved. Industrial Design sensitive to the local cultural heritage can create a cultural identity overcoming the imitative, borrowed culture. It is possible through design intervention in documenting traditional and existing knowledge, and dissemination through developing newer products. It should be in tune with availability of local resources and to satisfy the contemporary need. An example would also be appropriate to cite here is, with rapid computerization, one such need is designing computer interface for different languages in India. It is not only a challenge but an opportunity.

6.1.4.2 Craft based industry

In India, it is a well recognised fact that craft is an industry employing several thousands of people. The products that they make is a source of endless variety. Most of these are used to be functional. However at present, except for handloom products, craft objects have lost the role they used to play in daily life. With new materials and processes, most of these craft produced items have been replaced with cheaper products that are mass produced in small enterprises. Craft remains a neglected area in development efforts. Thus these traditional craft items must be used in alternative way to keep the traditions alive since these provide for livelihood of traditional craftsmen as well as preserves the traditional aesthetics and forms so encoded in this country. If craft products are not related to everyday needs, the industry may turn to manufacturing of curio articles for home market and exports.

If crafts have to retain its pre-industrialisation glory in daily life, the craftsmen may have to update their knowledge and skills to meet. Acceptance of modern materials, tools and methods can make them successful in maintaining their positions in the home market. There is an obvious need to generate new design capabilities in craftsmen, so that the products can be updated. The product range can also be extended to suit new needs. It is also important to offer simultaneous inputs to improve the technology used. Craft designs display styles that are highly specific to regions. Craftsmen are also proud designer themselves. Design educations for them must take these into accounts. Otherwise a centralized and universal educational or design assistance approach may only lead to crafts losing their regional flavour. An appropriate method for technology transfer to suit to their traditional skills needs to be studied.

Designer working in the craft sector may face a totally different situation. To develop craft based products, the designer must go through a new learning process and understand relationship between craftsmen, products and culture. He must get an acceptance in the craft guilds and win their confidence before they accept his ideas. Philosophy of Design Education should be such that a designer imbibes these values through his education.

6.1.5 Exploding population and employment generation

India has the distinction of having second largest population in the world. Most of the developed countries are witnessing negative growth of population. Against this scenario all developing countries including India still has a growing population rate increasing above 10 % per annum as per Census data of 2001, Government of India(www.censusindia.gov.in, Dec, 2006). Considering the sizable number of population involved, even a small development will make a significant impact in a country like India and large beneficiaries can be benefited compared to developed countries.

6.1.5.1 Education of the masses and removal of disparity in income distribution

Education for the large population in a country like India have to be done through mass media. “Information design’ can play a significant role in social, cultural and scientific

education of the masses. Industrial design can help in evolving new strategies of design to reach the vast masses. For example, 'design' knowledge in making one's own things using local materials can be communicated to people through mass media and adult education programmes. Proper 'Information design' can make adult education meaningful and productive.

Income distribution is one of the serious and explosive problems of any developing country. The fruits of design in organised structures seldom reach the poor majority. Once this vast mass can be reached through design, this disparity can be tackled. Design education and awareness in mass must be geared up for the same.

6.1.5.2 Employment generation

Exploding population growth in a developing country results in unemployment problem. Thus whereas in a developed country, the trend is for designing equipments and systems for reducing human workforce due to high labour cost, in a developing country like India, this philosophy is not always tenable. The philosophy of Design education must emphasize the designer's role not to unnecessarily reduce human work force, but to encourage design where human being is productively utilized. Questions raised is what is the employment generated for every million invested in an industry.

There is thus parallel activity being encouraged. Khadi and Village Industries Commission (KVIC), [Khadi=Fabric woven using hand spun yarn through handloom] propagates decentralised rural based industries and designers engaged work for improving design & utility of their products adding more value and changing images. Thus Industrial Design could play a vital role in innovating products with high market potentials which can be made with local skills.

Another good example can be revitalisation of vegetable dyes, terracotta, local toy and doll industry with proper design and marketing inputs can generate large employment potentials in the rural and semi-urban areas. 'Craft' based industries can make use of local trades which are often abandoned for 'employment' in cities. Agriculture based rural economy provides for seasonal employment to the rural worker can thus get regular employment through these activities. Low investment based transportation design development is also envisaged a potential area for successful utilization of local skills.

6.1.6 Vast rural population based on agrarian economy

In India, around 70 % of the population is rural population and they are primarily dependant on agriculture. Presently India is not only self reliant on food but has surplus food production. However value addition to the product is very low in the rural sector. It is the organised urban sector which is adding value selectively and make brands, and this does not benefit the common rural mass. Although India produces significant amount of fruits and vegetables, the actual processing of these for preservation and value addition is miniscule within 1-3 % of total produce. Huge rural population provide tremendous

scope for designing products and services. Areas requiring intervention are agricultural equipments and implements (Harvester, combines, thresher etc.), food processing and preservation (cold storage & warehousing) using non-conventional energy.

Generation of non-conventional energy in smaller scale appropriate to the sector itself is another challenge. Bio digester, gasifier, bio gas, bio manure, bio pesticides, bio diesel, rural transportation, vegetable dyes etc. are just a few. Rural sector also generates huge by-products such as straw etc. that are to be productively used. Banana stalk after harvesting can be extensively used for banana fibre extraction.

Design can help in bringing out products to satisfy cultural and social needs of our population. Needs of the rural population can be particularly well taken care through 'Design' which is sensitive to local needs. Enhancing local transportation would increase movement of produces from field / firm to market and vise versa.

6.1.7 Preservation of the environment

In a mad rush to development, ecological balance is threatened today with increasing environmental pollution and degradation. Fast degrading environment, depleting natural resources have dislodged population from their natural habitat and threatened the peace and very existence of a country.

Designing can play a vital role in searching for alternatives and innovating usable products, making use of new energy sources. Legitimate use of human energy still could be a viable solution even in present context in India specifically addressing semi-urban and rural development.

6.1.8 Recent trend: Globalisation and competitiveness of Indian design

Multinationals looking for product markets in culturally diverse countries have started realizing that they can expand their markets in developing countries not by forcing international products in these markets, but by responding to local needs through new product innovation. It is necessary to develop products by understanding current and potential needs of society using local materials and processes. 'Design' talents within the country are essential to absorb the continuous flow of new technologies from developed countries and adapt them to local conditions of manufacture. Design education must build in these capacity in the courses of design curriculum.

6.1.9 Building an Indian identity in products

The most challenging task of the designer is to build up an Indian identity in the products designed and manufactured for use by Indian population suiting their cultural needs and use. The tendency is to design universal products applicable for all. But if these products has to have an appeal to user, these products must be designed with a long term use in view. Products with a different identity can also attract foreign users. This is specially true in crafts products and products developed and manufactured to meet a local need.

6.2 Indigenous technology transfer to small enterprise : Present status

Technology transfer to small enterprise is important aspect for a developing country like India. This is also important for the globalization of the economy. With increasing competition from countries all over the world, it would be essential to absorb technology developed elsewhere as well as to develop technology indigenously. However certain technology thus developed also needs to be disseminated to the industry. Unless an appropriate methodology is formulated and tested for technology transfer to the industry particularly small enterprise, benefits of technology development will not percolate to the society.

In this thesis work, emphasis is technology transfer to the small enterprise. Since there are not many reliable documented work available in this area, search was narrowed down to rural technology, where considerable work has been carried out by various agencies and the scale of operation of the target group in this category also is similar as that of target group for our study, i.e. small enterprise except that our area is not demarked as rural small enterprise. However, similarity exists from the point of view of capital requirement of small enterprise and type of entrepreneur. Reviews mentioned below directs the scopes for technology transfer of Dipbahan- the tricycle rickshaw specifically developed to be manufactured by small enterprises.

6.2.1 Need of technology transfer

Dr. R. Chidambaram, Principal Scientific Advisor to the Government of India, commented (Kunnumkal and Sant, 2001-2002) in his Foreword to Part IV of Directory of Rural Technologies in November 11, 2002:

Excerpts:

"All of us want India to become a developed country in the fullest sense of the term in the shortest possible time. And each one of has perhaps a different definition of a 'developed country'. My definition is: "when the quality of life in our rural areas becomes comparable to that in the non-urban areas of already developed countries!".

"India has recognized ever since independence that its national development will be driven by science and technology and the large governmental effort in this direction has been wide-ranging. And there are achievements to show – indigenous nuclear power plants, our own satellites and missiles, the green revolution of the sixties, etc. – but much more remains to be done. There are very good reasons for developing technology: (a) creating national wealth, (b) improving the quality of life of the people, particularly those living in the rural areas, and (c) enhancing national security."

"Two-thirds of Indians live in villages and I do not see a significant demographic shift taking place in India in the foreseeable future. Even if one percent of the population shifts from rural to urban areas, that is ten million people ! And at present much of the rural population is involved directly or indirectly in agriculture, though there are also rural industries and a recent study by the Central Statistical Organisation shows that the share of the non-agricultural sector in the rural economy is slowly rising."

In the Preface to the Part I of Directory of Rural Technologies (DRT), the compiler of the compendium, published by National Institute of Rural Development, Hyderabad, Shri Mathew C. Kunnumkal and Professor Bharat R. Sant (Kunnumkal and Sant, 2001-2002) commented:

Excerpts:

"India is a vast country with varied climates and socio - cultural setting. Since independence, much progress has been made in the economic sphere including in the rural areas. Still much more desires to be done. Application of science and technology (S&T) to the improvement of rural areas is one of the key factors for rapid rural development. Many institutions have developed new and improved technologies and they have their own collections. Very rarely, all the available rural technologies are systematically compiled at one place. Council for Advancement of People's Action and Rural Technology (CAPART) made perhaps the first serious attempt and brought out seven volumes of Directory of Rural Technologies well-illustrated, well-written and each volume with one broad subject like farm and post harvest equipment, energy system, rural transport and communication, soil and water management etc. This was during the period 1980-1992. These volumes are still a valuable reference material."

Shri Arun Bhatnagar, Secretary, Department of Rural Development, Government of India, (Kunnumkal and Sant, 2001-2002) commented in his Foreword to Part I of DRT in January 1, 2001:

Excerpts:

"Some fifty years after the commencement of programmes of planned development, a significant proportion of population remains below the poverty line and many villages do not have road connectivity, access to safe drinking water, sanitation and other amenities. Also, while a range of technologies are being developed for the benefit of the common man, an increase in awareness in respect of such technologies is warranted. One factor preventing early dissemination and transfer of technology may well have been that adequate information in this regard is not readily available.

Towards this end, the effort made in the National Institute of Rural Development, Hyderabad through Shri Mathew C. Kunnumkal and Professor Bharat R. Sant in gathering information on various rural technologies and bringing out a "Directory of Rural Technologies" is commendable. The Directory could be useful as a Reference Book for science and Technology Institutions, Government Organisations, Rural Development functionaries and Non- Government Organisations and as a means to better appreciate the problems associated with the transfer and application of rural technologies."

Council of Scientific & Industrial Research (CSIR), New Delhi under Government of India had published a book titled 'Technologies for the Rural Sector' in the year 2000. In the Foreword to this book, Dr. R. A. Mashelkar, Director General of CSIR commented (Bhatia, 2000):

Excerpts:

"India lives in villages. Gandhiji's economic philosophy of making our villages self-supporting and self-reliant through decentralized production and consumption holds relevance and merit even today. Thus resources and materials generated in the villages need to be processed efficiently with minimal energy consumption levels and environmental degradation.

Council of Scientific & Industrial Research (CSIR) has been consistently endeavoring to unfurl new vistas for sustainable rural industrialization. The technologies reported in this compendium are the handiwork of thousands of scientists, engineers, technicians and all the team members associated in their development and dissemination.

.....profiles of 365 technologies, which encompass a broad spectrum of rural non-farm scenario. I am sure farmers, artisans, entrepreneurs, cooperatives, voluntary organizations, rural communities and the state development agencies would make a purposeful utilization of these technologies not only in India but in other developing countries as well'."

Dr. A. K. Bhatia, compiler of the compendium brought out by CSIR commented (Bhatia, 2000) in the introduction:

Excerpts:

"CSIR has been bring out compendia of it's technologies from time to time. The present publication is on the eve of the new millennium. The 365 profile listed here have been categorized for convenience under six groups viz.

i. Food and agro-based technologies.
ii. Building and construction technologies.
iii. Drinking water.
iv. Environment and sanitation.
v. Cultivation and processing of economic plants.
vi. Cottage and small scale industries.

CSIR would welcome feedback from the use of this document and of the technologies. CSIR and its laboratories would be happy to provide any further information that may be required by the potential users of these technologies or even generally on the technological needs. The publication would be incomplete without acknowledging the contribution of the myriad of scientists and technologists from CSIR laboratories who patiently put up with our demands for data and information….."

No where in the above Foreword or in the Introduction, it mentions about Design and Designer and about their contribution. Many times even a good technology fails because of not being able to deliver a marketable product due lack of design inputs. If one analyse the above technologies, it is evident that these are meant for Small enterprise and needs design inputs in terms of aesthetics, Human Factors, appropriate material and process selection etc., that falls into the ambit of design.

Council for Advancement of Peoples Action and Rural Technology (CAPART), Delhi is the first Government of India organization engaged in providing information on Rural Technologies for dissemination to the rural areas. It was formed by merging Council for Advancement of Rural Technology (CART) and Peoples Action for Development Initiative (PADI). In his introduction to the Rural technologies Guide published by CART, Mr. Balakrishnan, Director General of CART commented (Balakrishan,1985),

Excerpts:

"Between the conception and the creation…..falls the shadow, the poet said. Similar has been the case with the generation of technologies relevant to rural development and their percolation to the field. Efforts to transmit appropriate technologies to the rural people had been but scattered and sporadic. To make this endeavour speedier and systematic, the Council for Advancement of Rural Technology (CART) was constituted……

The mandate to the council includes acting as a clearing house of information and a data bank, and dissemination of knowledge on rural technology to the manufacturer of machinery, tools, equipment and spare parts so that large scale production of technically improved machinery and implements could be carried out.

As a first step towards the realization of these objectives, we are now bringing out a small compendium of rural technologies. The number, as may be seen, is small. It has been kept that way deliberately. Making the selection was, as expected, not an easy task. As a first exercise, we wanted to choose simple, low or nominal-cost technologies, which have applicability through out the country. Small is not only beautiful, small is possible. We have culled a fairly wide field and located technologies developed not only in our country but also those generated and tested in some other developing countries as well. As we go along, we propose to publish inventories of technologies specially suited to particular geo-physical regions of the country.

The information in this slim volume is presented in a simple language with the hope that the technology described will be understood by lay persons and field level extension personnel. Line drawing illustrations have been added to make comprehension easier. Cost estimates indicated are based on the current ruling prices.

It is well recognized that identification of technology needs has to be a two-way process; the demand coming from the ultimate users, and perceived needs based on the empirical findings of various technical institutions. This publication falls in the latter category. We shall be most grateful to the readers if they would kindly help to fulfill the former….. "

National Institute of Rural Development, an autonomous organisation, supported by the Ministry of Rural Development, Government of India is the country's apex body for undertaking training, research and consultancy functions in the rural development sector also published a set of 4 Directory of Rural Technologies (DRT) between January 2001 to November 2002, which emphasises the context specific technology transfer for manufacturing and distribution to different user groups.

6.2.2 Defining rural technology

In the Preface to the Part I of DRT, the compiler of the compendium, Shri Mathew C. Kunnumkal and Professor Bharat R. Sant elaborated (Kunnumkal and Sant, 2001-2002) about what constitutes a rural technology.

Excerpts:

"Many different terms have been used in the past – appropriate technology, intermediate technology, low- level-technology, low-cost technology and many others all with good intention and all for good reasons. There are many experts who feel that classifying a technology as hi-tech and low tech is not correct. Essentially, technology is one that works for specific purpose. Thus, rural technology is a theme that 'catalyses' rural development. Our mind set still does not accept a rural technology that needs large investment, sophisticated machinery and equipment, high profile marketing. But we must realize and accept the not – so – slow 'change' that is taking place in every sphere of life which will naturally find an echo in the scenario of rural technology. The reader will notice a reflection of the 'change' in this directory and the technologies that are described here. We have included some very new type of technologies that are claimed to be better and faster. Some investment figures may appear higher than the conventional mode of thinking. All these are departures from the conventional and should be considered as 'management of change' taking place towards continuous improvement in the product quality, improved 'skills' among the rural people or at least a desire to develop such skills, and larger market-local, national and international. The last one could be of great significance. In other words, for the rapid development of rural areas we have to strengthen our rural technology base and the technology transfer mechanism with focus on cost – effectiveness of the technology and a sustained market. DRT is perhaps the first step in the above chain of events."

R. C. Choudhury, Director General of NIRD, commented (Kunnumkal and Sant, 2001-2002) in his Foreword to Part II of DRT in April, 2001:

Excerpts:

"Rural Technologies (RTs) are often considered as low-level and low-cost technologies. However, this is no more true in the current globalization context wherein the advent of Information Technology and Biotechnology have virtually invaded the industrial scenario and the lives of the common people. The time is now ripe to maximize intervention of Science and Technology (S&T) for rapid rural development especially in improving the living standards of the rural poor."

In the Preface to the Part IV of DRT, the compiler of the compendium, Shri Mathew C. Kunnumkal and Professor Bharat R. Sant (Kunnumkal and Sant, 2001-2002) elaborated further about rural technology.

Excerpts:

"Rural technologies can be low tech – low investment or even be in the hi-tech – high investment range depending upon the local conditions. Their success is what matters and this success depends largely on creating, developing and expanding the market, both domestic and international. Thus, a good marketing strategy needs to be developed alongside technology selection and technology transfer."

"NIRD having felt the urgent need for extensive collection of RT database for the benefit of potential entrepreneurs and users of RT made an effort to prepare a database on common rural technologies. Accordingly, the first part of the Directory with 100 RTs in different disciplines was published by the Institutes in January 2001. The second part of the Directory with another set of 100 RTs covering 15 different disciplines - Building/Construction, Chemicals, Compost/ Fertiliser, Crop Improvement/Variety Development, Cultivation of Aromatic and Medicinal Plants, Energy, Food Products, Forestry, Jute and Jute Products, Knowledge Technology, Machinery and Equipment, Mushroom Farming, Post-Harvest Technology, Water Conservation/Purification, and Miscellaneous followed the strategy of a mix of modern and traditional technologies. The Directory is a valuable reference material for individual entrepreneurs, cooperatives, governmental organisations, non- governmental organisations (NGOs), financial institutions, rural banks, and promotional agencies. Such a compilation may also motivate the scientists to take up a challenge to improve further the existing technologies and innovate new ones in order to rapidly change the rural scenario towards better quality life. There is also a need for a closer cooperation between the social scientists and the technology developers so that the ground realities in the rural areas are understood and appreciated."

6.2.3 Other factors in transfer of technology

The compiler of DRT also elaborated (Kunnumkal and Sant, 2001-2002) about technology:

Excerpts:

"Technology is only one component, vital though, in the chain of events that implant S&T for the rapid development of rural areas. It is not a panacea for a total success of the project. The human element is equally and at times more important – sincerity, honesty, integrity and the much talked about managerial skill and leadership quality. Whereas the first three are basic human traits, the last one can be inculcated through deliberate learning-cum training programmes. Promotional agencies and government departments still will have to 'select' entrepreneurs and offer them training opportunities. They have also to provide necessary infrastructure and the 'environment' to attract the right entrepreneur. We hope that this DRT will encourage, inspire and

create awareness and interest among all the people concern with rural development through the intervention of S&T."

Coming to Science and Technology, it is worth to quote Akio Morita, the Chairman of the Board of Sony Corporation, while delivering the First (Inaugural) United Kingdom Innovation Lecture to an invited Audience at the Royal Society, London, on 6 February 1992 (Morita A., 1992).

Excerpts:

" 'S' (Science) does not equal 'T' (Technology) and 'T' does not equal to 'I' (Innovation). To translate my Lecture title into layman's terms it would be: 'Science alone is not Technology and Technology alone is not Innovation'. I believe that technology comes from employing and manipulating science into concepts, processes, and devices. As an outgrowth of science, technology fuels the industrial engine. 'Technologists' are the those rare individuals who have a wide understanding of science and engineering as well as broad vision and true commitment to the needs of society. People with this depth of understanding can adapt and apply technology with imagination, wisdom and humanity.

Just having innovative technology is not enough to claim true innovation. I see true innovation to be made up of three key elements which I call: 'the three creativities': Creativity in technology, Creativity in product planning and Creativity in marketing"

Developmental institutions like NIRD felt an urgent need for an extensive collection of rural technology data base as a Directory of Rural Technologies (DRT) which would benefit potential entrepreneurs and users of rural technology. Assumption was that the potential user of the technology must know certain details in a nutshell such as salient feature of technology, raw materials required, minimum economic unit, total investment, acceptability of the product, and marketability. Two more features- gender-bias of the technology and location specificity of the process were also added. The item on terms and conditions of technology transfer which is vital for decision making were also included. It was felt that the data base presented should be adequate for taking preliminary decision to set up a profitable enterprise. To elicit information from technology generators and technology transfer agencies, a proforma was designed to obtain basic information on rural technology and its transfer that will directly benefit the entrepreneur and motivate entrepreneurship.

In the Preface to the Part II of DRT, the compiler of the compendium, Shri Mathew C. Kunnumkal and Professor Bharat R. Sant (Kunnumkal and Sant, 2001-2002) commented:

Excerpts:

"The focus of the Directory is on motivating and sensitizing entrepreneurs to employ the fruits of S&T for rapid rural development rather than mare documentation.

While some technology generators found it a bit difficult to answer questions on product acceptability, marketability and technology transfer methodology, it was generally felt by all that these aspects need to be taken into consideration while developing technologies. Similarly RT users, government organisations like District Rural Development Agencies, Financial/Banking Agencies and NGOs should also appreciate that certain newer technologies may have a rather high initial investment but their field use will yield faster and superior results. We do hope that these two messages percolate through the rural technology transfer systems. ….There is an urgent need to meet the challenges posed by globalization, to change our mind-set, and to accept and absorb advance technologies (along with the traditional ones) so that we can leap-frog the rural development activity through the intervention of S&T."

AVS Reddy, Director General of NIRD, commented (Kunnumkal and Sant, 2001-2002) in his Foreword to Part III of Directory of Rural Technologies (DRT) in January, 2002:

Excerpts:

"Information is the key to the development of rural economy……This can revolutionize the thinking process of the rural people ... "Success breads success", it is said. The rural technology scenario, needs a revolution to enable accelerated rural development . The present economic climate of the country is perhaps most favourable to maximize the input of science and technology (S&T) for rural development. The first step in such a transformation is the information dissemination on available rural technologies (RTs) so that people can choose and adopt them for their benefit. …..The impact of rural technologies has to become more visible and their potential fully exploited. Technology generators alone cannot achieve this. Much has to be done beyond the technology development stage viz., successful transfer of technology, its diffusion, establishing economic feasibility, marketability of products, and availability of financial resources. Thus what we urgently need to evolve an effective technology delivery system for social transformation of the rural scenario. Social scientists, rural development functionaries, non-governmental organizations, and training institution will have to act as important links in the transformation chain. It is hoped that the present Directory (like the other two parts) will "catalyze" this transformation and motivate not only the potential entrepreneurs to set up rural enterprises but also the promotional and financial agencies in providing necessary funds, facilities, and incentives to ensure successful transfer of technology and sustained marketing of products and services. In turn, S&T institutions and individuals need once again to come forward with newer and improved innovations that are socially more acceptable, more eco-friendly and more cost-effective."

Dr. R. Chidambaram, Principal Scientific Advisor to the Government of India, commented (Kunnumkal and Sant, 2001-2002) in his Foreword to Part IV of Directory of Rural Technologies in November 11, 2002:

Excerpts:

"Choosing the right technologies to put the nation on the path of rapid development requires technology foresight. Of course, other initiatives are equally important and these range from infrastructure development (roads, transport and communication) to social development (literacy and women empowerment). Technology foresight involves determination of possible futures, taking into accounts existing as well as emerging technologies, of strategies likely to yield maximum economic, social, security benefits. Technology foresight must be distinguished from technology forecasting, which attempts prediction of future technological developments, without worrying about the impact of these developments on the economy, society or the environment. There is an institution in the Department of Science and Technology called the Technology Information, Forecasting and Assessment Council (TIFAC), which is doing pioneering work. One can say that Assessment, added to Forecasting, becomes foresight.

Technology Foresight analysis helps in the selection of critical technologies for development at any point of time and this has to be based on a national perspective. India does not have to follow the trodden path of technology development ; we can learn from the mistakes of others. India is a large country and its technology requirements also correspondingly span a wide range. It has to continue to develop strategic technologies – nuclear, space and defense-related. National security also requires development of technologies related to information security, counter terrorism and of "dual-use" (sic) technologies denied to India under the Technology Control Regimes. Technologies related to energy security, health water security, environmental security, advanced manufacturing and processing, advanced materials, etc. all are important for us. We seem to have special talent for the so-called "knowledge-based" technologies, viz. information technology and biotechnology. Amongst all these, I place rural development-related technologies also right priority.

Sometime back TIFAC had organized a discussion meeting in Delhi with the scientists of the International Institute of Applied System Analysis (IIASA) in Austria, near Vienna. In one of the presentations from IIASA, they talked of "European Rural Development". This surprised me and I said that I thought that the rural areas there were already developed! They said that one of their major problems was that potential leaders in the rural areas tended to migrate. That is a common problem between them and us….

…….With a total of 400 RTs spread over twenty six areas, entrepreneurs now have wider choice to select RTs to select RTs that they would like to take up individually or in a group as a cooperative, either for production purposes or for social benefits. In some cases, downsizing may have to be done with the help of professionals to reduce initial investment and meet prevailing market needs. In a few cases, potential markets, both domestic and international , can be additionally explored and established. The RTs,

which have been successfully tried out – and a special study is needed to identify them, can be straightaway replicated on large scale at different locations in the country after ascertaining the market needs. Much of the success in the technology utilization will depend upon the entrepreneur's innovativeness. Non-governmental organisations have an important role in the context."

6.2.4 Models of technology transfer

In the Preface to the Part IV of DRT, the compiler of the compendium, Shri Mathew C. Kunnumkal and Professor Bharat R. Sant commented (Kunnumkal and Sant, 2001-2002):

Excerpts:

"With much appreciation coming in for the Directory, we concurrently felt that RT compilation is not enough, the message must go beyond viz. transfer of rural technologies (TORT). As a small step in this direction, we organized a One-day Workshop on "Strategies for TORT" on March 15, 2002 with participation from all the technology generators who contributed to the three parts of the Directory. The objective of the Workshop was "To identify suitable rural technologies and formulate strategy for TORT for rural development based on the 300 RTs documented in the three parts (Part I, II, and III) of the DRT brought out by NIRD". The Principal Scientific Adviser (PSA) to the Government of India Dr. R. Chidambaram highly appreciated our efforts in the compilation of 300 RTs. He wanted us to identify a few selected RTs that can be replicated on a large scale in order to benefit people and economy. Accordingly as a result of the Workshop each institution that contributed RTs to the directory was asked to choose its two best technologies in the order of priority. And thus we have identified 120 RTs for large scale replication…… we feel that this may help in changing the mindset of technology policy makers and technology developers in the reorientation of their technology development plans and activities to meet the short and long term needs of the rural India.

In Part IV of the DRT, we have given emphasis on some newer areas not very much covered in the earlier parts viz. biotechnology, rural roads, rural sanitation and waste water treatment. With the completion of Part IV of DRT, we now have bank of 400 assorted RTs in some 25-30 areas, a fairly good number to choose from for anybody to start an enterprise individually or in a group. Some of the technologies documented here have already been commercialized and are in production stage. It should be easier to replicate them elsewhere depending upon the market needs. Others may need some effort in technology transfer which is always somewhat difficult for rural technologies. Some are very simple household technologies with community benefits. Some do need higher investment but it is necessary to view them more from societal and cultural angles rather than financial angle alone that will change the rural scenario at an accelerated pace. With enthusiasm of scientists, support of promotional agencies, and relatively easier availability of loans from banks and financial institutions it is expected that

potential entrepreneurs can implement projects through successful transfer of technology. Rural technologies can be low tech – low investment or even be in the hi-tech – high investment range depending upon the local conditions. Their success is what matters and this success depends largely on creating, developing and expanding the market, both domestic and international. Thus, a good marketing strategy needs to be developed alongside technology selection and technology_transfer – a function that can be taken up by a nodal network agency with support and encouragement of Government. In practice, "champions" can play a significant role in this development chain. We do hope that the present Directory, in line with the other three parts, will motivate entrepreneurs, consultants, NGOs, facilitators and all other participants in taking science and technology to villages for improving the lot of farmers and non-farmers alike.

In the Preface to the Part III of DRT, the compiler of the compendium, Shri Mathew C. Kunnumkal and Professor Bharat R. Sant commented (Kunnumkal and Sant, 2001-2002):

Excerpts:

"….An Ahmedabad-based group has initiated a worth-emulating bold experiment to help innovators in converting their inventions into production including marketing of products. This group strongly believes in focusing on technologies with specific applications for rural areas rather than limiting them to low-technology low-investment levels. This trends should help speedier rural development.

Our humble efforts in bringing at one place 100 RTs (or 300 RTs in the three parts) is only a small step in creating the much needed awareness among potential entrepreneurs to start tiny enterprises/services at the rural level. Our interaction with technology contributors both through correspondence and personal visits makes us feel that scientists, technologists, and innovators are indeed eager to see the transfer of their technologies actually taking place on-to-the-field but the crucial problems are identifying honest and sincere entrepreneurs, successful technology transfer mechanism, timely availability of bank finances, and marketing the products on a sustained basis. We do hope that the present Directory will further stimulate entrepreneurship, motivate technology transfer support, and encourage promotional and financial institutions to come forward for the ultimate development and growth of the rural areas."

The Ahmedabad based Groups that the editors talked about are- National Innovation Foundation (NIF), Grassroots Innovations Augmentation Network (GIAN) etc. The best part of their effort is that these groups have engaged Design Institution like National Institute of Design and Department of Design in IIT Guwahati as a part of their action plan to achieve their objectives.

Dr. R. Chidambaram, Principal Scientific Advisor to the Government of India initiated RuTAG (Rural Technology Action Group) an evolving mechanism to achieve accelerated

rural development through science and technology inputs. The excerpts from the documents circulated by the Office of the Principal Scientific Advisor to the Government of India is provided below:

RuTAG- an evolving mechanism

1. *One of the areas of focus of the Office of the Principal Scientific Advisor to the Government of India is related to the development and dissemination of technologies for rural development. Though there are many entities interested in doing this, the spread of rural technology has been diffuse, uneven, and slow and its full potential for generating a rapid multiplies effect in rural economy has remained unutilized. The main constraint preventing advances in technologies for rural application from reaching most villages in India in full measure seems to be the lack of local technology action groups who can assist in upgrading the assessment of the technology needs and the current technology status of different rural occupation groups, i.e. farmers, rural artisans and the landless, to enable them to add value to their products and services. Rural Technology support is critical for realizing the vast potential of the Rural Farm and Non-farm Sectors.*

2. *There are two possible approaches in this context;*
   i. *Collect all information on successful dissemination of technology in rural areas. The NIRD (National Institute of Rural Development), Hyderabad, has prepared a directory of rural technologies (four volumes) and is now selecting 20-25 among them, which have been most successful in the field. There are also directories prepared by the CAPART, the ICAR and the CSIR.*
   ii. *Find the technology needs in the field and identify technology solutions for the problems encountered.*

The ideal thing is for two approaches to converge. Many S & T NGO's (Non-Governmental Organizations with an S & T focus), and other agencies (voluntary and governmental) have achieved significant success in assessing the technology needs of a region and, perhaps up to a point, determined and implemented the technology solutions. On the other hand, it is possible to go on from there and refine and enhance these technologies and spread their reach, using the tremendous S & T platform that India has built up since independence.

3. There is practically no technology needed for rural development that is not available among, or which cannot be developed by Indian Industry; the problem often is in transferring it or in downsizing it, if necessary. Normally any technology is enlarged to benefit from economy of scale. On the other hand, what one loses in economy of scale by downsizing a technology for rural use, one can gain from the fact that the source of raw material in India- be it leather, milk, grain or anything else- is scattered and distributed. In this context, an international seminar was held during 7-9 October, 2003, in Bhubaneshwar at the regional Research Laboratory, a CSIR laboratory, on "Downsizing Technology for Rural Development", the deliberation in which has given valuable insights into this field. There is also no rural industry, for which there is not a

modern counterpart. If the experts from modern industry can be encouraged to help their rural counterparts, it can also help transform rural India.

4. As mentioned, S & T NGOs, government agencies, district level administration, and a few initiative from the industry have been successful in disseminating rural development technologies up to a point. The challenge is to establish synergy among all these efforts, which are often fragmented and needlessly duplicated, in order to nucleate new initiatives and to strengthen existing ones.

5. RuTAGs (Rural Technology Action Groups), that could provide the mechanism and the support needed for this synergy, have, accordingly conceptualized. This has been done with the help of Scientific Consultants in the office of the Principal Scientific Adviser (PSA) to the Government of India, who are experts in various aspects of rural development. It is felt that the PSA's office can help through the RuTAG mechanism- a Central RuTAG with specialists in various aspects of rural development-related technologies, and a local RuTAG, (to be headed by a retired senior Scientist/Technologist), and assisted by young rural technology professionals, for each region/area which will essentially do all the activities related to technology delivery. RuTAG is a synergizing and catalyzing mechanism, and not a major funding mechanism. RuTAG is conceived of as a mechanism to provide a higher level of S & T intervention and support, than hitherto achieved. This intervention, which is essentially demand - driven, could be for technology upgradation, high-tech delivery, technology training and demonstration or through any other innovative method.

6. The entities which are intended to be brought together by RuTAG are broadly:

- *(i). S & T institutions working in the area.*
- *(ii) S & T NGOs and voluntary agencies active in the area.*
- *(iii) Public Sector Undertakings (PSUs) and Corporate Industrial houses in the private sector committed to rural development and having a presence in the area.*
- *(iv) State and Central Government organizations already working for rural development in the area…..*

6.3 Conclusion

1. For a developing country like India, technology transfer for small enterprise is an important aspect. This is also important for the globalisation of the economy. With increasing competition from countries all over the world, it will be essential to absorb technology as well as to develop technology indigenously. However technology developed also needs to be disseminated to the industry. Unless an appropriate methodology is formulated and tested for technology transfer to the industry particularly small enterprise, benefits of technology development will not percolate to the society.

2. There are very good reasons for developing indigenous technology for:

(a) creating national wealth through employment generation and

(b) improving the quality of life of the people in mass scale through making appropriate facilities and services particularly for those living in the rural areas.

3. Many agencies have developed new and improved technologies and they have their own collections. These are aimed at serving as a means to transfer and appropriate application of rural technologies.

4. As an initial exercise, emphasis should be on choosing simple, low or nominal-cost technologies, which have applicability through out the country. Small is not only beautiful, small is possible. Feasibility has to be checked prior to bigger application.

5. Study of the Information provided in the compendium on rural technologies is not sufficient for an enterprise to apply the technology described directly in the field. Essential guidelines in the form of manual for making the devices were available as well as drawing for any of the equipments provide. These are some of the reasons that intended technology transfer never materialises with the help of these compendium.

6. Rural Technology compilation is not enough; the message must go beyond viz. transfer of rural technologies (TORT).

7. Present mind set still does not accept a rural technology that needs large investment, sophisticated machinery and equipment, high profile marketing. However, Rural technologies can be low tech – low investment or even be in the hi-tech – high investment range depending upon the local conditions. Their success is what matters and this success depends largely on creating, developing and expanding the market, both domestic and international. Thus, a good marketing strategy needs to be developed alongside technology selection and technology transfer.

8. To elicit information from technology generators and technology transfer agencies, a proforma was designed to obtain basic information on rural technology and its transfer that will directly benefit the entrepreneur and motivate entrepreneurship. While some technology generators found it a bit difficult to answer questions on product acceptability, marketability and technology transfer methodology, it was generally felt by all that these aspects need to be taken into consideration while developing technologies. Technology generators alone cannot achieve this. Much has to be done beyond the technology development stage viz., successful transfer of technology, its diffusion, establishing economic feasibility , marketability of products, and availability of financial resources. Thus we urgently need to evolve an effective technology delivery system for social transformation. This can “catalyse” this transformation and motivate not only the potential entrepreneurs to set up rural enterprises but also the promotional and financial agencies in providing necessary funds, facilities, and incentives to ensure successful transfer of technology and sustained marketing of products and services. In turn, S&T institutions and individuals need once again to come forward with newer and improved innovations that are socially more acceptable, more eco-friendly and more cost-effective.

Just having innovative technology is not enough to claim true innovation. True innovation is made up of three key elements called: “the three creativities”: Creativity in technology, Creativity in product planning and Creativity in marketing.

9. Scientists, technologists, and innovators are indeed eager to see the transfer of their technologies actually taking place on-to-the-field but the crucial problems are identifying honest and sincere entrepreneurs, successful technology transfer mechanism, timely availability of bank finances, and marketing the products on a sustained basis. Also potential leaders in the rural areas tended to migrate. There is need to further stimulate entrepreneurship, motivate technology transfer support, and encourage promotional and financial institutions to come forward for the ultimate development and growth of the rural areas.

10. Technology is only one component, vital though, in the chain of events that implant S&T for the rapid development of rural areas. It is not a panacea for a total success of the project. The human element is equally and at times more important – sincerity, honesty, integrity and the much talked about managerial skill and leadership quality. Whereas the first three are basic human traits, the last one can be inculcated through deliberate learning-cum training programmes. Promotional agencies and government departments still will have to ‘select’ entrepreneurs and offer them training opportunities. They have also to provide necessary infrastructure and the ‘environment’ to attract the right entrepreneur.

11. There are a few attempts and model in achieving the above. One is initiated by National Innovation Foundation (NIF) and it’s umbrella organizations such as Grassroots Innovations Augmentation Network (GIAN) etc. The other is RuTAG (Rural Technology Action Group) an evolving mechanism to achieve accelerated rural development through science and technology inputs initiated by Dr. R. Chidambaram, Principal Scientific Advisor to the Government of India. First model started showing promising results and the second is being initiated all over the country and in it’s nascent stage.

12. It would be appropriate if the three agencies e.g., the design creator, the entrepreneur to manufacture the products and the representatives from the intended user group come together. This is to ensure the smooth transfer of the concepts to the end products through a participatory approach. The resultant outcome would obviously be appropriate to the context and local need, and with due considerations would be ready for export to outside its origin.

13. Technology Transfer of Dipbahan

Technology transfer of Dipbahan was initially initiated through a new model of technology transfer that is being proposed or tried out currently based on sections 6.2. All the ingredients as mentioned in these models were more or less incorporated in this process. However this could not be termed as successful from the point of view of the designer since desired outcomes was marred by various changes into the design

transferred to the targeted NGO. The following describes this phase of technology transfer in the context of model proposed or practiced currently and various changes that were initiated in the product that can be attributed to shortfall of the proposed model of technology transfer:

Dipbahan and its design was transferred to an NGO, Centre for Rural Development, Guwahati by providing a complete functioning model unlike traditional process of technology transfer through drawings and specifications. Also a few key personals from the NGO was trained up for its manufacturing. Thereafter entire manufacturing of Dipbahan was left to the NGO.

The observation of the whole process was done closely and the following are the findings regarding success of design and technology transfer.

1. The NGO changed various dimensions, few of them intentionally and others unintentionally, due to the fact that only a physical working prototype was given to them and the persons trained for fabrication replicated them by using the sample provided by physically measuring the sample but without using any standard measurement and jigs and fixtures.
2. The changes made deliberately are because of perceptional difference and feedback available from rickshaw pullers. Most of these are not based on scientific basis but still executed by the fabricators. Some of the changes were due to the fault in process but conceived as deficiency of the design by the fabricators. Changes made deliberately are height of a member at mainframe. Height of the hood resulting in change of shape. Change of joining details due to failure of procured/outsourced material. Change in shape of the front end is due to non adherence to design through process i.e. bend, cut, and weld.
3. Similarly due to absence of an additional bar at top (Fig. 5.26, p 161) contributed in breakage of joint at the front end connecting the space structure with the head pipe (Fig. 5.24, p 161) and main frame. The joining points of main frame to platform were also found to be fracture prone as shown in Fig 5.30, p 164. Analysis of these are given at section 5.5 in Chapter 5 and was actually due to poor quality of pipe and bending stress due to 3D profile of the element. However overlooking these aspects, Centre for Rural Development, Guwahati changed the mainframe of original design. Also chassis was fabricated using square bar and angle replacing circular tube with flat bar as shown in Fig. 5.31, p 164.
4. Finally a ready made diamond frame for a rickshaw was used by NGO that resulted in negation of advantage available like ease of getting on and off to the pullers seat by the puller.
5. Similarly, angle of the passenger seat was changed based on the wishes of the rickshaw pullers. Traditionally rickshaw in other parts of the country has seat with inclination/slope of the seat, Fig. 6.1 which is comparatively better than the

rickshaws in North Eastern region, Fig. 6.2. Rickshaw puller's in Guwahati, many of whom have migrated from erstwhile East Pakistan (now Bangladesh) prefer seats inclined wrongly to the front. This results in uncomfortable seating postures for the passengers. However rickshaw pullers feel that they can propel the rickshaw easily if passenger seat is inclined this way.

Fig. 6.1 Rickshaw at Kharagpur, West Bengal with less seat inclination to the front

Fig. 6.2 Rickshaw in Guwahati, Assam with higher seat inclination to the front

To deduce conclusion from above,
Transfer of designs to small enterprise must be accompanied by appropriate jigs and fixtures and not merely with engineering drawings and sample. The entire design development required to be undertaken with participation from the potential or likely beneficiaries, specifically those who will implement the manufacturing process and operation of the designed products.

Chapter 7

Participatory Approach in Dipbahan+ Development and Transfer of Technology to Small Enterprise

The current chapter of this thesis deals in the manufacturing of the Dipbahan at the SMEs production facilities. Workshop based prototype of Dipbahan (Chapter 5) followed by refined version Dipbahan^{+} which was developed at the Department of Design, IIT Guwahati was shown to the representatives of the NGO, Centre for Rural Development, Guwahati and were involved in most of the developmental stages and trial modifications. In true sense, the entire development and production was carried out following a participatory approach, where they were involved as beneficiaries. This is because NGO is to manufacture the Dipbahan through mass production and introduce the same under the Rickshaw Bank Project. Existing and potential rickshaw pullers will actually ply these rickshaws on road and will also own these.

The technology transfer did not follow the conventional method, i.e. providing detailed engineering drawing of the product to the NGO, the actual manufacturer, leaving the onus of manufacturing to them with their understanding. Rather the development process followed by demonstration of each and every steps to the NGO physically (to provide actual dimensional aspect) and visually through CAD models. After a single piece of Dipbahan was fabricated by the NGO successfully, the NGO is expected to carry forward the know-how provided to them. The Dipbahan was developed to have its own distinctive identity. Retaining the form, shape and features of the Dipbahan, people are found to be meeting their own requirement as already seen in the market. As soon as the interim version of Dipbahan was introduced in the market, variations using few features of Dipbahan for passenger commutation were seen in use in several parts of the country.

The followings constitute the technology transfer process for the Dipbahan:

7.1 Planning the Production Process- Target Manufacturer and the Process

The initial 3 phases in morphology of design namely Feasibility Study, Preliminary Design and Detailed Design covered in the Chapter 3 and Chapter 4 are particularly in the area of Industrial design.

Once the design of the tricycle rickshaw was complete, its manufacturing is to be initiated. This requires a set of new skills different from that of design. These new skills are those of tool design and production engineering. In a commercial set up, based on the expertise available with the original project group, it may continue in its role of leadership. Much of the responsibility for fourth phase in the morphology of design, Planning the Production Process (Chapter3, Flow Chart 3.1, p 83) has to be shared with other areas of management. The decision to mass manufacture involves a substantial economic commitment. Therefore the level of confidence in the success of the product must be very high to support a positive decision and this decision must be made at the top level of management. The designer's confidence will have to be shared with the decision maker, who will re-evaluate this confidence, using additional information on

financial commitment, business conditions etc., before arriving at a final decision to initiate mass production of the designed product.

In this thesis work, mass manufacturing was actually implemented jointly in association with small enterprises; specifically to name, an NGO, Centre for Rural Development, Guwahati, a Fibre glass Reinforced Plastic component manufacturer, M/s National Associates, Guwahati and another small enterprise, M/s Tim Steel Innovatives, Guwahati in various stages. Thus decision making was fairly easy task. The production planning phase for a product like tricycle rickshaw involves multiple steps. These are however similar to mass production industry such as automotive industry and in particular to the bicycle industry. The steps given below typical of the mass production industries is followed for manufacturing Dipbahan in collaboration with local entrepreneur:

7.1.1 Detailed process planning required for every part, sub-assembly and the final assembly

First step in planning the production process, detailed process planning required for every part, sub-assembly and the final assembly was carried out. This information was displayed on process sheets, one for each part of sub-assembly. A sample process sheet is given as Appendix 2. Each process sheet contains a sequential list of operations that were performed to produce the particular part. Specifications for the raw material, clarification for any special instructions, and indications for the tools and machines required were provided in the process sheet. This step was particularly important and design features that lead to difficulties in production were revealed before regular production started. Such difficulties are normally minimised earlier through discussions between the product designers, tool designers and shop floor experts. Similarly, questions about materials are resolved by consultation with metallurgists/ material specialists, vendors and ancillary industry persons. For Dipbahan, the facilities available and to be established by the local entrepreneur and NGO as mentioned above have been analysed.

Difficulty in manufacture makes a product expensive; it is difficult to fabricate and takes extra time and is unreliable; the requested design geometry is hard to maintain during production, which demands proper allowances in design dimensions to meet the production clearances to make it easier to produce.

Design for assembly and manufacture is the analysis and redesign of a product to make it easier to produce.

Design for Assembly Design Guidelines ***(Boothroyd, Dewhurst and Knight, 2002)***

Design for assembly (DFA) entails making attachment directions and methods simpler, for example, making attachment easy by using snap fits instead of machine screws. It

involves application of attachment time and complexity models and basic rules and tables based on simplified time studies.

The most basic approach to design for manufacture and assembly is to apply design guidelines. After developing a design concept, one should examine it on each of the design guidelines and change the design to make it satisfy it. However it is to be noted that they are only heuristics that generally hold true, and application of the guidelines improves design concept on those goals.

These guidelines were used as checklists for each and every parts and also studied whether more than one parts can be combined to obtain a single parts. Similarly during assembly it was studied whether there was any obstruction in assembling the components. These above activities helped in incorporation of these guidelines. A review of this guidelines for their applicability is given below.

- Minimise part count by incorporating multiple functions into single parts.
  Bracket for fitting the rear wheel axle with body also designed to incorporate features (a slot for slide) for adjustment of chain tension. This resulted in single part that combined functions of two individual components.
- Modularise multiple parts into single subassemblies.
  Intermediate shaft with gears, bearings and bearing brackets assembled as single sub-assembly. Similarly, rear axle fitted with free wheel sprocket, bearings, bearing covers, mounting bracket and wheels are assembled as sub-assembly and on this body of the tricycle is mounted. There are more such sub-assembly.
- Assemble in open space, not in confined spaces.
  Dipbahans are always assembled in open space (Fig. 5.37 and 5.38, p 170).
- Make parts to identify how to orient them for insertion.
  This is evident in case of all sub-frames of Dipbahan. If oriented in wrong direction, they can not be inserted and assembled.
- Standardize to reduce part variety.
  To the extent possible this was done. Example is wheel mounting bracket for rear wheel and secondary shaft mounting bracket for gear assembly. These are same.
- Maximize part symmetry.
  This was done. For example, all the curvature of the tubular pipes are same so that setting of the roller bending machine is identical for all elements.
- Eliminate tangly parts.
  This was done at the stage of detail design of components.
- Colour code different parts that are shaped similarly.
  This was not applicable to large extent in case of Dipbahan components.
- Prevent nesting of parts.
  No parts have nesting property. However to facilitate transportation, many components like FRP hood, seat, mud guards etc. are designed to facilitate stacking without adverse effect of nesting.
- Provide orienting features on non-symmetries.
  This was done in case of sides and seat structure.
- Design mating features for easy insertion.
  Joinery for attaching different elements of the frame structure were done to facilitate easy insertion, e.g. Fig. 7.11, p 219.
- Insert new parts in an assembly from above.

Followed through out the assembly, e.g. Fig. 5.38, p 170 shows a hood assembled over the structure from top side.

- Insert from same direction or very few. Avoid assembly being turned over.
  Followed through out the assembly and assembly was not required to turn over at any point of time during assembly operation.
- Eliminate fasteners.
  As far as possible this was tried out and various elements of sides, seat structures were welded to reduce fasteners but it was not possible to eliminate these entirely.
- Place fasteners away from obstructions.
  This was done and no fasteners are placed in such a way that they face obstructions during fitting.
- Deep channels should be sufficiently wide to provide access to fastening tools. No channel is best.
  There was no channel provided in the design.
- Providing flats for uniform fastening and fastening ease.
  This was done for most of the joineries, e.g. Fig. 7.11, p 219.
- Proper spacing ensures allowance for a fastening tool.
  This was done for most of the joineries, e.g. Fig. 7.11, p 219, where the joinery provides sufficient space for maneuvering the fastening tools.

Each of these guidelines can be further broken down into categories.

System Guidelines:

These reduce the number of parts through functional and assembly modularity, and by reducing the variety of parts.

Handling Guidelines:

These simplify the handling aspect of the assembly process.

Insertion and Joining Guidelines:

These ease the actual attachment process.

The first two guidelines underlined are so important that they deserve special mention. There is no better way to simplify an assembly step than to eliminate it.

Fundamentally stated, the most effective DFA guideline is: “Eliminate all unnecessary separate parts”.

It can be succinctly stated by the acronym KISS—“Keep It Simple Stupid”

Design For Manufacturing (D.F.M)

Design for manufacture (DFM) entails making piece parts easier to produce from raw stock. Design for manufacture involves application of part-forming models, whether they are basic rules, analytic formulae, or complex finite element process simulations.

Dilemma is how to decide whether a part needs to be separate or can it be modularised into other parts. At a basic level, some tests of neighbouring parts can be applied. Few questions are given below. One needs to ask these questions regarding his design. Whenever the answers to all of these questions are “No”, then the parts may be

combined. This method was followed for the newly designed tricycle rickshaw and this is illustrated below.

- Must the parts move relative to one another?
  There are few parts that are essential to be moved relative to each other during the operation of the tricycle rickshaw. These are:
  i. Wheels relative to the fork (in the front wheel) and the body.
  ii. The front fork relative to the body.
  iii. Crank wheel and pedal relative to the body and the chain.
  iv. Rear sprocket and chain relative to the body.

  Corresponding measures required for the above are:
  i. Space around the movement of the wheel are to be free from obstruction and to prevent throwing up of mud and mucks to the body, suitable mud guards are required.
  ii. Space around the movement of the fork are to be kept hindrance free so that steering of the tricycle rickshaw is not hampered.
  iii. Space around the movement of the Crank wheel and pedal relative to the body and the chain are to be kept hindrance free so that steering of the tricycle rickshaw is not hampered.

Based on the above principles, seat and seat back for the Dipbahan^{+} version was integrated as a single component. Earlier seat and seat back were separate and once assembled do not require to move relative to each other. Integration resulted in reduction of material to the tune of 1.5 Kg amounting to Rs. 300.00 and reduction in assembly charges to the tune of Rs. 25.00 per rickshaw.

- Must they be electrically isolated?
  This aspect is not applicable for the tricycle rickshaw.
- Must they be thermally isolated?
  To ensure comfort to the user, it is better to provide insulating materials at the hood and at the back pane. In case of the hood, it is in vinyl fabric for interim version of the rickshaw and for the Dipbahan^{+} the hood was made in FRP material and provides better thermal insulation. For the seat back, there is sufficient gap with the rear panel. In case of Dipbahan, both the rear panel and the seatback are in FRP material and provide excellent isolation from heat generated due to sunshine.
- Must the parts be of different materials?
  As mentioned earlier, different parts of the interim model of Dipbahan were made in different materials. However with the help of guidelines of DFA and DFM and value engineering, variety of materials was drastically reduced. Thus in Dipbahan+ model, wood, mild steel sheet, aluminium chequered plates, mild steel wire mesh, foam,

fastener like nails were eliminated. FRP components replaced hood, back panel, seat with seat back, side panels, foot boards, rear mud guards etc.

- Does combining the parts prevent assembly of other parts?
  In the interim version of Dipbahan, the entire body structure was combined into one unit. This eliminated substantial number of components and fasteners. Although this did not prevent assembly of other parts, it was expensive to transport the whole frame. Thus this was broken down to following individual parts.
    1. Chassis
    2. Left side frame
    3. Right side frame
    4. Seat structure
    5. Binding members – 3 numbers
    6. Binding bracket for the chassis

  This violates the DFA guideline of minimising parts but was nonetheless cost effective. To address such trade-offs actual concept costing methods must be explored. Then numerical comparisons can be made between designs with more complex assembly versus designs with more complex piece parts.

  Most of the situation in this case i.e. reasoning used for application of DFA do not require numerical comparison except in case of calculation in reduction number of parts and cost of material and process. This as and when required was carried out actually in the shop floor by part count, weighing the components and process time using usual simple process.

  Similarly, initial prototype of Dipbahan had separate structure for the seat aimed at its fold ability so that in case of carrying only goods, better space utilisation is possible. The part bearing the passengers' load in this seat arrangement failed because of being a suspended beam. Later it was changed to column type arrangement, which on testing was found to be very stable. Folding type of seat arrangement was discarded in commercial production version to reduce cost of production and facilitate ease of maintainability. Also response from passengers itself were excellent compared to provision of using the tricycle rickshaw for goods carriage. It was decided that a separate version can be built later only for goods carriage purpose.

  Also combining of seat and seat back did not prevent the assembly but made it simpler to assemble. Similarly, compared to the traditional tricycle rickshaw, Dipbahan was designed with an integrated chassis. This made the chassis rigid and stronger as well as easier to assemble. Dipbahan also has integrated body with roof structure and rolling cage. This made it simpler and reduced numbers of components compared to a traditional rickshaw. Seat structure in addition to supporting the seat and seat back hold together the right and left frames and provided much required triangulation. These features made Dipbahan^{+} easy to manufacture and assemble.

- Will servicing be adversely affected?
  Integration and combining the various components in Dipbahan+ actually facilitated the servicing rather than adversely affecting the serviceability. The process matches with the existing capabilities of the small enterprises' manufacturing facilities and expertise. During the whole process, role of the present researcher was to supervise and suggest refinement in design and manufacturing on the spot, while the persons in those small enterprise including the NGO were actually setting up the manufacturing process.

DFM Guidelines

Here general design guidelines are difficult to formulate. Instead, guidelines were framed for the processes used to make each part.

For plastic parts, mould flow analysis can help indicate better part shapes for mould filling and solidification. In case of FRP components, the process is hand lay process. Here components were not given excessive depth except the hood. This is essential, since the resin applied to impregnate the glass fibre flows down until it is polymerized. This can weaken the vertical sides of the components.

Sheet metal parts guidelines for minimum bend radii and feature separation.

The rear end of the newly designed tricycle rickshaw had three dimensional curvature including the rear panel earmarked for insertion of advertisement. This curvature made fabrication and assembly of the rear panel difficult in sheet metal. Thus it was decided that only one curvature in vertical direction will be provided. To achieve this the curvature of the horizontal binding bars was reduced. These were modified on the same design without much difficulty. In the Dipbahan^{+} version, sheet metal was totally eliminated and this guideline is redundant.

Cast parts have recommendations for feature locations to provide material flow paths during mould fill. The only cast part used in Dipbahan is out sourced. However it had feature of slots for fastening this to the chassis and the guideline was met.

Machining operations have guidelines on dimensioning and tolerance.

This was maintained through extensive design of jigs and fixtures, both for the individual parts and for assembly of these parts to sub-assembly and final assembly.

It is impossible to provide guidelines for every production process; new refined processes are constantly under development.

Benefits of DFA and DFM

- Reduces part count
- Reduces cost
- Reduces time required for production.
- Reduces manufacturing errors

Potential Conflicts between DFA and DFM

Theoretically application of DFA and DFM guidelines can reduce manufacturing cost and increase quality. However, the guidelines do not necessarily always do this. One can increase part functionality to the point where parts become so complex they cannot easily be produced.

Implementation of design guidelines in the model

It was not possible to maintain all the guidelines stated, however, they have been followed to the extent possible by:

- Using same radius of curvature in all the pipes.
- Minimizing the use of screws and fasteners.
- Assembling always from above
- Minimizing welding
- Eliminating sharp edges and corners.

7.1.2 Design of tools and fixtures

Whenever a product is designed for commercialisation, manufacturing ease needs to be taken into consideration. To ease the manufacturing of multiple units, standard fixtures are to be designed. Second step in Planning the Production Process (Chapter 3, section 3.5.1) is Design of tools and fixtures for the tricycle rickshaw: This design work proceeded from the information developed in the operations analysis on the process sheets (sample process sheet provided as Appendix 2) and from the experience gained during the prototyping and product testing. Thus after the completion of the functional prototype and its testing taking mechanical, structural and other stability into account, building of jigs and fixtures were taken up. These were made as per the dimensions of the tricycle in the main drawing and the functional prototype made to achieve accuracy in the mass produced tricycle rickshaw.

The jigs and fixtures were fabricated to make it be sturdy so that it can be used for long periods. System of jigs and fixtures were designed to be simple and easy to handle. Since, the initial target was the manufacture of five hundred pieces, special attention was given to it. First of all the various ways of attaining the tricycle structure from fixtures were studied. Since the fixtures were to be mounted on work table, so the need of a flat base led to its fabrication in the square tube of 25 mm x 25mm.

In the interim version of Dipbahan, the fixture for the platform (sandwich, metal bar between two pipes) was made. In this platform over the first pipe of 25 mm diameter (lower element) a metal flat bar of 40 mm width and 5 mm thick was to be placed and welded. After this another pipe of 25 mm diameter (upper element) is to be welded. To achieve this, a clamp was designed to hold the combination. It could be released when not in use. The distance between the two pipes in the fixture was maintained by welding a piece between them. At the end of the fixture a plate with a v-groove was fitted so that

the extra length of the pipe could easily be cut. Plate in u-shape is welded on the front part to properly align the main socket. After fitting the first pipe inside the socket the metal bar is put over the pipe and the swiveling clamp is tightened to weld. The second pipe is fitted over the bar and the whole combination is turned by 180 degrees to weld. Now, to slide the various pipes within the socket, removable triangular arrangements are made. The angle of the triangle is made same as that required and is fitted to the main fixture. In the same way guide for other pipes were made so that these can be easily slide inside the socket. This completed the fixture for platform.

Once the individual fixtures for subassemblies were ready, next activity is preparing the fixture for space frame. The various points where joints were required were located. Once these points were located the pipes (making the space structure) could be easily fitted. Vertical removable tubes were fixed to the platform. For the seat a small circular guide way was provided in the top pipe of platform so that the links could be put in.

For the axle, tyres and brakes, marks are made on the platform fixture and they are fitted accordingly. With the use of these Jigs and Fixtures any production process can be sped up. It also helps in designing the product accurately in small scale.

Fig. 7.1 Jig for cutting rectangular section at an predermined angle

Fig. 7.2 Jig for cutting tubes at right angle

Fig. 7.3 Seat structure

The important achievement in the second generation design was concurrent design of jigs and fixtures for fabrication of the Dipbahan^{+}. The work involved design and fabrication of a set of jigs for cutting the individual members accurately without need to measure these members again and again (Fig 7.1 and Fig. 7.2). This eliminates the level of skill required for the worker and instead of skill worker, the work can be carried out by semi-skilled worker. It also standardised the whole process and eliminated the variations in these members, thus reducing the tolerance required and enhanced productivity.

The second tool developed is a set of jigs and fixtures for fabricating the body shell from the individual members cut using the first set of jigs. Since a single jig for the body shell will be a complicated one, sub-frames that were made out of the whole Dipbahan^{+} was taken as basis for designing the jigs and fixtures. As mentioned in Chapter 5, section 5.5, these sub-frames are mainframe and chassis, right side frame and Left side frame, seat structure and 3 numbers of cross binding members.

Two jigs (Fig. 7.4 and Fig. 7.5) were made for the right and left side frames, another two (Fig. 7.6 and Fig. 7.7) for the mainframe and chassis and two more for the seat and one for the front end (Fig. 7.8). These jigs are primarily for welding the individual pieces cut earlier using first set of cutting jigs into a sub frame. To joint the main frame with the chassis, another jig (Fig. 7.9) was designed. Between these two sub frames, the BB socket is welded with to obtain an integrated main frame and chassis.

Fig. 7.4 Jig for the right side frame for body shell which is fitted on the main frame and chassis of the tricycle

Fig. 7.5 Jig for the left side frame for body shell which is fitted on the main frame and chassis of the tricycle

Fig. 7.6 Jig for the main frame which is fitted to the chassis of the tricycle

Fig. 7.7 Jig for the chassis which is fitted to the mainframe of the tricycle

Fig. 7.8 Jig for the front end which is fitted to the main frame of the tricycle

Fig. 7.9 Jig for joining the mainframe and chassis of the tricycle

Once all sub frames are ready, these are welded together using fixtures to fabricate the main shell of the Dipbahan (Fig. 5.38, p 170). This ensures accuracy of dimension. After the shell is ready, it is sent for spray painting using automotive paints and the process is same as in case of the interim version of Dipbahan.

7.1.3 Planning and specifying for designing new production and plant facilities

Third step in planning the production Process (Chapter 3, section 3.5.1) is planning, specifying and designing production and plant facilities. This was carried out in consultation with the Centre for Rural Development, Guwahati and M/s Tim Steel Innovatives, Guwahati. Build up shed and machinery required for the plant along with the cost is prepared and made available to the enterprises and is enclosed as Appendix 3. All these machinery were readily available from market except one machine specific to the Dipbahan manufacture. This is roller type pipe bending machine and required specific fabrication. Centre for Rural Development, Guwahati went ahead with fabrication of the machine of their own using the services of outside vendor and could not come up with a machine with specified tolerance. Due to this accurate and uniform radius of curvature required in the tubular section were not possible in repeated operations. This led to the distortion of the form of the Dipbahan, the interim version of the newly designed tricycle rickshaw fabricated by Centre for Rural Development, Guwahati and fracture of tubes at bend (Fig. 5.34, p 164) leading to poor quality of the final product. Based on the experience with Centre for Rural Development, Guwahati, a pipe bending machine specific to the process of manufacture of the newly designed tricycle rickshaw was designed and fabricated in house with financial and material support from M/s Tim Steel Innovatives, Guwahati to manufacture Dipbahan^{+}.

7.1.4 Planning the quality control system

Fourth step in Planning the Production Process (Chapter 3, section 3.5.1) is planning the quality control system. For the tricycle rickshaw, there are 4 categories of material inputs based on the process used for assembly. These are:

i. The first category of material is out sourced parts as per Table 5.1, p 152 (Chapter 5). These are procured from outside. Based on market feedback both from dealers and users of existing rickshaw i.e. pullers and rickshaw garages as well as from the experience gained during the initial phase of the project, it was found that the KW branded products are the best in terms of metal components; for rubber products such as tyres and tubes, Ralson is superior and in chains Rolon is equally good. Therefore during the planning of the quality control system, it was emphasized that these items be procured from these brands only. Random checking to ascertain the dimensions within the tolerance limit is to be carried out to maintain proper quality.

ii. The Second category of product is items fabricated with Mild steel tubes, sections, sheets, wire mesh etc. Here input material is the main concern. First specification of this item is weight per unit length as given at column 2- Description of material in Table 5.2 in Chapter 5. This is strictly maintained within 2.5 % tolerance limit. In the second category of the product, there is two more sub set of materials. One is welding rods etc. For welding rod, only ESAB brand of welding rods were specified to obtain better welding joints. The second sub set is putty, primer and paints for the frame. In this case also, ICI branded DUCO automotive products were specified.

Regarding the dimensional accuracy of the frame, Jigs and Fixtures both for cutting the individual elements as well as for fabricating the entire integrated frame were designed and delivered. This ensured that the resultant product is within specification and quality is maintained. Quality of work of these items were maintained though allotment of job to a group with set production target within specific duration with fixed rate for each fabricated frame. If any items fall short of specification, the group will not get remuneration for the item and reworking is also to be done free of cost. Wastage limit was also another criteria arrived at after initial operation. If wastage is reduced without compromising the quality, the saving due to the reduction in wastage was distributed as incentive to the group. Thus motivation was built up within the system.

iii. For Dipbahan, interim version of the newly designed tricycle rickshaw, the third category of product is items fabricated out of wood. It is used for making floor panels and seat & seat back base. Here quality of wood is one important aspect. It was specified that only properly seasoned hard wood be used. For dimensional accuracy, templates were made and used. Strength is important since the luggage carried by the passengers will be kept on the floor and passengers will seat on the seat. Thus these elements are subjected to both static and dynamic conditions. Floor boards are covered with galvanized tin sheets in the production versions. In the prototype this was fitted with chequered aluminium sheets. The replacement was necessitated due to cost constraints. Quality of work of these items were maintained though the same process as mentioned in (ii) above through allotment of job to a group with set production target within specific duration with fixed rate for each items. If any items fall short of specification, the group will not get remuneration for the item and reworking is also to be done free of cost. Wastage limit was also other criteria arrived at after initial operation. If wastage is reduced without compromising the quality, the saving due to the reduction in wastage was distributed as incentive to the group. Thus motivation was built up within the system.

iv. The fourth category of products comprise of sponge, reskin, Velcro etc. for making seat, seat back, hood and rain guards. Regarding the sponge used for seat and seat back, only reputed branded products were specified and for synthetic tarpaulin, various samples were actually tried out and the one that performed better in terms of price, colour fastness under use and durability was selected. Surprisingly, the selected one was not the costliest. Dimensions of the items made out of this material were

maintained through accurate measurement and check. Items made out of synthetic tarpaulin are hood, side rain guard, back screen and seat covers.

v. In case of Dipbahan^{+} few items like wood, mild steel sheet and wire mesh, aluminium chequered sheets etc. were no more required and these were replaced with FRP components. Quality of the components were maintained through quality of input raw materials and workmanship. Dimension was easy to maintain due to the fact that these are made using moulds.

7.1.5 Planning for production personnel

Fifth step in Planning the Production Process (Chapter 3, section 3.5.1) is Planning for production personnel. Initial training of the manpower was done in the Department of Design, IIT Guwahati as part of design and technology transfer. The supervisor was a qualified Industrial Training Institute (ITI) trained professional. The workers engaged by Centre for Rural Development was also trained through an outside organization M/s. Geeta Steels, Guwahati for manufacturing operations in actual products. The workers were experienced in metal fabrication and they did not have much problem, except transferring engineering drawings and dimensions provided in CGS (Centimeter, Gram, Second) system, since they were conversant with Foot and inches. Although dimensions of the Dipbahan were mentioned in centimeters, being convenient for CAD drawing as well as for normal measuring, in case of weight, gram is too small unit for a vehicle and thus Kg was used in the thesis.

Job-specifications for each job were developed. This was done for assembly of bought out items, sub-assembly and final assembly. Assembly of wheels using rim, spokes, nipples, eyelets (metal washer in oval shape with circular holes at the center), hubs, ball bearing, racer for ball bearing, axle, laying the inner side of the rim with a cotton ribbon to cover the nipples and washer to prevent damage to the tube and finally mounting tyre and tube on the rim. Then the wheel was dynamically balanced. Other assemblies are fitting the front fork and handle, fixing the brake system, assembly of the chain sprockets, crank, pedals, free wheels, rear axle and bearings and bearing block to the frame etc.

Job specification and standard job activity times and motion studies were carried out by the person from SME after they were trained at Department of Design, IIT Guwahati. Being a technology transfer initiative, it was important to impart proper process to the SMEs for future work to develop their capacity to deliver a successful marketable product with all possible assistance including support in successful implementation and manufacturing process.

Standard times for most of the activities were determined through trial production over a period of a month and through time and motion analysis. The data was validated by rotating the groups over different job as well as rotating the team members in the group.

Based on the time taken to perform a specific task by a group, the actual wages of the members of the group were calculated for the task and labour costs estimated. This was intimated to the group and were offered job rate for the task with added incentive that they will be paid a minimum fixed wages on the basis of the study above. This was required to ensure the motivation to the work force that they will not loose in case of disruption of the work due to power failure and load shedding so common in the North Eastern Region.

Once all the above items were settled, production target was set and all resources were directed to achieve this.

7.1.6 Planning for production control

Sixth step in Planning the Production Process (Chapter 3, section 3.5.1) is Planning for production control: Work schedules and inventory controls (Buffa, 2005) are evolved based on initial target production of 1,000 tricycle rickshaw per annum. This literally translated to 3 rickshaws per day. Thus work schedules were formulated. These are:

i. For assembly of wheels a team of two persons were formed. This is the first team. One assembles the wheel with components and the other person carries out the dynamic balancing of the assembled wheel. The team at the end of the day also mount the tyres and tubes on the rim and complete the system ready for final assembly. Their targeted production id 9 completed wheels, 3 front wheels with short axle and ball bearing on racer and 6 rear wheels subdivided again as 3 with fixed hub and another 3 with free hub. This whole activity is preceded by a day of final assembly so that the assembly team is not required to wait for the sub assembly made by this team.

ii. Similarly the second team's work schedule is the assembly of the entire tricycle rickshaw with all other components and sub assembly such as assembly of puller's seat, front fork and handle, fixing the brake system, rear axle with wheel, free wheel sprocket, bearings and bearing block to the frame, chain, chain wheel, crank, pedals, rear view mirror, bell, reflectors, mud guards etc. The team comprised of 2 persons.

iii. The third team's work schedule is to cut all the elements after bending the pipes and fabricate the entire frame through welding. Within this team, job is sub-divided and a sub-team cuts and bends the pipes, another spot wells to obtain the over structure and a third one finally welds the frame completely followed by a person grinding the joints to finish. The team comprised of six persons.

iv. The fourth team's work schedule was sanding of the welded and grinded frame to remove any dust, applying primer and painting it. The team consists of 2 persons.

v. The fifth team of two carpenters had the work schedule of fabricating the required foot boards, 3 for the front and 3 for the rear, cutting the galvanized sheets to size, fitting the same with nails to the wooden boards. The same team is responsible for fitting these

to the tricycle rickshaw. The team also fabricates 3 sets of seat and seat back and provides the same to the sixth team.

vi. The sixth team in turn cover these with foam and synthetic tarpaulin. This team comprising two persons also stitches the rain guards and the back screen.

vii. The seventh team of two persons work schedule requires them to fix the seat and seat back, rain guards, back screen, hood and rear panel to the frame.

Thus there are seven teams of 18 persons altogether for fabrication and assembly of interim version of Dipbahan.

Compared to the above seven teams of 18 persons, the fabrication of Dipbahan+ required 6 teams with 17 persons. Difference was that the fifth team comprising of two carpenters were replaced with a team of fibre glass component maker consisting of 4 persons and sixth team had only one member for stitching the rain guards. The seventh team as usual used to fix the FRP seat, hood, floor boards, side panels and rain guards etc. to the body shell.

Next aspect was inventory controls. Since the targeted production was 3 rickshaws per day and rickshaw once fabricated were immediately delivered, the inventory control was accordingly planned. All the outsourced components were procured locally from dealers in Guwahati every fifteen day for 50 nos. of rickshaws. Reordering is done 10 days after receipt of the ordered material providing a lead time of 5 days. Inventory of wood was also similarly controlled. Here the advantage of maintaining inventory is the possibility of seasoning the wood before using the same. Mild steel items were procured after every 10 days for 40 rickshaws. This also provides for 3 days cushioning in case of non receipt of material in time. Reordering was not necessary and items were bought directly from dealers on spot. Foam items being bulky but readily available in the market were procured weekly. Synthetic tarpaulin was procured every fortnightly but this material was found to have erratic supply for the same quality and as and when available it was procured and stored. All other items were procured weekly.

Based on the division of work and work schedules, materials required for the manufacturing both direct and indirect, standard costs for labour, materials, and services were established. This was integrated with the accounting system of the organization.

7.1.7 Planning the information-flow system

Seventh step in planning the production process (Chapter 3, section 3.5.1) is planning the information-flow system. For the production process to be maintained and controlled efficiently, the information necessary for transmission of instructions and provision of feedback between the various persons involved were determined. SMEs associated with manufacturing of Dipbahan took initiatives for suitable design of all appropriate forms and records essential for the purpose and manageable by their existing staff. Computer was used to integrate with the existing system of the organisation.

7.1.8 Financial planning

Eighth step in Planning the Production Process (Chapter 3, section 3.5.1) is Financial planning: Although large sums of money are required to initiate production of a new product like a tricycle rickshaw, the strategy was formulated to reduce the same through various measures. The source of the financing for the project was carefully established. Initially, financial planning for the production and marketing of the tricycle rickshaw was based on a novel concept of Rickshaw Bank. The concept is detailed below.

Corporate Houses spend significant amount as advertisement expenditure. Part of this expenditure is aimed at creating exposure and awareness regarding them in the society to generate good will rather than the brand publicity. This amount can be utilized for sponsoring the Dipbahan for the rickshaw bank project and in return for their money, they can be provided with advertisement space at the back of the Dipbahan where they can insert either advertisement or socially relevant message that can create awareness and good will amongst the populace. This provides the corporate with better mileage since, these Dipbahan provides mobile advertisement with higher penetration. Thus the partial advertisement expenses of corporate houses are utilized towards a meaningful development process, which will not only serve its original objectives of its expenses but will also create an appropriate platform for the development of the marginalized migrant rural people in urban areas. In other term, it will optimize the value of expenses by creating a good number of employment opportunities for the needy people. The means and rate of recovering the capital was determined based on the strategy.

A survey conducted in the city of Guwahati revealed that only 5 % of rickshaw pullers own their vehicle. They also don't have access to banks since they do not have a permanent address and there is no introducer for them. Even after living in the city for 15 years, they are considered as migrants. Often the police pounced upon them since a large number of rickshaws are without valid license, since the pullers can not furnish the required documents for obtaining the necessary licenses.

The main concept of the Rickshaw Bank project (Appendix 1) is to issue an asset loan to the rickshaw puller with a provision to repay the original manufacturing cost of the rickshaw by a minimum installment rate on daily basis and as the borrower repays the loan the rickshaws are handed over to the pullers. The repayment amount is again reinvested in manufacturing new rickshaws to provide to other rickshaw pullers after deducting a small portion as administrative expenses towards management of the programme. This also provides for an extra advertisement to its original sponsor. An NGO, Centre for Rural Development, Guwahati initially generated funds for the working capital of the project from different public and private sector companies through incurring advertisement cost.

As the pullers become the member of the Rickshaw Bank, a rickshaw loan amounting Rs. 9000/- is sanctioned against their name with a provision to repay the amount by

paying Rs. 25/- per day. A passbook is issued in their name where savings and installment recovery status are properly maintained. The Rickshaw puller licenses are also provided along with photo Identification card to get rid of the harassment of police and municipality. Two set of uniform is provided to them for ease of identification as the bonafide member of the Rickshaw Bank and thus to work with dignity. Insurance coverage of Rickshaws for Rs. 7,000/-, for puller 50,000/- and for passenger 25,000/- is also ascertained in the project. Garages are appointed at various parts of the city as a part of daily collection centre and service stations for the rickshaws. Monthly meeting is organised in every garages to inform the savings and installment recovery status of the Rickshaw Puller. Decisions are being taken to resolve their problems and for smooth functioning of the project. Proper orientation is being given to their wives with a view to encourage them to come forward to be an earning member of their family. Besides, the project aims to ascertain a good livelihood environment of the rickshaw puller. Management and Monitoring Information System for Rickshaw Bank was built in VB.NET and SQL Server 7.0. This MIS keeps track of all daily activities and manages the banking activities of Rickshaw Bank.

Apart from the NGO, Centre for Rural Development, Dipbahan is also manufactured under license from IIT Guwahati by another small enterprise in Guwahati, M/s Timsteel Innovatives. Being a small private enterprise, its financial planning is similar to any small enterprise. However for marketing of its product, it operates the same way through collaboration with micro finance organization and various state and private organization involved in socially relevant cause of empowerment and employment generation.

7.2 Planning for Distribution

In the production-consumption cycle (Chapter 3, section 3.5.1), production is the first process and distribution is the second process. In an established industry, the product designer may not be directly involved in this phase. However, the problems of distribution have an important impact on the original design of the product. Products after the stage of manufacturing need to be properly distributed among the dealers to get the optimum output from the product. The success of the product is equally dependent on the distribution as on the other phases (Designing and Manufacturing). The fifth phase in the morphology of design, distribution do have an important impact on the original design of the product.

In case of the tricycle rickshaw too, the planning for distribution played an important part and the onus of solving the problems rests with the designer. Through planning for distribution phase an effective and flexible system of distribution of the designed tricycle rickshaw was planned and emphasized from the beginning of the design phase, but was implemented only in the second generation of Dipbahan. Going by the experience in the first stage, the following details are important.

7.2.1 Designing the packaging of the product

Theoretically, the first step in Planning for distribution (Chapter 3, section 3.5.1) is designing the packaging of the tricycle rickshaw. Although, the outer shape and size of the tricycle rickshaw was not allowed to be influenced by the necessity to effect economy in transportation costs in the first design of the *Dipbahan*, it was considered that this model will be delivered within a medium distance and the puller can ride this to destination. This also provided with added advantage of free publicity and exposure to the product being seen and appreciated on way to its destination. For the tricycle rickshaw, Individual and special packaging is not essential to secure protection from shock and weather. Neither special strapping nor palletizing required to facilitate handling. However in the second generation of the Dipbahan $^{+}$ modular and knock down model was due to the sole consideration of effecting economy in transportation costs. It was found that tricycle rickshaw being voluminous, it could not be transported through brake/parcel van in trains and it was not accepted by the buses plying in inter-town route. It could not be accommodated on the roof of a bus even after dismantling the wheels.

However the feature of knockdown was considered at the starting point of the design as mentioned earlier. Thus it was a preconceived and relatively easy task of designing the joinery. However joinery for separate side frames to be joined to the chassis and main frame as well as the seat structure to the assembled rickshaw. The three top bars were also used as binding bars for the two sides. The passenger's seat unit provides for triangulation for the space frame structure. All these joinery for ease of manufacturing and assembly requires to be identical. Also it should be easier to assembly. Two concepts were prototyped as shown in Fig. 7.10 and 7.11, p 219. These two concepts were evaluated in terms of Design for Manufacturing and Assembly guidelines and concept shown at Fig. 7.11, p 219 was accepted. Details of the concepts are given below.

Initial joinery details involved joining the left and right frame through front top binder and used male female socket type joinery that is fastened with nuts and bolts passing through the holes in both the elements as shown in Fig. 7.10, p 219. The details for top middle and top back binders are same. Joinery detail is also same for left and right frame through passenger's seat unit. The passenger's seat unit provides for triangulation for the space frame structure. The same joining detail is used also for fixing the left and right frame with chassis at the bottom and at the front end.

Final joinery details involved joining the left and right frame through front top binder and used one side opened U shaped bracket to which the other element is placed and then fastened with nuts and bolts passing through the holes in both the elements as shown in Fig. 7.11, p 219. The passenger's seat unit provides for triangulation for the space frame structure. The same joining detail is used also for fixing the left and right frame with chassis at the bottom and between left and right frame through front top binder, top middle and top back binders, but bracket welded facing different direction to provide

better triangulation. However at the front end, the initial male - female joinery detail is used as shown at Fig. 7.10, 219. Here a solid bar of the inner diameter of the tube used for the fabrication of the Dipbahan space structure with a hole perpendicular to the longitudinal axis is welded to one element. The other element is a tubular pipe drilled at the end to match the hole on the solid stud. This element is pushed on the stud to facilitate the passage of a bolt through the combined hole. This bolt is fastened with a washer and a nut to hold both the elements together.

There is inherent deficiency in male female socket type joinery that is fastened with nuts and bolts passing through the holes in both the elements as shown in Fig. 7.10, p 219. First, it require machining of the male socket accurately to match the inner diameter of the pipe used as female socket, drilling hole onto this round socket and welding this to the frames and chassis. The second difficulty is to drill an accurately aligned hole on to the female socket. After this was done, there is the third difficulty of aligning these during assembly and then passing a bolt through this combined hone to fasten then with a nut. Whole assembly is difficulty, since once the male socket is inserted into the female socket, the hole in the male socket is not seen and alignment is next to impossible. The fourth difficulty is that to assemble the whole rickshaw require simultaneous assembly of all the male female sockets. Thus this was discarded in favour of second concept except at the front end of the left and right frame joining point. Here because of only single joint and bent male socket it was comparatively easier. The second concept was easy to manufacture and assemble. U-brackets were made using a set of tool as shown in Fig. 7.12, p 219 using hydraulic press. 3 mm mild sheet is used and after pressing the sheet, the u-brackets are welded to the frames. During assembly, it is easy, since the holes on both the elements are visible. Also each joint can be assembled separately, since an element can be easily placed to the U-shaped bracket without having to move the other joints.

One more joinery was designed to join the post supporting the rickshaw puller's seat to the chassis platform and is shown in Fig. 7.13 and 7.14, p 219. This bracket is required to strengthen the combined structure of the chassis and main frame through triangulation.

To facilitate transportation, the side frames, chassis etc. in the knock down version were also stackable, like left frames with the left ones and right frames with the right ones.

Fig. 7.10 Initial concepts for knock down joinery

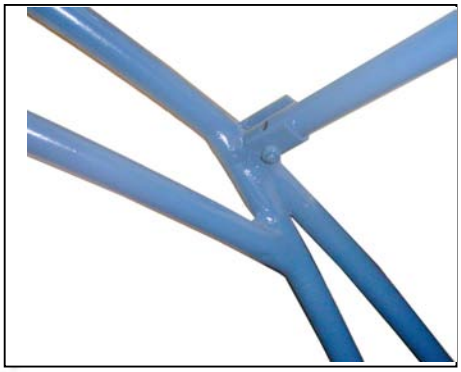


Fig. 7.11 Final details of knock down joinery

Fig. 7.12 Press tools to make U shape brackets

Fig. 7.13 Bracket fastened to chassis with nuts and bolts

Fig. 7.14 Bracket fastened to post supporting puller's post with nuts and bolts

A special plastic component was designed to hold any two nearby frames together to prevent scratches on the parts due to rubbing each other during handling and transportation before final assembly specially when more than one unit is required to be dispatched. However, the seat and seat back were integrated in this process as well as to reduce the costs of these components and facilitate stack ability. The hood was redesigned for stack ability and also visual features were added in the process to add appeal to the rickshaw. Similarly few minor changes were effected to the foot boards, side panels and rear panels to accommodate the nuts and bolts protruding out of the joints. Thus instead of designing special packages for the rickshaw, the rickshaw itself was redesigned to certain extent.

After the above exercise was over, the packages for the redesigned rickshaw was initiated. The packaging of the product gives an added advantage of:

- Less transportation cost.
- Easy to handle.
- No possible wear and tear of the structure in transport
- Secure protection from adverse elements of the weather by wrapping the materials inside with polythene sheets.

First consideration is from the point of view of packing material optimization. It was observed that ply-boards are commercially marketed in the regular size of 8' x 4', 6' x 4' and also 6' x 3'. Initial concept was to design the packaging of the Dipbahan with the constraints of packing in a box of 120 cm X 120 cm X 60 cm (4'x4'x2') with two rope handles at the sides to facilitate easy handling. Thus if size of packing box is fixed at 4' x 4' x 2', there is no wastage of packing materials and minimum work is required for making these boxes. This package is for one unit of Dipbahan.

Second consideration was the handling aspect by human being. 4' x 4' x 2' size box was found to be better from the point of handling by a single person. Once the size of the box increased, it required minimum 2 persons to handle this.

Third constraint is the space constraint in commercial vehicles used for transportation of goods. Different commercial vehicles were checked for the dimensions of their cargo bay and it was found that the floor dimensions are 6' x 8', 8' x 12', 6' x 12 etc. Thus package size of 4' x 4' x2' will be optimum for these vehicles.

However, Although the tricycle was designed for proper dissemble during transportation and re-assemble for use so that it can be stacked in a box, the targeted constraint of size of the box could not be fulfilled at the desired dimension of 120 cm X 120 cm X 60 cm (4'x4'x2') and a new box of dimension 180 cm X 150 cm X 90 cm. (6' X 5' X 3') was arrived at even though there are some wastage of packing material. For transportation, there was not much difficulty in optimizing the space.

7.2.2 Planning the warehousing systems

Second step in planning for distribution (Chapter 3, section 3.5.1) is planning the warehousing systems. In the case of the tricycle rickshaw, this was not a concern, since in case of rickshaw bank project; the finished rickshaws were directly handed over to the member of the rickshaw bank and were never stored in a warehouse. In case of the second organization, M/s Tim Steel, there are dealers all over the North East and these dealers are responsible for storage of the rickshaws. In case of Centre for Rural Development, they have fabrication units in various places and storage is not essential.

7.2.3 Planning the promotional activity

Third step in planning for distribution (Chapter 3, section 3.5.1) is planning the promotional activity. As a part of design and technology transfer package, brochures containing design and technical features highlighting the advantage of the new tricycle rickshaw were designed and delivered to the organizations concerned for promoting the

tricycle rickshaw. The brochure and promotional materials are found to be integral part of the design and technology transfer process because, it was seen that changing perception of people about rickshaw is one important aspect for success of the product and SMEs did not had the capability to do it of their own for designing promotional materials for this as well as for marketing effort. The experience of Coventry University associated with Knowledge Transfer Partnerships (KTP) is also found to be similar (Evatt, 2005). It was also found to be the lacuna in the existing transfer of technology, which only considered the products rather than considering it as an integrated aspect. It is important during product design in participation with SMEs as target manufacturer (in p 77 in objectives of the research), marketing support is important and these are required to be tackled in an integrated manner. The main brochure of Dipbahan^{+} was done by the author of the thesis. The others were done by the faculty of Department of Design as a part of departmental promotional material which also emphasized the Dipbahan as a product designed in the Department of Design, IIT Guwahati for the society.

Also to provide wide media publicity, press conferences, function to mark release of the newly designed tricycle rickshaw was held with wide participation from all section of the society. This activity provided a very positive impact from the promotional point of view. These rickshaws were branded as Dipbahan and were displayed in exhibitions organized by reputed organization like CII (Confederation of Indian Industries) and NECCI (North Eastern Chamber of Commerce and Industry) as a part of institutional participation by IIT Guwahati. The technical papers were also published in national and international conference (Appendix 5). Technical sales brochures containing design information and test data were also developed (Appendix 4)

Another aspect of promotional activity was meeting with decision makers in public service. To convince the advantages of non-polluting means of transport through modern tricycle rickshaw like Dipbahan was a Herculean task. Even then this was done with positive outcomes. Persons involved were Deputy Commissioner of districts, Commissioners/Executive officers of civic bodies like municipal corporations/ committees, Ministers of Rural Development, Tribal Development etc. As a part of the project, researcher of this project wrote to each and every person that matters. This had enormous impact due to the brand image of IIT Guwahati and Department of Design.

Design and technology fusion that resulted in Dipbahan and its impact on employment generation was presented to a distinguished gathering in a 'Design and Technology Conclave' organized by CII (Confederation of Indian Industry) and NID jointly in Shillong.

Dipbahan+ was also exhibited in Mumbai PANIIT conclave and featured in PITech, IIT alumni's magazine and in many regional, national and international media.

7.2.4 **Designing the product for conditions arising in distribution** (Dipbahan +)

Fourth step in planning for distribution (Chapter 3, section 3.5.1) is designing the product for conditions arising in distribution. Such factors as shelf-life, attractive display and final conditioning, before delivery to the consumer may affect the design of the product.

Enough flexibility in the design was provided to allow for special modifications such as opting for synthetic hood rather than the composite hood; going for tape woven seat and seat back (that are popular in Delhi etc.). The additional space provided in the front (front of the cycle handle) can be used for putting an open box to allow the driver to keep various utility items. The tricycle rickshaw can be provided with folding seat (opens upward) to allow the passenger to keep extra goods. Colourful ornamentations those are very popular in Indian context with paintings of famous hero/heroin, god/goddess or even natural scenery or auspicious symbols to suit customers' needs. To facilitate this, side of the hood was left free from any other details. The design also provided for further adding available optional features as required by the customer, in this case a storage space that is modular additions to the system to segregate open storage space below the seat through addition of another side used in the Dipbahan $^{+}$ (Plus) and then providing with a lockable cover. However this feature is not available in the 1st generation Dipbahan. If required, the tricycle rickshaw can be made to enlarge its capacity. This is required specifically to address the situation in specific region like, north Bengal, Coastal West Bengal like Digha and Orissa. This is because as seen in the Fig. 2.23, p 42, the pullers use a rickshaw van based on the tricycle rickshaw platform but carries much more passengers than the actual tricycle rickshaw. Although school van Dipbahan Ankur was designed to accommodate more children by stretching the platform and enlarging the area above the platform and rolling prototype produced, addressing this particular situation to accommodate grown up persons will require different approach.

7.3 Modularity and new product based on the existing design of the Dipbahan through academic industry interaction

Extending the tricycle rickshaw design based on it's modularity to facilitate design and fabrication of multiple versions such as school van, garbage disposal van, delivery van and vending cart etc. through industry's participation is another important phase in design development process. A derivative in the form of Garbage disposal van was finalized its computer simulation was carried out for various iterations (Fig. 7.15-7.16). A scale model (Fig. 7.17-7.18, p 223) was also made prior to functional prototype was fabricated. It is branded as *Dipbahan Pariskar* (Fig. 7.19- 7.22, p 223).

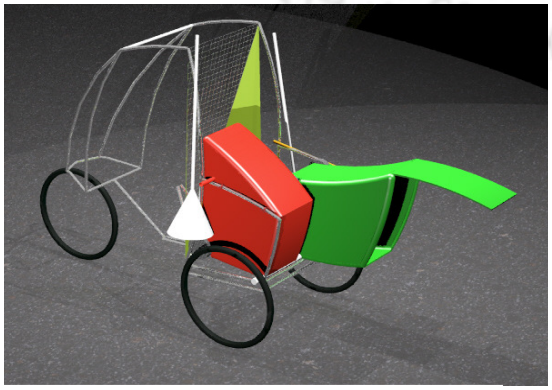


Fig. 7.15 CAD model of Pariskar rear 3 quarter view

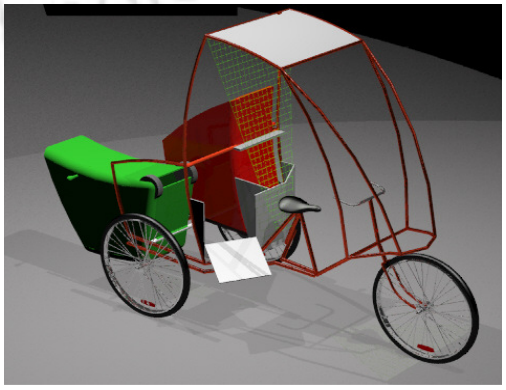


Fig. 7.16 CAD model of Pariskar front 3 quarter view

Fig. 7.17 Scale model of Pariskar front 3 quarter view

Fig. 7.18 Scale model of Pariskar rear 3 quarter view

Fig. 7.19 Garbage disposal van with Dipbahan

Fig. 7.20 Dipbahan Pariskar on display

Fig. 7.21 Front 3 quarter view of Dipbahan Pariskar: has the same length, breadth and height as that of Dipbahan+

Fig. 7.22 Rear 3 quarter view of Pariskar, it has identical wheel base and track as that of Dipbahan+

In case of Dipbahan Pariskar, basic chassis and mainframe as well as the front end is same as that of Dipbahan+. The rear vertical posts were shifted to the position behind the puller and joined at the point of connection between the left and the right frame. The design provides for collection and disposal of household solid wastes and two garbage bins are fitted for segregation and dumping of biodegradable and non-biodegradable

wastes separately. These are colour coded as green and red for respective type of waste. To facilitate durability, these are made out of FRP with embedded structure in metal. For ease of operation, these can be tilted to the rear so that bins can be emptied effortlessly. Bins are also provided with covers. Behind the puller's seat, an equipment bay is provided to hold various items that the puller needs during his work. These includes broom, spade etc. Prototyping of Dipbahan was completed in the Department of Design, IIT Guwahati and handed over to an NGO engaged in collection and disposal of domestic solid waste for trial. It has received excellent response both from the citizens and the users, i.e. garbage disposal persons.

7.4 New development through small enterprise as a part of design and technology transfer

As part of transfer of technology to the intending manufacturer through their active participation from the design and development stage and also to generate new products based on Dipbahan+ an exercise was carried out to make a school van (Fig. 7.23- 7.25) where all the components of the participatory model was involved. The product was successfully developed for commercial introduction and branded as Dipbahan Ankur.

Fig. 7.23 Dipbahan Ankur school van has its length, breadth (of body) and height increased by 200 mm, 200 mm, 150 mm respectively compared to length, breadth and height of Dipbahan+

Fig. 7.24 Rear view of Dipbahan Ankur; it has identical wheel base and track as that of Dipbahan+

Fig. 7.25 All the variations of Dipbahan seen displayed at exhibition organized by Confederation of Indian Industries (CII) in Guwahati

Dipbahan Ankur was designed to accommodate more children by stretching the platform by 20 centimeters and enlarging the area above the platform by extending the side frames by 10 centimeters on each side over the rear wheels to accommodate the bench type seats. For the safety of the school children, entry and exit was placed at the back of the puller's seat and he can control the opening of the door. It was provided with space below the hood to stack the bags and water bottles etc. To prevent suffocation of the children, design provided ample ventilations by use of perforated mild steel sheets and an open upper back with bars. Rain guards were provided and even if it is pulled down, the front side behind the puller's seat being open, the children were comfortable. All sides panels were made out of FRP as was done in case of Dipbahan+. The design after due consideration was prototyped as rolling functional prototype by the Small Enterprise, M/s Timsteel Innovatives itself and trial taken for commercialization. Excellent response has been received from various schools in the city.

7.5 Extension of Design : Participatory and users' Intervention

Success and confidence gained after fabrication of the Dipbahan Ankur and request from District Rural Development Agency, Tinsukia in eastern Assam for design development of a vending cart to be used by the self employed youth to sell meet products at the road side market, work was started for the same through M/s Timsteel Innovatives, Guwahati, a small enterprise. The design was completely based on the modularity of the Dipbahan+ and its other derivatives. In this case design started based on the school van design and few changes that were initiated are, removal of the doors behind the puller and bench seats. The vending cart being specifically for vending of meat products and the following facilities were designed and integrated in it.

- A stainless steel tray spread over the width of the cart was provided for display and stacking of the products.
- A cool box was provided to store the products in hot summer days.
- A cutting block platform with support from the chassis was built in.
- A space for keeping a balance was provided.
- A cash box was integrated.
- A solar operated lamp was also integrated to light up the cart during dark.
- A specially made folding stand was fixed to the chassis and main frame to facilitate lifting of the cart during vending and cutting of meat to prevent shock and impact to the wheels.
- Screens were provided to close the cart when not used on all four sides.
- Waste water collection and disposal was built in.
- A small container was installed to provide water for washing of hands etc.
- A small integrated container was built in to store cutting knives etc.

This vending cart, Fig. 7.26- 7.28, p 226 has been commercially introduced by Tinsukia District Rural Development Agency in collaboration with district veterinary department in

the Tinsukia town and will be extended to other parts of the state. It is also modifiable for fruits and vegetable vending also and will be introduced in these form in a short time.

Fig. 7.26 Front three quarter view of the vending cart: it has the same dimensions as that of Dipbahan Ankur, the school van based on Dipbahan+ including the side frames

Fig. 7.27 Side view of the vending cart, it has its length, breadth (of body) and height increased by 200 mm, 200 mm, 150 mm respectively compared to length, breadth and height of Dipbahan+

The write up in Assamese language on Vending cart seen in Fig. 7.26- 7.28 mentions that it is a mobile mutton vending vehicle for self employment introduced by district rural development agency and design developed by IIT Guwahati

Fig. 7.28 Rear three quarter view of the vending cart with foldable screen cover and advertisement space

7.6 Further initiatives by direct users : indicating user specific development

Individual entrepreneurs seem to imitate a successful design to meet the demand locally. Various design and fabrication including copying of the new tricycle rickshaw was observed after the interim Dipbahan (Fig. 5.27, 5.28 and 5.29 in pp161-162) version was launched in market and these are partially documented here. These design were emulated even using wood in absence of mild steel fabrication facility in far flung areas (Fig. 7.35 and 7.36, p 228) Apart from legal issues on these developments, it should be seen that no hazards are caused in terms of creating new products without involvement of experts; this invites a practice of participation of user-manufacturer-expert system.

Fig. 7.29 Dipbahan imitated in Guwahati with similar rear end, seat and hood structure

Fig. 7.30 Dipbahan imitated at Bokakhat in eastern Assam with similar rear end, seat and partial hood structure

Fig. 7.31 Three quarter front view of Dipbahan imitated at Bokakhat in eastern Assam with similar rear end, seat and hood structure

Fig. 7.32 Three quarter rear view of Dipbahan imitated at Bokakhat in eastern Assam with similar rear end, seat and hood structure

Fig. 7.33 Three quarter front view of Dipbahan imitated at Coch Behar in North Bengal with similar rear end, seat and partial hood structure

Fig. 7.34 Three quarter rear view of Dipbahan imitated at Coch Behar in North Bengal with similar rear end, seat and partial hood structure

Fig. 7.35 Three quarter front view of Dipbahan imitated in wood at Sadiya in Eastern Assam with similar rear end, seat and hood structure

Fig. 7.36 Three quarter rear view of Dipbahan imitated in wood at Sadiya in Eastern Assam with similar rear end, seat and hood structure

Fig. 7.37 Three quarter front view of Dipbahan imitated at Tinsukia in eastern Assam with similar rear end, seat and hood structure

Fig. 7.38 Three quarter rear view of Dipbahan imitated at Tinsukia in eastern Assam with similar rear end, seat and hood structure

Fig. 7.39 Three quarter front view of Dipbahan imitated at Tinsukia in eastern Assam with similar rear end, seat and hood structure but bus type seat

Fig. 7.40 Three quarter rear view of Dipbahan imitated at Tinsukia in eastern Assam with similar rear end, seat and hood structure but bus type seat

Fig. 7.41 Three quarter front view of Dipbahan imitated at Bokakhat in eastern Assam with similar rear end, seat and hood structure

Fig. 7.42 Three quarter rear view of Dipbahan imitated at Bokakhat in eastern Assam with similar rear end, seat and hood structure

Fig. 7.43 Three quarter front view of Dipbahan imitated at Guwahati in Assam with similar hood structure using a normal traditional rickshaw

Fig. 7.44 Three quarter rear view of Dipbahan imitated at Guwahati in Assam with similar hood structure using a normal traditional rickshaw

7.7 Post marketing scenario

It is seen that the spurt of development of variety of tricycle rickshaw started only after the introduction of Dipbahan in market. This is also because of the fact that in the initial stage, the NGO, Center for Rural Development could not cater to the huge market available and remained untapped. To fulfill this vacuum, various local entrepreneur tried to fabricate something similar to the Dipbahan and all of a sudden, there were numerous development in tricycle rickshaws. However, with every passing day, imitation is giving way to genuine Dipbahan^{+} due to its inherent form, function and quality. Also another manufacturer has started manufacturing and presently, there is no short supply.

Proliferation of imitated Dipbahan also indicates that the transfer of design and technology was appropriate and can be easily absorbed by the small enterprise.

Imitation of Dipbahan at various local areas also created advantages for introduction of genuine Dipbahan^{+}. This is because of the fact that earlier, normal traditional tricycle rickshaw used to be available for Rs. 6,500.00 at time of inauguration of interim version of Dipbahan. Thus when Dipbahan+ was introduced at a price of Rs. 13,500.00, its price was directly compared to the traditional tricycle rickshaw inspite of having better features. However with the introduction of imitated version of Dipbahan at around Rs. 10,500.00 to 11,500.00 paved way for smother introduction of Dipbahan+ at its own price. This is because of the fact that buyers no more compared its cost with traditional tricycle rickshaw.

Other aspect is that with the introduction of Dipbahan, passengers started for demanding better comfort and convenience and with changed perception, more and more rickshaws are seen in the market. This resulted in enhanced employment, dignified labour and less of pollution.

Chapter 8

Conclusion: Achievement, Recommendations and Scopes for Further Work

Traditional tricycle rickshaw has some shortcomings in terms of user satisfaction. The present design development in this work attempted to solve some of these shortcomings. The new design can be manufactured easily since the whole design development has been done through participatory approach and the interim version was subjected to extensive real life road trials with direct users in extreme situations. The new design has been well received by the users due to its various advantages, for both the puller and the passengers, specifically its seating comfort, weather protection and its new look that has given it its unique identity. This chapter discusses various aspects of achievement of the research work, the problem solved through the approach 'Research by Design" and evaluation of the work achieved against targeted aims and objectives set at the beginning of the research – i.e. make it ready for production and use, recommendations and scopes for further work in the research area.

The project contributed to knowledge in this area, i.e. design development for SMEs and Technology transfer to 3 SMEs was in Indian context and the designed tricycle rickshaw (Dipbahan) are currently manufactured and products are in the market working successfully. Until this work was started (as mentioned in the Chapter 6 of the thesis, design and technology transfer attempted by various agencies including IIT Bombay, NARI and others were not always successful anywhere including North Eastern Region of India, and was without any interaction between the designer/ innovator and the implementer (i.e. SMEs). Theoretically concepts in different form was put forward by different authorities and persons but never implemented to see the effectiveness and detail a process. The thesis work through this activity has shown that it is effective and this knowledge can be utilized for other projects too. The work also shows that if SMEs are engaged from the beginning, they are able to develop more products in similar lines of their own. However a holistic approach is essential to take the products to market and this involves not only products and systems but allied services starting from promotional brochure to financial arrangement. The thesis work throws light in this area and creates new knowledge in this domain.

8.1 Achievement

The present study was aimed at design development of an indigenous tricycle rickshaw, its prototyping and manufacturing system management for small enterprise.

The specific objectives were to:

i. Study the **present limitations of existing design** and **manufacturing technology** of **traditional tricycle rickshaw** in **Indian context**.
ii. Study **localized transportation** using **Human Powered Vehicles** (HPV) for **preservation of the ecology** and as a means of **sustainable development** in the **context of a developing country** and its **appropriateness**.
iii. Design development of a tricycle rickshaw using **appropriate technology** for **its manufacture**. Design development of the tricycle for **multiple uses** such as School van, delivery van, garbage disposal van etc.

iv. To see the **design and technology transfer** to the **targeted beneficiary** i.e. local Small enterprise initially **without participation from the designer** and in the next step **through participation of the designer** with the Small enterprise.

Initially evolution of Human Powered Vehicle was studied, specifically bicycle and tricycle to understand the foundation of design on which a tricycle rickshaw is based. Tricycle rickshaw and its derivative were studied both locally and globally. After this study, a field based study was carried out to establish limitations of the existing design and manufacturing technology of the traditional tricycle rickshaw to achieve the aim and specific objectives of the research. Direct observation method was used for data collection. The findings in brief are given below.

It is found that with rising concern for global warming and related ecological issues, concept of sustainable development is gaining ground. This is specifically important for developing countries, since these countries are still having increasing trend for population growth and related issues of food, transportation, energy shortages etc. Sustainable development is a concept and there are various definitions exist. Sustainable development concept is intended to maintain the delicate balance between improvement of lifestyles and well being and preserving natural resources and ecosystems (www.gdrc.org/sustdev/definitions.html). A development process is sustainable if it meets the needs of the present without compromising the ability of future generations to meet their own needs.

Design development of Dipbahan if viewed from above perspective, fulfils the requirements of sustainable development. Advantages of Dipbahan^{+}- a HPV are:

- It is a non-polluting (air, noise pollution) mode of transportation during operation.
- Generates less pollution during its manufacture and disposal compared to motorized mode of transport.
- Cost effective with increasing fuel prices for short distances.
- Provides for income generation for the vast unemployed youths of the country.
- Lower cost of capital for each vehicle and each employment generated.
- Due to its low weight, load on road infrastructure is less.
- It uses less material than the existing tricycle rickshaws.
- Tree felling is banned in North Eastern Region of India and Dipbahan^{+} is manufactured without use of wood and helps in preservation of the ecology. Being long lasting, it has added advantage in terms of saving of materials required for its replacement. All the iron components are recyclable and process developed during design development of Dipbahan^{+} using FRP materials provide for recycle of FRP waste and end of life FRP items from these Dipbahan^{+}.
- Dipbahan and its variations use puller's seat made out of discarded car tyres and thus helps in recycle and reuse of precious resources. This not only reduces pollution during manufacture but problems of disposal of used tyres.

- Dipbahan and its variations through its design and allied service provides makes rickshaw pulling a dignified avocation for employment to unemployed youths of the country and this improves their standards of living through income generation.

Against the above advantages, the limitations are:

It can not be a replacement of modern day mode for medium and long distance travel due to limitations on part of the operator to manually pedal it around 30-40 kms per day (Rajvanshi, 2002). To travel more than the above distance, and still to remain non-polluting during operation will require the rickshaw to be fitted with electric propulsion system that can either use solar photo-voltaic electricity or normal electricity available. Later option will require convenient charging stations.

Shortcomings of traditional tricycle rickshaw are:

- Rickshaws are not given due importance in developing countries because of common perception (www.johost.eu) about these mode of transport as slow, low grade, low-tech product (Wheeler, 1998). Not much research has been carried out to improve these and the tendency of the people in growing cities is to disband these (www.itdp.com, http://list.jca.apc.org/public/sustran-discuss).
- The traditional tricycle rickshaw does not meet ergonomic requirement of the rickshaw puller as well as the passengers.
- These are not safe in present day traffic conditions.
- Aesthetics of these are not appealing to many in current situation.

However tricycle rickshaw and its derivatives can be the most appropriate means for localized transportation in a developing country.

Based on findings from the study mentioned earlier, a product brief was derived and design development of a tricycle rickshaw using appropriate technology for its manufacture was done with the financial assistance from North Eastern Development Finance Corporation (NEDFI), Guwahati.

It was found that the resultant product, the tricycle rickshaw branded as Dipbahan and its derivatives are successful in the market place.

8.1.1 Achievements against set objectives

It is essential that the achievements of the design project is compared against objectives set earlier to judge the success of the effort and this is summarized below:

Various salient features of Dipbahan+ (Fig. 5.35, 5.36, p 168-189) and its variations are considered for judging the achievements as mentioned in the following discussion:

Overcoming the limitations of **existing design** in Indian context.

The study undertaken to find out the limitations of existing design of a traditional tricycle rickshaw in present context (to arrive at context specific feature and aesthetics for the newly designed tricycle rickshaw) revealed the followings (mentioned in sub-section 2.1.6, pp 53-54 and reproduced here for ease of reference):

i. There is no protection from the elements of nature in an inclement weather for the puller and it is not sufficient even for the passengers.
ii. The tricycle rickshaw is not comfortable for the passengers due to variety of reasons, some region based, such as narrow seat, excessively tilted seat, double row seat etc.
iii. 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 these were designed primarily for the basic functional use for moving on road almost one and a 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.
iv. Getting on and off the tricycle rickshaw is difficult due to the height of the footboard. It is much difficult for older persons and children.
v. The tricycle rickshaw is heavy in weight.
vi. The stability of a tricycle rickshaw is a concern due to high Center of Gravity (CG).
vii. Tricycle rickshaws available in India are with insufficient space for carrying luggage by the passengers or after a marketing trip for which these are extensively used. In-sufficient space for carrying luggage leads to difficulty in traveling with luggage in the tricycle.

Against the above shortcomings of the traditional tricycle rickshaw design, Dipbahan+ features are mentioned below that meets the user requirements.

Design and Human Factors considerations:

i. The overall structure protects the puller as well as passengers from the elements of nature (sunshine, rain etc.) though the weight of the tricycle remains similar to the existing ones.
ii. Incorporates Human dimension for Ergonomic seating arrangement (Chakrabarti, 1997). The passengers feel comfortable due to the design of the seat. The angle between the seat and the backrest is maintained at around 100 degrees (Fig. 5.35, p 168), which ergonomically is optimum angle for general purpose. Passenger seat for 2 persons is sufficiently wide and deep to accommodate majority of the passengers. The hand rest is given sufficient height of 19 cm from seat surface. The seats are at such a height so that passenger's legs can easily rest on the surface of the platform. It provides ample legroom for the passengers.
Iii. - The shape of the design conforms to aerodynamic orientations with a space frame structure enveloping the puller and the passengers which smoothens manual maneuverability and also protects the occupants from direct impact by other vehicles due to accident as a result of crashes during operation on road to the maximum extent possible.
- The enclosure also acts as a rolling cage and protects the occupants in case of over turn.

- It has been provided with a set of rear wheel brake so that it can be safely stopped by applying brake through the foot pedal. Normally, traditional rickshaws have front wheel braking only and this does not provide smoothness while slowing down the speed and sudden application of brake results in overturn during higher speed and frequent breakage of front axle.

- For the rickshaw puller clear vision is one of the most necessary requirement. The cone angle of 75 degrees in the vertical direction and 30 degrees in the horizontal direction is incorporated.

- It has an aesthetically appealing form which is visually perceived light with contemporary visual identity giving it a feeling of sophistication, sporty and dynamic(Fig. 5.36, p 169), and a overall new look among the existing models of tricycle rickshaws (Fig. 6.2, p 198).

- A set of effective mudguards (Fig. 5.35, p 168) for use in rainy weather.

iv. The tricycle rickshaw has easy access to facilitate the user to get in and out of the tricycle rickshaw (Fig. 5.16, p 153). For the puller this has been achieved by removing the top bar (Fig. 5.21, p 157) of the regular diamond frame made possible due to adaptation of space structure in the interim version of Dipbahan. In the modified Dipbahan^{+} version, the main frame along with chassis itself was redesigned and fabricated using 25 mm x 50 mm tubular section (Fig. 5.35, 168). For the passengers, the floor level was lowered to the chassis level and this coupled with support to hold for getting in and out of the tricycle rickshaw provided ease of access.

v. It is lighter than the traditional rickshaw by approximately 24% (Table 5.5, p 163).

vi. Keeping up to the present day transportation needs, the tricycle is able to take quick turns and is stable with low centre of gravity due to lower position of passengers' seat.

vii. Proper space for carrying the luggage is provided (Fig. 5.35, p 168). Reinforced platform (Fig. 4.7 and Fig. 4.8, p 122) for enabling it to support the structure and carrying of luggage is used; it optimizes the available space. Due to the flat horizontal floor and space structure with seat supported on side frames, ample space was available for carrying luggage. The space below the passenger seat is also enclosed from back by the rear panel and at the sides by side panels (Fig. 5.35, p 168). This enclosure make goods safe for transportation and also protect it from soiling in rainy days from mud and muck that gets thrown by the wheels.

Overcoming the limitation of **manufacturing technology** of **traditional tricycle rickshaw** in Indian context.

Findings from the study undertaken to find out the limitations of the **manufacturing technology** of **traditional tricycle rickshaw** in present context (to arrive at **appropriate technology** for **manufacture** of the newly designed tricycle rickshaw) are mentioned in sub-section 2.1.5.2, pp 48-51 (summary of these are reproduced below for reference).

Traditional rickshaws used various skills that were common at that period of time like black smithy, carpentry, tailoring etc. Currently these are becoming scarce in towns and cities and also materials like wood are becoming not only scarce but expensive specifically where rickshaws are made in a localized manner. In NER, tree felling has been banned for more than a decade to preserve the ecology of its fragile eco-system. Thus appropriate technology for manufacturing currently common and materials readily available are required to be used for fabrication of tricycle rickshaws. This leads to Mild steel iron and arc welding along with FRP can be very appropriate manufacturing technology at present.

Against the traditional rickshaw manufacturing process, Dipbahan^{+} manufacturing is mentioned below:

Manufacturing process considerations:

- Modern technology of arc welding, drilling etc. that is presently common even in rural areas is used for fabrication.
- Basic structure welded into sub-frames- chassis, left and right side, seat frame and cross binding bars. All these are fixed into one shell through nuts and bolts.
- It is manufactured using modern technologies and materials including composites (FRP) and spray painting. Specification is for powder coating the MS structure for durability and finish.
- To built in standardisation and quality, the manufacturing process uses various jigs and fixture for the fabrication of Dipbahan^{+}
- Components that are used extensively and are subject to wear and tear requiring replacement are outsourced from the market for ready availability.
- Dipbahan^{+} design is modular to facilitate variations on the same platform.
- Only a few types of materials are used in Dipbahan^{+} against variety of materials used in traditional rickshaw such as mild steel, wood, aluminium, coir, rexin, bamboo, canvas etc.
- In case of process used also, Dipbahan^{+} uses minimum variety of process. Thus traditional process that are becoming increasingly rare even in rural areas such as blacksmithy, carpentry etc. are replaced with arc welding, drilling and composite forming. These are suitable and appropriate in present context.

Maintenance

- For ease of maintenance and replacement of worn out parts, most of the components that are readily available in the market (Table 5.1, p 152) are used for steering, transmission, wheels, tyres and tubes, and brakes etc.
- It can be easily maintained through conventional rickshaw mechanics and fabrication units having welding machine.

Indian Context was explored for various aspects such as: way the common Indians travel, the types of ownership of the tricycle rickshaws, its manufacturing set up, ornamentation of the tricycle rickshaw that provide identity to the rickshaws etc. related to design of the Dipbahan+ including localized transportation. These were used to arrive

at the design of Dipbahan and its variations and the acceptance and success of the Dipbahan shows that the design is Indian context specific. It is found that

- People prefer Dipbahan, since they can carry significant amount of luggage with them during traveling including eatables. Sufficient space provide for luggage meets the requirements of the Indian users.
- Dipbahan provides a semi-open structure with folding rain guards and facilitates flexibility for sunny, rainy or cloudy day travel in India's very diverse climatic conditions. In summer people prefer to travel in semi-open vehicles due to hor sunshine and high temperature and in monsoon, people need protection from heavy rain in most part of India. Design of Dipbahan takes care of these aspects.
- Indians has a habit of using any product in many different ways in different context. Dipbahan has been seen used for transporting people to places, school children to school and back, transport luggage, industrial goods, food items, vegetables and fruits, carrying LPG cylinders, vending and in a few cases even patients to hospitals. Thus needs of Indian users are met by Dipbahan.
- Owners and drivers of Dipbahan are found to decorate their vehicles in a very colourful way through painting natural sceneries, portrait of god and goddesses, film hero and heroines etc. at the rear folding rain and wind guard and also fixing various decorative and ornamental pieces including plastic garlands onto their rickshaws. The scopes provided for the above evoked their interest and provided a scope for them to create an identity for their rickshaw through this type of customization. It is also found that many Dipbahan after 2-3 years use were repainted specially the tubular structure in multiple colours that made these very colourful and added an unique identity to each individual rickshaw.
- The rickshaw pullers that wanted to own the rickshaw of their own but could not due to their deplorable economic conditions were provided micro-credit through Rickshaw Bank concept already mentioned in Chapter 7 under section 7.1.8, pp 215-216. Rickshaw pullers have become empowered by obtaining ownership and after initial repayment for owning the rickshaw, they are no more required to pay a significant portion of their daily earning as hiring charges. This has improved their economic situation and status. Rickshaw puller's avocation no more remains undignified for the unemployed youth in many parts of North Eastern Region, as evident from the numbers of Dipbahan introduced in the market in last 3 years.
- For insertion of advertisement to generate revenue to subsidise the cost of the rickshaw to affordable level, almost flat rear panel was designed (Fig. 5.36, 169).
- Old and modern goes hand in hand in India and both traditional rickshaws, Dipbahan and Dipbahan^{+} rickshaws are seen plying on road with integration with existing habit of the population. In absence of any patent or design registration effort, many persons are copying the design of Dipbahan to meet their contextual requirement and are readily plying in various parts of NER and other parts of India.

Localised transportation and Multiple uses of tricycle rickshaw:

Tricycle rickshaw and its derivatives are used for meeting various localized transportation needs currently in North Eastern Region of India are mentioned in Chapter 1 under section 1.3 in pp 13-14. Thus in addition to transporting passengers, it is also used to transport school children inappropriately (Fig. 2.22 in p 42). Similarly garbage disposal from narrow roads and lanes, use of tricycle based derivatives extensively (Fig. 2.24 in p. 42) is a need of the society today. These areas provides for immediate scope and action for design. While designing a tricycle rickshaw from the beginning, keeping in view modularity (Otto and Wood, 2001) for designing derivatives will help in the long run and reduce cost of design development. This also provides for capacity planning for the manufacturing so that facility can be economically feasible. Thus design development of tricycle rickshaw modifiable for multiple uses such as School van, delivery van, garbage van etc. were included.

To fulfill these requirements, in addition to passenger versions of Dipbahan, Dipbahan^{+}, and a few more versions are designed and manufactured such as garbage disposal (Fig. 7.20, p 223), school children van (Fig. 7.23, p 224), vending cart (Fig. 7.26, p 226) etc. These are accepted by the users and are on road working successfully. Thus design effort to meet localized transportation need has been fulfilled.

Cost

- The interim Dipbahan was introduced at a cost of Rs. 7,500.00 compared to Rs. 6,500.00 for the traditional rickshaw (Fig. 2.7, p 39). After 3 years, its price has escalated to Rs. 10,500.00
- The final model of the rickshaw Dipbahan^{+} is retailed at Rs. 13,500.00 The difference in price is attributed to additional features and margin to be provided to dealers and retailers, which is well accepted in market.

Branding

- The new tricycle rickshaw was branded as Dipbahan (Fig. 5.27, 5.28 and 5.29, pp 161-162) to differentiate from normal rickshaw even psychologically, which was upgraded to Dipbahan^{+} (Fig. 5.35 and Fig. 5.36, pp 168-169).
- The new tricycle rickshaw has been imparted multi colour to make it easily visible and recognizable as well as to fulfill existing transportation rules.
- Space has been left free at the sides of the hood for customization by individual owner through ornamentation that is so much prevalent among the rickshaw pullers (Fig. 5.35, p 168).

Demonstrate the **design methods** and **technological details** (through product design **process, prototyping and testing):**

Product design methodology propagated by Morris Asimow mentioned in Chapter 1 under section 1.7, p 30 and discussed in Chapter 3 in detail under section 3.5.1, pp 83-85 was practically demonstrated to the target manufacturer, in this case 3 Small and

Medium Enterprises (SMEs) from Guwahati in North Eastern Region of India i.e. Centre for Rural Development, Timsteel Innovatives and National Associates. The Design methodology adopted for this purpose was found to be simple to understand by the employees of the SMEs while transferring design and technology and thus helped in subsequent design process by the target manufacturer in a conventional way.

Technological details in terms of the technology used for the manufacture of the newly designed tricycle rickshaw, Dipbahan and its variations and the process of design development, prototyping, testing and manufacturing were appropriately demonstrated to the target manufacturers through training at Department of Design, IIT Guwahati and also at the manufacturing facilities of the SMEs and it was found that they could adopt these within their constraint resources such as infrastructure for the design to be successfully implemented.

Technology transfer

To see the effectiveness of design and technology transfer to the targeted beneficiary i.e. local Small enterprise and to validate our hypothesis that design development in participation helps in smooth transfer of technology, initially design of the newly developed tricycle rickshaw was provided to the NGO. The NGO was told about the various processes and technology etc. required to manufacture the rickshaw and left it to them to implement it of their own **without participation from the designer** in the same manner that traditionally technology transfer takes place.

In the next step, in design and technology transfer process and implementation was **through participation of the designer** with the SMEs throughout the design development and its implementation and results were visible in terms of product features including quality and aesthetics'.

It was found that results were better when designer participated with the SMEs.

No patents process was attempted for the design and technology used and essence of technology transfer was not only to see the adaptability by the local collaborating SMEs for the manufacture of Dipbahan, but was also aimed at facilitating anybody interested in design development of Dipbahan to improve or modify the design as per their contextual requirement. The success of the process is evident from the proliferation of imitations of Dipbahan in the market, that this has been achieved.

Target manufacturer:

Target manufacturers for newly designed tricycle rickshaw, Dipbahan and its variations were small and medium enterprises, in many cases tiny enterprises in the context of North Eastern Region of India. These are decentralized enterprises specifically in North Eastern Region of India who are interested in undertaking manufacture of the design. Based on the above understanding, three different enterprises were collaborated. These are all from Guwahati city in NER of India.

1. Centre for Rural Development, an NGO working in developmental sector in NER

2. Timsteel Innovatives, a small enterprise working in iron and steel fabrication, and
3. National Associates, another small enterprise working in FRP fabrication.

All the above enterprises are continuing the manufacturing of the Dipbahan and its variations. CRD has 5 manufacturing facilities spread all over India and Timsteel Innovatives has 4 variations of Dipbahan (Dipbahan+ passenger rickshaw, Dipbahan + Pariskar- a garbage disposal vehicle, Dipbahan+ Ankur- a school van and a vending van) manufactured in their factory. The growth of the activity supports the fact that the target manufactures are benefited from the design and development activity and selection of target manufacturer are relevant.

The area of work was considered as a part of system design approach of transportation design for the fact that this is the first level for any transportation aspect and at best can be useful for meeting localized transportation needs as given below in details.

- An NGO, Centre for Rural Development (CRD), Guwahati participated in the design development of Dipbahan, manufacturing it and introducing this through the Rickshaw Bank Micro Credit scheme. It introduced more than 10,000 interim version of Dipbahan all over the states of Assam, Tripura, Tamilnadu, Uttar Pradesh, Delhi, Madhya Pradesh etc. through the Rickshaw bank project, a micro-credit venture for income generation.
- As a promotional effort and a part of the design process, the rickshaw was branded as Dipbahan, which has created a name and good will in all areas where it has been introduced.
- Indian Jute Industries' Research Association (IJIRA), Kolkata, under Ministry of Textiles, Government of India sponsored the design development of Jute Composite based components used in the Dipbahan^{+} and National Associates, Guwahati collaborated in design development of composite components for the Dipbahan^{+} and it's derivatives like Dipbahan Pariskar and Dipbahan Ankur.
- Another local small enterprise M/s Tim Steel Innovatives, Guwahati came forward for participating in further development of the Dipbahan and with their participation, Dipbahan was redesigned to overcome existing shortcomings and Dipbahan^{+} was designed with Jute composite materials for different component replacing various items like wood, aluminium, mild steel sheet and wiremesh, and simplifying the assembly to achieve cost reduction.
- A completely new tricycle rickshaw manufacturing unit with a capacity to manufacture 5,000 Dipbahan^{+} per annum was conceived in participation with M/s Tim Steel Innovatives, Guwahati, a comprehensive Project report was prepared based on which the facility came up at Palasbari near Guwahati.
- Dipbahan^{+} tricycle rickshaw was selected by the West Bengal government and it was successfully introduced in all districts of the state by West Bengal Marketing

Board. This was followed by introduction by North Eastern Development Finance Corporation in Agartala in the state of Tripura and in Imphal in the state of Manipur involving NGOs. Rastriya Gramin Vikash Nidhi, Guwahati took up the implementation of Dipbahan+ in all over Assam under micro credit scheme also involving NGOs to manage the scheme. In the near future it is expected to be introduced in Bangladesh and Sri Lanka too; negotiations are underway.

- To facilitate transportation over long distance, the Dipbahan+ design was refined to incorporate knock down ability.
- A number of initiatives were undertaken to see feasibility to derive multiple use variations based on the platform of the new tricycle rickshaw. A municipality solid waste (garbage) disposal van was conceptualized. With sponsorship and participation for the design development from the M/s Tim Steel Innovatives, Guwahati the Dipbahan+ and it's derivatives, a garbage disposal van was prototyped and manufactured. Garbage disposal van was branded as Dipbahan Pariskar (Fig. 7.20, 7.21 and 7.22, p 223). Xuoni Axom, an NGO in Guwahati undertook the trial of Dipbahan Pariskar for implementing solid waste collection from households and its disposal as a economically viable proposition and as means of income generation for unemployed youth using Dipbahan Pariskar.
- A school van to carry school kids was designed, prototyped and manufactured by M/s Tim Steel Innovatives, Guwahati with guidance from the designer. This was branded as Dipbahan Ankur (Fig. 7.23 and 7.24, p 224).
- Design development of a vending cart to be used by the self employed youth to sell meet products at the road side market based on the modularity of the Dipbahan+ and its other derivatives - school van was carried out through M/s Timsteel Innovatives, Guwahati, a small enterprise. The vending cart (Fig. 7.26-7.28, p 226) has been commercially introduced by Tinsukia District Rural Development Agency in collaboration with district veterinary department at Tinsukia town and will be extended to other parts of the state. This vending cart is also modifiable for fruits and vegetable vending and will be introduced in these forms in a short time.
- The Limca Book of Records has included the achievements in terms of numbers of Dipbahan introduced within a short time as a record in India.

It is observed that, success of the research work is based on the active participation from the small enterprises including NGOs. The model of design development, technology transfer and manufacturing approach in participation from Small Enterprise is found to be effective and can be successfully extended to other products. Presently Dipbahan's manufacturing and induction in the market is initiated by many governmental, non-governmental, private and public agencies to provide employment and empowerment to the socially and economically disadvantaged people in the country in a dignified way.

Ongoing development as continuation:

- In addition to the above, a few studies were initiated with students of Assam Institute of Management, Guwahati to study the effect of Dipbahan as a means of income generation and various aspects of the life of Rickshaw pullers opting for it.
- There is a spurt of manufacturing of tricycle rickshaw similar to the one done under this research project by unorganized manufacturers. A few organizations also came forward to design tricycle rickshaw to meet their perceived need.
- A vernacular film titled “Aami Asomiya” has been made and released using Dipbahan as a means of earning livelihood to exemplify the hard labour that a rickshaw puller puts in is dignified even for the present generation of youth.

8.2 Scopes for further research

Further development possibilities of variations such as delivery van, livestock transportation van, water tanker etc. is underway.

Another area for further research is regarding the conversion of this tricycle rickshaw to electric powered ones using photo voltaic solar panels for charging the storage battery and then propelling the rickshaw through electric motor. During the design phase, these possibilities were considered and formed one of the constraints in the second layer of priority. Instead of purely being a solar powered rickshaw, this design can be a power assist type. Whenever the rickshaw puller finds it difficult to pedal the rickshaw due to heavy load or inclined road, he can opt for power assist from the electric motor.

The approach of design development, prototyping and manufacturing management through participation from small enterprise can be extended to other industrial products also. Further work in this direction is required and this if implemented successfully can help in entrepreneur development also and successful incubation of technology.

8.3 Recommendation

Based on the result achieved in this research, it is recommended that, design and technology developing institutions can follow the process of design development, prototyping and manufacturing management through participation from small enterprise approach for successful implementation and dissemination of the technology developed. In this case, the designers, scientists and technologists working for developing design and technologies to be used by the common masses may engage the participation of targeted manufacturer, specifically small enterprises from the beginning. This is to facilitate easy implementation of the design and technology developed and also to take care of the advantages and limitations of the target manufacturer and users during design and development stage itself.

8.3.1 Precautions foretold

During the research and later it was observed that the individual entrepreneurs seem to imitate a successful design to meet the demand locally. Various design and fabrication including imitation (Fig. 7.29 – 7.44, pp 227-229) of the newly designed tricycle rickshaw was observed after the interim Dipbahan model was launched in market and these are documented (Chapter 7, Section 7.6). Apart from legal issues on these developments, it should be seen that no hazards are caused in terms of creating new products without involvement of experts; this invites a practice of participation of user-manufacturer-expert system. Thus an experiment was carried out to make a school van - Dipbahan Ankur where all the components of the above participatory model was involved. The product was successfully developed for commercial introduction.

8.3.2 Monitoring group for sustainable and appropriate design and development

This chapter concludes the study with precautions to be taken for uncontrolled design development and following suggestions were made for setting up monitoring group for appropriate and sustainable development in the area of localized transportation using human powered vehicles.

1. Any form of HPV that ply on road requires fulfillment of minimum criteria for road worthyness, safety etc. Although HPVs can positively contribute to the growth of a country, if it is overlooked, can jeopardize the safety of the user. It was observed that the space structure designed for Dipbahan was widely imitated, most of the time wrongly even in wood and this seriously reduced the safety aspects and during accident on road can be fatal for the users.

2. The introduction of Dipbahan has positively changed the common people's perception regarding tricycle rickshaw as means of localised transportation. More and more people started using these vehicles. To maintain this positive aspect, it is essential that a minimum criteria be evolved for designing and operating tricycle rickshaw on road. Since any automobile operating on road requires roadworthy certification, there can a process to ascertain the roadworthy ness of a tricycle rickshaw or its derivatives used for passenger transportation keeping in mind safety involved.

3. At present, there is no standard available for any tricycle rickshaw or its derivatives. A standard specification must be made to be available for the manufacturer to follow and this should be strictly adhered to.

4. To achieve the above and to sustain the design development of HPVs, it is suggested that a monitoring body comprising of expert designer in this area, transportation system design experts, ergonomists, traffic police and policy makers from regional planning bodies be constituted to monitor the activities in this areas.

5. Alternatively, an autonomous body registered under society's registration act may be created within an institution like IIT to monitor appropriate and sustainable development in this area as well as for evaluation and certification. This body should be funded by central government and manned by experts from relevant areas.

8.4 Concluding remarks for indigenous design development and technology transfer

The thesis work transpires a need to develop indigenous design with Indian need and context. The design and development of product such as tricycle rickshaw and the process followed as mentioned in this thesis work would enhance with the participatory approach. A similar functional product with new contemporary look would get better market acceptance and value addition. The small enterprise can benefit from the participatory approach by building its capacity to design new products in house; this process would It also help in modernization of traditional products by imbibing new process and technology and diversification through modularity.

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AUTHOR INDEX (Referred in the Thesis)

APPENDIX 1

A Ray of hope for urban poor: Project Rickshaw Bank.

It was observed that the members of rural population are increasingly migrating to urban areas in search of better livelihood. However in absence of adequate skill and training they have to face the urban misery against that of rural poverty, resulting in sub-human living. Inability to acquire skills for a desired job leads them to the vicious cycle of contractor or moneylenders where their struggle becomes a never-ending process. In such situation they ultimately hire a rickshaw for their alternative employment. But their major chunk of income goes on hiring charges and they hardly can save money for their future expenses. As a result, even in their lifetime some of them can't own a rickshaw. A survey conducted in the city of Guwahati revealed that only 5 % of rickshaw pullers own their vehicle. They also don't have access to banks since they do not have a permanent address and there is no introducer for them. Even after living in the city for 15 years, they are considered as migrants. Often the police pounced upon them since a large number of rickshaws are without valid license, since the pullers can not furnish the required documents for obtaining the necessary licenses.

Centre for Rural Development (CRD), an NGO working in the developmental sector especially rural development with a commitment to contribute towards the enrichment of the poor marginalised migrants of the city of Guwahati came up with an innovative idea of running a Rickshaw Bank in 2004 to cater to this urban poor and marginalised population. CRD had initiated the project Rickshaw Bank with technical assistance from IIT Guwahati. The idea was translated into action with the help of a tricycle rickshaw designed by A K Das, in the Department of Design, IIT Guwahati that can help in attracting passengers for using rickshaw to commute short distances. The project has been under implementation since November 2004. Till date almost 3000 rickshaws have been disbursed to the beneficiaries. The main objective of the project was to issue an asset loan to the rickshaw puller with a provision to repay the original manufacturing cost of the rickshaw by a minimum installment rate on daily basis and as the borrower repays the loan the Rickshaws are handed over to the pullers. The repayment amount would again be reinvested in manufacturing new rickshaws to provide to other rickshaw pullers.

Besides, the project proposes to ascertain a good livelihood environment of the rickshaw puller, by providing them comprehensive packages like insurance coverage, required licenses, Photo ID card, uniforms and a passbook for savings and repayments. The organization also proposes to generate funds for the working capital of the project from different public and private sector companies through incurring advertisement cost.

Facilities to the Rickshaw Puller:

As the pullers become the member of the Rickshaw Bank a rickshaw loan amounting Rs. 9000/- is sanctioned against their name with an instruction to repay the amount by paying Rs. 25/- per day. A passbook is being issued in their name where savings and

installment recovery status are properly maintained. The Rickshaw puller licenses are also provided to get rid of the harassment of police and municipality. Two set of uniform is provided to them to work with dignity. Insurance coverage of Rickshaws for Rs. 7,000/- , for puller 50,000/- and for passenger 25,000/- is also ascertained in the project. The orgnisation has also appointed ten garages up till now and these garages are the daily collection centre and service stations for the rickshaws.

Other support services to the Rickshaw Puller

Monthly meeting is organised in every garages to inform the savings and installment recovery status of the rickshaw puller. Decisions are being taken to resolve their problems and for smooth functioning of the project. Proper orientation is being given to their wives with a view to encourage them to come forward to be an earning member of their family. With due discussion with the rickshaw pullers and their family members, the organisation also facilitates the process of procuring LPG connections to the beneficiaries of the project “Rickshaw Bank”.

Reference from http://www.crdev.org, Dec, 2005

APPENDIX 2

Process planning for the new components and sub-systems designed and to be fabricated in house for the newly designed tricycle rickshaw, Dipbahan^{+} by a SME was considered. Standard components readily available in the market and used (Chapter 5, section 5.2, Table 5.1) in Dipbahan^{+} was not considered for this aspect. The new components and sub-systems can be grouped into two . First group is mild steel items and the second group is FRP components specifically for Dipbahan+ version and rain guards etc. All these above components and subsystems can be manufactured by SMEs with conventional workshop.

A process sheet considers three types of timings.

I. Setting time: This includes setting up of the machine, preparation of tools, study of blue prints etc.
II. Machining time: This is the time in which tool does the cutting operation.
III. Auxiliary time: This includes clamping the job, unloading, measuring etc.

In all time 25% fatigue allowance has also been included.
For fixing standard time for the above, work study is used.

Sample Process Sheet
(for fabrication of the chassis and main frame for single chain Dipbahan^{+} model)

Chassis and mainframe is an integrated piece made out of following components.

1. Head pipe- out sourced from market.
2. 3 pieces of mild steel 50 x 25 mm rectangular sections of 2 mm thickness.
3. Body bottom socket- outsourced from market.
4. 2 components made of mild steel 50 x 25 mm rectangular sections of 2 mm thickness.
5. 1 piece of mild steel 40 X 5 mm flat bar, 150 mm in length bent at the centre for connecting components given at the Sl. No. 4
6. 2 pieces of 19 mm diameter mild steel pipe connecting pullers' seat post with the main frame for reinforcement.
7. 1 piece of 25 mm diameter mild steel curved pipe as end binding element for connecting item no. 4 of the chassis.
8. 2 numbers reinforcement element of mild steel 40 X 5 mm flat bar of 150 mm in length for bearing block attachment bracket.
9. 4 numbers U-shaped brackets of 3 mm thickness mild sheet plate for fixing rear end of the side frames.
10. 1 piece 19 mm solid rod for fixing the front end of the side frames.

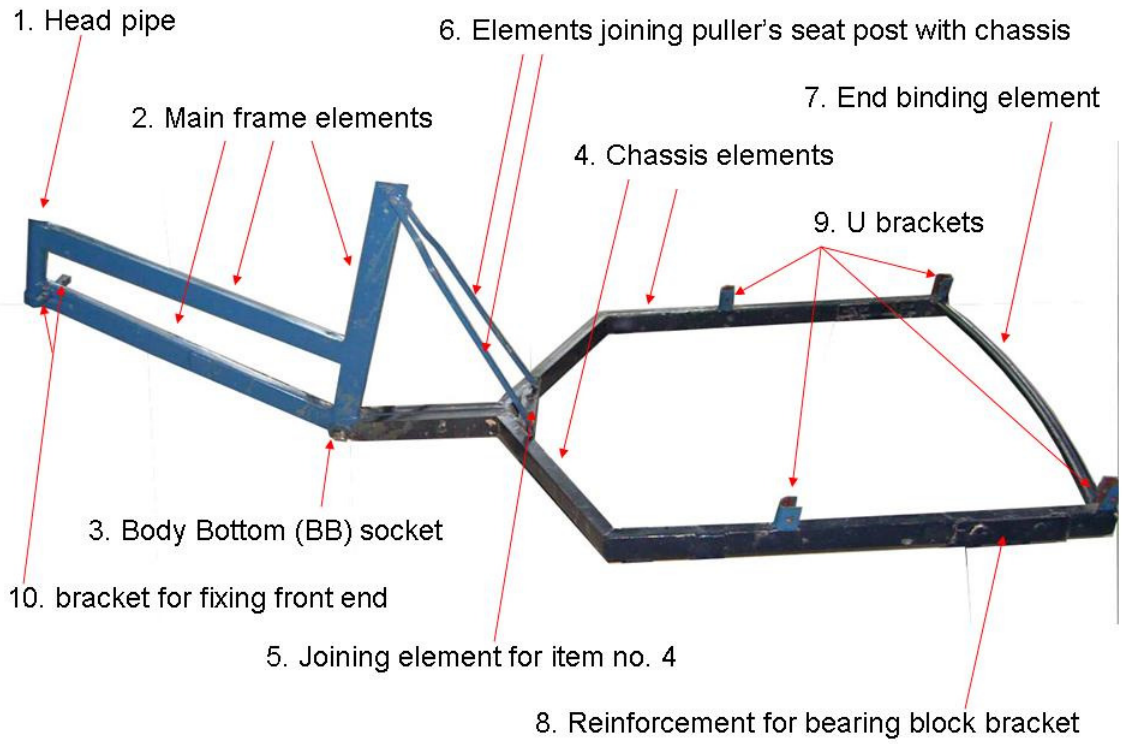


Fig. PS 1 Integrated mainframe and chassis for Dipbahan+

Process sheet 1

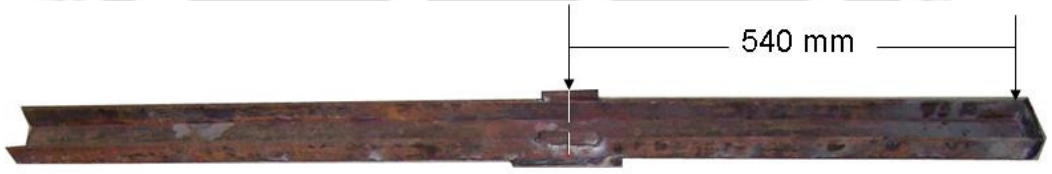
Raw material:
Mild steel rectangular box section of 50 mm X 25 mm, Thickness 2 mm
Mild steel round tube of 25 mm outer diameter, Thickness 2 mm
Mild steel flat bar of 40 mm, Thickness 5 mm
Mild steel solid round bar of 19 mm diameter
Mild steel sheet, Thickness 3 mm

Sl. No.	Operation	Jig used	Machine	Setting Time (Sec)	Auxiliary Time (Sec)	Machining Time (Sec)	Total Time (Sec)
1.	(Item no. 2 in Fig. PS 1)						
	A. Cut a piece of 540 mm length from 50 mm X 25 mm section using Jig_1.	Jig_1 (Fig. PS 2)	High speed cut off machine	60	60	90	210
	B. Cut a piece of 575 mm length from 50 mm X 25 mm section using Jig_2.	Jig_2 (Fig. PS 3)		120	120	120	360
	C. Cut a piece of 565 mm length from 50 mm X 25 mm section using Jig_3.	Jig_3 (Fig. PS 4)		120	120	120	360

Sl. No.	Operation	Jig used	Machine	Setting Time (Sec)	Auxiliary Time (Sec)	Machining Time (Sec)	Total Time (Sec)
2.	Drill a hole of 20 mm diameter on B for inserting item no. 10 in Fig. PS 1.	Integrated jig with drill vice	Pedestal drilling machine	120	120	150	390
	Drill a hole of 10 mm diameter on A for fixing the puller's seat spindle (not shown here)			120	120	150	390
3.	Cut a piece of 100 mm length round rod of 19 mm diameter	Integrated Jig with HS cut off machine	High speed cut off machine	60	60	180	300
4.	Drill 2 holes of 8 mm diameter, 20 mm away from both end.	Integrated jig with drill vice	Pedestal drilling machine	120	120	240	480
5.	Spot weld the 3 members- A, B and C, and item no. 10	Jig_4 (Fig. PS 5)	Welding machine	120	120	150	390
6.	After spot welding, remove from jig_4 and place it in Jig_6 along with head pipe (Item no. 1 in Fig. PS 1) and body bottom socket (Item no. 3 in Fig. PS 1) and finish complete welding.	Jig_6 (Fig. PS 6)	Welding machine	150	150	300	600
7.	(Item no. 4 in Fig. PS 1) Cut two pieces of 1,575 mm length from 50 mm X 25 mm section using Jig_5.	Jig_5 (Fig. PS 7)	High speed cut off machine	150 X 2	150 X 2	300 X 2	1,200
8.	(Item no. 5 in Fig. PS 1) Cut a piece of 40 X 5 mm flat bar of 150 mm length.	Integrated Jig with HS cut off machine	High speed cut off machine	60	60	60	180
9.	Bent the piece (Item no. 5 in Fig. PS 1) at desired angle of 120° at the centre for connecting the components given at the Sl. No. 4		Hydraulic press	60	60	60	180
10.	(Item no. 7 in Fig. PS 1) Using roller pipe bending machine (Fig. 4.1), roll a pipe of 25 mm diameter to required curvature.	Jig not shown here	Roller Pipe bending machine	90	90	120	300

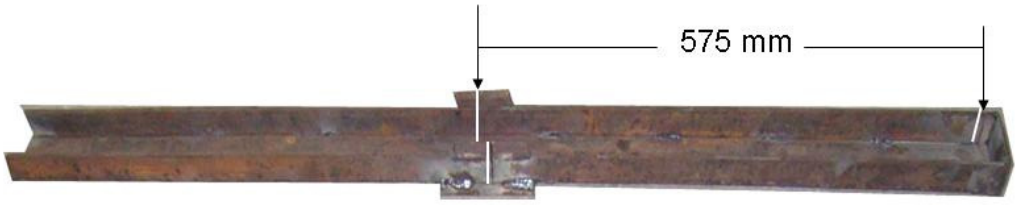
Sl. No.	Operation	Jig used	Machine	Setting Time (Sec)	Auxiliary Time (Sec)	Machining Time (Sec)	Total Time (Sec)
11.	(Item no. 7 in Fig. PS 1) Cut a piece of length of 840 mm from the curved pipe to be used as end binding element for connecting item no. 4 of the chassis.	Jig not shown here	High speed cut off machine	45	45	120	210
12.	(Item no. 8 in Fig. PS 1) Cut 2 pieces of 40 X 5 mm flat bar of 150 mm length to be used as reinforcement elements for bearing block attachment bracket.	Integrated Jig with HS cut off machine	High speed cut off machine	60 X 2	60 X 2	60 X 2	360
13.	(Item no. 8 in Fig. PS 1) Drill two holes of 10 mm diameter on these pieces at 50 mm from the centre.	Integrated Jig with HS cut off machine	Pedestal drilling machine	90	90	120	300
14.	(Item no. 9 in Fig. PS 1) Cut strips of 50mm X 100 mm from mild steel sheet of 3 mm thickness.	Jig not required	Hand shearing machine	60 X 4	60 X 4	150 X 4	1,080
15	(Item no. 9 in Fig. PS 1) Press 4 numbers of strips using die and punch press tools to make u brackets, 1 strip at a time.	Die and punch type press tool (Fig. PS 8)	Hydraulic press	45 X 4	60 X 4	60 X 4	660
16.	Cut the U brackets at required angle at both end 10°	Integrated Jig with HS cut off machine	High speed cut off machine	60 X 4	60 X 4	120 X 4	960
17.	Drill 8 mm holes through sides on the u brackets	Integrated jig with drill vice	Pedestal drilling machine	60 X 4	60 X 4	120 X 4	960
18.	(Item no. 6 in Fig. PS 1) Cut 2 pieces of 19 mm diameter pipe of length 500 mm to be used reinforcement elements between mainframe and chassis.	Jig not shown here	High speed cut off machine	45	45	120	210
19.	Flatten one end of each pipe for 25 mm.	Jig not required	Hydraulic press	45	45	120	210

Sl. No.	Operation	Jig used	Machine	Setting Time (Sec)	Auxiliary Time (Sec)	Machining Time (Sec)	Total Time (Sec)
20.	Bend both elements of item no. 4 as required to place these in Jig_7. Place these and pieces of item no. 5, 7, 8 and 9 in Jig_7 and spot weld. Remove from the jig and finish weld the frame	Jig_7 (Fig. PS 9)	Welding machine	300	300	1,200	1,800
21.	Assemble main frame, chassis and item no. 6 joining point being body bottom (BB) socket and element 6 and finish weld.		Welding machine	300	240	900	1,440
22.	Grind all weld joints to obtain smooth surface	Jig not required	Handheld portable angle grinder	150	150	900	1,200
Total Time				3495	3495	7740	14730
Time in minutes				58 minutes 15 seconds	58 minutes 15 seconds	129 minutes	245 minutes 30 seconds



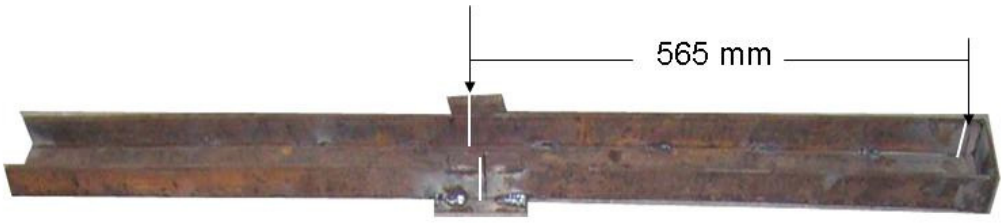
Jig_1 with straight end to cut pullers post

Fig. PS 2 Jig to cut a piece of 540 mm length from 50 mm X 25 mm section for mainframe



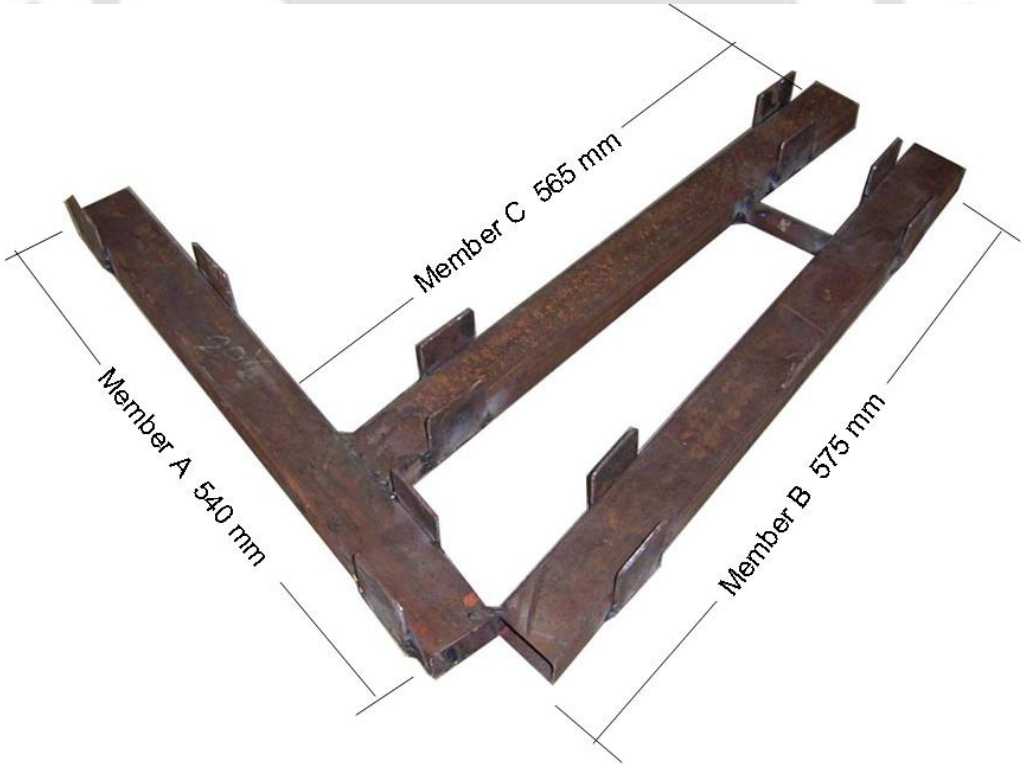
Jig_2 with angular end to cut main frame member

Fig. PS 3 Jig to cut a piece of 575 mm length from 50 mm X 25 mm section for mainframe



Jig_3 with angular end to cut main frame member

Fig. PS 4 Jig to cut a piece of 565 mm length from 50 mm X 25 mm section for mainframe

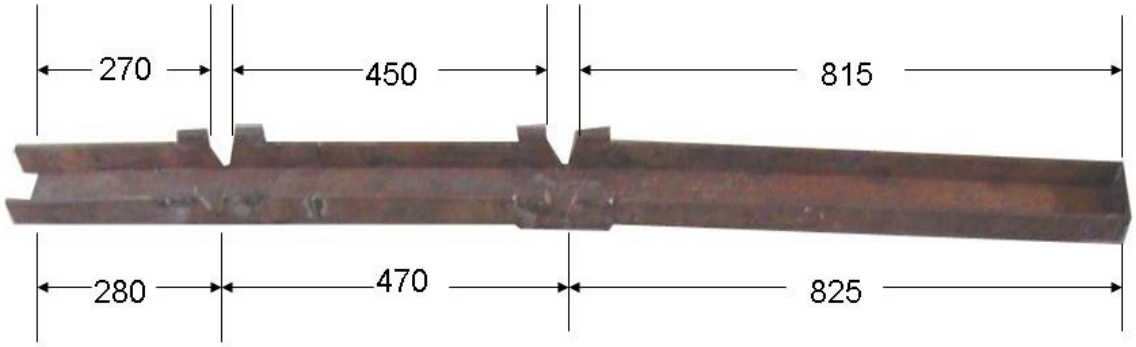


Jig_4 for welding of main frame members together

Fig. PS 5 Jig to assemble and weld 3 pieces of 50 mm X 25 mm section to fabricate the mainframe

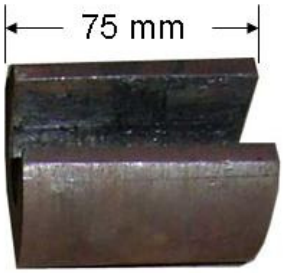
Jig_6 for assembly and joining of mainframe with body bottom socket

Fig. PS 6 Jig to assemble and weld mainframe elements with BB socket and head pipe

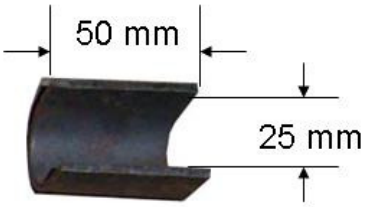


Jig_5 To cut angular groove to bend and weld for the chassis member
Member to be placed up side down after cutting one groove.

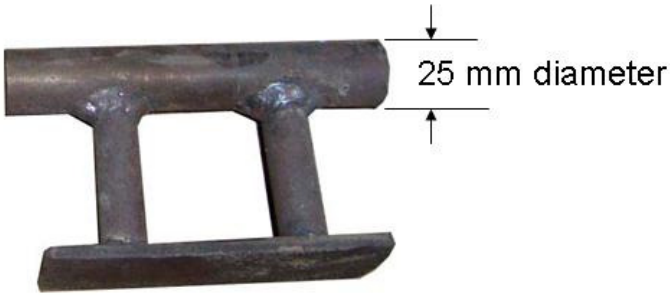
Fig. PS 7 Jig to cut a piece of 1,575 mm length from 50 mm X 25 mm section for chassis



Press die for U bracket



U bracket after pressing



Punch for U bracket

Press die and punch for U bracket

Fig. PS 8 Press tool die and punch along with a u bracket

Jig_7 for assembly and joining of chassis elements

Fig. PS 9 Jig to assemble and weld different elements of chassis

APPENDIX 3

Project cost for setting up of Dipbahan manufacturing unit for Rickshaw Bank Project

A. List of Equipment required for the project and estimated cost.

Sl. No.	Items	Qty.	Cost in Rs.
01	Power sheet shearing machine	01 no.	Rs. 1,10,000.00
02	Gas Welding set with oxygen and acetylene cylinders	01 set.	Rs. 40,000.00
03	Power hackshaw machine	01 no.	Rs. 1,00,000.00
04	Hydraulic press	01 no.	Rs. 40,000.00
05	Centre Lathe machine with all accessories 4' bed	01 no.	Rs. 4,80,000.00
06	(i) Drilling machine bench type with all accessories (ii) Roller type pipe Bending machine with accessories (iii) Manually operated sheet folding machine with bending blade (iv) Arc Welding, Air Cooled machine with all accessories	01 no. each	Rs. 80,000.00 Rs. 40,000.00 Rs. 70,000.00 Rs. 50,000.00
07	i) Hand grinder/ Angle grinder (Rs. 7,000/-) ii) Bench Grinder (Rs. 6,500/-) iii) Drill Machine (Rs. 3,000/-) iv) Heavy Duty Drill Machine (Rs. 6,000/-) v) Portable Drill Machine (Model : PR 132) (Rs. 4,500/-) vi) Portable Drill Machine (Model : KU-10) (Rs. 3,500/-) vii) High Speed Cut of Machine (Rs. 12,000/-) vii) Disc Sander (Rs. 7,500/-)	01 no. each	Rs. 50,000.00
08	Drilling Vice	02 No	Rs. 5,000.00
09	Portable sheet cutting machine	01 No	Rs. 5,000.00
10	Spray painting machine with Reciprocating Air Compressor (Auto cut switch) with 5 HP Electric Motor & 250 litre Tank with all accessories.	01 no.	Rs. 55,000.00
11	Pedestal grinder	01 No	Rs. 10,000.00
12	Milling Machine with all accessories	01 no.	Rs. 5,00,000.00
13	Spanner set, Hammers, punch, Anvil etc.	2 sets	Rs. 20,000.00
14	Cycle wheel balancing unit	2 set	Rs. 2,000.00

Total	Rs.16,57,000.00
Additional amount required for electrical connections etc. (Approx. 8.5%)	Rs. 1,43,000.00
Total(A)	**Rs.18,00,000.00**

B. Factory shed:

Trussed structure roof with CG sheet and 25.0 cm thick brick wall up to window sill and 12.5 cm thick above sill level up to roof level.
300 square meter @ Rs. 5,000/- per square meter **Total(B)** **Rs. 15,00,000.00**

Grand total(A+B) **Rs. 33,00,000.00**

Dipbahan
Dipbahan
Dipbahan
Dipbahan
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Dipbahan
Dipbahan

TH-0529_994802

Dipbahan, *the new tricycle rickshaw designed in the Department of Design, IIT Guwahati is the result of an effort to design an appropriate and aesthetically appealing form, visually light with contemporary visual identity giving it a feeling of sophistication, sporty and dynamic. Aerodynamic orientations of the design with space frame structure enveloping the driver; Reinforced platform for enabling it to support the structure, it optimizes the available space.* ***Dipbahan*** *is designed for easy access to facilitate the user to get in and out of the tricycle rickshaw, provides ample legroom for the passengers, proper space for carrying the luggage, incorporates Ergonomic seating arrangement and has a structure for the protection of the user and the puller from the elements of nature without increasing the weight of the tricycle and maneuverability manually. It also has a set of effective mudguards. Keeping up to the present day transportation needs, the tricycle is able to take quick turns and is stable with low centre of gravity.*

Dipbahan *intends to protect the occupants from direct impact by other vehicles due to accident resulting out of crashes during operation on road to the maximum extent possible by providing an enclosure so that no other vehicle will directly hit the user of the tricycle. A rolling cage is provided to protect the occupants in case of over turn.*

Dipbahan *is manufactured using modern technologies and materials.*

Dipbahan *designed by Prof. Amarendra Kumar Das*
Department of Design, Indian Institute of Technology Guwahati *under projcet '****IITG-NEDFi Design Initiative****' sponsored by*
North Eastern Development Finance Corporation, Guwahati.

Jute Composite components incorporated in ***Dipbahan*** *through joint collaboration between* ***IITG*** *and* ***Indian Jute Industries Research Association*** *(****IJIRA****), under Ministry of Textiles, Govt. of India*

Development of multi-varients of ***Dipbahan*** *sponsored by*
M/s. Tim Steel, Guwahati .

Commercial implementation of varients of ***Dipbahan*** *by M/s. Tim Steel, Guwahati under license from IIT Guwahati*

For commercial and technical details contact:
Prof. A. K. Das, Department of Design, Indian Institute of Technology Guwahati, Guwahati 781039
Telephone: +91-361-2582454(O), 099540 27062(M); Fax: +91-361-2690762; e-mail: *dasak@iitg.ernet.in*

M/s Tim Steel, P. B. Road, Rehabari, Guwahati 781 008
Telephone: +91-361-#######(O), ###### ######(M); Fax: +91-361-#######; e-mail: *######@iitg.ernet.in*

Department of Design

Dipbahan Eco-Friendly Tricycle Rickshaw

An appropriate and aesthetically appealing form and yet visually light, (Visual identity-contemporary, sophisticated, sporty and dynamic), Stability of the proposed design, easy access to facilitate the user to get in and out of the tricycle, ample legroom for the passengers, Ergonomic seating arrangement, protection of the user from the elements of nature without increasing the weight of the tricycle excessively which will affect the maneuverability manually, effective mudguard and protection of the occupants from direct impact from other vehicles, proper space for carrying the luggage. Keeping up to the present day transportation needs, the tricycle should be able to take quick turns, acquire lesser space and should be able to use the modern technologies for manufacturing and materials etc.

Dipbahan

IITG - NEDFi design initiative

Design by **Prof. A.K. Das, Dept. of Design, IITG**
& Manufactured by M/s Tim Steel Guwahati

Visit at: http://www.iitg.ernet.in/engfac/design/public_html/index.html

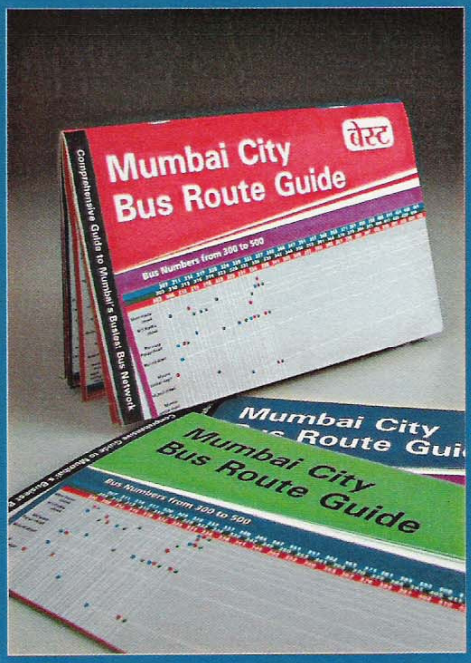
Department of Design

Indian Institute of Technology Guwahati

The Design programs offers opportunity for creative exploration and learning in areas that embrace science, technology, humanities, arts, and management. The program aims to train design students as professionals who are strong in conceptual thinking and skills that enable them to design tangible product and communication systems. A faculty team drawn from industry and academia form a multi disciplinary mix with specialization in the field of Industrial Design and Communication Design. They are engaged in the activities of Design education, Design research and professional consultancy services. The areas of their expertise are in the following –

1. Product Design, Development and Engineering
2. Usability Engineering and Human Computer Interaction studies
3. Ergonomic studies and evaluation
4. Design management
5. Design pedagogy
6. Graphic Design
7. Exhibition Design
8. New Media studies

Communication Design



Information Design: Design project

Explorations in lighting design

Product Design

Tricycle Design : Prof. A. K. Das

Visit us at: http://www.iitg.ernet.in/engfac/design/public_html/index.html

APPENDIX 5

List of Publications, Technical Papers and Proceedings generated from the thesis

Sl. No.	Title of the paper	Name of the conference, Date	Organised by	Publication and Remark
1.	Recent Trend in Rapid Prototyping Technology and Determining Factors for it's Appropriate Selection	National Conference on Recent Advance in Manufacturing Engineering 2004 [RAIME04] 30-31 January'04	National Engineering Collage, Kovilpatti, Tamilnadu, India	Paper presented and published in the conference proceeding
2.	Design of a Eco-Friendly Tricycle for in campus use based on Principles of Environmentally Conscious Design And Manufacturing	National Conference on Environmentally Conscious Design and Manufacturing 2004 [ECDM04] 23-24 July'04	Kumaraguru College of Technology, Coimbatore, Tamilnadu, India	Paper presented and published in the conference proceeding
3.	CAD and Rapid Prototyping as an Alternative of Conventional Design Studio	2nd International Engineering and Product Design Education Conference [IEPDE04] 2-3 Sept'04	TU Delft, Delft, The Netherlands participation with The Design Education Special Interest Group (DESIG) of The Design Society,	Paper presented and published in the conference proceeding *'Changing Face of Design Education'*
4.	Integrated Product Design Using Rapid Prototyping Technology and Rapid Tooling In Concurrent Engineering Approach	11th International Manufacturing Conference in China [IMCC], 18-20 Sept'04,	Shandong University, Jinan, China in association with National Natural Science Foundation of China and 8 other institutions	Paper published in the conference proceeding *'Advances in Materials Manufacturing Science and Technology'* Journal of Materials Science Forum Vols. 471-472 Trans Tech Publications Ltd.
5.	Philosophies of Design Education in context of a developing nation	3rd International Engineering and Product Design Education Conference [IEPDE05] 15-16 Sept'05	School of Design and Media Arts at Napier University, Edinburgh in participation with The Design Education Special Interest Group (DESIG) of The Design Society	Paper presented and published in the conference proceeding *'Crossing Design Boundaries'*
6.	Integrated design of Dipbahan- the eco- friendly tricycle rickshaw and its allied services	Annual International Conference of Society of Operations Research [SOM] 16-18 Dec'05	Department of Management Studies, School of Management Pondicherry University,	Paper published in the conference proceeding

Sl. No.	Title of the paper	Name of the conference, Date	Organised by	Publication and Remark
7.	Application of e-manufacturing (rapid prototyping) in a Reverse Engineering and Redesign Product Development Process	National Conference on Recent Advances in Manufacturing Technology [RAMT 2006] 3rd February'06	Department of Mechanical Engineering Velammal Engineering College, Chennai, Tamilnadu, India	Paper presented and published in the conference proceeding
8.	Human Powered Vehicle for Multi-Purpose Application in the Context of Developing Nation	Tools and Methods for Competitive Engineering 2006 [TMCE 2006] 18-22nd April'06	Delft University of Technology, Delft, The Netherlands and University of Ljubljana, Slovenia,	Paper published electronically in the conference website online
9.	Recycling and Reuse of FRP Waste Produced During Manufacturing	National Conference on Innovative Practices for Sustainable Energy and Waste Management 27- 28 April 2007	Sri Ramakrishna Institute of Technology Coimbatore, India and South Dakota School of Mines and Technology, USA	Paper published in the conference proceeding

Sl. No.	Title of the Article	Journal	Issue / Volume	Remark
1.	Hand-pulled rickshaws in India to be a thing of the past - A detailed article on Jute composites developed for Dipbahan+	JEC Composites, an international journal on composites, published from Paris, French	March 2006 issue (No. 23).	Editor of the journal opined that the Jute composite being bio-composite is environment friendly and Dipbahan will help to cut down vehicular pollution in India
2.	Dipbahan – an Eco-friendly Tricycle Rickshaw - Success story of Dipbahan and its variations designed in IIT Guwahati	PI.TECH, PAN IIT Tech Review	Volume 1, Issue 3, published in December 2006	Issue specifically covering 'India's Rural Transformation Technologies lead the way' mentioned that Dipbahan is one product that comes as a contribution from the IITs to the Indian common man.

APPENDIX 6

1 → 2 → 3

Wooden body is made through carpentry

Wooden body is covered with aluminium sheet for the exposed areas

Wooden body is fitted with locally made components (Table 2.1, p 49) and coir fibre padded seat back is covered with hesian cloth and rexin.

i → ii → iii

Passenger's seat is made in wood and fitted with springs

Seat cover, seat back, foldable canopy's canvas cover are stitched by tailor and are fixed with the body, seat and canopy.

Passenger's seat is padded with coir fibre, covered with hesian cloth and finally with rexin cover.

A → B → C

Outsourced tricycle rickshaw components (Table 2.2, p 50) are assembled to obtain the main frame

Locally made components (Table 2.1, p 49) are assembled with the outsourced component derived frame

Basic chassis fitted with wheels is ready for mounting the wooden body and passengers' seat

Wooden body and passengers' seat is mounted on the chassis fitted with wheels and decorations are added on the body

Folding canopy structure is locally made out of bamboo and covered with canvas top and fitted to the body using locally made bracket

A traditional tricycle rickshaw locally assembled is ready

Flow diagramme of traditional rickshaw manufacturing process

APPENDIX 7

Inhouse made parts are suffixed with (I) and outsourced parts are suffixed with (O)
Chassis and main frame, left and right frames, seat structure and binding bars are fabricated inhouse.
FRP items - hood, rear panel, floor panels, side panels , mudguards and seat are moulded inhouse.
All other readily available components as labelled above are outsourced from market and used for ease of maintenance at local rickshaw workshop.

Diagramme showing components made inhouse and outsourced used in theDipbahan+

Inhouse made parts are suffixed with (I) and outsourced parts are suffixed with (O)
Chassis and main frame, left and right frames, seat structure and binding bars are fabricated inhouse.
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