DEVELOPMENT OF ELECTRIC CYCLE RICKSHAW

Final Project Report
Submitted to
Ministry of Non-conventional Energy Sources (MNES),
Govt. of India, New Delhi
(Ref. No. 6/4/5/97-NT)

By

Nimbkar Agricultural Research Institute (NARI),
P.O. Box 44, Phaltan-415 523
Maharashtra, India

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EXECUTIVE SUMMARY

1. INTRODUCTION :

India has about 18 million petrol-powered two wheelers and about 1.5 million petrol and diesel-powered three wheelers. These numbers are growing at a healthy rate of 15% per annum. The air and noise pollution resulting from these vehicles poses a major health hazard. In addition, the country has to spend its valuable foreign exchange to purchase the fuel required to run these vehicles.

An alternative non-polluting transport system already exists in most Indian cities in the form of the cycle rickshaw. Close to 1 million cycle rickshaws are estimated to ply the Indian roads providing employment to about 700,000 rickshaw pullers. Unfortunately, deliberate policies in most of the urban areas of developing countries have been made by the concerned authorities to phase out this environmentally friendly means of transport.

Nevertheless, the existing rickshaws have several drawbacks. The gearing and the mechanical advantage of the pedal is very poor, making the rickshaw puller work very hard for climbing even a slight slope. The braking system is also very poor with the rickshaw having only front brakes. Thus when going downhill at high speeds, sudden braking produces a catapult effect. Similarly, the seating arrangement is very uncomfortable and the aerodynamic drag of the system is very high. It is therefore humanly degrading to pull the existing inefficient cycle rickshaw.

The rickshaw manufacturing presently is a footpath industry with no quality control and there are as many rickshaw designs as cities in which they ply. Also these rickshaws are so poorly made that they have to be completely replaced in a couple of years.

For these reasons, a need was felt to improve the existing rickshaw and to bring quality control in its manufacture. Further the potential of such improved cycle rickshaws powered by electric motor and batteries to provide an attractive alternative to petrol and diesel-powered three wheelers was recognized.

Thus an electric cycle rickshaw has been designed, fabricated and tested at NARI. This rickshaw is christened as ELECSHA. The trademark has been registered and a patent filed on it. This report gives the details of ELECSHA development.

2. OBJECTIVES OF THE PROJECT :

a) To develop an efficient electric rickshaw. The efficient cycle rickshaw developed by NARI will be fitted with suitable electric motor, interface card and batteries.

b) To make three such rickshaws and test them in Phaltan town for six months.

c) To discuss with prospective entrepreneurs, the possibilities of manufacturing the electric rickshaws on a limited scale which then could be test marketed in Pune.

3. DESIGN METHODOLOGY FOR ELECSHA :

The design methodology used for developing ELECSHA was as follows :

An improved pedal cycle rickshaw (IPCR) was developed at NARI. This was done by modifying the existing cycle rickshaw and hence has 5-speed gears, reduced length of long chain drive, back wheel braking, better suspension and less aerodynamic drag. The IPCR enables a rickshaw puller to take two passengers on a 6-10% slope quite easily and without getting down from his seat. This IPCR was converted into an electric rickshaw by going through the following steps :

i) Motor wattage determination by calculating rolling friction, aerodynamic drag, acceleration of vehicle and inertial resistance of moving parts.
ii) Battery number estimation.
iii) Designing of D.C. drive and controller.
iv) Designing of battery charger.
v) Designing of a gear box.
vi) Fabrication of prototype electric rickshaw

vii) Road testing.

viii) Data collection and design modification.

In the first phase, lead acid batteries, motor and electronic card were installed on IPCR. Due to the 25-30 km/hr speed of this first generation ELECSHA and the weight of the batteries, the fragile rickshaw frame was found to become unstable. Also the thin tyres could not handle the weight. Hence thicker tyres, shock absorbers and a sturdier frame were introduced to develop the second generation ELECSHA. However, this model of ELECSHA still had one backwheel drive causing it to move towards one side. This put a considerable strain on the hands of rickshaw driver. To alleviate this problem a differential gear system was installed on the back wheel giving a third generation ELECSHA. However, this caused a power loss making it difficult to climb uphill. Thus a 2-speed gear box was designed, developed and installed in the ELECSHA. The gears could be shifted by a foot-operated lever. Thus this fourth generation ELECSHA consists of batteries, motor, controller, differential system and 2-speed gear box.

Based upon this methodology the following design resulted :

1. PMDC motor size : 1.2 kW
2. Battery size and numbers : 3 numbers 100 amp deep discharge batteries.
3. A mosfet-based D.C. drive
4. A differential gear system for backwheel drive.
5. A 2-speed gear box for climbing uphill.

The details of the design of different components are given in Chapter II.

4. ELECSHA TESTING AND RESULTS :

Three ELECSHAs were designed, fabricated and tested. Each ELECSHA represented a generation of development. The three rickshaws have together logged 6000 kms in trial runs in and near Phaltan. There was a tremendous response to ELECSHA from the local populace. Hence quite a number of commercial enquiries have been received. ELECSHA was also featured prominently in mass media, in TV, radio and print media.

Economic analysis of ELECSHA as a taxi was also done (Chapter IV) and it is shown that ELECSHA owner will make a net profit of Rs. 18,000/year for first five years (he has to repay the loan in 5 years) and about Rs. 45,000/year after that.

Energy analysis of ELECSHA vis a vis petrol autorickshaw was carried out. From power-plant to traction-energy point of view, ELECSHA was found to consume 131 Whr/passenger-km as compared to 175 Whr/passenger-km consumed by petrol autorickshaws. Thus ELECSHA uses 25% less energy than petrol autorickshaws and appears to be superior to petrol autorickshaws on all fronts viz. economic, environmental and energy.

In preliminary discussions with manufacturers, though they appeared to be quite enthusiastic, none were willing to take up the production immediately. Most of the respondents would like to see more extensive trials and a stamp of approval from the Automotive Research Association of Indian (ARAI), Pune.

5. CONCLUSIONS :

a) Three electric cycle rickshaws, christened an ELECSHA have been designed, fabricated and test run a combined total of 6000 kms.

b) ELECSHA is powered by deep cycle discharge batteries and has a PMDC motor, differential gear system, 2-speed gear box and mosfet-based D.C. drive.

c) ELECSHA can travel upto 70 km/charge and at a speed of 25-30 km/hr with two passengers and a driver on level roads. The charging can be done overnight by a stand alone 36 V, 15 amp charger.

d) With 2-speed gear box, ELECSHA can go uphill 10-15% slope with two passengers at 15-20 km/hr. It also has the capability of starting from zero velocity to go uphill with full load.

The cost of ELECSHA is estimated to be Rs. 90,000/-. However, this is expected to reduce under large scale manufacturing.

6. RECOMMENDATIONS :

a) **Technology issues** : Ferrite magnets used in PMDC motors and the PMDC motors themselves should be exempted from sales and excise taxes. Duty on imported deep cycle discharge batteries should be reduced till Indian manufacturers start producing light-weight batteries. MNES should also make budgetary provision for thorough testing of ELECSHA at ARAI and production of 50 ELECSHAs for test marketing.

b) **Policy issues** : Government should enact legislation to permit only improved cycle rickshaws and electric rickshaws in congested areas of inner cities, as well as to provide low interest loans to the rickshaw-owners to purchase such rickshaws. MNES should initiate a national program on electric vehicles akin to those on biogas, biomass gasifiers etc.

7. ACHIEVEMENTS OF THE PROJECT :

a) Complete designing of improved (IPCR) and electric cycle (ELECSHA) rickshaws.

b) Identification of vendors for development and fabrication of various components for ELECSHA.This included PMDC motor, 2-speed gear box and electric controller.

c) Making available an economic, environmentally benign and energy efficient alternative transport system for India. Besides being a sustainable transport system this will also provide large scale employment and extra income to rickshaw pullers.

CHAPTER I

1. INTRODUCTION :

Most of the cities in developing countries are highly polluted. The main reasons are the air and noise pollution caused by transport vehicles, especially petrol-powered two and three wheelers. For example, in India there are close to 18 million petrol-powered two wheelers and about 1.5 million petrol and diesel-powered three wheelers and their population is growing at a healthy rate of about 15% per annum [1]. Besides being a major hazard to people's health, these machines are guzzling huge amounts of petrol and diesel for which the country has to pay dearly in foreign exchange outflow. In fact it is a common sight in developing countries that during traffic jams in congested areas of cities these vehicles produce tremendous pollution.

However, there already exists a non-polluting transport system in most of the cities. It is cycle rickshaw. If an improved and modified cycle rickshaw can be converted to an electric cycle rickshaw then it can provide a non-polluting and a very silent transport system for urban and rural areas of India. Besides, it is a very energy efficient and cost effective vehicle. Work done at our Institute has shown that improved cycle rickshaws powered by electric motor and batteries have a potential to provide an attractive alternative to petrol and diesel-powered three wheelers. At the same time they can also provide large scale employment and extra income to the rickshaw puller.

2. EXISTING CYCLE RICKSHAWS :

There are guestimates that close to 1 million cycle rickshaws ply the Indian roads carrying about 3-4 billion passenger-km/year. In some cities they are the major means of transport. They provide employment to about 700,000 rickshaw pullers, are very maneuverable and are completely non-polluting and hence environmentally friendly means of transport [1]. It is very unfortunate that deliberate policies in most of the urban towns of developing countries have been made by the concerned authorities to phase out these rickshaws. These non-polluting vehicles are being replaced by polluting (both air and noisewise) petrol and diesel-powered three wheelers. Our data show that three wheeler diesel tempos in Lucknow city (capital of Uttar Pradesh) produce close to 70-80 decibel noise at a distance of 1-2 m, besides belching out huge amounts of particulates into the air [1].

Nevertheless, the existing rickshaw is very poorly designed and so it takes a heavy toll on the health of a rickshaw puller. The existing cycle rickshaw has hardly changed since it was introduced in 1930's and 40's in India. The gearing and the mechanical advantage of the pedal is very poor. Hence the rickshaw puller has to work very hard while climbing even a slight slope. A common sight is of a rickshaw puller getting down and pulling on foot the rickshaw with passengers. The braking system is also very poor with the rickshaw having only front brakes. Thus when going downhill at high speeds, sudden braking produces a catapult effect. Similarly the seating arrangement is very uncomfortable and the aerodynamic drag of the system is very high. It is therefore humanly degrading to pull the existing inefficient cycle rickshaw. Yet because of poverty, laborers do become rickshaw pullers and suffer adverse consequences to their health. The rickshaw manufacturing presently is a footpath industry with no quality control and there are as many rickshaw designs as cities in which they ply. These rickshaws are so poorly made that they have to be replaced completely in a couple of years. Thus there is a need to improve the existing rickshaw and bring quality control in its manufacture.

Our Institute has therefore designed an improved cycle rickshaw and converted it into electric rickshaw. The details of this development are given in this report.

3. OBJECTIVES OF THE PROJECT :

a. To develop an efficient electric rickshaw. The efficient cycle rickshaw developed by NARI will be fitted with suitable electric motor, interface card and batteries.

b. To make three such rickshaws and test them in Phaltan town for six months.

c. To discuss with prospective entrepreneurs the possibilities of manufacturing the electric rickshaws on a limited scale which then could be test marketed in Pune.

4. OUTLINE OF THE REPORT :

The report is divided into the following chapters :

a) Design methodology for rickshaw (Chapter II)

b) Fabrication and evolution of ELECSIIA (Chapter III)

c) Results and Discussion (Chapter IV)

d) Conclusions and Recommendations (Chapter V)

CHAPTER II

DESIGN METHODOLOGY FOR RICKSHAW

As discussed before, the existing cycle rickshaws are very poorly designed. Hence as a part of previously funded project from E & Co, New Jersey, NARI had modified the rickshaw. The improved pedal cycle rickshaw (IPCR) has 5-speed gears, reduction in length of long chain drives (which are in existing rickshaws), back wheel braking, better suspension and less aerodynamic drag than the existing ones. Fig. 1 shows the improved NARI cycle rickshaw. Tests done at our Institute have also shown that it enables a rickshaw puller to take two 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 90 Kg. Its life is estimated to be between 7-10 years.

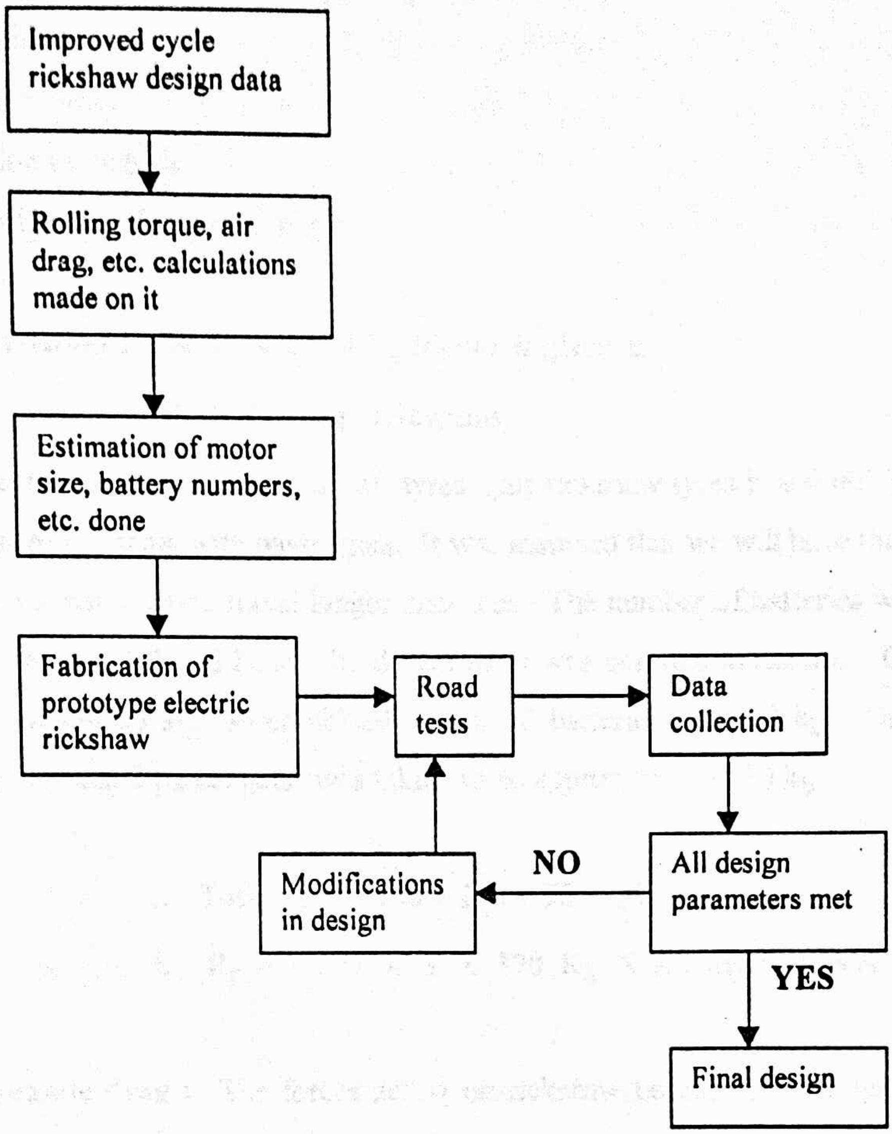
Our data from urban towns of India has also shown that lots of rickshaw pullers are migrant laborers from villages and have sometimes only the rickshaw as their sole possession. Hence at night when they sleep, they often do so on the cramped seat of the rickshaw for the fear of it being stolen. Our new 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. 7,000/- in mass production and compares very well with Rs. 4000-5000/- which is the cost of existing regular rickshaws [1].

This modified rickshaw was then converted into an electric rickshaw. This electric rickshaw was christened as ELECSHA and the trademark has been registered. A patent has also been filed on it.

Fig. 1. Improved cycle rickshaw designed at NARI.
Also shown is the trolley version.

The design methodology used for developing ELECSHA was as follows :



In any electric vehicle the major components are :

1. PMDC motor.
2. Battery for powering the motor.
3. Electric controls or DC drive which helps the motor to smooth start.
4. High current switches for isolating the system from battery.

Designing was done for each of these components and the calculation details are given below:

II-1. Motor wattage calculations:

The forces acting on a rickshaw are [2]

a) Rolling friction

b) Aerodynamic drag

c) Acceleration of vehicle

d) Inertial resistance of moving parts

A) **Rolling friction :** The force of rolling friction is given as

$$R_r = C_r \cdot Mg \quad \text{(Newtons)} \qquad \text{---------} \ (1)$$

Where C_r is the coefficient of friction of tyres (for rickshaw tyres it is 0.007/tyre [3]), and M is the mass of rickshaw with passengers. It was assumed that we will have three batteries in the rickshaw so that it could travel longer distances. The number of batteries were calculated as shown in section II-2 and hence the design basis was iterative in nature. On an average each battery weighs 33 kg, so combined weight of batteries was 100 kg. The weight of 3 persons (1 driver and 2 passengers) was taken to be approximately 180 kg.

$$\therefore \text{ Total mass} = 180 + 100 + 90 = 370 \text{ Kg}$$

$$\therefore \quad R_r = 0.007 \text{ X } 3 \text{ X } 370 \text{ Kg X } 9.8 \text{ m/s}^2 \cong 76 \text{ N}$$

B) **Aerodynamic drag :** The forces acting on rickshaw because of aerodynamic drag are given by Darcy equation :

$$R_d = C_D \ A\rho \ V^2/2 \quad \text{(Newtons)} \qquad \text{---------} \ (2)$$

Where C_D = drag coefficient, A = frontal area of rickshaw, m^2, ρ = density of air, 1.2 Kg/m^3 and V = the velocity of vehicle, m/s. As the vehicle was expected to go at varying speeds, the maximum drag was used in motor calculations. C_D was taken to be ~ 1 (for the maximum resistance) whereas A = 1.5 m^2 .

The calculation results are shown in Table 1.

C) **Acceleration of vehicle :** It was assumed that the vehicle will reach 30 km/hr from rest in 1 minute. This acceleration rate is comfortable at velocities involved.

$\therefore a = V / t$, where t = time

and $R_a = M . a$ (Newtons) ---------- (3)

Where R_a = Force due to acceleration of vehicle.

The calculation results are shown in Table 1.

The inertial resistance of parts are negligible as compared to the above forces and were neglected [2].

$\therefore$ Total force $R_T = R_r + R_d + R_a$ (Newtons) ----------- (4)

and Total power $= R_T . V$ (Watts)

Results are shown in Table 1.

Table 1. **Total power required for ELECSHA at various speeds**

Force characteristic	20 Km/hr	25 Km/hr	30 Km/hr
	Velocity of rickshaw		
Rolling friction, R_r	76 N	76 N	76 N
Air drag, R_d	27.7 N	43 N	62.5 N
Acceleration, R_a	34 N	42.8 N	52 N
Total	137.7 N	161.8 N	190.5 N
Velocity (m/s)	5.5	6.94	8.33
Power (kW)	**0.76**	**1.12**	**1.59**

The designing was done for rickshaw speed of 25 Km/hr. For this speed a 1.2 kW PMDC motor was chosen. After a great deal of difficulty, a party in Pune was identified which could manufacture a compact motor of this size.

II-2. Battery specifications :

Most of the batteries used for EV applications are lead acid types. They are heavy but are rugged. Other batteries like NiCad etc. exist but are very costly. Hence the designing was done using the existing lead acid battery data.

The major consideration in battery sizing is the space used and weight of the battery. Space considerations were dictated by its availability in a rickshaw, especially below the seating arrangement. It was decided to put the battery compartment under the seat. Also the compartment was designed so that the center of gravity of the whole vehicle should be in the middle of the vehicle. Otherwise with heavy batteries, there could be a tendency of the rickshaw to topple backwards.

At the outset it was decided to use the automotive batteries. This was because of their easy availability and ruggedness. The data sheets of these batteries (N type) from Exide company were used.

It was also decided that an electric rickshaw should travel about 70 km in one charge. This distance was decided based upon anecdotal data of distance travelled by autorickshaws in Pune. Since the motor power was 1.2 kW and the average speed of the rickshaw was expected to be 25 km/hr, the total time the rickshaw can travel in one charge would be ~ 3 hours. Thus the total energy required would be 5.625 kWh (this includes the efficiency of charging and discharging of batteries).

The voltage and the number of batteries to be used were calculated as follows :

$$\text{Power} = 1.2\ \text{kW} / 0.8 = 1500\ \text{W} = \text{I (amps)} \cdot \text{V (volts)} \qquad \text{-------} \ (5)$$

The motor efficiency has been assumed to be 0.8

$$\text{Battery weight} = f\ \text{(amp-hrs)}$$

Volume available under the seat in rickshaw was ~ 0.1 m^3 and area ~ 0.34 m^2 . The data for Exide batteries (N type) yielded a relationship for Amp-hrs vs. weight, which was

$$\therefore\ \text{Ah} = 3.38\ \text{W}, \quad \text{where W = weight in Kg.} \qquad \text{----------} \ (6)$$

Each battery was assumed to be 12 V. So for N batteries voltage = 12 N and

$$\text{I (amps)} = 1500\ \text{(watts)} / 12\ \text{N (volts)}$$

If the batteries are to run for X hours, then amp-hrs is given as :

$$\text{Amp-hrs} = I.X \qquad \text{---------- (7)}$$

The batteries data also yielded a relationship between area of batteries A, and their weight W, and was given as :

$$A = 2.4 \times 10^{-3}\ W \qquad (m^2) \qquad \text{---------- (8)}$$

Equations (5) to (8) were then solved to yield a table for number of batteries vs. hours of usage. For our purpose, 3 batteries were found to be adequate. This resulted in voltage design of 36 V and 100 amp-hr battery capacity. There were three types of batteries used;

a) Trojan deep discharge lead acid batteries, 27 TMX - WNT
b) Exide automotive batteries, EF 100
c) Exide deep discharge tubular batteries, EL 100

II-3. Software for controller :

The controller or D.C. drive is the heart of the system. It allows soft start of the motor, does not allow current overload to it and should (ideally) provide dynamic braking. A software was made according to our specifications and the controller was contracted to an outside party.

Consequently, a couple of Pune parties were contacted to design the D.C. drive. One party, M/s Theta Controls designed the controller, which has worked satisfactorily. However, the controller is big in size and yet to be made water proof and weather proof. Though it is functional, for large scale manufacturing, it requires some major modifications.

Another company, Curtis Instruments (India) was contacted in Pune. Their parent company in US is the world's largest producer of DC drives. Their controller which was purchased is a very compact, lightweight unit and has worked very well. It is totally sealed and hence is weatherproof. The controller used is Curtis-make mosfet PMC 1204.

Fig. 2 shows the block diagram of the controller designed by Pune party and Fig. 3 shows the block diagram of the electrical circuit of rickshaw. High current switches were also designed and installed in the circuit.

The explanation of various blocks in Fig. 2 is as follows :

A. Input - D.C. supply : Input from the 36 V battery bank.

B. Chopper : This is solid-state power MOSFET based cct. It is connected between input and output load. MOSFET is a lossfree device and it requires very low input drive power. This circuit controls the motor input by changing its duty cycle.

C. Chopper drive cct : This is an interface between chopper and input control cct.

D. P.W.M. cct : This cct converts the input control signal into variable duty cycle so as to get required output. P.W.M. cct gets input from enable control cct, current control cct and voltage control cct.

E. Enable cct : This cct enables or disables the function of the P.W.M. and in turn the motor speed is enabled or disabled. The enable cct can operate by sensing the speed, battery terminal voltage and external start/stop switch or any other input.

F. Speed control cct : Takes input from speed set potentiometer and feedback from armature voltage and creates the error signal so that the P.W.M. cct can keep the output constant.

G. Current control cct : Load current is sensed from shunt and compared with fixed set limit so as to ensure that load current is not exceeding the preset limit.

II-4. Battery charging strategy :

For any electrical vehicle, the battery charging can either be done on a stand alone basis i.e. it is charged at whatever place an electric outlet is available or there have to be charging stations, akin to petrol stations for regular automobiles. In charging stations it is envisaged that the discharged batteries will be replaced by fully charged ones. In our case, since this was the first such vehicle anywhere, the option of stand alone charging was found to be useful. Consequently, a party in Pune (NANA Industries) was contacted to design a suitable charger for our ELECSHA. They designed a 36 V, 15 amp charger which could charge 100 Ah batteries in about 8-10 hours. Efforts are underway to design a small SMPS (Switch Mode Power Supply) - based charger which can be mounted on the ELECSHA itself so that it can be charged any place. A party in Pune has been given a contract to make it. Also efforts

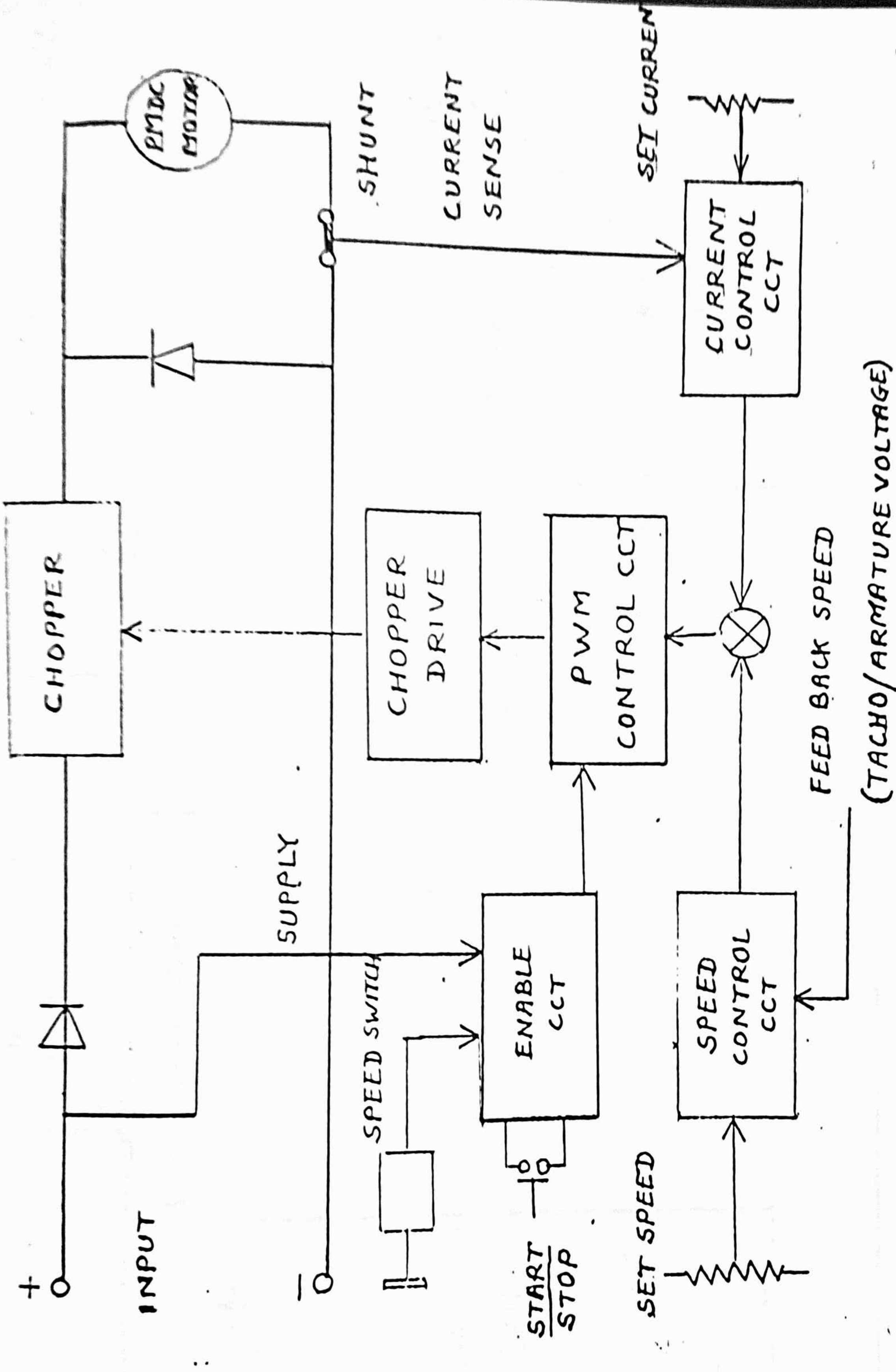


Fig 2. Block diagram of DC drive controller for ELECSHA (developed by Pune party)

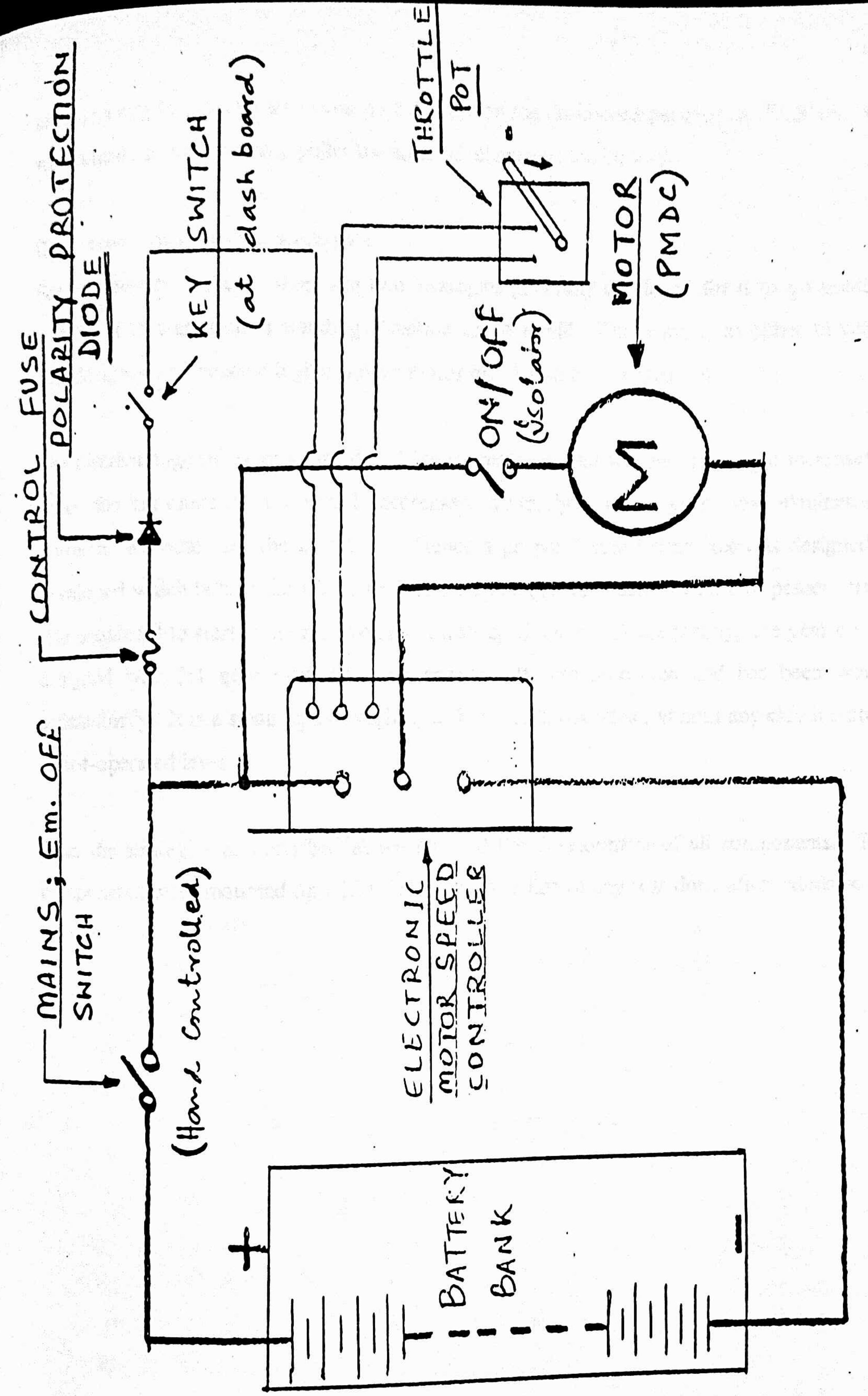


Fig 3. Typical block diagram of electrical circuit for ELECSHA

are underway to mount a small charge indicator on the dashboard panel of ELECSHA, which will indicate to the rickshaw puller the state of charge of the battery.

II-5. Gear box design strategy :

For any electric vehicle, there are two strategies generally employed for it to go uphill and also for it to start from a standing position to go uphill. These are : a) either to have an overdesigned and hence a higher power motor or, b) to have a gear box.

The disadvantage of overdesigned and bigger motor is that the battery weight increases and hence the km range of the vehicle decreases. Properly designed gear box eliminates this problem. We opted for the gear box. Hence a proper 2-speed gear box was designed and developed which helped the ELECSHA to go uphill (10-15% slope) with two passengers and also enabled it to start from zero velocity on an uphill climb. Consequently, the gear box was designed with 3:1 gear ratio and two speeds. It was fabricated and has been working satisfactorily. It is a small light- weight gear box which operates (without any clutch plate) by a foot-operated lever.

Thus the strategies as described above allowed the development of all components. These components were mounted on ELECSHA and their fine tuning was done after extensive road testing.

CHAPTER III

FABRICATION AND EVOLUTION OF ELECSHA

As discussed in Chapter II, the existing cycle rickshaw was reengineered to make it better. This improved rickshaw (IPCR) was then converted into ELECSHA. Thus in the first phase, lead acid batteries, motor and electronic card were installed on this improved rickshaw. Fig. 4 shows the first generation ELECSHA with regular cycle rickshaw tyres and chassis.

It was found that because of speed of ELECSHA (with motor and batteries it was running between 25-30 km/hr) and the weight of the batteries, the fragile rickshaw frame was becoming unstable. Also the thin rickshaw tyres could not handle the weight. Hence it was decided to introduce thicker tyres, shock absorbers and a sturdy frame. Thus the second generation ELECSHA was developed and is shown in Fig. 5. The weight of this rickshaw was 230 Kg and its dimensions were 239 cm (L) X 133 cm (H) X 105 cm (W). This rickshaw has logged ~ 4000 kms in trial run.

However, this version of electric rickshaw still had one backwheel drive and hence put a considerable strain on the hands of rickshaw driver, since there was a tendency of rickshaw to move towards one side. It was therefore decided to install a differential gear system on the back wheel. Since the power and load of ELECSHA is not very large, a small differential gear box should have been sufficient. Unfortunately, small differentials are not available in the market.

Hence a differential system of existing Vikram tempo (8-seater) was suitably modified for ELECSHA width and installed in it.

With this modification, ELECSHA ran very smoothly on level roads with excellent balancing and no problem to the driver. This was the third generation of ELECSHA. However, with the use of differential gear box, there were power losses in it and thus climbing uphill and starting ELECSHA on uphill from zero velocity became difficult. Thus a need was felt to install a gear box between the motor and the differential.

Fig 4. First generation ELECSHA with cycle rickshaw tyres and chassis

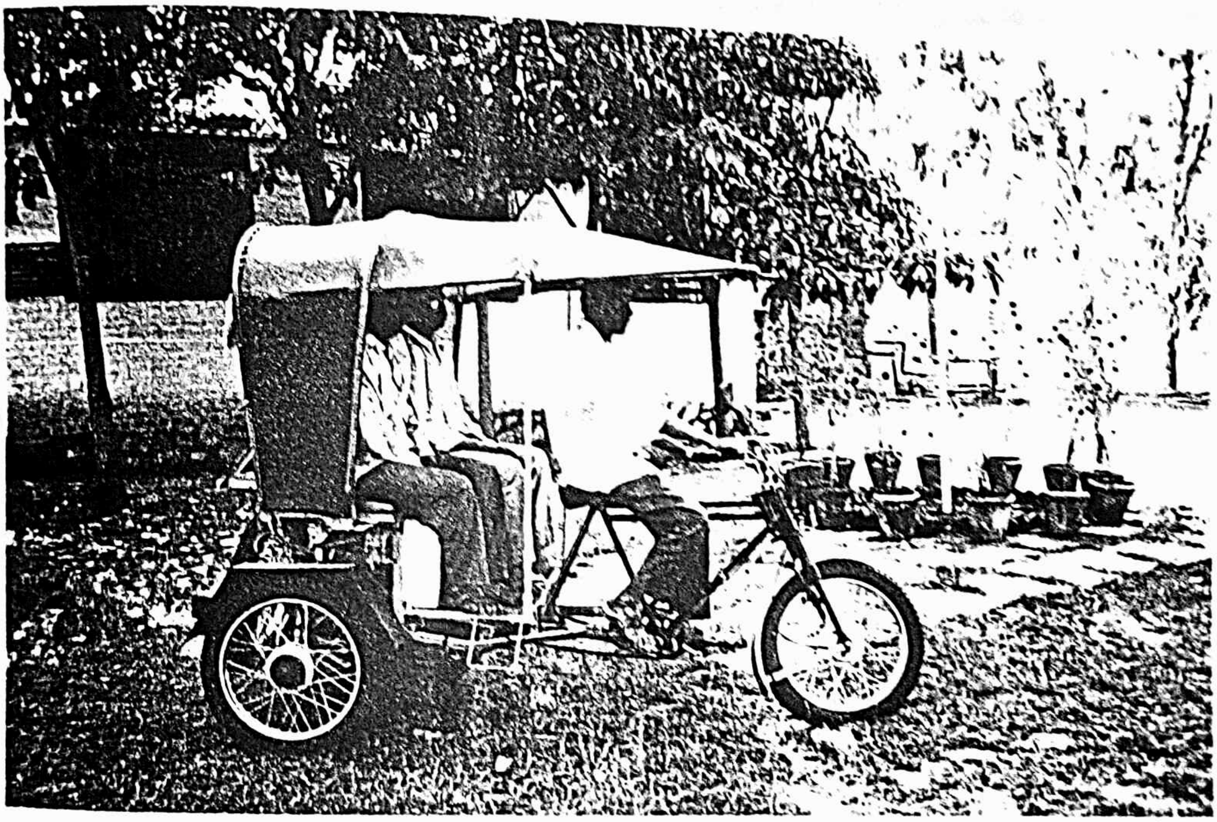


Fig 5. Second generation ELECSHA with bigger tyres and shock absorbers

A gear box was suitably designed and developed and was installed in the ELECSHA. The gears could be shifted (without clutch plate) by a foot-operated lever.

With this installation, the design of ELECSHA was complete. The fourth generation ELECSHA therefore consists of batteries, motor, controller, differential system and 2-speed gear box. Fig. 6 shows the photograph of the final ELECSHA. Its technical specifications are given in Table 2. This rickshaw has logged 2200 kms in trial run and is being offered to a Pune party for road field trials. Thus the three different ELECSHAs made in NARI have logged a total of more than 6000 kms in field trial runs. We believe that the final design of ELECSHA is ready for commercialization.

It was necessary to make three ELECSHAs because it speeded up the design and implementation process. When the modifications in design were being done on one, the others were undergoing extensive load testing and evaluation.

Fig 6. Final ELECSHA model

Table 2. Specifications of ELECSHA (final design)

1.	Pay load	: 180 Kg (2 passengers + 1 driver)
2.	Vehicle weight	: 307 Kg
3.	Range	: 70 Km (80% discharge of battery)
4.	Top speed	: 35 Km/hr
5.	Battery type	: Deep discharge lead acid batteries, 100 Amp-hr
6.	Battery weight	: 130 Kg (EL-100) and 105 Kg (Trojan)
7.	Battery peak voltage	: 36 V
8.	Battery cycle life	: 500 cycles
9.	Charger	: 36 V, 15 A, 0.5 kW stand alone charger
10.	Charging time	: 10-12 hours
11.	Motor	: 1.2 kW, PMDC, 4 brush motor
12.	D. C. drive	: Curtis-make mosfet PMC 1204
13.	Transmission	: Backwheel drive with two speed 3:1 gear box and differential gear on the back wheel.
14.	Frame / body type	: M.S. angle iron construction
15.	Length / width / height	: 232 cm (L) X 108 cm (W) X 185 cm (H)
16.	Ground clearance	: 180 mm.
17.	Turning radius	: 2.2 meters.
18.	Maximum grade climbing ability	: 15%
19.	Tyres / wheels	: Vikram Tempo tyres / wheels
20.	Brakes	: Hydraulic type

CHAPTER IV

RESULTS AND DISCUSSION

IV-1. Data on kilometers travelled :

The total kilometers travelled by ELECSHA are shown in Table 3. Also shown are the number of charging cycles for different batteries till today (Table 4).

Table 3. ELECSHA Run

ELECSHA No.	Kms travelled
ELECSHA 1	2547
ELECSHA 2	1369
ELECSHA 3 (with gear box)	2104

Table 4. Battery charging cycle numbers

Sr. No.	Battery description	No. of cycles charged
1.	Trojan deep discharge 27 TMX - WNT	23
2.	Exide EF-100	104
3.	Exide EL-100	24

IV-2. Anecdotal data on ELECSHA :

During the last year, the three ELECSHAs have travelled extensively in Phaltan, Baramati and Lonand. Baramati and Lonand are adjoining towns (~ 25 km from Phaltan). There has been tremendous response to these ELECSHAs by local population. Most people have enquired as to when this ELECSHA` will be put in the market. Some have come to NARI to enquire whether they can purchase it and when.

We also got an autorickshaw driver to run our ELECSHA. He drove it without any difficulty and wanted to buy one if easy credit loan could become available from the bank. He was particularly appreciative of its low noise.

Thus with trial runs in Phaltan, it is evident that ELECSHA will be accepted readily by consumers.

There was also quite a bit of publicity given in news media to ELECSHA. It was featured on Doordarshan, Star News and BBC. Also quite a number of articles on it have come out in newspapers.

IV-3. Economic analysis of ELECSHA :

It is also instructive to do an economic analysis of running ELECSHA as a taxi. This will show its economic feasibility vis a vis existing autorickshaws (petrol and diesel-powered). For this a proper costing of ELECSHA has to be done.

Based upon our data of fabricating ELECSHA in NARI's workshop and extrapolating it for mass production, the following costing resulted (Table 5).

Table 5. Cost of various components of ELECSHA

Sr. No.	Components	Cost (Rs.)
1.	Rickshaw chassis / body	25,000/-
2.	Lead acid tubular battery (3 nos.)	16,000/-
3.	PMDC motor	12,000/-
4.	Controller (mosfet-based)	13,000/-
5.	Gear box (2 speed)	7,000/-
6.	SMPS-based charger for batteries	8,000/-
		Total Rs. 81,000/-

With 10% profit, the cost will come to Rs. 89,000/-. For renewable energy devices there is no sales tax and excise and hence for our calculations we can consider the final cost of ELECSHA to be about Rs. 90,000/-.

Assumptions used for running ELECSHA as taxi are :

1. Charging of battery will require 5.625 kWh/day. Electricity cost is Rs. 5/kWhr.
2. Maintenance cost of ELECSHA is taken at Rs. 1000/year.
3. Loan for buying ELECSHA will be @ 15% p.a. and payable in 5 years.
4. ELECSHA will charge Rs. 4/km as taxi fare. This is slightly less than Rs. 4.5/km charged by autorickshaws in Pune.
5. Batteries will have to be replaced every alternative year. This will give higher running cost. However, with good deep discharge batteries like Trojan etc. the batteries can last upto 5 years. This will reduce the running cost drastically.
6. ELECSHA will run 50 kms/day on an average and for 300 days/year. ELECSHA is capable of going 70 kms/charge, but based on the data available from Pune for autorickshaws we have taken 50 kms/day as the average run per day.

With these assumptions, the ELECSHA owner will make a net profit of Rs. 18,000/year in first 5 years and about Rs. 45000/ year from sixth year onwards, after the loan is repaid. Thus ELECSHA running as a taxi can be an attractive economic activity. Besides it is non polluting and hence can be introduced in inner city areas.

Details of the costing calculations are shown below in Table 6.

Table 6. Cost / benefit calculations for ELECSHA running as taxi

Expenditure

Figures in Rupees

Item	Year 1	Year 2	Year 3	Year 4	Year 5
1. Loan repayment	18,000	18,000	18,000	18,000	18,000
2. Interest payment	13,500	10,800	8,100	5,400	2,700
3. Running cost	9,438	9,438	9,438	9,438	9,438
4. Battery replacement	-	16,000	-	16,000	-
Total Rs.	**40,938**	**54,238**	**35,538**	**48,838**	**30,138**

After fifth year (when loans have been paid) the total running cost will be Rs. 9,438 and every second year Rs. 25,438 (during battery replacement years).

Earnings and Profit

Figures in Rupees

Item	Year 1	Year 2	Year 3	Year 4	Year 5
1. Earnings @ Rs. 4/km	60,000	60,000	60,000	60,000	60,000
2. Running cost	40,938	54,238	35,538	48,838	30,138
Profit @ Rs. 4/km	**19,062**	**5,762**	**24,462**	**11,162**	**29,862**

Hence in first five years, the net profit will be about Rs. 18,000/year. After 5 years, the net profit will be ~ Rs. 50,562/- during battery lean years and Rs. 34,562/- when the new battery is put.

IV-4. Energy Analysis of ELECSHA :

It is also instructive to compare ELECSHA with regular petrol/diesel autorickshaws in terms of energy efficiency. From power-plant to traction-energy point of view, ELECSHA consumes 131 Whr/ passenger-km as compared to 175 Whr/passenger-km consumed by petrol autorickshaws. In this calculation the following assumptions were used :

a) **ELECSHA :**

i) Electric power plant efficiency including T & D losses = 0.255

ii) Charging / discharging efficiency of batteries = 0.64

iii) It can take 2 passengers to 70 km in one charge

iv) Energy used for powering ELECSHA = 3.6 kWh

b) **Petrol autorickshaw :**

i) Average mileage = 25 km/l of petrol (for 2 passengers)

ii) Calorific value of petrol = 8.74 kWh/l

Thus ELECSHA uses 25% less energy than petrol autorickshaws. From the above calculations it is evident that on every front-economic, environmental and energy ELECSHA is superior to petrol autorickshaw.

We also feel that small systems like rickshaws are most suited for electric vehicle development. This is because the present level of battery technology precludes large power output from light- weight batteries. Hence, the electric rickshaw can be easily designed with the existing motor and battery technology and to our mind is the best option for battery-operated vehicles, especially for a fair weather country like India.

Besides creating a non-polluting transport system in India, electric rickshaws will also provide dignity to rickshaw pullers. Presently rickshaw pullers are treated as belonging to the lowest rung of the society. Large number of rickshaw pullers told us that a motorized rickshaw will give them dignity. It is felt that the police and the people in general treat the motorized transport drivers with slightly more respect. Besides giving dignity, electric rickshaws can also provide extra income to the rickshaw puller since he can ply his rickshaw to greater distances in one day.

IV-5. **Commercialization of ELECSHA :**

Preliminary discussions with various manufacturers have been initiated to manufacture the ELECSHA. The manufacturers have included TI Cycles in Chennai, Hero Cycles in Delhi, Scooters India in Lucknow, and some smaller manufacturers in Lucknow, Pune and Baramati. The response from them is mixed. Some of them want ARAI stamp of approval, while others want more extensive trials, before they can commit themselves for manufacturing of ELECSHA.

Thus it is felt that it might be useful to set up 50 ELECSHAs in various cities. This will help in extensive testing. Besides, in making 50 ELECSHAs, initial teething problems of manufacturing will also be solved. There is also a need to test ELECSHA at ARAI, Pune.

A small private party in Pune has approached us to buy one ELECSHA and run it in Pune as a private vehicle. We hope to supply one unit to them in near future.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

V-1. Conclusions :

Based upon the present work, following conclusions can be drawn :

1. An electric cycle rickshaw, christened as ELECSHA has been completely designed, fabricated and test run at NARI.
2. ELECSHA is powered by deep cycle discharge batteries and has a PMDC motor, differential gear system, 2-speed changeable gear box and Mosfet-based D.C. drive.
3. ELECSHA can go upto 70 Km/charge and runs at 25-30 Km/hr with two passengers and one driver on level roads. The overnight charging is done by a specially designed stand alone 36 V, 15 amp charger.
4. With 2-speed gear box, ELECSHA has the capability of going uphill (10-15% slope) with two passengers at 15-20 Km/hr. It also has the capability of starting from zero velocity to go uphill with full load.
5. Three ELECSHAs have been fabricated and they have been tested in and around Phaltan. They have run a combined total of more than 6000 kms in test runs.
6. There has been enthusiastic response from local populace to ELECSHA. Various enquiries have been received regarding its price and marketing.
7. Major achievement of NARI in this project has been the complete designing of these vehicles and identification of parties in Pune for development of various components for ELECSHA.
8. Thus PMDC motor fabrication, and 2-speed gear box and electric controller development was successfully carried out.
9. The cost of ELECSHA is estimated to be Rs. 90,000/-. This includes an SMPS-based onboard charger.
10. The technology of ELECSHA is ready for commercialization.
11. Discussions with various parties have been initiated for commercializing it.

V-2. Recommendations :

Based upon this work, the following recommendations can be made :

A. Technology Issues :

1. One of the major components of electric vehicles (EV) is the PMDC motor. MNES should make a provision for exempting these motors from sales and excise taxes. This should be made applicable only for the electric vehicles program. Also these PMDC motors require ferrite magnets. MNES should recommend that these magnets should also be exempt from the above taxes.

2. The Indian batteries manufacturers are not yet making lightweight deep discharge batteries for EV purposes. MNES should provide incentives to the battery manufacturers, so that they can make these batteries. Obviously, the market volume at present is probably not enough for these manufacturers. Alternatively, MNES should recommend to the Finance Ministry that the duty on imported deep cycle discharge batteries should be reduced till the EV market picks up and the local battery manufacturers produce lightweight batteries.

3. Specifically MNES should make budgetary provision to NARI so that ELECSHA is tested thoroughly at ARAI in Pune. This test will help in increasing the confidence level of entrepreneurs who want to manufacture ELECSHA.

4. There is a need to put about 50 ELECSHAs in cities like Pune and Lucknow for test marketing them.

B. Policy Issues :

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

2. 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, it should get all the benefits presently available to these systems.

3. There is a need for National program on Electric vehicles to be run by MNES. This will be similar to biogas program etc., where EV users and manufacturers are offered soft loans to buy and sell EVs. We would not like to suggest subsidy, but urge MNES that through IREDA very soft loans should be provided for this program.

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