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Solar Based Micro Hybridized Auto-Rickshaw and its Feasibility Analysis for Bangladesh

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Abstract: Automobile rickshaws are small, three-wheeled vehicles which are being used thoroughly in many Asian countries (i. e. Bangladesh, India, Pakistan etc.) for the sake of transportation of public and goods. The vehicles are small and narrow allowing for easy transportability in busy Asian metropolises. In Bangladesh, auto rickshaws/easy bikes commonly offer their taxi-services, as they are incredibly inexpensive to operate. Concurrently these three-wheelers running on fuel cause severe air-pollution and produce considerable amounts of greenhouse gasses (i.e. carbon dioxide). This paper presents a transportation system based upon auto rickshaws that operate in an eco-friendly way. Existing vehicles are to be substituted by a micro cross type system redesigned in a manner which boosts the efficiency of the vehicle. In addition, a recharging infrastructure is proposed that will allow for the power-packs to be charged using partially alternative energy such as solar power. Thus far, we have appeared at the existing vehicle and the environment, in which it operates, made a model of the vehicle in SolidWorks13 software and investigated re-charging infrastructure requirements and designs. The goal of the research presented in this paper is to develop a compact, robust and affordable hybrid system as a way to significantly reducing fuel consumption and exhausts of auto-rickshaws.

Keywords: *Solar Power, Hybrid, Micro-Hybrid, Auto-Rickshaw, Environment Friendly Vehicle, Photovoltaic.*

Introduction:

With continued economic growth, all sectors of Bangladesh are developing day by day. With this development, megacities of the country are experiencing more traffic. Buses, Rickshaws and Auto-Rickshaws (Electric or ICE run) are the main public transports in it's megacities (i.e. Dhaka, Chittagong, Rajshahi). [1] The word rickshaw's is originated from Western language, and it converts to "a human derived vehicle". The word was first used in 1887[2] In Bangladesh the rickshaw commenced as a three-wheeled transport, known as pulled rickshaw, generally ripped by one man with one or two voyager. The rickshaw is a source of employment for male labors in Bangladesh from the 19th century being one of the oldest functions of transportation. The auto-rickshaw and the relatively modern iteration of the e-rickshaw (electronic rickshaw) because of their low cost is becoming more popular than taxis in 21st century. [3] In Asian megacities like Mumbai, Dhaka, Kolkata, Bengaluru, Chittagong this vehicle is mostly used for medium travelling distance (1 to 7 km's). Auto-rickshaws are a common means of public transportation in many developing countries in the world. [4, 1] Auto-rickshaw is a three wheeler mostly running on fuel (CNG/LPG) or electrical energy.] Those running on batteries by means of electricity are often called "Easy Bikes", locally. This is a very cost effective vehicle. LPG and CNG are non-renewable energy sources. At present in Bangladesh the fuel price is increasing day by day. That's why the auto rickshaw drivers are claiming more money from the passengers. Burning of petrol, natural gas and oils produces carbon dioxide, which is responsible for global warming. Moreover exhaust gases release different types of deadly fluid aerosols and chemicals to the atmosphere which is very harmful for humans and animals. [5, 6] Presently there are many different auto-rickshaw types, designs, and variations. The most common type is characterized by a sheet-metal body or open frame resting on three wheels, a fabric roof with drop-down area curtains, a tiny cabin at the front for the driver (sometimes known as an auto-wallah) with handlebar controls, and a valuables, passenger, or sewing-embroidery space at the rear. [7] The best way to redesign the rickshaw is to make the key power source replenishable. One way to do this is to use an energy system that can take advantage of several sources of renewable energy - namely, electricity. Auto-rickshaws are a great prospect for electrification because of relatively low velocity and a relatively small distance protected in a day. [1, 4, 8, 9]In this paper a mechanism using micro hybrid system to run a car rickshaw is shown and defined. Solar energy and thermal energy can be used to drive the auto-rickshaw jointly by means of hybridization. Solar energy is chosen here because Bangladesh gets huge amount of energy from the sun. Here the best sunlight hours received is in Khulna ranging from 2.86 to 9.04 hours and in Barisal with readings varying from 2.65 to 8.75 hours. [10]

Theory:

In this proposed vehicle, electrical and thermal energy sources are combined via micro hybrid system. As energy sources ICE and Batteries are being used. These two power sources are hybridized. The battery is charged my means of national grid and solar energy. There are several hybridization methods available like Series, parallel, series-parallel and complex; parallel hybridization is implemented here. The basic difference between a hybrid and a conventional vehicle is the braking system. Hybrid vehicles use regenerative braking system; an energy recovery module which slows down the vehicle by transforming it's kinetic energy into a form used immediately to other works or stored for further use. Thus hybrid vehicles are less fuel consuming.[11].Figure-1 shows the schematic diagram of the vehicle power train.

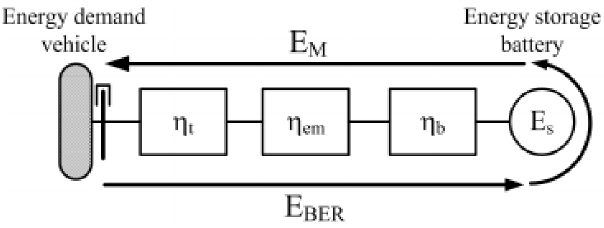

***Figure 1:** Schematic diagram of power train [9]*

Topology Optimization:

In addition to the element sizing and control engine optimization, the topology selection also plays an important role in the general hybrid drive train optimization. In figure, an understanding is given of different locations of joining of the hybrid system to the drive coach. If more hybrid driving modes can be used, then fuel saving potential rises. Depending on the topology a number of the hybrid functions can be utilized very well and other functions increase difficulties. In Table- I an overview is given of the pros and cons of the different topologies. Via this qualitative comparison it can be concluded that topology 1, 3, and 5 perform the same and are therefore favorable.

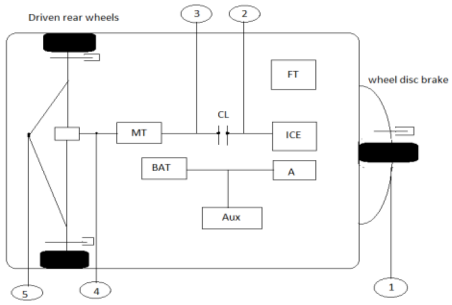

***Figure 2:** Topology designing of the proposed vehicle [9]*

A Table showing the topological analysis is give below:

Topological Options for Proposed vehicle: ++ = very good, + = good, - = bad, ∅ = not possible

Topology	1	2	3	4	5
Regenerative Braking	+ +	−	+	+	+
Electric Driving	+ +	∅	+	+ +	+ +
Charging (Driving)	−	+ +	+ +	+	+
Easy Mounting	+ +	−	−	−	+
Compacting	−	+	+	−	−
Start-Stop	∅	+ +	+	∅	∅
Motor-Assistance	+	+	+	+ +	+ +
Possibility Score	***43%***	***25%***	***40%***	***25%***	***50%***

Table 1: Topological Analysis

Figure-2 shows the topology designing of the proposed vehicle. The numbering indicates the possible locations of the components of the system. Here, ICE-Internal Combustion Engine, A-Alternator, FT-Fuel Tank of the vehicle, CL-Clutch (Wet-Plate type), BAT- Battery, Aux- Auxiliary Parts.

Power Analysis:

This paper focuses on micro hybridization of three-wheeler auto-rickshaw. Topology of the proposed system is shown in Table-I. This system has a conventional ICE and an electrical energy source namely, Li-ion battery used generally for medium load transfer.

A micro hybrid vehicle uses a ‘start-stop system’, a regenerative breaking technology is applied here for stopping an ICE when the system pulls to a stop and to restart it by pushing the accelerator. A vehicle can be hybridized in many different mechanisms. Micro hybridization is the simplest type. Here the proposed vehicle is being designed and the power calculations along with fuel consumption economy has been done under typical conditions and the parameters (with dimensioning) of the machine elements are given as per local market specifications available in Bangladesh.

Engine Specifications and Testing:
The specifications of the experimental engine are given below in a table-II: [12, 13]

Parameters	***Dimension (SI unit)***
Piston Diameter	.050228 × 10^{-3}Meters
Bore Radius	0.025114 × 10^{-3}Meters
Length of the Bore	0.046 Meters
Length of Stroke	0.042 Meters
Cubic Capacity	69.9 × 10^{-6} Cubic Meters
Type of Engine	2 Strokes
Number of Cylinders	01 pcs
Torque	12.531 N-m
Engine Efficiency	25%
Fuel	Petrol/Octane
Volume of Engine Cylinder	19 Cubic Meters (Approximate)
Brake Power	2.61kW @ 5000 rpm speed

Table 2: Experimental Engine Specifications [14]

Power calculation for experimental ICE:
Power calculation for ICE shown in Table-III.

Particulates	Equation	Value
Displacement of engine	$\pi . S^2 . B . n$	69.79×10^{-6} Cubic Meters
Stroke	$\frac{4D}{\pi B^{2n}}$	0.042 Meters
Bore	$\frac{4D}{\pi Sn}$	0.046 Meters
BMEP	$\frac{2\pi \times Torque}{Displacement\ of\ Engine}$	1129773.7 Pa
Fuel Consumption		10 kg/hr (Assumed) = 0.014 m^3/h (As 1kg/sec = 5 m^3/hr)
Mass Flow Rate	$\frac{Volume\ of\ Engine\ Cylinder \times}{Time \times 10(}$	0.014 m^3/hr = .0028 kg/sec
Angular Velocity	$\frac{2\pi N}{60}$	521.5 rad/sec (N = Engine Speed in rpm)
S.P. Fuel Consumption	$\frac{Wt. of\ Fuel}{Brake\ Power}$	0.036 kg/kW (Approximately)

Table 3: Power calculation for IC engine

Solar PV Module specifications and Calculations:
The battery used as electrical energy source will be charged in two ways, from National Grid and Solar PV module respectively. A perfect designed PV module is needed to charge the batteries. The specifications of the PV module are given in the following Table-IV below.

Parameters	***Dimension (SI units)***
Solar Panels	2 pcs
Rated Output	12V-180 W (Total)
Dimensions	1.5 × 0.8 × 0.05 meters
No. of Cells per Panel	N/A (variable)
Efficiency	18% (Approximately)
Battery	24 Volts, 4 pcs
No. of Solar Cells	60 mono crystalline cells

Table 4: Experimental PV module Specifications [15]

Power Consumption for PV module:

Total Power = $Total\ weight\ of\ vehicle \times g \times speed \times gradient\ of\ velocity$

= $500 \times 9.8 \times 35 kmph \times .03$ Watts

=$500 \times 9.8 \times 9.7 mps \times .03$ Watts

=1426 Watts Here, the induction motor used is of 12V-1kW rated.

Current Flow = $\frac{P}{V} = \frac{1500}{36} \approx 42$ Amp.

Load Current per Day = $Current\ Flow \times Running\ Time\ per\ Day \times 1.2$

=42 × 5 hrs × 1.2 ≈ 250 Amp.hrs/Day

Capacity of the Battery = Load Current per Day × 1.2 = 300 Amp.hrs/Day (overall 25% losses)

Power required to run the motor = Capacity of Battery × Voltage Difference

=250 × 36 = 9000 Whrs/Day

No. of Batteries to be used = $\frac{1430}{378}$=4 pcs

Now, here The Capacity of Solar Panel is 12V-180W,

Current Flow = (180/12)/4 = 3.75 Amp to each Battery

Charging Time = 250/3.75 = 66.67 hrs

If one Solar Panel is used then in 8 hrs of daylight the system will be charged $\frac{100 \times 8}{73.8}$ or 12%. But if the numbers of solar panels are increased then this charging would be more efficient. This percentage of charging can be increased by increasing the number of solar panels. If two solar panels are used, then the system will be charged 24% using PV module.

Feasibility testing:
Feasibility of this proposed system is analyzed by means of system installation cost and it's impact on environment.

Cost Analysis:
Total power calculated to run the system = 1426 watts
Power required to run the motor 9 kwatts.hr/day=9 unit
In Bangladesh commercial electric line cost 25 bdt/unit
Requires =9000/ 5*36*4=12.5 hours to charge the full battery.
Cost to charge the battery= 12.5*25=312.5 bdt/day
Case-1: When 1 pcs of Solar Panel is used,
PV module will supply 12% of total power.
So PV module will supply=9000*.12=1080 watts/day
So, Cost reduction= (1.08kw.hr*25) =27 bdt/day
Typical 180 W PV module costs approximately 40-45 k bdt.
For two 40K payback time=40000/27=1482 days=4.05 years (approx.)
For two 45K payback time = 45000/27=1667 days=4.57 years (approx.)
Case-2: When 2 pcs of Solar Panel is used,
PV module will supply 24% of total power.
So PV module will supply=9000*.24=2160 watts/day
So, Cost reduction= (2.16kw.hr*25) =54 bdt/day
Typical 180 W PV module costs approximately 40-45 k bdt.
For two 40K payback time=80000/54=1482 days=4.05 years (approx.)
For two 45K payback time = 90000/54=1667 days=4.57 years (approx.)
Thus, Case-2 is more favorable.
Figure-3 shows a graphical representation of the cost analysis of the system installation.

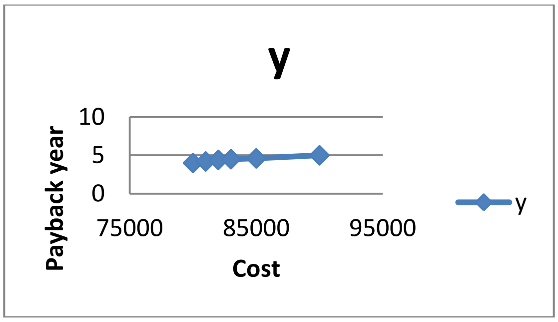

Figure 3: *Graphical representing cost analysis of proposed system installation.*

So, the payback time of this proposed system is between 4-4.5 years (approximately). A typical auto-rickshaw running age is between 18-20 years without much fluctuations in it's performance [16] .Figure-4 shows the relation between the running age and performance of a typical auto-rickshaw of Bangladesh.

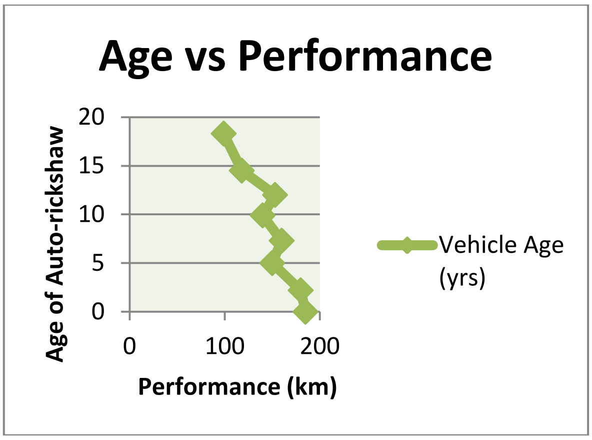

Figure 4: *Graphical relation between running age and performance of a typical auto-rickshaw.*

This proposed system needs 4-4.5 years to gain the installation cost, this payback time is only about 22.5-25% or ¼ th of the total running lifetime of an auto-rickshaw.

Environmental Impact Analysis:
Environmental impact analysis of a system is a mathematical prediction of that shows how much environment friendly that system is or how much harm can it cause. It is a very important factor regarding feasibility measurement of a system. This research is mainly focused on lessen the conventional energy consumption via using renewable energy in Bangladesh.
In Bangladesh, electricity is mainly produced by using thermal power plants. Those thermal power plants are a key source of CO2 gas emission resulting in enhanced greenhouse effect. [5] A 500MW thermal power plant can produce upto 1 kg/kWhr production of electricity.[17]
Table-V gives a complete knowledge about CO2 emission from the power plants of Bangladesh.
All these properties are approximate and some are estimated.

Installation Name	Capacity (KW)	CO2 emission (tons/day)	Nature of Combustion
Ghorashal	955	12.926	Oil Ignited
Barapukuria	250	5.685	Coal Fired
Ashuganj	660	4.1096	Oil Ignited
Khulna	225	2.5699	Dual Fuel
Haripur AES	360	1.789	Gas
Katakhali	50	0.72399	Oil Ignited

Table 5: CO2 emission rate (estimated) from some power plants of Bangladesh. [18, 19, 20, 21]

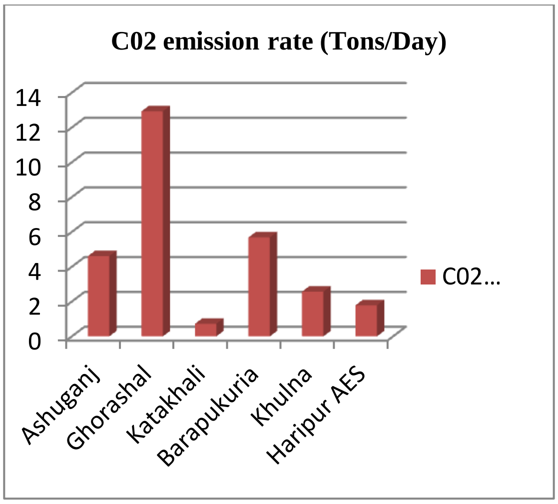

Figure 5: CO2 emission rates of various power plants in Bangladesh.

Figure-5 shows CO_2 emissions of various power plant of Bangladesh. Our proposed vehicle system offers about 24% less power consumption from National Grid. So, a big number of these proposed vehicles will save more electrical energy resulting less emission of CO2 from the fuel fired power plants.

Here, Katakhali Power Plant (Rajshahi) of 50MW capacity will be kept under consideration for calculation.

Assuming the plant as a 24 hrs/day working system,

Maximum electricity supplied by the plant = 5000 kWhr

The daily CO2 emission from Katakhali = 0.72399 tons

Daily emission of CO2 per kWh energy = $\frac{Daily\ CO_2 emission}{Capacity\ of\ the\ Plant\ per\ Day\ in\ kWhr}$ = 1.44798×10^{-4} tons

Now, if this proposed vehicle system is implemented on Rajshahi City then,

Let, The numbers of proposed auto-rickshaws = 2000 (estimated)

Energy savings per day per vehicle = 2.16 kWh [From previous feasibility calculation]

Total energy savings per day = (2000*2.16) kWh = 4320 kWh

CO2 emission to produce 4320 kWh supply is $=(4320 \times 1.44798 \times 10^{-4})$tons = 0.62553 tons (w.r.t. Katakhali Plant)

Lessen of CO2 emission from Katakhali via using this system = $\frac{0.62553}{0.72399} \times 100 = 86.4\%$

From the above analysis it can be surely said that the proposed vehicle system if implemented in Rajshahi City, then per day CO2 emission can be reduced upto 86.4% and power can be saved upto 4320 kWhr per day. This analysis was performed considering no system loss; there remains a 25% system loss in thermal power plants. If the system loss is considered then actual percentage of CO2 emission lessens from Katakhali Plant will be about 76-82%.

This feasibility analysis shows this system not only a cost effective but also an environment friendly one. This analysis mathematically proofs that vehicle system to be an effective one.

Properties of proposed mechanism and comparison with other systems:

1. Less noise production.
2. Less fuel consumption.
3. Environment friendly.
4. Less vibration.
5. Utilization of renewable energy.
6. Economical.
7. Finally, The system goes with the flow of modern technology.

Differences among typical (ICE), electrical and hybrid auto rickshaw:

Typical	***Electrical***	***Hybrid***
Huge amount of fuel consumption	Electrical power is used which is not always available in Bangladesh	Uses both electrical and Thermal energy. So pressure on only one energy source reduces
Its pretty costly since fuel price is too high	Takes a lot of Electrical energy to charge the battery. so it can be considered costly too	Less costly because the battery can be charged by solar energy too.
Not environment friendly	Environment friendly	More environment friendly than typical rickshaw
Too much noise produces	Noise production less	Noise production less than typical one
Can carry more load than electrical Auto rickshaw	Carries less load than both of them	Can carry more load than electrical one
Vibration more	No vibration	Less vibration

Conclusion:

In the above described hybrid system A whole system combined with an ICE and electrical power source (rechargeable battery can be charged by solar power and national grid) was used which is not so familiar fromthe perspective of Bangladesh. Some of the data were collected from different auto rickshaw driver. Some data were neglected which were far away from the majority. Quite similar mechanism now a days can be seen in different automobiles but here the system is applied to a three wheeler.

Personal recommendations:

1. The engine being used here is an old one. The efficiency of the system can be improved by using a modern or developed one.
2. Since a new generation and developed system is introduced here so the driver needs to be a skilled one.
3. Wind turbine can be used in front of auto rickshaw to take out more advantage of the system.

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