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RESEARCH ARTICLE

Design, Construction and Performance Study of a Solar Assisted Tri-cycle

Mahadi Hasan Masud[1*], Md. Shamim Akhter[1], Sadequl Islam[1], Abdul Mojid Parvej[1], Sazzad Mahmud[1]

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Abstract

Solar energy is one of the important sources of renewable energy which can be a feasible alternative to fossil fuels. There are many works has been done in order to incorporate solar energy to everyday transportation including tricycle. However, most of the tricycle develops are expensive and not feasible for developing countries. In this study, a cheaper solar tricycle with more capability of utilizing the solar energy is designed for developing countries. The main content of the tricycle is Solar PV panel, Brushless PMDC motor, controller, and battery. The power transmission of the solar tricycle is also simple. It is found that tricycle serves 24% back up for running, by the solar panel. Also, the total construction cost of the tricycle is only 240$ with near about zero impact on the environment. This paper highlights the advantages of the dual mode of charging, including the economic and environmental feasibility of the tricycle.

Keywords

tricycle, solar energy, PV Cell

[1] Department of Mechanical Engineering,
Rajshahi University of Engineering & Technology, Bangladesh

[*] Corresponding author, e-mail: masud.08ruet@gmail.com

1 Introduction

From the beginning of the industrial revolution, the rate of energy consumption has increased at an alarming rate due to the synergistic effect of individual energy consumption and population. This situation can be overcome with mass production of the photovoltaic (PV) cell which uses solar energy with low fluctuation converted into electrical energy. The electrical energy is obtained by converting the Sun's energy by the photovoltaic (PV) cell. By using this method, solar vehicles can be run which reduce the pressure on the energy sector as well as help to make the environment green. Although it is not a popular vehicle, but for reducing CO_2 emission and to make the environment pollutant free, energy systems will require a large share of renewable energies, such as solar photovoltaic power, which is used in the tricycle here [1].

The motive force to a shaft by an electric motor which is run by solar energy after some important conversion in electric vehicles instead of an internal combustion engine which is environmental pollution free is the basic working principle of a solar assisted tricycle. The electricity produced by photovoltaic (PV) cells using sunlight powers the electric motor directly for driving of solar-powered vehicles (SPVs). During sun shining the electricity is produced by PV cells otherwise, the vehicles use consuming energy in its batteries. There are different types of tricycles which can be classified as paddle tricycle, motorized tricycle, and electric tricycle. Paddle tricycle requires a lot of energy to paddle the tricycle which makes the user tired. Concentrate [if the user is a student] on the lesson become very tough when they reach their educational institution after peddling a paddle tricycle. Next, the motorized tricycle is powered by fuel but which is costly. Besides that, this tricycle will produce a bad impact on our environment by warming the earth. Lastly, the electric tricycle is based on the battery is run by using solar energy [2]. For dreaming a healthy city, the electric tricycle is the best among three cycles. They emit fewer fumes, offer the city dwellers to work without being sweaty and getting a car without waste. Here, in the below Table 1 a list of solar powered vehicles which are constructed in different areas of the world with its construction cost, year, places and features are shown.

Table 1 List of solar powered vehicles constructed in different places:

Year	Construction area	Features	Cost ($)	References
1955	General Motors Powerama	It consists of 15-inch “Sunmobile”, but due to its small size, the Sunmobile could not be driven by a human.	410	[3]
2008	Woodbridge Elementary School in California	The solar-powered tricycle was simulated, which was energized by a 600-watt motor and speeds of up to 17mph.	500	[4]
2009	Woodbridge Elementary School in California	A solar powered vehicle was constructed having a 100W solar panel, 750 W DC motor, battery, and controller.	540	[5]
2010	Christu Jyothi Institute of Technology & Science (CJITS), Jangaon	A new innovation of a solar tricycle had invented which was made with a 40W solar panel, motor, and mechanical gears.	500	[6]
2011	University of Engineering and Technology, Lahore in Pakistan	An electric reverse tricycle (two wheels at the front and one at the back) for one person was invented which is powered by solar energy.	600	[7]
2012	India	A hybrid solar car was introduced which consists of internal combustion engine (ICE) and solar panel, electric motor powered by storing battery system energized by a solar panel.	1000	[8]
	India	A study about the design and feasibility of solar powered bicycle had given where the 250W motor and 2 solar panels of 20W were used and maximum speed 25 km/h was found.	800	[9]
2013	A group of PEC mechanical engineers	Three batteries and a 250 watt motor inside the vehicle was used. The motor, which weighs approximately 5kg, gets its power from solar energy. This vehicle can reach speeds up to 15kmph.	700	[10]
2014	India	A vehicle consists of 850 W motor, 4 batteries and 4 solar panels of 100W and the average speed was 15-20 km/h was made.	1500	[11]
	India	A solar tricycle, especially for a handicapped person, was constructed by a 250-watt motor, the three-wheeler can reach speeds of up to 33 km/h and load carrying capacity are 90 kg.	950	[12]
	Group Name: “Team Solar Pedal”	A solar powered vehicle was constructed where 850 W motor, 4 batteries and 4 solar panels of 100W was used. Its average speed was 15-20 km/h.	1100	[13]
	Pakistan	A scooter made of 350 W DC hub motor and 4 solar cells for charging the 48V/20AH battery was invented.	650	[14]
2015	India	A simulated model for charging plug-in electric vehicles from a common solar panel had introduced.	700	[15]
		A solar power assisted tricycle had evaluated which consists of 300 W motor, 2 batteries of 12V, 20 W solar panel and the maximum speed of a plain flat road with zero slopes without pedaling was 9 km/h.	900	[16]
		A solar power tricycle had invented on the basis of the 75W solar panel and 250W DC motor which load capacity is 90 kg and highest speed is 15 km/h.	650	[17, 18]

Beside all of this, a prototype hybrid solar vehicle has developed to do several experimental activities. [19]. Also, a discussion about the environmental issues of solar power assisted vehicle over conventional IC engine has performed [20].

The main concern of this tricycle is to improve efficiency and lowering costs so that it can be feasible to all. The CO_2 emission has increased from 12 billion metric tons to 32 billion metric tons from 1965 to 2010 A.D [21]. The rate of emission of CO_2 is an indication of global warming. So, this will be environmental pollution frees too. The cost of recently invented solar vehicle is varies between 600-4000. To reduce the cost of the solar vehicle is another challenge. The cost of this vehicle is targeted to reduce around 250-300. Most of the solar vehicle has been made for one person. Here, a solar tri-cycle can carry two people. Here the target was to design and construct a lightweight tricycle too.

2 Materials and methods

2.1 Main parts of Tricycle

The Solar tri-cycle is a three-wheeled vehicle, assisted by solar energy or fully powered by solar energy. A brushless DC motor, solar panel, battery, charge controller was used as the component. The energy obtained from solar radiation by two direct forms:

i) Electricity obtained from the solar cells due to excitation of the semiconductor on PV cell.

ii) Solar collectors accumulate the heat.

The main components of PV solar systems are i) solar panels or solar arrays, ii) balance of system, iii) load [22]. The working principle of solar cells is based on the photovoltaic effect, i.e. due to electromagnetic radiation potential difference is created at the junction of two different materials. The conversation of chemical energy into electrical energy is done by a battery. The chemical reactions take place in galvanic Cells will generate electricity involving the transfer of electrons. A rechargeable battery is likely to store energy or discharge energy in many times, storage battery, on the other hand, a non-rechargeable or primary battery is contained fully charged, and discarded once discharged.

The charging action is occurring by converting the positive, active material into oxidizing and the negative material for consuming electrons. The electrolyte is supplied as a buffer for electron flow between the electrodes. The external circuit is operated by the current flow with the help of constituent electron.

The DC current is converted to an AC current with the help of a brushed DC motor which main parts are a commutator and brushes. Due to the flowing current through the armature windings, the nearby magnets repel the EM (electromagnetic) field for the same polarity and the attraction of magnets of opposite polarity will rotate the magnet. Fig. 1 shows the power generation system for the tricycle.

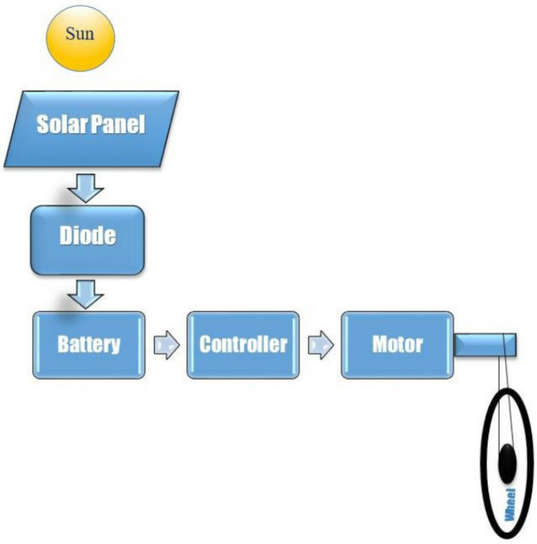

Fig. 1 power generation system for a tricycle.

The solar energy from the sun on solar cells will generate the potential difference at the intersection point of two materials for electromagnetic radiation. A galvanic cell, i.e. a battery is used to produce electricity by transformation of an electron in electrochemical reactions.A rechargeable battery is used to accumulate charges. These electrons constitute the current flow in the external circuit. The mechanical energy is obtained with the help of a DC motor which converts direct current (electrical energy). Finally, the obtaining energy is used to transmit power from the motor to the wheel with the help of the chain drive system.

2.2 Design and Construction

The weight of the chassis should keep minimum to improve the acceleration and full speed. Materials for chassis should have enough strength to withstand the load of the vehicle and driver. Mild Steel Pipe is such kind of pipe that is comparatively light in weight and has enough strength to carry loads of the driver, vehicle, and small load. The transmission of power from the battery to the wheel is done by a chain drive which is clearly shown in Fig. 2.

Fig. 2 Power transmission from motor to wheel

Fig. 3 and Fig. 4 represent the Conceptual view and Experimental view of the tri-cycle showing all the main parts and required dimensions.

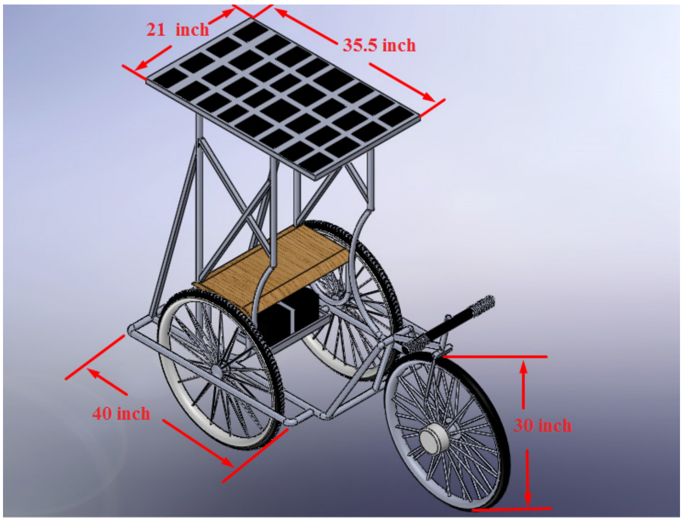

Fig. 3 Conceptual view of the tricycle

Here, d = tricycle wheel rim diameter in the meter. r= tricycle wheel rim radius in meter, ω = Angular velocity of the tricycle in rad/s., N = Speed of tricycle wheel in RPM, v = Speed of tricycle in km/h, the N_1=Normal reaction of the road on each tire of the tricycle in Newton. , μ=Coefficient of friction = 0.3, F= Frictional force between tire and road in Newton, T=Torque developed on the shaft due to frictional force in N-m, P= Power required riding the tricycle in Watt, I=Moment of inertia in m^4.

Table 2 Required important formula used to design the tricycle

Description about the required equation	Formula
Tricycle wheel rim radius, r	r= d/2
The friction force acting on each tire, F	$F = \mu N_1$
Torque developed on the shaft due to the frictional force, T	$T = F \times r$
Angular velocity of tricycle, ω	$\omega = v/r$
Power required to ride the tricycle, P	$P = \frac{2\pi NT}{60}$
Bending stress developed in the MS pipe used as the main material of the tricycle, Ϭ	Ϭ = WI/Z $Z = \frac{\pi}{33}\frac{D^4 - d^4}{D}$

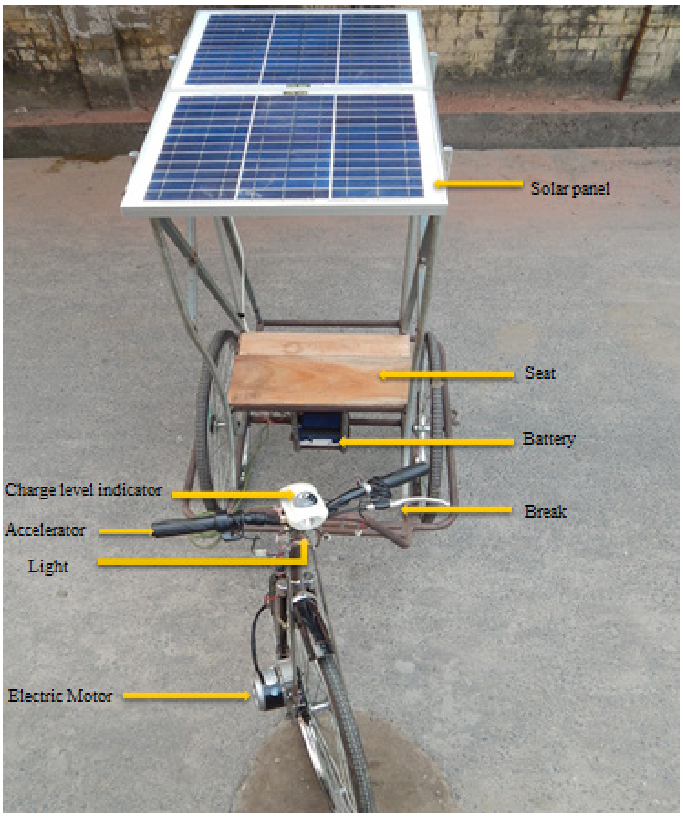

Fig. 4 Experimental view of the tricycle

2.3 Investigation

2.3.1 Charging the battery

At the very first a sunny placed was selected for charging the battery of the tricycle. Then solar panels and batteries were made the series connection and then connected with each other to complete the circuit. A diode was used to the flow of current in one direction. After completing the circuit connection, tricycle was placed at the selected sunny place. Between 1-hour time interval, voltage and current were measured by a multimeter. Voltage was measured directly, but the current was measured with respect to 15-ohm resistor. Then the power was calculated which showed the level of charge of the battery. This procedure also followed to run the tri-cycle with only the battery which was charged fully. It took 11 hours to complete charging of the battery.

2.3.2 Discharging the battery

At the beginning, 5 km area was selected at a certain sunny place to run the tri-cycle. After one round within that selected area, the level of charge was measured. This procedure was repeated until the tricycle was stopped due to discharge the battery. After 5 rounds, the tri-cycle was stopped. But the level of charge was about 15 percent. The tri-cycle served 25 km. It took about 2 hours and 30 minutes.

2.3.3 Charging and discharging simultaneously

At the starting, battery was charged fully with the help of electricity. Then solar panel was connected to the battery. Then it was run within that selected 5 km area. After one round within that selected area, the level of charge was measured. This procedure was repeated until the tricycle was stopped due to discharge the battery. It was found that, after 6 rounds, the tricycle was stopped. But the level of charge was about 15 percent. The tricycle served 31 km. It took about 3 hours.

3 Results and discussions

From the experimental values, the findings that are obtained by observation are shown in Table 3.

Table 3 Important data that are found from the experiment

Features	Capacity
Maximum load carrying capacity in (kg)	150
Maximum speed in (km/hr)	26
Charging time of battery without operation in (hr)	11
Movement of fully charged battery in (hr)	2.30 (equivalent to 25 km)
Movement with charging the battery by using solar energy in (hr)	3.00 (equivalent to 31 km)

It can be said that, the tricycle construct with low cost and light weight, which can carry a 150 kg load with 26 km/h speed which is really a better one. It can also move a greater distance as found from the Table 3 which is equivalent to 25 km with a full charged battery, but 31 km in the case of a battery which charging in the running time. So, when the solar system is active, the storage system can get back up about 24% which is equivalent to 6 km.

3.1 Charging the Battery

The charging of the battery is done by solar energy. As it takes approximately 11 hours from being fully charged, but as solar energy with high intensity is not present for the full time of a day, for this reason charging was done in two different days in the full sunshine. The level of increasing charges by day time is shown in Fig. 5, in which level of charges (%) exists in the vertical axis and time of day is on the horizontal axis. Also, the standard deviation is shown in Fig. 5.

The experimental data were taken on six different days. For charging the battery fully, every time two days were taken. The experimental date for charging the battery was 3rd to 8th September 2015. Theoretically, the charging profile should be linear, but not exact in our study because the solar intensity on the panel varies by time of the day. After 60% level of charge, the slope was downward because data was taken on the next day morning. At the end of charging, the rate of charging the battery was slow because the reaction rate of the battery was slow. Also, as Fig. 5 shows the standard deviation too, from the graph it was found that the maximum level of standard deviation is only 1.527 which is really small. So finally it can be said that the similar characteristic of charging is found for all the different days.

3.2 Discharging the battery with a solar panel

The battery was connected to the motor that runs the solar tricycle. While running the tricycle discharging was started. Discharging the battery while running the tricycle is a linear phenomenon. Fig. 6 shows the relation between the levels of charges (%) with a time of the tricycle. It clearly displays the decreasing of the storing energy due to consumption with the increasing of time.

Discharging of the profile of the battery with solar panel is shown in Fig. 6. On Fig. 6, the level of charge is reduced from 100% to 15%. Theoretically, the discharge curve should be linear, but on Fig. 6 it slightly deviates from the linear phenomena. It took approximately 3 hours for discharging the battery. It was found from the discharge curve that in the first half hour battery lost its 8% storage energy. But for the next every half hour discharge percentage was 17%, 15%, 11%, 14% and 20% respectively.

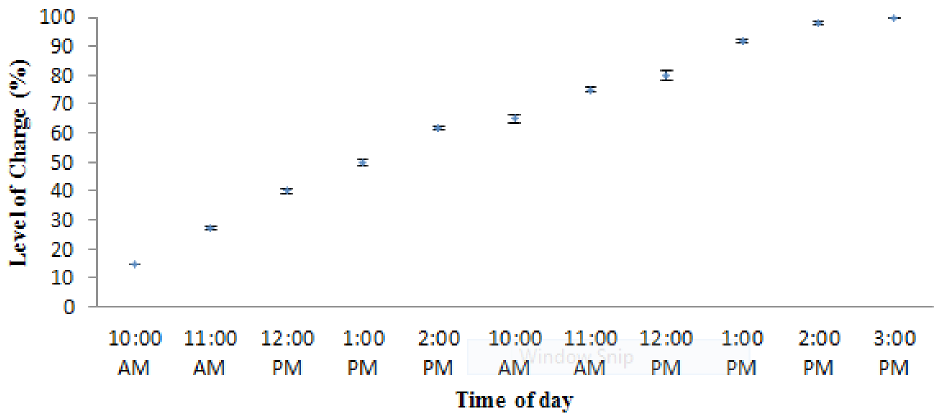

Fig. 5 Level of charge vs Day Time curve

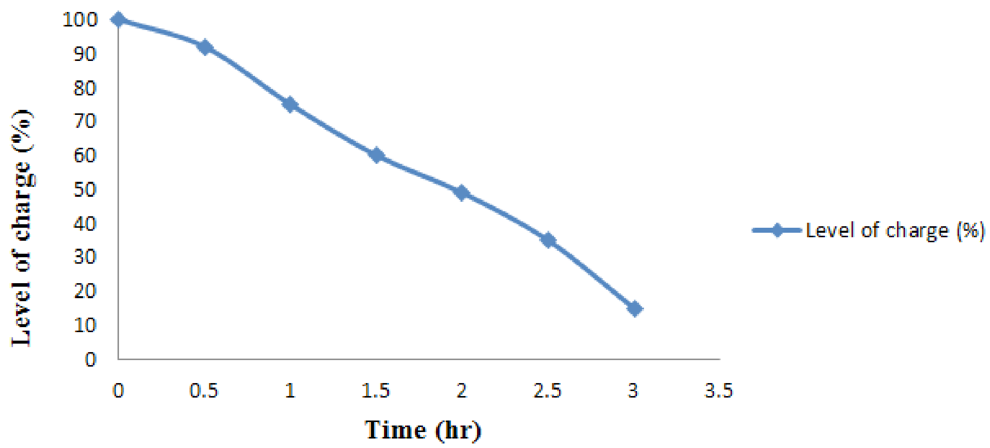

Fig. 6 Level of charge vs time curve

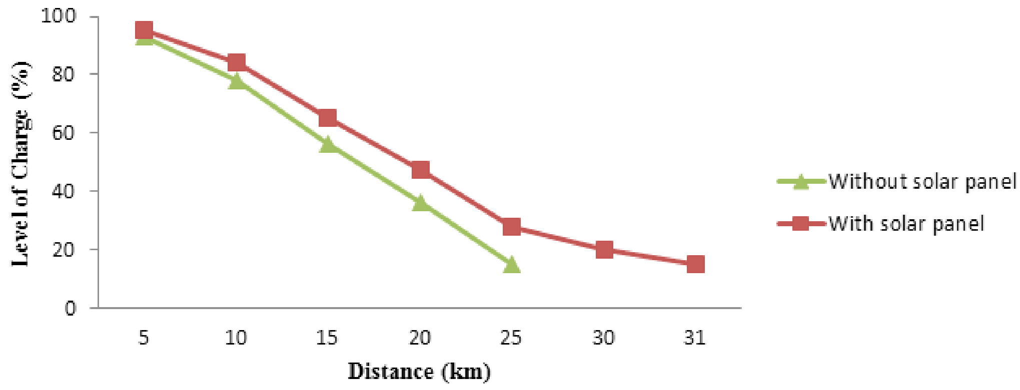

Fig. 7 Level of charge vs distance curve

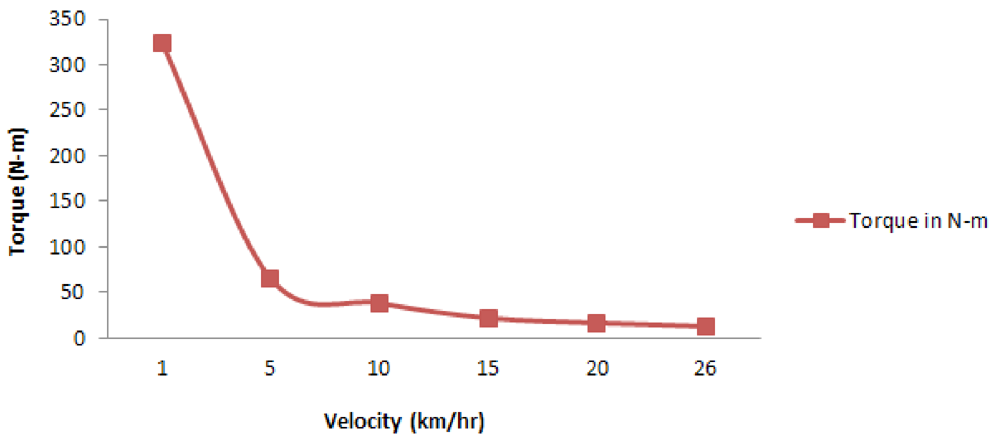

Fig. 8 Torque vs Velocity Curve

3.3 Charging and Discharging Simultaneously

In this portion two curves were found, one of which represents discharging the battery without connecting to the solar panel and the second one shows the discharging characteristics of the battery when it is connected to the solar panel. The variation of the level of charges with discharging without solar and discharge with solar is the main outcome of Fig. 7.

Fig. 7 shows the two curves of discharging the battery. The green line on the curve indicates discharging the battery without solar panel and the red line indicates discharging the battery when the solar is acting. Red line curve passed over the green line curve because some charge was accumulated in the battery during discharging. As a result, the red line ends at 31 km which is 6 km far from the green line end point. It shows the performance of solar assisted tricycle. So by activating the solar panel during discharge of the battery, solar tricycle runs more 24% than the running without the solar panel.

3.4 The torque required for different speed

Torque is also an important factor for designing the tricycle because torque is required to move the vehicle from a stop. The required formula for calculating the developed torque in the tricycle is already shown in Table 2. It is mainly important for acceleration, not for maintaining speed. In order to get up speed and overcome the wind resistance and friction torque is initially required. So torque is required to move the vehicle from a stop and helps it get up steep hills. From the Table 4, it is observed that with the decreasing of torque-velocity increases.

Table 4 Data table for torque at different speeds.

Observation no.	Velocity in km/h	Torque in N-m
1	1	324
2	5	64.8
3	10	38
4	15	21.6
5	20	16.2
6	26	12.5

Fig. 8 represents the relation between torque and velocity of the tricycle. From Fig. 8, it is seen that initial torque is high. With increasing speed, torque is reduced. At maximum speed, torque is minimized. At the beginning when the velocity is only 1 km/hr, the torque developed was 324 N-m, but with the increasing velocity, torque is also reduced. As in 5 km/hr velocity developed torque is 64.8 N-m and finally, at 26 km/hr velocity, torque is reduced to a minimum value of 12.5 N-m.

4 Feasibility study

4.1 Costs

The main parts of the constructed solar tricycle are Solar Panel, Battery, Motor, controller and three wheels with equipment. The cost of this equipment's with the material cost and setting the cost of the tricycle is shown in Table 5.

Table 5 Cost with different equipment's used in the construction of tricycle:

Description	Price in BDT
Solar Panel	3000
Battery, Motor, controller	8000
Materials and equipment	3500
Three Wheels with equipment	3000
Setting cost	1500
Total	19000

Here the total cost is 19000 BDT or 243.59$. This is comparatively lower than other solar tricycle. In previous construction, the cost was 400-2000 which is already shown in Table 1. But the constructed solar tricycle costing only around 240$. So the construction cost of the solar tricycle is reduced here. So in this cost analysis, it is seen that our tricycle is economical than other solar assisted tricycle.

4.2 Environment

The air pollution that warming the earth as a result of pollutants from the automobiles, which is about 23% of the total air pollution as shown in Fig. 9. One of the great problems faced in urban areas throughout the world is the increase in vehicles due to an imbalance between the public transport and the increase in population which, finally results in a huge amount of air pollution.

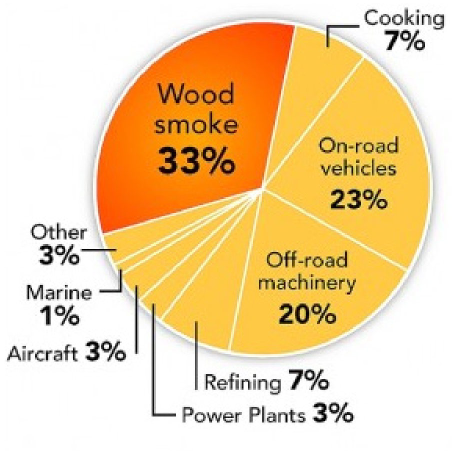

Fig. 9 Different reason of air pollution [24]

With the increasing rate of population, the number of vehicles is also increasing due to the imbalance between these two factors and finally the pollution rate is also increased [23]. Over the last two decades, many experiments have been done to control emission from IC engine. So in this respect, this solar tricycle may be one of the solutions because of pollutant free property.

4.3 Payback Period

The time at which the initial cash outflow of an investment is anticipated to be recovered from the cash inflows created by the investment is known as Payback period. This is the simplest investment assessment practices.

Based on the nature of cash inflow per period from the investment such as even or uneven, there is a different formula for calculating payback period [25]. For even cash inflow

$$\text{Payback Period} = \frac{\text{Initial Investment}}{\text{Cash Inflow per Period}}$$

Here, Initial Investment= 19000 tk
Cash inflow per period= X
Period= Year

<u>**Calculation of X:**</u>

If the tricycle is charged totally by using only solar energy, then it will take almost 11 hrs, when there is sufficient availability of solar energy. From Fig. 5 it is seen that it took two days to done the job.

But if it is completed by using electricity, then some bill should be paid. So, here our concern is to calculate the bill of electricity for fully charging the battery.

Given, Capacity of Battery= 28Ah, Voltage= 24V, Resistance of the Electric wire=13.3 , Voltage in the connection line=230 V.
In the time of charging the battery, From Kirchhoff's Law, I= (230-24)/13.3 =15.48 A
Time required for charging the battery by electricity, t= 7 hr
We know, W=V*I*t = (24*15.48*7) = 2600.64 Wh = 2.6 kWh= 2.6 unit
In Bangladesh, average electricity cost per unit= 7 tk
So, total expense = 7*2.6=18.2 tk/day
But, as if we use PV cell for charging the battery it will take two days, so this bill will cover for two days as we compared it with the PV cell.
So, total expense = 18.2/2= 9.1 tk/day
Cash inflow per period, X= 3321.50 tk/year

$$\text{So, Payback Period} = \frac{\text{Initial Investment}}{\text{Cash Inflow per Period}}$$

$$= \frac{19000}{3321.50} = 5.72 \text{ years}$$

The payback period seems a little bit higher as the manufacturing cost of prototype tricycle caused higher due to the retail price of the components. This period will be reduced when the tricycle is constructed in mass quantity.

5 Conclusion

The objective of this study is to design and construct of a cheaper solar assisted tricycle. The body of a tricycle, charging system, battery and the power transmission system are designed. After performance study, it is obtained that storage system can run the tricycle about 25 km and it gets back up about 24% power from a solar system which is equivalent to 6 km, if the solar intensity is around 1150 w/m^2 at the time of running of the tricycle. The maximum speed of the tricycle has been found at 26 km/h. This ensures continuous energy input to the tricycle without any additional cost. So, the tricycle designed and constructed in this study can be used as a green vehicle in developing countries due to its less expensive and zero pollution effect nature.

References

[1] Nunez, P., Farias, T., Brito, M. C. "Day charging electric vehicles with excess solar electricity for a sustainable energy system." *Energy*. 80, pp. 263-274. 2015. https://doi.org/10.1016/j.energy.2014.11.069

[2] Ravikumar, K., Sachin, R., Ganesh, T., Deep, V. "Design of Solar Tricycle for Handicapped Person." *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*. 5(2), pp. 11-24. 2013.

[3] Sunmobile 2012. [Online]. Available from: https://en.wikipedia.org/wiki/Sunmobile. [Accessed: 18th July 2015].

[4] Elementary School Teacher Builds Solar-Powered Tricycle 2008. [Online]. Available from: http://www.treehugger.com/bikes/elementary-school-teacher-builds-solar-powered-tricycle.html. [Accessed: 10th July 2015].

[5] Prabhu, V. N., Manigandan, N. "Design and Fabrication of Solar Transport Vehicle." *IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*. 4(2), pp. 14-19. 2012.

[6] WARANGAL 2010, CJITS students make solar cycles. [Online]. Available from: http://www.thehindu.com/todays-paper/tp-national/tp-andhrapradesh/cjits-students-make-solar-cycles/article524676.ece. [Accessed: 19th July 2015].

[7] Solar powered Reverse Trike 2011. [Online]. Available from: http://www.instructables.com/id/Solar-powered-Vehicle. [Accessed: 22th July 2015].

[8] Singh, R., Gaur, M. K., Malvi, C. S. "Study of Solar Energy Operated Hybrid Mild Cars: A Review." *International Journal of Scientific Engineering and Technology*. 1(4), pp. 139-148. 2012.

[9] Bachche, A. B., Hanamapure, N. S. "Design and Development of solar assisted Bicycle." *International Journal of Engineering and Innovative Technology (IJEIT)*. 2(6), pp. 452-457. 2012.

[10] Pedalling on solar power, 2013. [Online]. Available at http://e-man2100.blogspot.sg/2013/05/pedalling-on-solar-power-tnn-may-9-2013.html. [Accessed: 23 July 2015].

[11] Alisaa, K., Ankita R., Shivangi, S. "Solar Powered Vehicle." *International Journal of Electronics Electrical and Computational System*. 3(3), pp. 110-115. 2014.

[12] Jeyaraman, P., Praveen, V., Rajamurugu, N. "Fabrication of Solar Electric Tricycle for Handicapped Person." *International Journal of Pure and Applied Research in Engineering and Technology*. 3(4), pp. 285-292. 2014.

[13] Pedaling to solar-powered energy, 2014. [Online]. Available from: http://thedailycougar.com/2014/04/28/pedaling-solar-powered-energy [Accessed: 23th July 2015].

[14] Pooja, Iyer M, Teja, G. R., Prasad, V. S. "Design and Fabrication of Solar Electric Scooter." *International Journal of Research in Engineering and Science (IJRES)*. 2(5), pp. 21-28. 2014.

[15] Singh, R., Gaur, M. K., Malvi, C. S. "Study of Solar Energy Operated Hybrid Mild Cars; A Review." *International Journal of Scientific Engineering and Technology*. 1(4), pp. 139-148. 2012.

[16] Arulbel Benela, R., Jamuna, K. "Design of Charging Unit for Electric Vehicles Using Solar Power." In: 2013 International Conference on Information Communication and Embedded Systems (ICICES), Chennai, 2013, pp. 919-924. https://doi.org/10.1109/ICICES.2013.6508236

[17] Sankar, R., Pushpaveni, T., Prakash, R. "Design and Development of Solar Assisted Bicycle." *International Journal of Scientific and Research Publications*. 3(3), pp. 452-457. 2013.

[18] Arsie, I., Rizzo, G., Sorrentino, M. "A Model for the Optimal Design of a Hybrid Solar Vehicle." *Review of Automotive Engineering*. 29, pp. 439-447. 2008.

[19] Adinolfi, G., Arsie, I., Martino, R,, Giustiniani, A,, Petrone, G., Rizzo, G,, Sorrentino, M. "A Prototype of Hybrid Solar Vehicle: Simulations and On-Board Measurements." In: *Proceedings of Advanced Vehicle Control Symposium AVEC*, Kobe, Japan, pp. 917-922. 2008.

[20] Das, S., Kumar, A. "Concept of Electromagnetic Solar Based Power Drive for Automobile." *International Journal of Advanced Science and Technology*. 76, pp. 21-28. https://doi.org/10.14257/ijast.2015.76.03

[21] Beedu, R. "Design, Development and Performance Evaluation of Solar Power Assisted Tricycle." *International Journal of Research in Engineering and Technology*. 4(7), pp. 513-517. URL: http://esatjournals.net/ijret/2015v04/i07/IJRET20150407082.pdf

[22] Zeman, M., *Introduction to Photovoltaic Solar Energy*. 2014. [Online]. Available from: https://courses.edx.org/c4x/DelftX/ET.3034TU/asset/solar_energy_v1.1.pdf [Accessed: 25th July 2015]

[23] Harish, M. "A Study On Air Pollution By Automobiles In Bangalore City." *Management Research and Practice.* 4(3), pp. 25-36. 2012.

[24] USA Air Pollution Pie-Chart, Chart Template & Designs Category. [Online]. Available from: http://www.cleanri.com/category-chart/477/. [Accessed 19 July, 2015].

[25] FX, OCTA. n.d. "Payback Period Formula _ Examples _ Advantages and Disadvantages." [Online]. Available from: http://accountingexplained.com/managerial/capital-budgeting/payback-period. [Accessed: 23rd July 2016].