Andrei TOANCHINĂ

URBAN ELECTRIC TRICYCLE

Abstract: *An important play in an economic development and evolution of a country has the field of transportation. In most countries, transportation with personal car has started to become a problem, the streets are far too small and narrow for the large number of cars, and the population has started to grow considerably. Looking forward, technology advances with fast steps, deploying more and more types of electric, small, and different styles of vehicles. These include the electric tricycle. People travel with tricycles, primarily, because of the deficiency of other transportation and comfort, offering the benefits of speed and low cost. Because of the small structure of the commercial tricycle, passengers are crowded inside to maximize the number of passengers on the journey. Nowadays, engineers struggle to minimize this negative influence caused by tricycles, while continuing to design a vehicle that satisfy the necessary everyday transport of a growing population. This paper comes with an innovation, a structure that modifies its size. Therefore, it's projected a tricycle that can increase the capacity, fulfilling two important factors: functionality and comfort.*

Key words: *transportation, vehicle, tricycle, electric, folding, solar powered, design*

1. INTRODUCTION

The use of automobiles started to grow a lot faster than the human population, with saturation nowhere in sight. If present trends continue, more than 3 billion automobiles could be in use by 2050, that means more than 20 cars per 100 persons, with tasks such as fuel shortages, vandalism, sabotage, etc. This may cause apprehension in everyone's heart that vehicles powered by other energy sources are not a nice thing to have, but for sure, a necessity. Therefore, is projected a solution in the electric tricycles. An effective replacement, such as this, will certainly reduce automotive dependency [1].

The electric tricycle is an electrically powered vehicle that has zero carbon emission that can be used to carry a few passengers in short distances in small streets. This type of vehicle uses an electric direct current (d.c.) motor that gives motion to the rear wheels of the tricycle. This motor is power-driven by direct current from the battery group. The battery group is charged by a solar panel system directly installed on the roof of the tricycle, so even when the vehicle is moving, this panel will charge the battery to refill some power that has already been used. The tricycle's battery is also charged every time it brakes.

Electrically powered vehicles tend to cost more than their gasoline equivalents. The reason for that is that gasoline vehicles have advanced from a long time of intensive engineering, beside electric automotive have been virtually ignored for couple of years. A research found out, that electric vehicles ride about 20% more kilometres per litre than the equal gasoline engine model. Since all electric vehicles have become more and more popular, a question should be if the energy used to build gasoline engines for conventional vehicles is less than the production of an electric motor (fig. 1).

Not unexpectedly, there is a huge range of emission of CO_2 during the industrial of lithium batteries, especially as developments in fabrication of these batteries are happening almost every day. The manufacture - related emissions range is between 40 to 350 kg CO_2 per kWh of battery capacity. A 30-kWh battery pack from an electric vehicle can be equivalent to 4.5 tons of CO_2 just to produce its batteries. A lot of the studies specify that the used energy to manufacture the powertrain of a vehicle powered by an electric motor is greater, perhaps as much as 30%, than that used to build, for a gasoline engine, the internal combustion train [2].

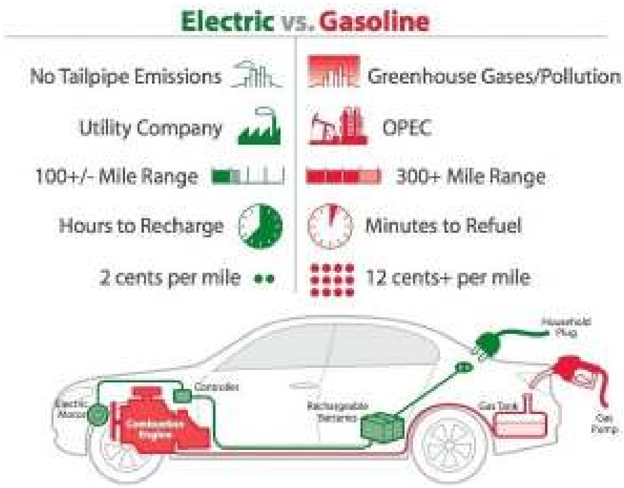

Fig. 1 Electric vehicles against gasoline vehicles [3]

The aim of the paper is to add to the current hand-powered tricycle, an electric power train and control system, to give the users a better level of mobility. The design purposes involve an affordable and simple projection for controls and power train, a design that has to be reliable and functional.

To design an ergonomically improved trike that can offer a great riding experience and determine a reliable and effective manufacture that maintains a continuous growth for the system will be the main purposes for this paper.

2. ADB ELECTRIC TRYCICLE DESIGN

Developed countries, has already an efficient public transport system and numerous private vehicles. However, the case is different in some evolving countries where transport infrastructure and roads are insufficient. In countries like the Philippines, roads are small and narrow, making transport very hard, and roads are often crowded. This daily limitation suggests the need for more creative means of transport.

In recent years, the Asian Development Bank (ADB), have collaborated with, the Philippines government, the Department of Energy (DOE), on a project that focuses on the adoption of large-scale electric vehicles across the country. The project included the adoption of an e-trike, the short term for an electric tricycle (fig. 2), and the development of a maintainable local electronics industry using innovative technologies and a solid supporting plan for operators and drivers. The use of an electric tricycle has some benefits, including greater energy efficiency, making it more environmentally friendly and more profitable for drivers [4].

Fig. 2 ADB electric tricycle

To obtain the best, electric tricycle is one of the newest products in the marketplace. It combines the ease of use of a tricycle with the performance of an electric motor. People claiming an electric tricycle are elderly, rehabilitation patients and delivery drivers.

The benefits are easy to notice, because coming to work in a relaxed way or riding on an afternoon, can still bring the delight of fresh air and sunlight. With an ability to select engine start-up, getting the right amount of daily workout is fun and easy. Most city travellers claim that the journey is much shorter due to the ability to travel on sidewalks or bicycle routes.

The most important aspect of an electric tricycle can be the protection for the environment and the energy saving. Emissions of electric vehicles are not harmful to atmospheric gases, even the power source can come from water, wind, light, heat, etc., which leads to solve many concerns that people cause by exhausting oil resources. In addition, electric vehicles can use low-energy night-time power, energy-generating equipment capable of balancing and practicing at night, while increasing their own economic benefit, thing that is also convenient.

Yet, the experience of riding a tricycle has some disadvantages and side effects. First of all, most models are not safe because the bodywork is considered too small and cabined, where, only up to four or, in some cases, five passengers can fit. Based on a survey, 7% of people had an accident in a tricycle. Secondly, since the majority of drivers are aiming to carry as many passengers as possible, most passengers are not offered a comfortable experience during the journey because they are crowded into a small space [5].

From the passenger's responses, some of the requirements for an electric tricycle were to improve interior space, more comfortable seat and additional safety features. These have been a priority in design considerations for the ADB electric tricycle. A great help in the design process was the anthropometric measurements of the Philippines population. The followers have implemented the first comprehensive anthropometric measurement of Philippines workers performed by Jinky Del Prado-Lu. These measurements were considered to be satisfactory and closed to be used because, based on the survey results, most of the passengers came to the age group of 15-34 years [6].

The Department of Energy (DOE) has started a design contest for electric tricycles named "Bright Now! Do Right. Be Bright. Go E-trike!" (fig. 3). With this contest they tried to promote Philippines's innovation and engineering in creating the Philippines version of these tricycles.

Fig. 3 "Bright Now! Do Right. Be Bright. Go E-trike!" contest poster

All Philippines nationals of legal age could join in this contest, whether individuals or groups living in the Philippines. Competitors were asked to present 2D and 3D-assisted drawings with the best artistic and functional design in AutoCAD format (fig. 4). The project had to fit a maximum of six passengers, without counting the driver for the three-wheeler electric vehicle [7].

Fig. 4 Top 3 winning designs

Based on an international safety and manufacturing requirements, the design consultant evaluated these models, and a design was used for mass production resulted (fig. 5 and fig. 6).

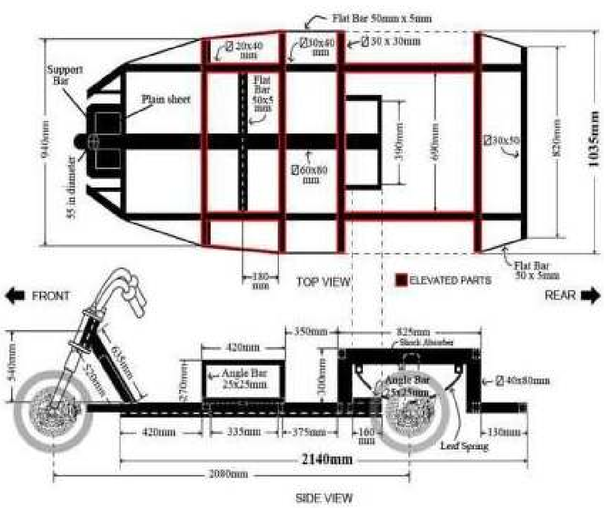

Fig. 5 ADB Chassis Design

Fig. 6 ADB e-trike dimensions

As a summary, in the next figure is shown the general design process of an electric tricycle (fig. 7).

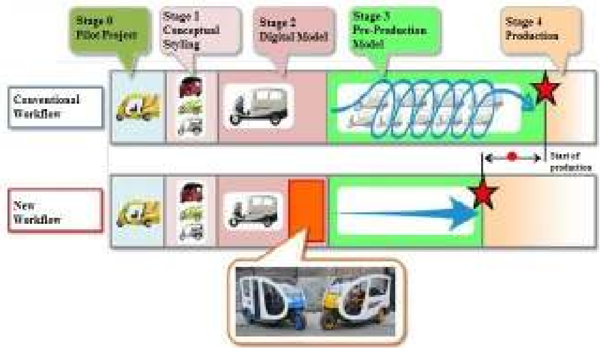

Fig. 7 Body design process flow [5]

3. ELECTRICAL SYSTEM DESIGN

The tricycle design is structured by an electric motor, a drive system, power supply, motor, and steering controls (fig. 8).

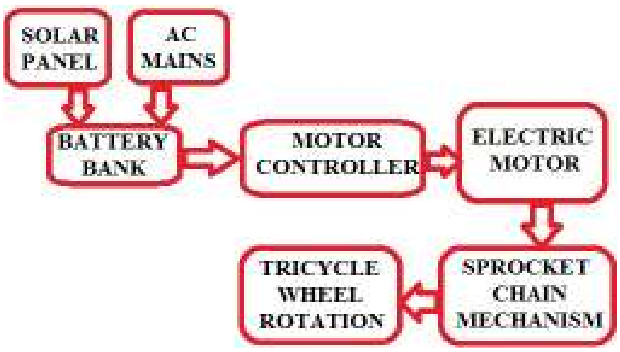

Fig. 8 Block diagram of the electrical system design

The electric motor is a mechanism projected to convert electricity into mechanical energy. The most used type of engine is the induction motor because all the advantages of electricity are combined, such as low cost, simple controls, easy delivery and clean handling. Together, with a simple building and with its variability, the engine is modified to wide ranges of loads and better efficiency.

Power is a measure that calculates the efficiency of the energy consumed. By power, we mean how fast energy is applied, by dividing the full energy or time until the moment of power is realized.

Therefore, raising a bucket of water with an electric motor in a certain time, the required power is expressed by the formula:

$$P_{mec} = \frac{F \cdot d}{t}(W) \qquad (1)$$

where:

$$F = force(N)$$
$$d = part\,diameter(m)$$
$$t = time(s)$$

For measuring the mechanical power, the most used unit of measurement is horsepower, abbreviated HP, which is equal to 0.736 kW (kilowatts - internationally used for the same purpose).

The relationship between power units is:

$$P(kW) = 0.736.P(cv)$$
$$P(cv) = 1.359\,P(kW) \qquad (2)$$

Because energy is the same, all the time, it can be expressed in different forms. When connecting a resistor to a voltage source, an electric current will pass through the resistance to heat. Resistance absorbs energy, transforming it into another form of energy, called heat. The electricity is absorbed by the electric motor from the power supply, turning it into mechanical energy [8].

A direct current motor drives the solar powered tricycle, fitted in front axis frame and functioned by solar energy. The solar panel that is mounted on the roof of the tricycle will charge the battery when the vehicle is standing still or in motion.

The tricycle is fitted with a direct current motor on the front axle of the vehicle with power rating of 250W and with a rolling speed of around 45 km/h. It comes with a lithium-ion battery pack of 70 Ampere-Hour (fig. 9), a photovoltaic solar panel with capacity of 20W, a 3kW brushless 36 to 72V DC motor with sensors and a 48V 500A motor controller for brushless DC motors with regenerative breaking and BMS interface for low voltage [5].

Fig. 9 Cnntny Li-ion Battery Lifepo4 48v 70Ah

The electric tricycle drivetrain of the motor, motor controller, on-board charger and other related accessories will be put organised along with the batteries below the floor. To protect the warranty for the parts by the manufacturer, the compartment will be protected from flooding and it will be accessible only to qualified persons for security reasons.

4. TRICYCLE BODY DESIGN AND MATERIALS

The requirements for a good tricycle include spacious interior, comfortable seats and added safety points. One of the requirements from the passenger's responses were to improve the interior space and more comfortable seats. These have been the priority in design considerations for the ADB electric tricycle.

Our project design started with the previous analysis of the ADB e-trike (fig. 10), a tricycle built for the use of Philippines country.

Fig. 10 ADB E-trikes

Having this design as an essential, we came with some improvements.

This electric tricycle's design has three components: the chassis, the bodywork and the electromechanical drive system.

The chassis consists on an assembly of a base frame and a platform where the components are mounted (fig. 11). These include the suspension system, such as shock absorbers, leaf springs, wheels, axles and brake system. The bodywork is the element that provides the visual appearance of the vehicle in shape, colour and details.

Components that are attached to the bodywork includes headlights, signal lights, interior lights, indicators, dashboard, side mirrors, rain cover, seat and upholstery, luggage compartment and other equipment required.

The electromechanical drive system provides the movement of the tricycle and consists of a motor, a controller (with regenerative breaking option), an acceleration, a key switch, a forward / reverse switch, a high voltage and low voltage switchgear and a rechargeable system which may be used independently.

Selecting the right material for the chassis it's an important job in giving the tricycle, the anticipated safety endurance, strength, and reliability. The strategy behind choosing the material for chassis was to reach the best joining area, great flexural rigidity, minimum weight but maximum strength for the tubing. After short researches on the internet [13], [14], there were two materials that could meet our intensions: AISI 1018 steel and SAE-AISI 4130 steel. By comparing these two on cost and properties, the 1018 is a better material to work with.

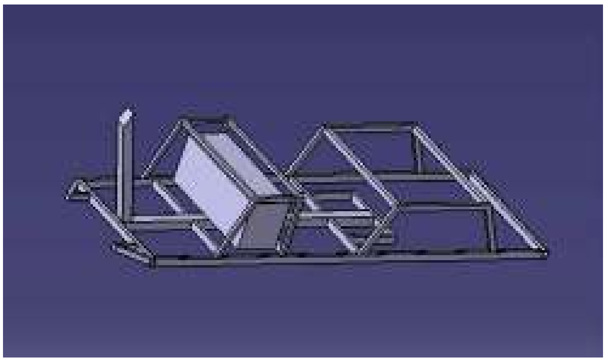

Fig. 11 Tricycle chassis

The frame has two independent rear suspensions adopted from a car. These suspensions should provide a comfy ride for the driver and he's passengers [9]. The suspension on the front wheel is a fork type. Having a delta wheel configuration (fig. 12), one front wheel and two rear wheels, we used a Suzuki motorcycle's front fork [10].

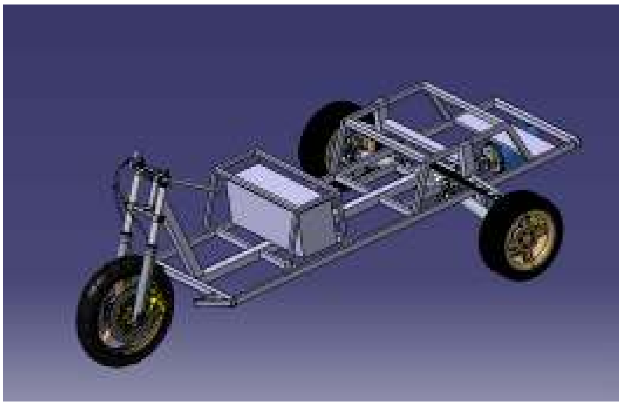

Fig. 12 Wheel configuration

If we want to overcome the lack of speed, we need to design a small tricycle, to ride fast on narrow roads and between other vehicles. The problem is, having a small tricycle will reduce the number of passengers. So, I designed a tricycle that can change it's inside seats. The tricycle can ride with only three seats for a better space for the passengers, to carry their big luggage or it can ride with 7 passengers if needed.

The cabin layout was modified. The driver's and passenger's seating position were changed for the driver to seat alone, for a better manoeuvrability of the vehicle and communicate with the passengers effectively. The passenger's seats were modified to seat back to back, for a better inside space and for an intimate ride favourable to each passenger (fig. 13).

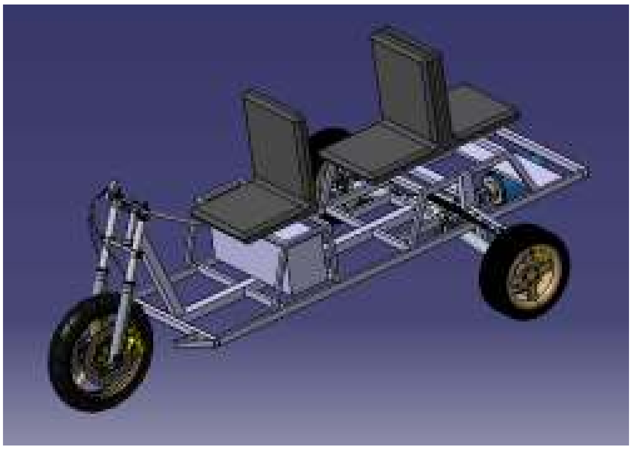

Fig. 13 Tricycle cabin layout

To accommodate the rear passenger, the rear gate will be a door that can be opened for loading from the back, and it can be also used for carrying long items. The rear door has a utility, a compartment where various things such as emergency kits and other similar items can be stored (fig. 14).

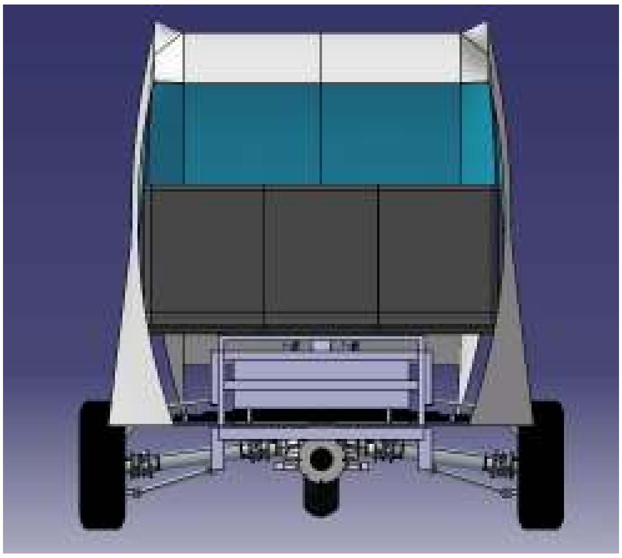

Fig. 14 Rear door access

Solar or Photo Voltaic (PV) converts the solar, energy that comes from sunlight into electric energy or electricity [11]. The solar panel system will be mounted on the roof of the tricycle (fig. 15).

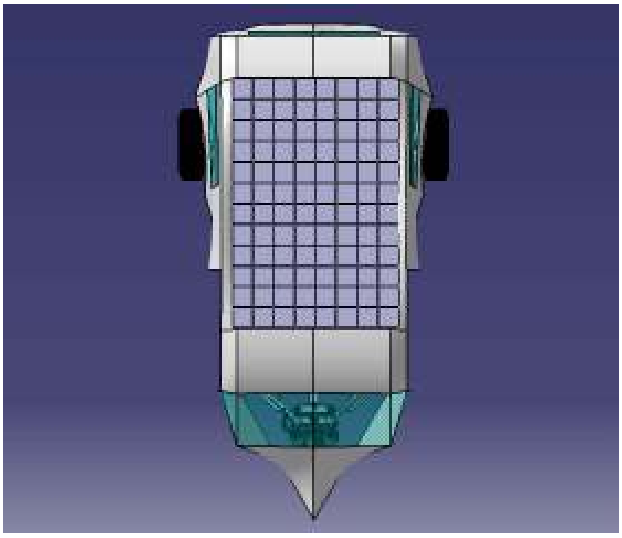

Fig. 15 Solar panel

To maintain a minimum overall weight and a good strength a GFRP (Glass Fibre Reinforced Polymer) will be used for the tricycle body. This type of fibber glass has a very high strength to weight ratio. It has a low weight of 1 to 3 kilograms, and it can resist to saltwater, chemicals and another environment [12].

The 3D CAD of the electric tricycle is shown in the next figure with all the parts in it (fig. 16).

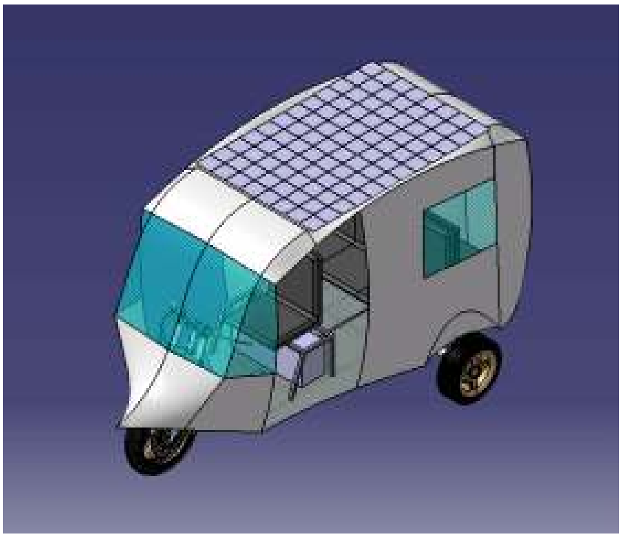

Fig 16. 3D CAD model of the tricycle

5. CONCLUSIONS

The improvements made for our electric tricycle design are structured in three categories: safety, functionality, and comfort. Having these three factors in mind, it was designed a safe and comfortable tricycle for commercial transport.

Comparing the electric tricycle with other conventional petrol tricycles, the e-trike gives you a cost savings. The carbon economy is another advantage, compared to the conventional tricycles, which leads to a better option if smart choices are made to fight global warming.

Being safe in the car is a complex part so that the vehicle is designed in a way that the driver does not exceed the set limit of 45 km/h and this helps to minimize risks at high speed.

To conclude, the project goals is to offer another source of energy for vehicles and a fresher air for all the traffic participants and pedestrians, leading to avoid the automotive dependency.

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Author:

Eng. Andrei TOANCHINĂ, Master student, University Politehnica of Bucharest, Department of Engineering Graphics and Industrial Design, E-mail: toanchinaa@gmail.com