

## Design and Implementation of a Solar Powered Three Phase Automatic Mini Billboard

*Osador A.O.<sup>1\*</sup>, Olagbegi P.<sup>2</sup>, Osifo T.I.<sup>3</sup>, and Ehi-Eromosele F<sup>4</sup>.*

Department of Mechanical Engineering, University of Benin, Benin city, 300213, Nigeria.

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### ABSTRACT

*The idea of outdoor advertising will always be bought by enterprises to be employed in revealing areas containing a dense amount of traffic. In as much as there will always be more expensive forms of advertisements, there will always be companies that are seeking other cost effective means of advertisements and the advertising agencies are always there to fill in the gap. An optimum design of a billboard for advertising with the use of solar energy to power three screw jacks that carry a display board each, upwards and downwards, sequentially timed so that one display board is up while the other two boards are down, and the next board rises up and completes its stroke just when the previous board begins to move downwards. In this paper, a cost-effective billboard that displays six different adverts at three stages was successfully designed.*

## 1. Introduction

Advertising via billboards is a kind of outdoor advertising procured by enterprises in revealing areas containing a lot of traffic, in which they are seen by transiting pedestrians and motorist. The imperative ambiguity tagline utilization has grown to be steadily outstanding in billboard advertising recently [1]. The clarity of advertising via billboard to such a lot of businesses are believed to have a communicative effect on the audience and function which is very varied from different advertising media as it gives the maximum demand in “advertising communication” [2,3]. Advertising on billboards and advertising nonetheless stays as a power house and pile driver of economic growth and sustainable progress of an economy. It sprouts continual financial system for countries, and on the other hand, economies primarily based totally on outdoor advertising can benefit in advancing superb monetary turnover and propel ambitions for an economy. The use of outdoor billboard data channel is one of the bunches of information avenue, nevertheless, continuously uncovered to intensify objections and prejudices within side the public sphere [4]. An inter-dependency research is a robust mainstay for gaining knowledge on billboard missions in public areas. It explains the cause; man, merchandise and the surroundings have bearing, [5] schemes steered in the direction of the intention of assembly of the services or products needs of mankind in a specific environment. Billboard layout ideas take on a crucial position within side the business world. It is strategically not unusual to attract the eye of all readers who use the roads to the products and services on show and their prowess. No one speculates a commercial enterprise challenge without the purpose of creating the goods or services recognized to the destination audience. The use of billboard

advertisement as communication framework set up in key areas in parks and open areas to tell or remind the general public of creating sure crucial choices of goods or services is pointed out in their study [6]. Adept communication methods can beef up an innovative partnership amongst customers as advertisers and designers, serving as the business enterprise as a draftsman to the dispatch of messages to be broadcast [7].

Over time, billboard advertisements and other forms of advertisements have proven to not only just be a medium for marketing but also for passing vital information to the public. To bring on board underserved populations, however, problems thrive as their communications alternatives are greater confined than the ones accessible to the greater advantaged individuals, [8, 9]. Flourishing healthcare communications, certainly have need for encompassing the disadvantaged groups adequately, allowing flow of message which preferably might be understood, acknowledged, and embraced, allowing possibilities for the belief of a more healthy living and districts [10]. Whether commercial enterprise agencies desire to or not they will implement techniques in this rigid and stern marketing race to publicize what they have got in the event that they have to stay in commercial enterprise.

Advertisements via Billboard is an exceptional manner for Small and Medium Enterprises to raise trademark attention in their district. But traditional and digital billboards provide distinctive benefits. For instance, digital billboards have a manner of snatching interest by virtue of the lights, colorations and motion picture. On the other hand, traditional billboards will mostly usually be profitable over an extended duration of time, however in addition they have their limits. For example, in case you are trying out advertisements, you cannot make modifications to the traditional billboard advert, however you can effect sudden and simple modifications to your digital billboard advertisements. Advertising via billboards blooms a background to perform with sure volume of ambiguity contiguous with the manner of dissemination due to the fact clients would not regard lexical vagueness to be a poor language factor, however as an alternative intention to apply it creatively [11].

The structural design of a billboard can be with a mono-pole supporting system or multi post supporting system. A comparative cost and wind deflection was carried out, and an optimum design was presented in their study on multi post supporting system [12]. Billboards can have display configurations that are double faced; which can be two parallel faces or V-faced to enable better wind deflections [13], while an optimum choice for roads with intersections, some are tri-sided to also cater for wind loads [14].

There are and will always be enterprises seeking cheaper forms of advertisement, either due to budget cuts or the lack of funds channeled in that direction. How then do we satisfy both consumers without causing much of a distraction to the drivers? Comparison of the effects of different types of digital billboard advertisements on drivers' attention allocation for changing images is not as much for videos, but more than that of static images [15]. This gives a good balance of getting the attention of both drivers and pedestrians but also not being much of a distraction to drivers. The billboard designed in this work has three boards, each like the traditional billboards with static images, and the transitioning mode being a vertical sliding of the display boards. So, this works entails a billboard that displays up to six adverts at three different stages, with three adverts to one face and three to the other face of the billboard, powered by renewable energy in the form of solar, of which the sun light is in abundance in Nigeria.

## **2. Materials and Method**

The machine design consideration entails;

- i. A simple design for small scale advertisement and easy to transport to its desired location
- ii. Use of locally sourced materials
- iii. The use of acrylic sheets as opposed to glass for durability
- iv. The use of plain bearings which isn't only cost effective but requires less maintenance

The machine design consists of mild steel angle bars for the structural frame of the billboard, and mild steel rectangular bars are used for the support for the screw jacks. Three screw jacks are bolted individually to the three boards, for one board to display adverts on both sides, and because the screw jack is self-locking, it prevents the load from being back-driven. The screw jacks are connected to a control system of three timers and six relays connected to the jacks to keep one board up for two minutes while the others stay down. On a board, there are four bearings, two on each side of the board to guide its path during motion. Sheet metals cover the top, and around the structure of the billboard except the area which displays the adverts, and this area is covered with Perspex. The screw jacks are connected to a switch which is connected to a battery that's connected to a solar panel.

## 2.1 Detail Design

### 2.1.1 Forces on the Structural Frame

The forces acting on the structural frame of the billboard are those due to the following: Weight of motor and screw jack, weight of billboard and weight of screw jack support plus fasteners (bolts, nuts and washers).

Weight of motor and screw jack =  $5.5\text{kg} \times 9.81 = 53.955 \text{ N}$

Weight of display board =  $3.401\text{kg} \times 9.81 = 33.364 \text{ N}$

Weight of screw jack support (plus fasteners) =  $0.5\text{kg} \times 9.81 = 4.905 \text{ N}$

Forces acting on one frame =  $53.955 + 29.43 + 4.905 = 92.224 \text{ N}$

Total forces acting on structural frame =  $92.224 \times 3 = 276.672 \text{ N}$

### 2.1.2 Screw Jack Design

Diameter of screw from the bending theory

$$\sigma = \frac{F}{A} \quad (1)$$

$$A = \frac{\pi D^2}{4} \quad (2)$$

$$D^2 = \frac{4F}{\sigma \pi} \quad (3)$$

$F = mg = 3.901 \times 9.81 = 38.269\text{N}$

Therefore,  $D = 7.9 \text{ mm}$

A screw jack with a mean diameter; 'D' = 9 mm was selected, which can carry more load with the same yield strength up to;

$$F = \frac{D^2 \sigma \pi}{4} = 44.538\text{N}$$

Therefore specified mean diameter of screw 'D' = 9mm.

### 2.1.3 Force required to raise the load

Using the screw jack analysis;

Effort applied horizontally to raise the load is given by:

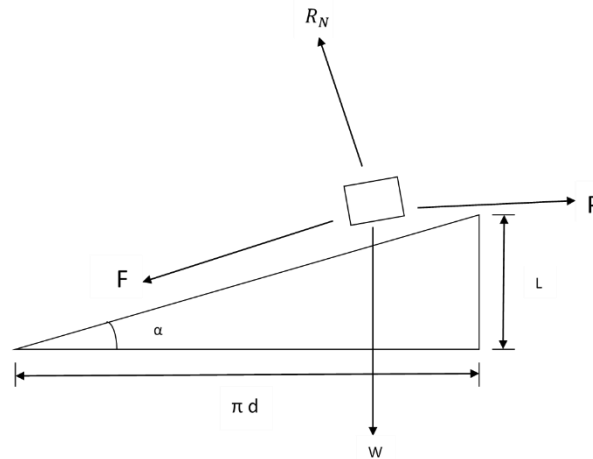
$$P = W \tan(\alpha + \varphi) \quad (4)$$

Specified Design values for Screw Design

Weight carried by the screw =  $3.901 \times 9.81 = 38.269\text{N}$

Single start screw;  $l = p = 1.25\text{mm}$

Specify the coefficient of friction between the screw and nut;  $\mu = 0.05$   
 Check selected Design values if self-locking condition for screw is achieved  
 For self-locking;  $\pi \times \mu \times D > l$   
 $\pi \times \mu \times D = \pi \times 0.05 \times 9 = 1.4137 \text{ mm}$   
 $l = 1.25 \text{ mm}$



**Figure 1: Analysis of force required to lift given load**

Since  $\pi \times \mu \times D > l$ , the condition is satisfied for the selected design values.

$$\mu = \tan \varphi \quad (5)$$

$$\varphi = \tan^{-1} \mu = \tan^{-1} 0.05 = 2.8624^\circ$$

$$\tan \alpha = \frac{l}{\pi D} \quad (6)$$

$$\tan \alpha = \frac{1.25 \times 10^{-3}}{\pi \times 9 \times 10^{-3}} = 0.04421$$

$$\alpha = \tan^{-1} (0.04421)$$

$$\alpha = 2.5314^\circ$$

Effort required raising the Load

$$P = W \tan(\alpha + \varphi) \quad (7)$$

$$P = 38.269 \tan (2.5314 + 2.8624)$$

$$P = 3.6133 \text{ N}$$

Torque required to raise the Load to the display height of 18" (0.4572 m)

$$T = P \times L \quad (8)$$

$$T = 3.6133 \times 0.4572$$

$$T = 1.652 \text{ Nm}$$

Design specifications at Output

The display board travels 18 inch = 0.4572 m in 20 second at 90°.

$$\omega = \frac{\theta}{t} \text{ rad/s} \quad (9)$$

$$\omega = \frac{90}{20} = 4.5 \text{ rad/s}$$

$$\omega = \frac{2\pi N}{60} \quad (10)$$

$$N = \frac{60 \omega}{2\pi} = \frac{60 \times 4.5}{2\pi} = 42.972 \text{ rpm}$$

#### 2.1.4 Power required

The power required to lift one board:

$$P = T \times \omega = \frac{2\pi NT}{60} \quad (11)$$

$$P = \frac{2\pi \times 42.976 \times 1.652}{60}$$

$$P = 7.435 \text{ W}$$

Total power required by the system;

$$P_{total} = 7.435 \times 3 = 22.305 \text{ W}$$

#### 2.1.5 Frame Structure

The dimensions for the frame was specified at 0.0381m angle bar all through;

2.1336 m length angle bar

1.2192 m length angle bar

0.381 m length angle bar

0.1524 m length angle bar

#### 2.1.6 Sheet Metal Casing

The dimensions for the casing for the roof and the bottom part of the frame was specified using 1mm thick sheet metal.

1.2192 × 1.3716 m sheet metal

0.381 × 1.3716 m sheet metal

0.381 × 1.2192 m sheet metal

#### 2.1.7 Perspex Casing

This was used as casing for the top part of the frame which is the display area, and the thickness is 0.002 m.

1.2192 × 0.6096 m

0.381 × 0.6604 m

#### 2.1.8 Billboard display board

The display board is the part that does the actual display of advertisements and it is made of plywood.

1.21.92 × 0.60.96 × 0.01.27 m

#### 2.1.9 Solar power design

The installation of the solar power entails the auditing of the system's total electrical load so as to get the minimum required battery and solar PV panels.

The total electrical load is shown in Equation 12.

$$P_{total} = \sum(I_n V_n) \quad (12)$$

For the total power rating of the three screw jacks;

$$P_{total} = 22.305 \text{ W}$$

The requirement for electrical power is 22.305 watts; at 12 volts for one hour, the battery capacity is determined in amp-hour;

$$\text{Battery Capacity} = \frac{\text{total power}}{\text{operational voltage}} \times \text{time of operation} \quad (13)$$

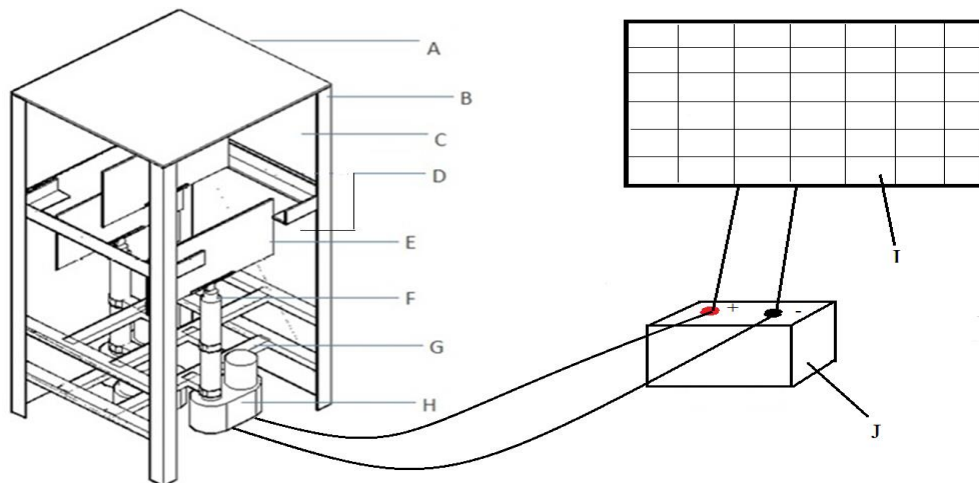
$$\text{Battery Capacity} = \frac{22.305}{12} \times 1 = 1.86\text{A-h}$$

A battery of 12v, 30A is used so as to achieve a continuous operation at night. The capacity in watts-hour of the solar PV cell to charge the battery is determined;

$$P_p = \frac{\text{Battery energy}}{\text{charge time(hours)}} \quad (14)$$

$$P_p = \frac{22.305}{0.5} = 44.61$$

A 50W solar panel was used



PART LABEL	COMPONENT
A	Stainless steel sheet
B	Frame
C	Perspex
D	Stainless steel sheet
E	Display board
F	Screw jack
G	Support
H	Motor
I	Solar Panel
J	Battery

**Figure 2: Assembly of the phase solar powered billboard**

### 3. Results and Discussion

Each of the three screw jacks which are being used to propel the board upwards and downwards deliver a speed of 1500 rpm which moved the load one stroke a distance 0.457m for 20 seconds. After the screw jacks and the boards were installed as desired, the control system which consists of 3 timers and 6 relays were integrated into the system design. The relays and timers are to sequentially raise and drop the boards in the order of the required display with one board required to be up (at maximum height of 0.457m from the starting point) whilst the other two boards are down, and the board on display stays up for a delay time of 120 seconds.

When power is input into the control system, the timer is activated and at the set time, the first relay is activated and thus the first jack is lifted upwards. This timing is such that a display board is always completely up just when another board begins its journey downward, thereby not having a chance to display an empty billboard. Also, in cases of a downtime, due to electrical or mechanical failure, there will always be advertisements on display. This order of timing was set for this work after fabrication was completed, and it can always be configured to any timing sequence of choice of the user.

#### 4. Conclusion

Throughout the execution of this work, the primary objective had been to demonstrate the feasibility of producing an indigenous fabricated automatic billboard to display six different advertisements at three stages, with two advertisements per stage. Another major advantage during the development of this work was low cost of fabrication and the availability of materials sourced locally. A billboard that can serve as the traditional billboard, yet an interesting design to catch the attention of road users with its design and transition system, but yet not much of a distraction to drivers was designed and implemented.

#### Nomenclature

$R_N$	Normal force (N)
$P$	Effort required to raise the load (N)
$F$	Force (N)
$A$	Area
$D$	Mean Diameter of the screw (m)
$W$	Weight to be lifted (N)
$l$	Lead of screw
$P$	Pitch of screw
$T$	Torque (Nm)
$L$	Load distance (m)
$N$	Number of revolutions per minute
$I$	Current (A)
$V$	Voltage (V)
$P_{total}$	Total power required by the system (Watts)
$P_p$	capacity of the solar PV cell (Watt-hour)

#### Greek letters

$\phi$	Friction angle
$\sigma$	Stress
$\alpha$	Helix angle
$\omega$	Angular speed (rad/s)
$\mu$	Coefficient of thread friction

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