

A Design Approach to Improve Existing CNG Filling Station by Improving the Layout

Muhammad Abdus Samad

Department of Industrial & Production Engineering
Shahjalal University of Science & Technology
Sylhet, Bangladesh
Samad-ipe@sust.edu

Abdullah Al Rahi

Department of Industrial & Production Engineering
Shahjalal University of Science & Technology
Sylhet, Bangladesh
dimitristillalive@gmail.com

Pritidipto Paul Chowdhury

Department of Industrial & Production Engineering
Shahjalal University of Science & Technology
Sylhet, Bangladesh
pridipto@gmail.com

Eshayat Hasan Chowdhury Angon

Department of Industrial & Production Engineering
Shahjalal University of Science & Technology
Sylhet, Bangladesh
chowdhuryangon@gmail.com

MD Mosharaf Hossain

Department of Industrial & Production Engineering
Shahjalal University of Science & Technology
Sylhet, Bangladesh
Mosharaf14@student.sust.edu

Abstract

Filling station has become one of the most heavily used facilities in the modern age. The number of filling stations especially in Asia are on a continuous rise. As of November 2017, the number of filling stations in India are 60,799. But with unplanned layout planning, no specific line for different vehicles- the total productivity as well as waiting time drastically increases. Altogether the service time increases and most of the customers leave the stations being unsatisfied. This study attempts to design an alternative filling station from the perspective of a third world country. With the rising innovation in the solar power and growing popularity of electric vehicles- filling stations are not only limited to fuel pumps but also the plug-in charging station. To combine fuel stations and plug-in charging stations in a single station in a third world country has its challenges. This study steps towards to design the facility layout as well as a cheaper combined filling station which serves the purpose of refueling while serving the purpose of plug-in charging. The effectiveness of our approach will be tested with Arena software, AutoCAD are used in this study.

Keywords

Facility layout, Filling station, Electric car, Service time, Alternate design, Customer satisfaction.

1. Introduction

In recent years, the number of vehicles have increased at a rapid rate. And instead of using public transport as their daily transportation people are using private vehicles; this not only increases the traffic as well as the total number of vehicles. And a recent study shows Approximately 300,000 of the 1 million vehicles on the roads are now CNG-fueled[1]. Moreover, ride sharing services like UBER, Pathao, Shohoz, etc are playing influential roles in increasing the number of CNG(Compressed natural gas) fueled vehicles. The current situation demands more filling stations but the alarming part is most of the filling stations in Bangladesh are not well planned, unsafe, unplanned layout and these stations act as factors behind traffic jams. The number of operated CNG filling stations in Bangladesh is significant. And this number is on the hike in Bangladesh as well as in other neighbor countries.

Table 1: List of Operated CNG Filling Stations [2]

Serial No.	Name	Amount
1.	Bogura	23
2.	Brahmanbaria	5
3.	Chadpur	2
4.	Chattogram	67
5.	Cumilla	56
6.	Dhaka	171
7.	Feni	12
8.	Gazipur	76
9.	Hobigonj	8
10.	Jamalpur	1
11.	Kishorgonj	5
12.	Laxipur	2
13.	Manikgonj	17
14.	Moulvibazar	11
15.	Munshigonj	5
16.	Mymensingh	13
17.	Narayangonj	41
18.	Narshingdi	18
19.	Noakhali	5
20.	Netrokona	1
21.	Pabna	7
22.	Sirajgonj	3
23.	Sunamgonj	4
24.	Sylhet	35
25.	Tangail	14

The table indicates the number of up and running CNG filling stations in 25 districts of Bangladesh. It should also be noted that most of these stations are not planned let alone well planned, poor facility layout. This not only increases service time, waiting time but also risks safety.

As Bangladesh is on the edge of being considered as one of the developing countries; the opportunities for new technologies can no longer be denied. Electric vehicles are a comparatively fresh concept in Bangladesh. But globally, electric car market share is on the rise: at the end of 2018, it stood at 4.6 percent, almost double from what it was in 2017, according to the Centre of Automotive Management (CAM), a German research and consultancy institute [3]. And steps are being taken to introduce electric vehicles to the people of Bangladesh. Such as; Local

automobile company Bangladesh Auto Industries Ltd (BAIL) is all set to make electric vehicles from next year with an initial investment of \$200 million[4]. Hybrid cars are already running on the streets of Dhaka. A study shows-with efforts aligned towards improving fuel economy, reducing harmful gas emissions, and promoting a sustainable and environment-friendly national vehicle policy, Bangladesh's mobility paradigm is set to shift at a rapid pace. As with any other developing nation, Bangladesh's electric mobility landscape is dominated by last mile connectivity vehicles, comprising majorly of electric bikes and rickshaws. 600,000 electric bikes, 500,000 electric rickshaws are on-road and more than 1800 hybrid cars were sold in 2017-18[5]. This is a clear indication that electric vehicles will occupy a larger share and charging stations will also be needed. Renault, Tesla, BMW are some of the top electric vehicles manufacturing companies. They are implementing their charging stations throughout the cities where electric cars being used the most. Nitol Motors is set to come with a locally-assembled electric vehicle by next year, in yet another big stride for Bangladesh's fledgling automotive industry[6]. It is imminent that electric vehicles will enter Bangladesh's automotive industry. A filling station with CNG filling workstation and electric vehicle charging station is a completely new concept. The objectives of this study are-

- To study the existing filling stations layout in Bangladesh.
- To propose a newer filling station layout while implementing CNG and charging workstation at the same time.

2. Research Methodology

The existing layout is developed by studying several numbers of filling stations of Bangladesh. Existing layout contains several risk factors as well as having zero to no planning. No separate lanes were found for the vehicles, not enough space for vehicles to operate safely. Proposed layout is designed to solve the issues as well as implement solar powered charging stations for electric vehicles. A small fleet of CNG cars needing fast refueling will have different requirements than a large fleet of CNG school buses or refuse trucks that can be refueled on a time fill system. These too will be different from a commercial CNG station requiring larger equipment, greater redundancy, fuel storage, and multiple dispensers. To properly size a CNG fueling station it is important to know as much as possible about the vehicle fueling rates and arrival patterns. In particular, the designer will need to know the peak hourly fueling rate, not just the daily or weekly usage. At first the process map is designed. As different customers will have different needs; the process map will also vary depending on the needs.

2.1 Values of Electric Vehicles

There are several social, environmental, and economic implications associated with electric vehicles replacing internal combustion vehicles. All-electric vehicles (BEVs) have no tailpipe emissions, which as a result improves air quality and lowers health risks. Electric vehicles also help the nation reduce its reliance on foreign fossil fuels. In addition, electric vehicles have one-tenth the number of parts that gasoline-powered vehicles have [3], thus requiring less maintenance, and saving drivers time and money. The cost table can isolate the reasons why we should be interested more in electric vehicles. Having several risk factors as well as environmental issues gasoline powered vehicles should not be considered as the only choice for transportation. Table 2 shows price comparisons of electric vehicles to an average gasoline-powered car for varying distances traveled. This table compares the average cost it takes to travel a certain number of miles (one way) for an electric or gasoline powered car [7].

Table 2. Comparison of travel costs for electric vehicles and gasoline-powered cars.

Distance to Destination (miles)	Tesla	Nissan Leaf	Plug-in Toyota Prius	Ford Focus Electric	Chevrolet Volt	Average Gasoline Powered Car	Ford Focus (gas)
10	\$0.42	\$0.36	\$0.35	\$0.38	\$0.42	\$1.63	\$1.21
20	\$0.84	\$0.72	\$1.02	\$0.77	\$0.84	\$3.26	\$2.42
30	\$1.26	\$1.08	\$1.77	\$1.15	\$1.26	\$4.89	\$3.63
40	\$1.68	\$1.44	\$2.52	\$1.54	\$1.80	\$6.52	\$4.84
50	\$2.10	\$1.80	\$3.27	\$1.92	\$2.81	\$8.15	\$6.05
60	\$2.52	\$2.16	\$4.02	\$2.30	\$3.83	\$9.78	\$7.26
Electrical Efficiency (kWh/100 mi)	35	30	29	32	35	N/A	N/A
Miles per gallon	N/A	N/A	50	N/A	37	23	31
Battery Range (mi)	208	84	11	76	38	N/A	N/A

2.2 Solar Powered Charging Stations and Bangladesh

The climate of Bangladesh is subtropical in the center-north and tropical in the south [8]. It can be said that country remains mostly sunny during the year. And in cities and in villages there are several projects and households that are using solar power as their primary energy source. Which is not only cost effective but also ensures the proper use of renewable energy. Thus the concept of solar power isn't a new concept for Bangladesh. Table 03 shows the average daily sunshine hours in Dhaka.

TABLE 03: the average daily sunshine hours in Dhaka [8]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hours	9	8	7	6	5	3	2	2	3	6	8	9

The table ensures that solar powered charging station idea is not merely an idea but also a sustainable one.

2.3 Benefits of SPCS (Solar Powered Charging Station)

Before explaining how a SPCS works the benefits must be denoted. Physically, SPCS are typically structures several feet tall with solar panels on slanted roofs and with an electric charging station underneath [9]. One social value associated with SPCS is convenience since SPCS can be installed at many diverse locations such as work places, shopping centers, restaurants, rest stops along highways, gyms, parks, and more, allowing people to charge their vehicle while completing daily activities that concludes the fact the installation process being comparatively easier.

An infrastructure of many SPCS allows EV (Electric Vehicle) owners to charge their EV more frequently, which facilitates driving further before returning home. SPCS also provides shade for the charging vehicle. Shade significantly reduces the internal temperature of the vehicle and protects the car from sun damage. SPCS can increase the number of green jobs with needs for installation, maintenance, and operation. An estimated number of 4000–5000 jobs will be created per year. With proper training these works can be skilled and act as future innovators in the renewable energy sectors.

In addition, SPCS would attract more customers to the establishment. A study showed that 50% of Americans believe it is “very important” that employers are environmentally responsible [10]. Also, that study found that 57% of consumers believe it is important to support products with environmental benefits and 51% will pay more for them, even during tough economic times [10]. SPCS could also serve as an educational tool, especially if installed at a school. The SPCS could raise awareness of solar power and electric vehicles, and could possibly encourage homeowners to install solar panels themselves.

2.4 Solar Powered Charging Station and How It Works

Publicly accessible ‘fast charger’ or ‘super charger’ outlets provide power to the battery at a faster rate. The rate of charge is usually from 25 kW to 135 kW and can recharge an EV battery in around 30 minutes [11]. To provide this amount of power is very much possible with a solar powered station. Moreover, in absence of sunshine alternate electric grid power will always be available. The whole system will be monitored by a server and client is informed through mobile application.

Figure 1 shows the idea of solar charging station. The station will be activated through registered client ID. With that ID signed into the official application of a smartphone, customer can easily recharge their EV. The solar panels produce electricity via the panels and stores that energy which is provided later to the EVs.

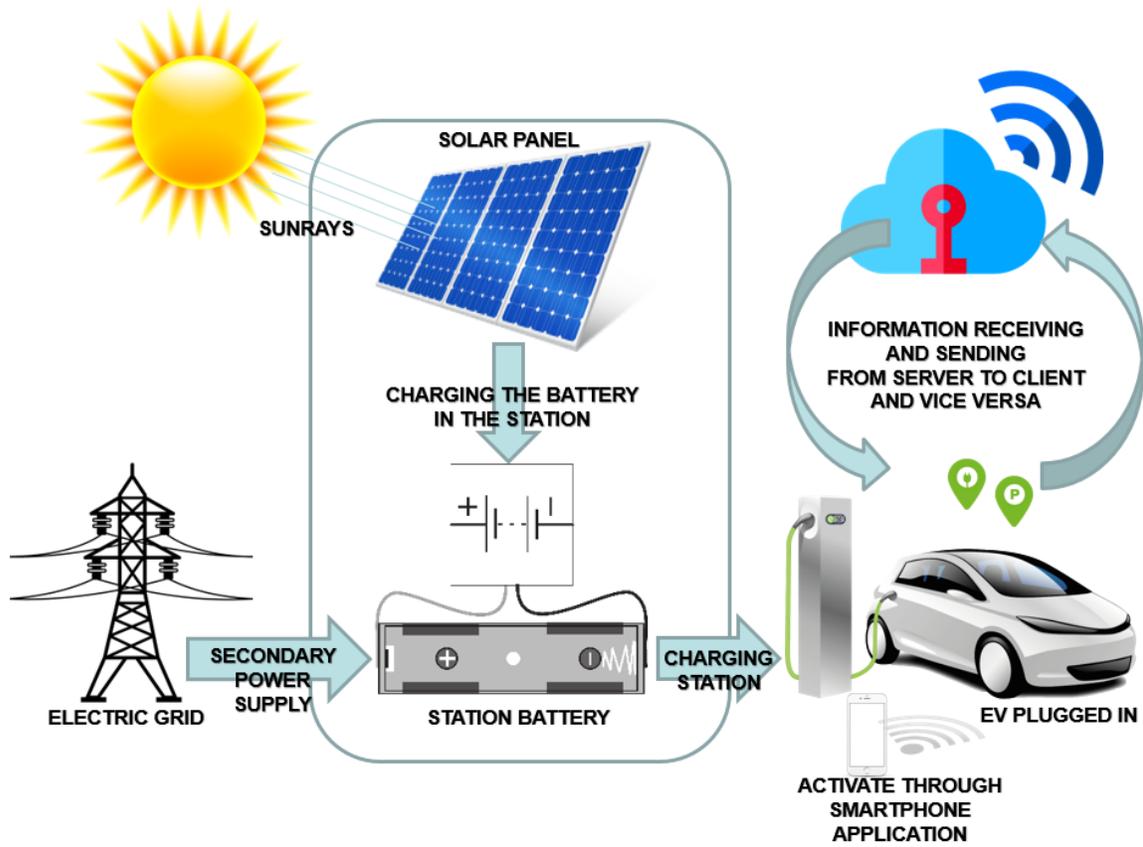


Figure 01: Solar Charging System Model

2.5 Process Map

Process Mapping is used for this reason to illustrate the exact relations and sequences of different sections and activities while customers enter and exit the model, using Operation Process Chart (OPC) standard symbols. Fig.02 shows the schematic process map. In the process it shows the process when the customer selects CNG station and Charging station. 'X' denotes the point after selecting CNG refueling. For electric vehicle charging there will be a specific app to initiate the process. The app will notify the driver how much charge is needed and how much time will take to complete the full charge. After refueling/ recharging the drivers will drive to the exit zone.

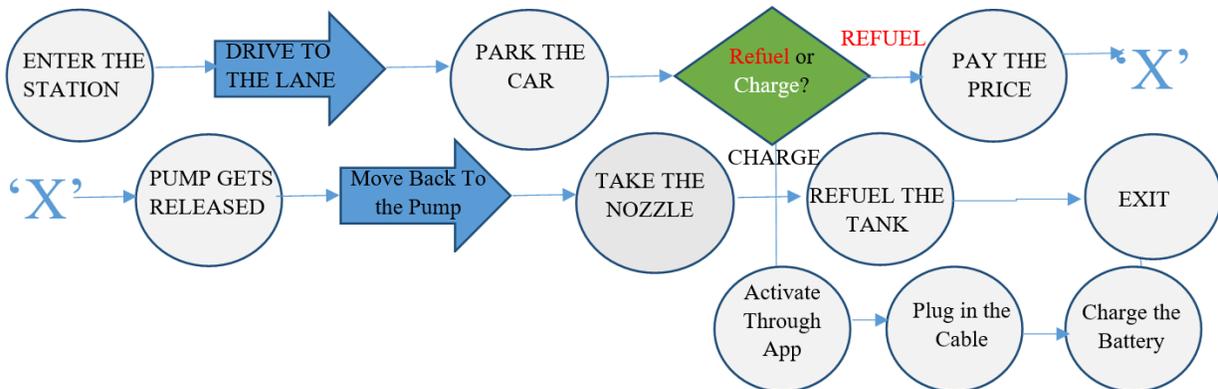


Figure 02: Process MAP

3. Layout of the Filling Station

There are several problems which are significant in traditional layout of filling stations of Bangladesh. Primary visits to the nearest CNG filling stations and after studying several previous studies some defects were isolated. They are-

- Excessive waiting time and service time for no specific lane for the vehicles.
- No specific cash receiving or giving system.
- No specific lanes for entering or exiting vehicles. Moreover, no proper sign.
- The distance between the fuel tank and the service station is not maintaining the safety guidelines.
- Frequent accidents. Not enough safety tools in the inventory. Not enough Personal Protective Equipment.

3.1 Existing Traditional Layout

The problems which were mentioned previously, all of them are present in the existing layout.

- Not enough distance from the main road
- No separate lane
- No digital signs
- No shop
- No parking space
- Not enough staffs

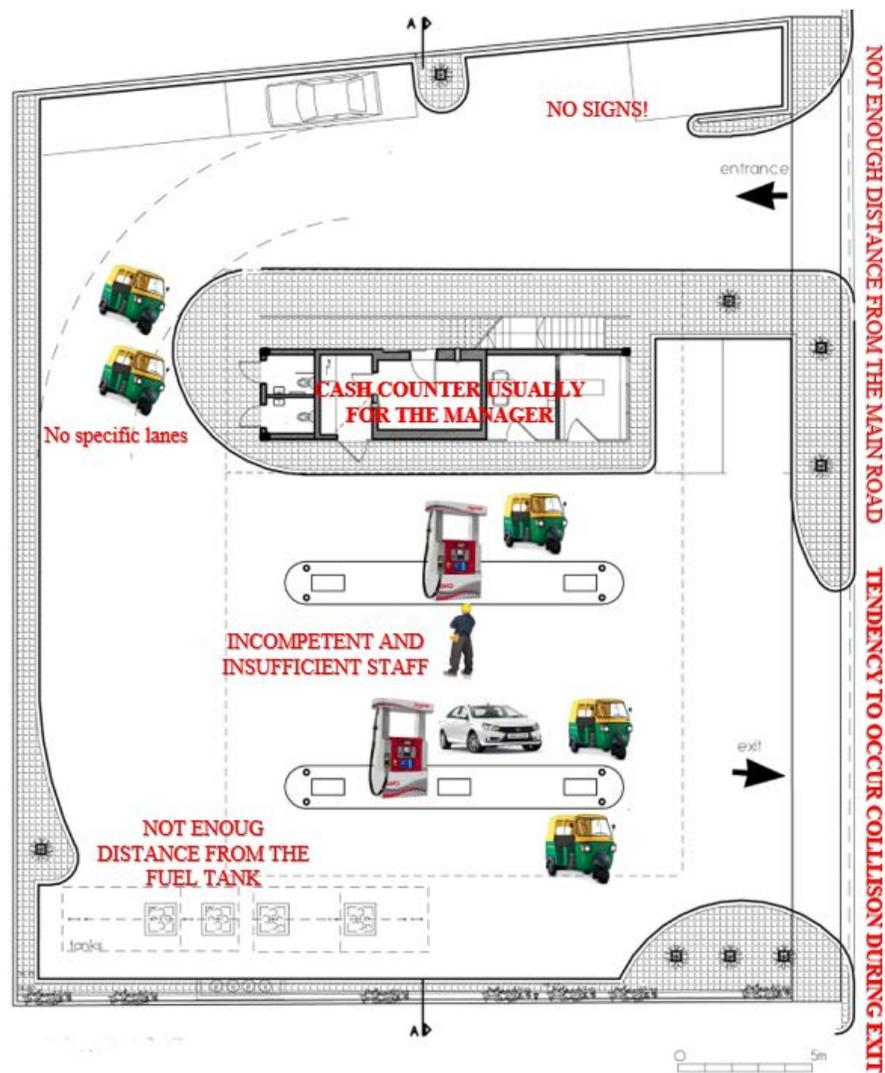


Figure 03: Layout Showing the Existing Layout of Most of the CNG Stations

3.2 Proposed Layout with Solar Charging Station

This layout design tries to solve the problems that appear frequently in the traditional unplanned designs. This layout includes-

- Shop for the customer to buy necessities.
- Parking lot.
- Solar charging station for EV
- Proper signs
- Specific lanes for vehicles.
- Proper payment station and staff position.

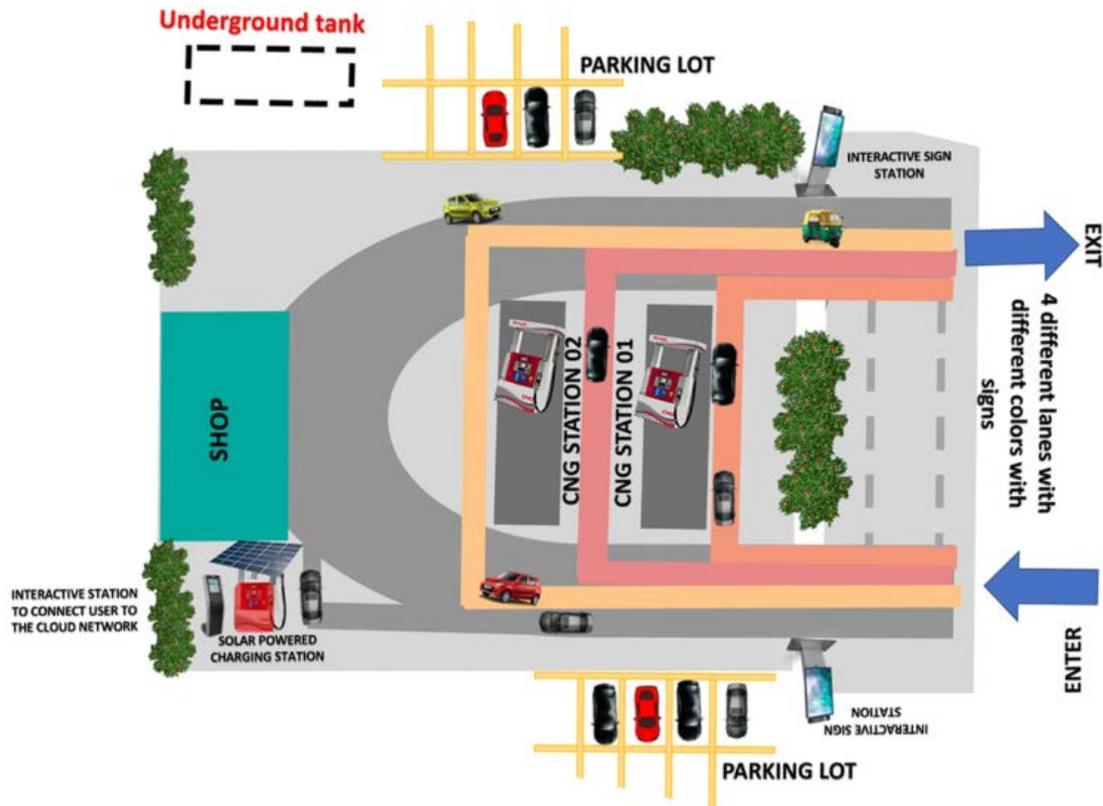


Figure 04: Proposed Layout for Filling Station

This layout emphasizes on the separation of lanes. 4 different lanes are colored in 4 different colors. Moreover, the interactive smart sign station gives out instruction to the drivers. As the lanes are separated and not more than 2 vehicles can stay in front of the filling station, this enhances the service time and waiting time also. Interactive sign station shows how many vehicles are on the line and estimates the time of waiting. As a result, if a driver is in a hurry he will know whether he can get the service early or not.

Parking lot has specific space. Fire safety equipment are stored in the shop. Shop serves as the manager desk, customer reception as well as in case of any emergency the drivers can always reach out to the person in charge of the station. Underground tank is kept at the safest distance.

Lastly these steps were maintained throughout the layout design [12]-

- Signs should be located so as not to reflect the sun into the face of motorists and should be large to be seen from a distance. As interactive sign station has digital displays it will not be creating any issues.
- Stations are to be equipped with fire-fighting and fire protection equipment

- All volatile flammable liquid storage tanks shall be installed below ground.
- Integral containers of adequate design and capacity should be provided for waste.
- Stations should be erected on level rather than sloping site to prevent rolling ordiscarded materials such as cans, drums, etc.
- Area of land to be developed should be sufficient to allow maneuvering of vehicleswithin its cartilage but should not be less than 1100 m2 with a minimum frontage of9 m on the primary street.

4. Results

As this study focused on developing a layout to resolve the common problems of traditional layout of filling station. This study also focuses and emphasizes on the future of Electric vehicles and its position in Bangladesh. This study tried to project light on the existing layout by designing a mock layout of traditional layout. The matter is really alarming that almost all of the station don't have proper sign as well as no separate lanes for vehicles. The layout tries to solve this problem by implementing 4 different colored separate lanes. And the interactive sign stations always keeping a count of the vehicles and the rough estimation of the station lets the driver know about the waiting time. And it is very possible to reduce waiting time drastically by implementing different lanes for each CNG station. And solar powered charging station is positioned at the corner because as the number of Hybrid and EV is still lesser than CNG vehicles it should be considered as smart idea not to include this station in between the CNG station.

5. Discussion

As the timeframe was short and the research was independent, background study wasn't as vast as it should have been. With more resources more station can be included in the study. More study can bring out more aspects, more sectors to improve. In this study we only focused on the faults of current few station while there are actually several stations with potential layout design. The separated lanes are curved arc from the main road to avoid any kind of accidents. The signs always alerting the drivers to drive safely. And the station doesn't permit any refueling without proper documents. Separate lane reduces the chances of collisions. Figure 05 denotes the smart lane and the neon signs which will be implemented so that driver can notice the lane from distance. Lastly it can be said this study is just a mere effort to raise the awareness of the faults of current layout of Bangladesh. And enlightens the future prospect of electric vehicles in Bangladesh.

Figure 05 shows the top view of the smart lane plan for the facility layout of the CNG filling station.



FIGURE 05 : Separate smart lane for the station

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Biographies

Muhammad AbdusSamad is an Associate Professor of department of Industrial and Production Engineering at Shahjalal University of Science & Technology, Sylhet, Bangladesh. Mr. Samad has previously published researches on the application of lean tools to improve productivity as well as worked with various aspects of ergonomics. Simulation modeling and value stream mapping have also been his fields of research works.

Abdullah Al Rahi is a student of department of Industrial & Production Engineering at Shahjalal University of Science & Technology, Sylhet, Bangladesh. Mr. Abdullah published a conference paper regarding a survey on customer satisfaction in the restaurants of Bangladesh. He has been awarded as the national finalist for science communication in FAMELAB British Council. Public speaking and science communication have been his field of passion. His research interests include manufacturing, simulation, supply chain, lean, quality control and facility lay-out planning

MD Mosharaf Hossain is a student of department of Industrial & Production Engineering at Shahjalal University of Science & Technology, Sylhet, Bangladesh. Mr. Hossain has completed some notable lab projects at his Department. His research interests include manufacturing, simulation, optimization, lean, operation researches and facility lay-out planning.

Eshayat Hasan Chowdhury Angon is a student of department of Industrial & Production Engineering at Shahjalal University of Science & Technology, Sylhet, Bangladesh. Mr. Eshayat has completed some small lab projects at his Department. His research interests include manufacturing, simulation, optimization, lean, operation researches and facility lay-out planning.

Pritidipto Paul Chowdhury is a student of department of Industrial & Production Engineering at Shahjalal University of Science & Technology, Sylhet, Bangladesh. Mr. Chowdhury has completed some small lab projects at his Department. His research interests include manufacturing, simulation, optimization, lean, operation researches and facility lay-out planning.