

## SIMULATION STUDY ON CNG STATION DISTRIBUTIONS IN INTERCITY NETWORK USING ARENA SOFTWARE

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### ABSTRACT

The current world is following strategies to exit from energy crisis. In Bangladesh changing the vehicle fuel to the Compressed Natural Gas (CNG) is the priority enforcement. Recently, the number of CNG fuel based vehicles in Bangladesh is growing rapidly due to low price and availability of CNG. This change needs some planned substructures. One of the most important substructures is the CNG refueling stations distributions. Necessity of making a systematic process to locate CNG stations is vital because at present there is no fixed system to locate CNG stations throughout the country. This research estimates the optimum number of CNG stations in the selected intercity network and present an investigation prevailing queuing system and performance of the existing CNG filling stations by using ARENA software. The study has found the unplanned locations of CNG stations in the selected road.

**Keywords:** Simulation of Queuing System, CNG Stations, Fuel Demand Method.

### 1. INTRODUCTION

Consumption of Natural Gas has been increased rapidly in current world making CNG one of the most important energy sources in the world. During last Decade the consumption of a CNG is increased almost 25% in share. By 2020 it is predicted to increase its energy share to 50% from the present of 22%.

The use of CNG fuel as an alternative to the conventional fuel in public and private transport vehicles benefits by reducing air pollutants like carbon monoxides and particulates [1, 2]. Like in China and India, in Bangladesh, various conservative measures or strategies are being considered by the Government in order to deal with the environmental problems. One of these strategies is to millions of vehicles used in public fleet including private car, passenger car, microbus, three-wheeler, trucks from gasoline to CNG. This conversion will bring significant economic and environmental benefits of the country; will reduce dependency on the imported fuels, increasing national security and lowering foreign trade deficit [3].

As a result the number of CNG refueling stations is growing in keeping pace with the ever-increasing demand. Currently, there are about 500 CNG refueling stations in around the country. Among them 213 have started operation during 2008-2009 fiscal year (FY) [4]. A planned network/distribution of CNG refueling stations is the present demand in this sector due to the rapid growing of CNG-run vehicles and CNG refueling stations. To find the better location pattern of CNG

filling stations, the optimum number of stations in the intercity network should be known first. In this research, the optimum number of CNG stations in selected intercity network is estimated using the fuel demand method.

Again, simulation is the imitation of some real thing, state of affairs, or process. The act of simulating something generally entails representing certain key characteristics or behaviors of a selected system. In this study the key performance of each server in CNG stations located in the selected area is approximately measured through a simulation study using the ARENA software [5]. ARENA is used to analyze the different queuing system to reduce the waiting time and increase the utilization of the server [6]. The statistical characteristics of different activities are found using the ARENA input analyzer. The simulation results support the result found in the fuel demand method. In the previous work, all CNG stations are considered as single server queuing system and the manual simulation is used. The present study considers all running server in stations.

### 2. CNG STATIONS EXPANSION IN BANGLADESH

Natural gas is major source of energy for Bangladesh meeting 70% fuel requirements of the country. The country has witnessed a tremendous growth of compressed natural gas-run vehicles in the recent years (Figure 1 and 2). A sizeable number of gasoline-run

vehicles have been converted to CNG-run vehicles. The rising cost of auto fuel in the recent years contributes to conversion of vehicles engines to CNG. This growth of CNG-run vehicles contribute to the rapid growth of CNG filling stations and workshops (Figure 3 and 4).

### 3. MATERIALS AND METHODOLOGY

For the proper distribution of CNG filling stations, the need of using case-study is obligated. An intercity network, Sylhet-Jaflong is chosen as case study. In order to estimate the optimum number of CNG stations in this road, this research uses an estimated fuel demand method to estimate demand of total fuel amount. ARENA software is used to determine some performance indicators of each server of CNG stations located in the selected area. The performance indicators are utilization, average waiting time and average number of waiting cars. Both methods are described in details below:

#### 3.1 Estimated Fuel Demand Method

For determining the number of CNG stations in the road, the demand of fuel amount should be estimated. For estimating the fuel demand in the selected road, there should be use of machines measurement kilometer and fuel consumption average of different vehicles in the road network to the following equation:

$$D = \sum (L_i T_{vi}) \eta_v \quad (1)$$

where,  
 $l$  is road index,  $v$  is vehicle type index,  $L_l$  is length of road  $l$ ,  $T_{vi}$  is amount of passing vehicles in type of  $v$  in the way of a distinguish time output and  $\eta_v$  is the amount of vehicle special fuel consumption from type of  $v$  in the distance unit.

According to the capacity of a standard fueling station, the amount of required CNG station would be calculated by the following equation.

$$NS = \frac{D}{SC} \quad (2)$$

where,  $NS$  is amount of required CNG station in the study range,  $D$  is total estimated demand in study range and  $SC$  capacity of a CNG station for preparing the fuel demand.

#### 3.2 Simulation Using ARENA

The field data are collected by observation and interviewing method. Those data are used to estimate the characteristics of different activities using ARENA-10 input analyzer. A model of CNG station (multiple servers) is developed using the ARENA software.

### 4. DATA ANALYSIS AND RESULTS

#### 4.1 Fuel demand estimation

The total distance of the Sylhet-Jaflong road is 57 km. There are seven CNG stations in this road.

These seven CNG stations are situated within 8.5 km from the sylhet side. But there is no CNG station in rest of 48.5 km.

In this road to determine the number of CNG stations required to fulfill the demand, the total number of vehicles runs in three links: *Sylhet-Jaflong*, *Sylhet-Kanaighat* and *Sylhet-Gowainghat* are collected and shown in Table 1, Table 2 and Table 3.

So, the Fuel Demand for Sylhet-Jaflong Network

$$\begin{aligned} D_1 &= (57 \times 3250 \times 0.0407) + (57 \times 2250 \times 0.0407) \\ &+ (57 \times 667 \times 0.0407) + (57 \times 600 \times 0.1) + \\ &(57 \times 468 \times 0.1) \\ &= 20394.221 \text{ m}^3 \end{aligned}$$

Again, the Fuel Demand for Sylhet-Kanaighat Network,  $D_2 = 1458.918 \text{ m}^3$  and the Fuel Demand for Sylhet-Gowainghat Network,  $D_3 = 1481.5832 \text{ m}^3$

There are number of buses or trucks are run by diesel or petrol. The diesel run buses are  $T_{v1} = 228$  and diesel run-trucks are  $T_{v2} = 1560$ . If all diesel-run vehicles are converted into CNG-run vehicles, then fuel demand,

$$D_4 = (57 \times 228 \times 0.1) + (57 \times 1560 \times 0.1) = 10191.6 \text{ m}^3$$

Total fuel demand according to the equation (1):

$$\begin{aligned} D &= D_1 + D_2 + D_3 + D_4 \\ &= (20394.22 + 1458.918 + 1481.5832 + \\ &10191.6) \text{ m}^3 = 33526.5922 \text{ m}^3 \end{aligned}$$

Now, according to the capacity of a standard fueling station, the fuel capacity of a CNG station is equal  $730 \text{ m}^3/\text{hr}$ , i.e.  $17520 \text{ m}^3/\text{day}$ .

So, the amount of required CNG station in the Sylhet-Jaflong road according to equation (2):

$$\begin{aligned} &= \frac{33526.5922}{17520} \\ &= 1.91 \approx 2 \end{aligned}$$

The total distance of the Sylhet-Jaflong road is 57 km. There are seven CNG stations running in this road. These seven CNG stations are situated within 9 km from the Sylhet side. But there is no CNG station in rest of 48 km.

#### 4.2 Simulation analysis using ARENA model

Rockwell ARENA is a simulation and automation software from Rockwell Automation, Inc. ARENA is being widely used in simulating business processes and various kinds of discrete event operations. Required data for building the ARENA model are collected from the observational process. Statistical distributions of those collected data are found using Input analyzer incorporated in ARENA-10. From the input analyzer we get the statistical distributions and expressions for inter-arrival time and service time of each server as listed in Table 4. The developed model using the ARENA-10 is shown in Fig-6. After running the model in ARENA for

several simulation replications the output is found as shown in Table-5.

## 5. DISCUSSIONS

The results found in Section-3, we find that two CNG stations are estimated to fulfill the fuel demand in Sylhet-Jaflong road. Currently there are seven CNG stations running in this road, so it suggests us that number of CNG station are itself dense in this link of road. The results in Table-5 predict that utilization of a server and average waiting time are not still in the satisfactory level in those CNG stations. Most of the servers are utilized less than 60%. Less average waiting time represents that cars do not need to wait in the queue. Withdrawal of some stations might increase the utilization. So from the both analysis we recommend that any other increase in number of CNG station is not required in this route. Even stations on that route should be relocated.

## 6. CONCLUSION

The required number of CNG stations in given Sylhet-Jaflong road by the fuel demand method is estimated in this paper. ARENA model helps us to identify the performance indicators for each CNG stations. The utilization of each station is not in the satisfactory level. This study suggests that suitable number of CNG stations located properly may increase the utilization of CNG stations. Suitable locating of CNG filling stations would result in saving resources and expenses, reduction of delay time and increasing of the security.

## 7. FUTURE WORK

The future work of this research is to estimate the number of CNG stations in the intercity network of the whole country as well as in the divisional city. The location of each CNG station will be determined using the layout and location theory.

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## 8. MAILING ADDRESS

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Table 1: Vehicles run in Sylhet-Jaflong road  
(Length: 57 km)

Type $T_{vi}$	Number (per day)	Fuel consumption (per meter), $\eta_v (m^3)$
four stroke	3250	$4.07 \times 10^{-5}$
car / micro	2250	$4.07 \times 10^{-5}$
Laguna	3500	$4.07 \times 10^{-5}$
bus	600	$1 \times 10^{-4}$
truck	468	$1 \times 10^{-4}$

Table 2: Vehicles run in Sylhet-Kanaighat road  
(Length: 54 km)

Type $T_{vi}$	Number (per day)	Fuel consumption (per meter), $\eta_v (m^3)$
four stroke	144	$4.07 \times 10^{-5}$
car / micro	70	$4.07 \times 10^{-5}$
Laguna	96	$4.07 \times 10^{-5}$
bus	96	$1 \times 10^{-4}$
truck	48	$1 \times 10^{-4}$

Table 3: Vehicles run in Sylhet-Gowainghat road  
(Length: 53 km)

Type $T_{vi}$	Number (per day)	Fuel consumption (per meter), $\eta_v (m^3)$
four stroke	192	$4.07 \times 10^{-5}$
car / micro	56	$4.07 \times 10^{-5}$
Laguna	144	$4.07 \times 10^{-5}$
bus	96	$1 \times 10^{-4}$
truck	24	$1 \times 10^{-4}$

Table 4: Statistical distributions of different activities in CNG stations

Name of CNG station	Statistical Distribution (Expression)	
	Inter-arrival time (min)	Server
Biroti CNG station (Mirabazar)	-0.5 + LOGN(1.65, 1.33)	1. 0.5 + ERLA(0.397, 3)
		2. 0.5 + ERLA(0.778, 2)
		3. 0.5 + 5 * BETA(0.895, 1.01)
Surma Autocare center (Shivgonj)	-0.5 + WEIB(2.11, 1.31)	1. 0.5 + GAMM(0.588, 2.39)
		2. 0.5 + 4 * BETA(1.72, 1.41)
		3. 0.5 + LOGN(1.58, 1.36)
Al-jalal CNG station (Tilagor)	-0.5 + LOGN(1.77, 1.39)	1. 0.5 + 4 * BETA(1.26, 1.97)
		2. 0.5 + LOGN(1.42, 1.26)
M/S sawkat CNG station (Khadimnagor)	-0.5 + WEIB(2.18, 1.34)	1. 0.5 + GAMM(0.654, 2.21)
		2. 0.5 + GAMM(0.478, 2.36)
R Rahman & sons CNG Filling station (Pirerbazar)	POIS(1.1)	1. 0.5 + LOGN(2.05, 1.81)
		2. 0.5 + ERLA(0.413, 3)

Table 5: Performance indicators of servers of CNG stations

CNG station	Server utilization (×100%)			Avg. num. of waiting cars			Waiting time (min)		
	1	2	3	1	2	3	1	2	3
Biroti CNG station (Mirabazar)	0.32	0.69	0.39	1	8	1	0.010	0.118	0.010
Surma Auto care center, (Shivgonj)	0.67	0.42	0.33	3	2	1	0.059	0.016	0.015
Al-jalal CNG station. (Tilagor)	0.54	0.59	N/A	4	6	N/ A	0.025	0.030	N/A
M/S Sawkat CNG station, (Khadimnagor)	0.28	0.52	N/A	1	3	N/ A	0.002	0.018	N/A
R Rahman and sons CNG filling station. (Pirerbazar)	0.69	0.54	0.82	2	3	2	0.022	0.017	0.075

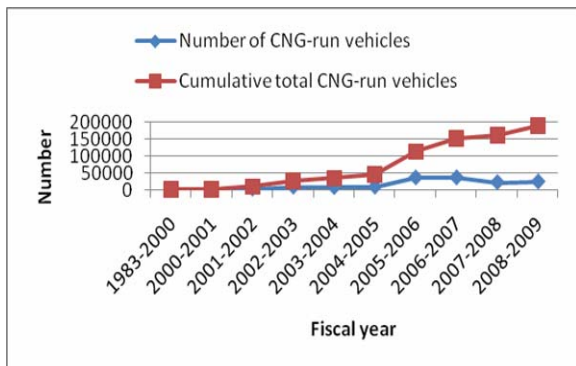


Fig 1. CNG-run vehicles growth between 1983 and 2009 [source: RPGCL]

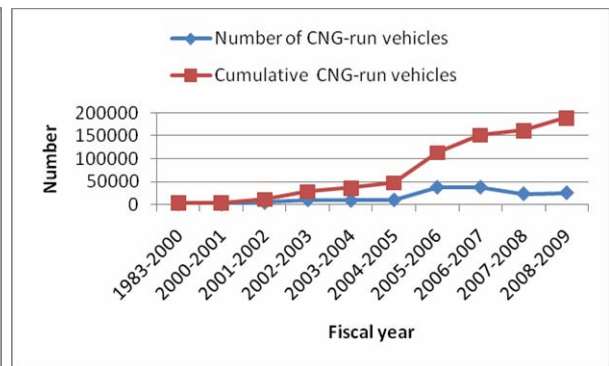


Fig 2. Converted vehicles growth between 1983 and 2009 [source: RPGCL]

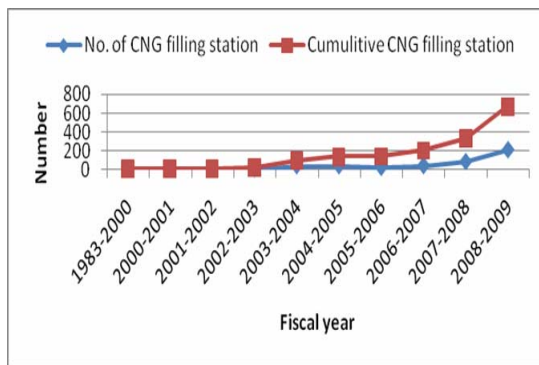


Fig 3. CNG filling station growth between 1983 and 2009 [source: RPGCL]

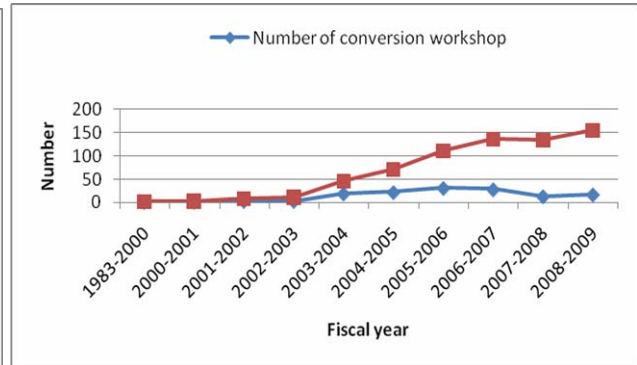


Fig 4. CNG workshops growth between 1983 and 2009 [source: RPGCL]

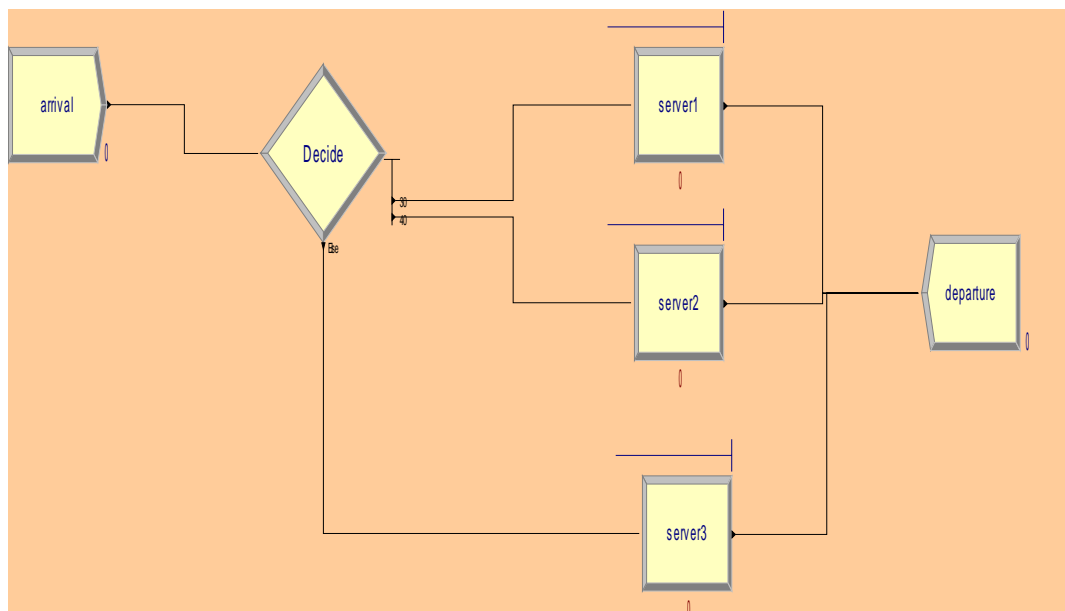


Fig 5. A model of CNG station using ARENA software