Layout of Gas Station Based on Multi-Agent Simulation

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***Abstract*— Owing to the unreasonable layout problem and the excessive number of gas station in some regions of China, this paper attempts to discuss the principle of rationality and related factors for the gas station layout. In determining the relationship between the number of stations and motor vehicle demand, this paper simulates the vehicle's selection of price by using Starlogo simulation platform. While it focuses on researching the traffic flow density and the impact of the consumer price preferences, and analyzing the influence of the station network layout because of price changing. Finally, it attempts to provide a reference for the relevant decision-making.**

***Index Terms*—Multi-Agent Simulation; Complex Adaptive System; Starlogo; Layout of Gas Station**

I. INTRODUCTION

Energy is the important strategic issues which are of common concern to countries around the world, moreover, oil is a very important part of the energy consumption. With China's rapid economic growth, the demand for oil is rising, the crude oil imports rose sharply, and the foreign dependency rate rose to 57% from 32% in the beginning of this century.

In recent years, with the national economy continues to climb and the sharp increase in the domestic car ownership, the demand for gasoline and diesel increased dramatically. The data show that in recent decades, the motor vehicles used about 85% of the total production of gasoline and 20% of the total production of diesel fuel. While the motor vehicle fuel consumption has become one of the largest users in crude oil consumption, and the car became the main factors of the growth of oil consumption. By the end of this year, China's car ownership has more than 100 million. It will become increasingly prominent in oil supply and demand, owing to the car ownership in the rapid growth.

Refined oil is a special commodity and strategic material. While it is important to establish the sales and service network for Retail Gas Station which distribution should be reasonable, competitive and orderly, and fully functional system. Review of the current situation in China, the distribution of gas stations is not reasonable, which is more concentrated near the town or few national highway, and less gas station in rural. For one gas station of Sinopec the average fuel sales is around 1700 tons per year, but it is about 6000 tons in an advanced foreign gas station.

From the perspective of the development of foreign gas stations, the development process of the foreign gas stations should change from less to more, then gradually adjust to reach a broadly balanced between demand and supply. In the United States, the total number of the nation's gas stations reached its highest point of 263,000 in 1977,, and the growing competition in the gas station market lead to the process of natural selection. After that, the number of the nation's gas stations has been in a downward trend, has been roughly steady at 150,900. [1] The distribution of the gas stations network or highway network is closely related to vehicle flows in the U.S., and maximize to consider vehicle refueling and convenience. While it tends to be concentrated in industrial and urban areas, or the entrance along the highway.

Currently there are 95,740 gas stations in China, in which PetroChina Company has 18,233 gas station, accounting for nearly 2 percent of the total number of stations; the Sinopec has 28812 gas station, accounting for the total number of stations about1/3; other state-owned, private and foreign stations totaled 48,695, accounting for 50.9% of the total number of stations.[2]

Statistics data show that about 10 developed countries, in the United States, Japan, Germany, the United Kingdom and others, the gas stations the number of relevant data, the average number of the other 10 countries was only 2.8 per hundred kilometers, but in China the average number is up to 5.7 per hundred kilometers, almost 2 times the average number of the other 10 countries. According to the survey, a province in China gas station density reached 9.19 per hundred kilometers, the radiation radius of a single station is very low, and average a gas station only 141.8 cars are provided refueling services.

Due to the rapid development of computer, the simulation methods become more and more effective in

doi:10.4304/jsw.9.3.627-633

the quantitative research realm. While agent-based modeling method is also an important tool that can help researchers to explore the emergence of complex behavior. Some researchers also try to discuss the transportation networks based on multi-agent simulation.

He and Tong(2012)[3] build a multi-agent architecture in order to process continuous queries of moving objects in mobile and wireless network. An interactive environment of multi-agent system has been designed, and the cooperative multi-agents can complete the continuous geospatial queries in it. Their experiments result shows that the multi-agent simulation method is an effective method.

Meng and Lu(2011)[4] try to research the Networked Software System that can be considered as a dynamic, random and complex character on the functional, behavioral and structural aspects. In order to research its reliability, they propose a new approach based on Multi-Agent modeling and simulation use the Netlogo simulation platform to analyze an example and to verify the effectiveness of the method.

Xu and Luo(2012)[7] build a multi-agent based model, which there are three layers: transport-admin agent layer, node-station agent layer and taxi agent layer.they try to simulate urban intelligent transport system use this model,and try to reduce traffic congestion and air pollution.

In this paper, we try to discuss the principle of rationality and related factors for the gas station layout, determined the relationship between the number of stations and motor vehicle demand, to build an Agent model on the Starlogo simulation platform which based on complex networks and complex adaptive systems, then to simulate traffic flow Game, including the number of gas stations, and the characteristic attributes, finally try to analyze a single gas station site how to influence the entire gas station network.

II. INFLUENCING FACTORS ANALYSIS ON THE GAS STATION DISTRIBUTION

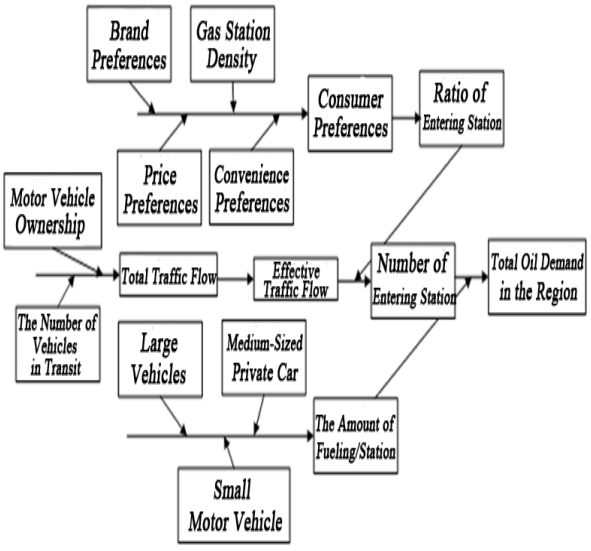
In the face of such fierce competition in the refined oil retail market, how to use scientific methods to adjust the distribution of the gas station, and to effectively enhance the market competitiveness of the petrochemical sales enterprises in the retail market, it is the current problems to be solved.

Integrated many aspects to consider, the distribution of gas station should take into account the following factors:

- The socio-economic development of the region: the region's economic development is the basis of factors which should be considered first when considering the distribution of gas station, while the region's economic development level and the consumer spending power should be put in the first place.
- The area of motor vehicle ownership and transit number of motor vehicles: In recent years, the civilian vehicle growth rate in China is about 20% per year, which makes the consumer a sharp increase in the demand of oil and gasoline, will ultimately affect the distribution and scale of the regional gas stations.
- The density of the gas station: To increase the effective radiation radius of a single gas station, it is help to improve the service efficiency of the gas station, and it is effective and reasonable to optimize the allocation of resources.
- The region's overall layout and road development planning: The overall layout of a regional and road development planning has a great influence on the distribution of gas station layout.
- The differentiation of the adjacent gas station sales strategy: Due to the different amount of gas stations which nature is different in the intra-regional network, the brand influence and the level of service of various gas stations, all of these will ultimately affect the amount and the distribution of the gas station in region.

The measure of a gas station, the most fundamental indicator is how much of the amount of fuel in the period of time, that the total number of oil products for motor vehicle. In this regard, we need to analyze its influencing factors. While the factors affecting the oil sales volume can be summarized as four variables: (1) The total traffic flow in a period of time, (2) Effective traffic flow,(3) The ratio of entering the stations based on consumer preferences, (4) Refueling amount of a vehicle.

In summary, we know that the reasonable location has a decisive effect on other related factors, and directly affects consumer behavior. When drivers refueling, they will consider brand influence of the gas station, oil quality and technical parameters (including indicators of energy consumption, pollution coefficient, burning coefficient), the quality/level of service, the advantages and the sales price. All of these factors have a direct impact on the sales and profits of the gas station. So we can build an evaluation model to analyze the number and scale of Gas station (Figure.1).



Figue 1. Evaluation Model for the Number and Scale of Gas Station.

III. Multi-Agent Simulation Model

Compared China's oil companies with the large foreign oil companies, there is a large gap in the gas station layout planning of the city. There have just some simple planning principles in the planning of our gas station, but the large foreign oil companies pay more attention to the scientific method. In this paper, we attempt to build a multi-agent simulation model to analyze the impact of various factors on the gas station layout. While we also propose a multi-agent simulation model to describe different roles of agents in gas station, and to design behavior, simulation parameters of agents.

A. Agent Behavior Designs

1) Type and Number of Vehicle

As a motor vehicle with a diversity of characteristics, there lead to many different vehicles entering various gas stations due to the geographical differences, including large vans, medium-sized sedan, miniature, compact motor vehicles etc. But the same vehicle refueling also exist little difference, so it is difficult to find a same amount of fuel. While the amount of fuel for each vehicle of different types and the proportion in this region also can be designed, the specific data are shown in Table 1.

TABLE Ⅰ.
THE AMOUNT OF FUEL FOR DIFFERENT VEHICLE

Vehicle type	The amount of fuel for each vehicle(Liter)	Proportion(%)
Large vehicle	150	10
Medium-sized family car	75	20
Small compact car	50	70

2) Refueling Rule

There exist very different amount of fuel due to different type of vehicle, and drivers' the refueling habits also vary from person to person. The real amount of fuel should be taken into account the filling probability level of drivers refueling and drivers' refueling habits. While in this model it can be simplified, and we assume that the drivers choose refueling to full tank when remaining fuel in the tank below the minimum deposit amount.

3) Effective Traffic Flow

The effective traffic flow refers to the number of vehicles per unit time through gas stations. Actual traffic volume is restricted by the time significantly. In actual road network the traffic flow is a bidirectional flow, it has a great relationship with the car traveling speed and the lane number of road sections. While in this model assumptions, the traffic volume is average traffic flow, that it does not change with time, but only related to and location factors.

4) Ratio of Entering the Stations

In actual process, the ratio of entering the stations should take into account such factors, including the intensity of the gas station, the striking logo of the gas station, the speed limit near station, and consumer preferences. According to the above factors, this model assumes that combined with consumer preference and gas station properties, and use different color to mark the different type of gas stations. In accordance with the drivers of consumer preferences, it relates to four influencing factors as follows:

- The brand preferences: These consumers priority to Sinopec, China National Petroleum and other brand gas station, they pay more attention to oil quality and level of service.
- Price preferences: these consumers are more sensitive to the refined oil pricing mechanism. As the gas station taking lower price, consumers consider the price factor as their own preference. When the higher prices exceeded their spending power, they even choose to walk or public transport travel.
- Convenience Preference: As entering the gas station the speed limits, turn restrictions, number of lanes, number of channels, and other service factors should be considered, then such consumers give priority to the distance factor and the convenience factor.
- Density Preference: When the gas station density is too high in a certain area, the consumers give priority to away from this area, and to select the smaller density area refueling. As the effective traffic flow is too more in a density of a smaller area, considering the time factor, these consumers preference to refuel at the time of less traffic flow.

5) Assuming Sales Volume

In order to calculate the maximum value of the distribution and scale of the gas station in a region, it assumes that sales volume is at break-even point, as the lowest volume is in the case of the gas stations without deficit. The sales volume at break-even point is related to the scale of the gas station and management level. Considering practical factors, this data is determined by the gas station construction and investment costs (including fixed costs and variable costs) and oil sales gross margin. Due to fixed costs and variable costs varying with different types and scale of gas stations, the sales volume has also been different at break-even point. In this model, assuming that:

Sales volume = Refueling volume each vehicle × Vehicle number × Prices of refined oil

B. Simulation Interface Design

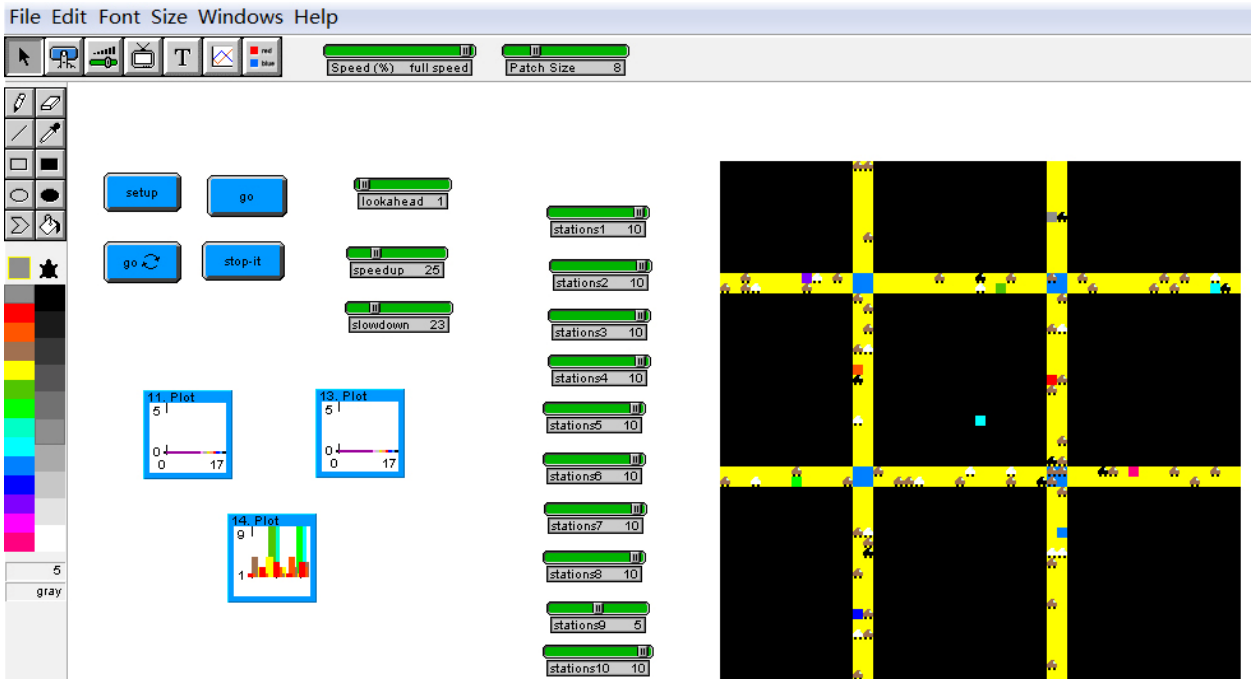
This paper takes the agent-based modeling method and uses Starlogo software to simulate the relationship between the number of gas station and urban motor vehicle ownership according to certain rules.

StarLogo[8] is an agent-based simulation platform developed by MIT, and also is a programmable modeling environment for simulating many real-life phenomena. In Starlogo simulation environment, agent is an autonomous entity, has the ability to make decisions, they can be representative of the types of vehicles, biotechnology etc.

There are two class agents in this paper, that they are gas stations and motor vehicles, representing an entity with independent decision-making ability. It is assumed

that in the market environment each agent will have its own strategy, in order to distinguish them then marked them in accordance with the different colors.

In simulation interface, the control buttons are divided into two kinds. The control function of Gas stations and vehicle agents is divided into the agents' initial quantity, initialization properties, and the agents' game behavior. The counter is used to calculate the number of gas stations changing with the time, and the chart describes the number varying. The simulation interface is shown in Figure 2:



Figue 2. Evaluation Model for the Number and Scale of Gas Station

IV. Simulation Parameters Design

A. Road Network Design

Due to the road layout is critical for the gas station network layout, then the road network is not like radiation diffusion mode in Starlogo, but use the coordinate grid mode. While it should be really reflect the situation of the road network. At the same time, taking into account the car running in the road network, in this paper it adopts the vehicle turning mechanism when encountering crossroads. In this model it takes a 50% probability to turn when the vehicle encounters a crossroads. Its code implementation process is as follows:

```
if ( pc = sky ) and (( random 100) < 50 )
    [ rt 90
      jump 2 ]
```

Meanwhile, in order to take into account the speed limit of the vehicle in the actual road network, in order to prevent the occurrence of crash, clogging and other phenomena, the speed limit is taken. Its code is implemented as follows:

```
if speed < 0.01 [setspeed 0.01]; also adjust speed
based on SpeedLimit and radar
if speed > SpeedLimit [setspeed SpeedLimit]
                      jump speed]
```

B. The Color and Number of Motor Vehicles

In this paper using the simplified way, two class agents are assumed for simulation model, that they are gas stations and motor vehicles. While the number of gas stations is assumed for 10. The model assumes that there exists three types of vehicles, sets the proportion of the number in according to the statistics of the actual traffic flows, and uses color to distinguish the three type of vehicles, as shown in Table 2.

TABLE Ⅱ.
PARAMETER HYPOTHESIS OF VEHICLE

Vehicle type	Color	The amount of fuel for each vehicle(Liter)	Initial oil amount	Proportion (%)
Large vehicle	Black	150	300	10
Medium-sized family car	White	75	150	20
Small compact car	Brown	50	100	70

C. Gas Station Parameter

The model assumes that there are 10 gas stations, and the 10 gas stations located on both sides of the road. In the network diagram, we primarily determine the distribution of the gas stations by coordinates(shown in Table 3).A single gas stations entity's property is described by the oil price and the amount of fuel. The simulation results are expressed in the form of a graph.

The program code of gas station is implemented as follows:

```
if (who mod 10) = 0
   [setshape 1  setc green stamp green setxy 2 13]
  if (who mod 10) = 1
 [setshape 1  setc sky stamp green setxy 8 -11 ] ……
```

TABLE III.
PARAMETER HYPOTHESIS OF GAS STATION

Gas station No	Color code	*Coordinate position*	
		X coordinate	***Y coordinate***
1	Green	2	13
2	Sky	8	-11
3	Violet	-17	14
4	Pink	15	-5
5	Gray	7	20
6	Lime	-18	-6
7	Orange	-12	5
8	Red	7	4
9	Blue	-12	-19
10	Cyan	23	13

D. Simulation Rules

Firstly the gas station is set up in road network, marking gas station: Gi, (i = 0,1,2,……,9). Then to set three attribute values for each gas station agent: (1) Pi: the initial price value for each gas station; (2) G(x, y) coordinate values; (3) Gas station No. While another attribute variables are Si and Ti. Si represents the refined oil stock of the i-th gas station. Ti represents the number of vehicles via the i-th gas station in each time. And the oil price(Pi) of each gas station can be set by slider group. The motor vehicle emerges randomly on the highways. To take account of limit factors of entering station, the car may consume a certain amount of oil in simulation process, when the fuel is less than the limit value, considering at this gas station refueling. The program code is as follows:

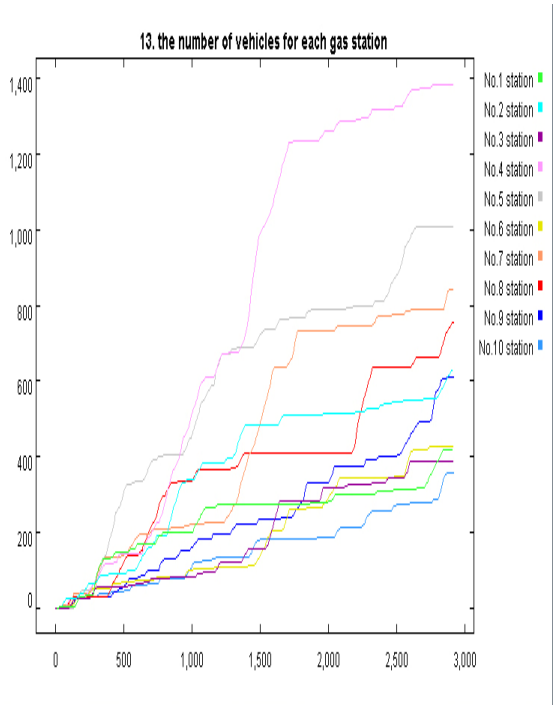
```
if ( (color-of one-of-stations-here) = green )
      [set  stations1cars (stations1cars + 1)
          if  ( energy < 150 ) and ( color = black)
          [ setstations1addoil  ( stations1addoil + 150 )
setenergy 300  ]
          if   ( energy < 100 ) and (color = white)
          [ setstations1addoil  ( stations1addoil + 75 )
setenergy 150  ]
           if  ( energy < 50 ) and (color = brown)
          [setstations1addoil  ( stations1addoil + 50 )
setenergy 100  ] ]
```

V. Analysis of Simulation Results

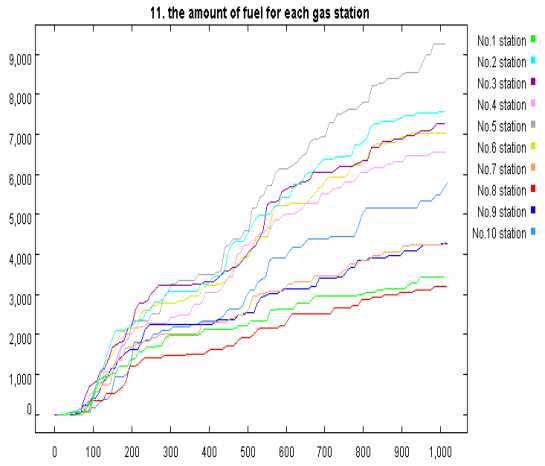
This simulation is based on a simplified model, and the main purpose is to observe the change of oil price in the gas station and the vehicle location distribution how to affect the trend of the number of refueling vehicles and refueling amount. Such simulation result can be used as reference for the gas station layout.

Comparison of two cases is analyzed as follows:

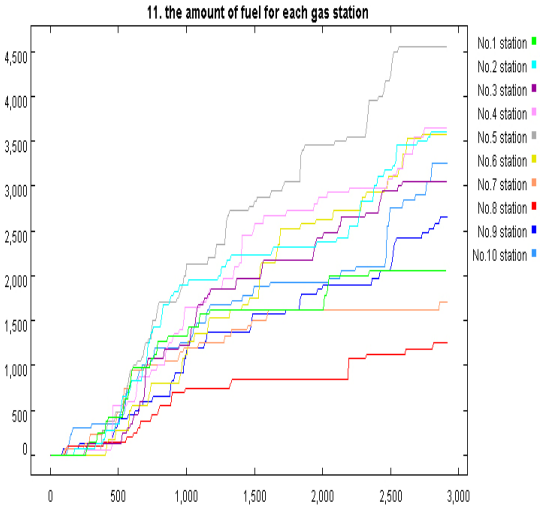
- To set the lowest price for the No. 9 gas stations, its coordinates is (-12, -19), and the color code is blue. Trend in the number of vehicles for each gas station is shown in Figure 3, the trend in the amount of fuel for each gas station is shown in Figure 4, and the vehicle location distribution is shown in Figure 5.
- To reduce the oil price of the No.6 gas station, its coordinates is (-18, -6), and the color code is lime. Then to increase the number of cars in the right lane, and these gas stations(No.2, No.5 and No.8) is here (shown in Figure 8). Trend in the number of vehicles for each gas station is shown in Figure 6, and trend in the amount of fuel for each gas station is shown in Figure 7.



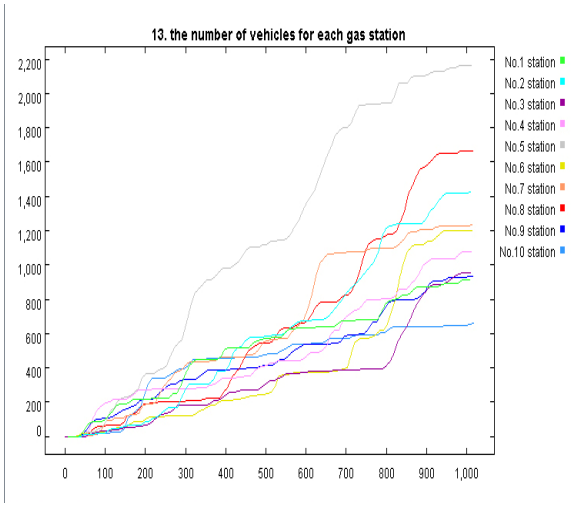
Figue 3. Trend in the number of vehicles for each gas station-1.



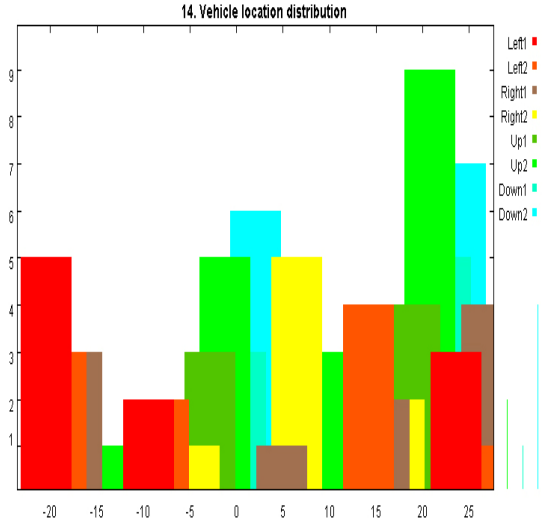
Figue 8. Trend in the amount of fuel for each gas station-2.



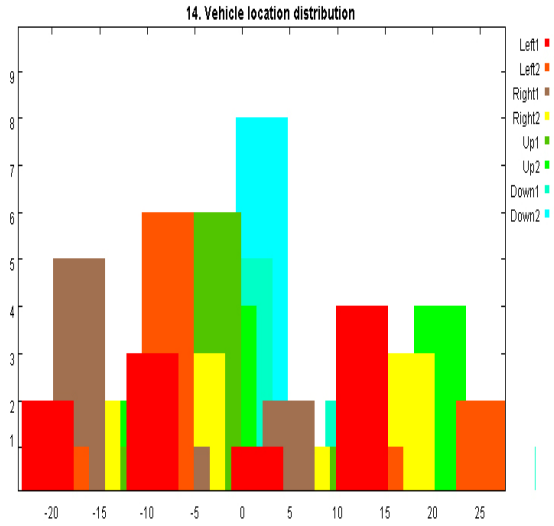
Figue 7. Trend in the amount of fuel for each gas station-1.



Figue 5. Trend in the number of vehicles for each gas station-2.



Figue 6. The traffic flow density -2.



Figue 4. The traffic flow density -1.

From the simulation results graph, we should observe the following condition:

- When the oil price of a single gas station changes, the vehicle will make a choice between the nearby gas station, and the number of vehicles via this gas station will get a certain change. There is a certain impact on traffic flow and the amount of fuel for the gas station. While the layout and scale of gas station will change accordingly.
- When increase the number of cars in the right lane, the vehicles via these gas station (No.2, No.5 and No.8) changes significantly, but the amount of fuel for No.8 gas station varies slightly, it can be inferred the location of this gas station is poorly placed and should be redesigned.

VI. CONCLUSION

At present the gas station location study is just in the quantitative research stage in China, the location of gas stations is mostly based on a qualitative basis, such as environmental safety factors, economic factors, and the convenience factor. This paper attempts to simulate the traffic flow and the vehicle's selection of price for the gas stations by using Starlogo simulation platform. While it focuses on researching the impact of the consumer price preferences, and analyzing the influence of the station network layout due to price changing. Then it attempts to provide a reference for the relevant decision-making.

The model of this paper needs further improvement. In this paper the gas station layout simulation only considers the traffic flow and the game competition of the gas stations between price changes and consumer choice. While further analysis on the multiple choice of consumers can be offered under the influence of other constraints, such as brand influence, the traffic flow density near the gas station, and so on.

ACKNOWLEDGMENT

This work was partially supported by a grant from the National Natural Science Foundation of China （No. 70671107）

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