Research on Access Speed of the Stereo Garage Based on Queuing Theory

Xianglei Zhu [1a], Shuang Lv [1b] and Jian Meng [1c]
[1]China Automotive Technology & Research Center,300300 Tianjin, China

Keywords: Stereo garage; Queuing theory; M/M/S; Access speed;

Abstract: With the contradiction between urban parking problems, three-dimensional garage is an effective way to alleviate the problem of urban parking difficult, but due to the current three-dimensional garage planning unreasonable problems, some three-dimensional garage access inefficient, three-dimensional garage construction after the use of low and serious of the waste of resources, so the rational optimization of three-dimensional garage vehicle access speed is particularly important. Based on the theory of queuing theory, this paper presents a method to optimize the speed of vehicle access. Firstly, the paper analyzes the factors influencing the access scale of the three-dimensional garage and determines the index of the access speed of the three-dimensional garage. Then, based on the theory of queuing theory, the three-dimensional garage access is determined and the M / M / S, The Model of Stacker with Tendency Selectivity Coefficient. And constructs the optimization model in consideration of the tolerance of different customers. Finally, an optimization method for improving the access speed of three-dimensional garage is proposed by selecting different stacker and different speed calculation.

1 INTRODUCTION

At present, relevant researches have been carried out on the three-dimensional parking at home and abroad. Scholars conducted research on the characteristics, scale, and access efficiency of the three-dimensional garage. Zhou Qicai analyzed the parking status and parking service of the three-dimensional garage in the literature [1]. The model discusses the application of parking space utilization and the probability of parking rejection in a three-dimensional garage. It also discusses the possibility of setting a parking buffer to improve the service effectiveness of the parking system. In the paper [2], Jiang Daijun analyzed the mechanical characteristics of the roadway stereoscopic garage, and analyzed the reasons for queueing at the garage entrance and queue and the queuing model according to the queuing theory, and optimized the queue captain and total service time by mentioning a new scheduling strategy. In the paper [3], Zhou Xuesong analyzed and compared the optimal control strategies of two typical three-dimensional garages for access vehicles, namely selecting different objective functions—time and energy consumption, and establishing their optimal control strategy for access vehicles and their The simulation results are analyzed to illustrate the current research status of the optimal control strategy for the access vehicle and its importance in the stereo garage. In the paper[4], Xu Genning proposed four kinds of scheduling principles in order to achieve efficient access to mechanical parking garages, and set up a mathematical model that takes the average access time of the garage as the objective function. In the paper [5], Zhou Zhiyong introduced the multi-service channel loss system to the parking lot queuing system, used the theory of queuing theory and the "birth and extinction process" to establish a probability model of vehicle parking conditions, and improved the vehicle accessibility of the parking lot. In the paper[6], Zhou Qicai analyzed the average parking time for different parking uses, and proposed the concept of parking system fluency and its calculation method. Li Jianfeng in the paper [7] through optimization of the genetic algorithm to optimize the scheduling strategy of the three-dimensional garage, established a mathematical model with the total access time as the objective function. Xi Zhenpeng analyzes different strategies for accessing vehicles in the paper [8]. He chooses the standby strategy as the main strategy, and the parking priority at the peak is the secondary strategy to improve the efficiency of the access garage of the three-dimensional garage. The paper [9][10][11] demonstrated that there is a quantitative relationship between the service time of the stacker and the location of the stacker according to the different ways of location path selection, which shows a positive correlation. And through the argumentation of this correlation, the shortest path configuration method is given. Therefore, the rational planning of a three-dimensional garage and the improvement of the operating efficiency of the three-dimensional garage are of great significance to the promotion and operation of the three-dimensional garage.

2 INFLUENCE FACTORS AND INDICATORS OF STEREO GARAGE VEHICLES ACCESS SPEED

2.1 Influence Factors of Stereo Garage Vehicles Access Speed

The access speed of the solid garage affects the efficiency of the stereo garage, and it is an important index to evaluate the service level of the solid garage. Therefore, improving and optimizing vehicle access efficiency of three-dimensional garage is particularly important for the operation of three-dimensional garage.

The influencing factors of the access speed of the vehicle in the three dimensional garage are mainly as follows:

（1）The number of entrances and exits for stacking garages and stackers;

（2）The access efficiency of the stereo garage stacker;

（3）The traffic organization around the stereo garage.

It can be seen that if we want to improve the access efficiency of the three-dimensional garage, it should be analyzed from the determination of a reasonable number of entrances and exits and the number of stackers and the improvement of the operating efficiency of the stacker.

When studying the access efficiency of a stereo garage, we assume that the number of parking spaces has been determined and sufficient. At this time, the vehicle waiting time only needs to consider the waiting time for the stacker service. The storage process of the stacker is the same as the process of picking a car, and the service rate is also the same. Therefore, only the stored car process is discussed in this article. The stacker crane picking process is not described here any more. The stacker crane model is also suitable for picking up cars. process.

2.2 Index of Access Speed of Stereoscopic Garage Vehicles

（1）Average waiting time

The average waiting time for the parking garage is the time from the arrival of the vehicle to the entrance and exit, waiting in line to receive the stacker service.

（2）The average car waiting for the captain

The average waiting queue captain for a stereo garage is the sum of the number of vehicles that are being serviced by the stacker and the number of vehicles that are waiting in line to receive service.

（3）Average storage time

The average parking time for a stereo garage is the total time from the arrival of the vehicle to the entrance and exit, waiting in line to accept the stacker service, and parking at the designated location.

3 THE M/M/S STACKER MODEL WITH REFERENCE TO THE PREFERENCE COEFFICIENT

3.1 Basic Theoretical Analysis of the Model

（1）Input process

1）Customer number. Assume that the number of vehicles arriving in a stereo garage is unlimited. The number of customers is .

2）Type of arrival. The arrival of the vehicle is a single vehicle arrival. The time interval of arrival is distributed in the second chapter. It has been verified by the data and in accordance with the Poisson distribution.

（2）Service organization

1)The number of service desks. When considering the number of stackers, the stacker is a service desk, and a stacker corresponds to an entrance and exit, and how many stackers correspond to the number of service desks.

2)Service time distribution

Each vehicle receives service, and it is placed in a parking space at a designated location. The time at which the vehicle receives service at the stacker is the access time of the stacker. Because the location of the vehicles in the garage is random, the stacker crane access time is also random. According to the statistical distribution of the garage service time, the corresponding service time of the vehicle is also approximately subject to the negative exponential distribution [4].

（3）Queuing rules

When the vehicle arrives in the garage, if the parking space is full, it needs to wait in line, the queuing rule is the waiting system first to first service, so the analysis is obtained, the stacker service model is M/M/S model.

（4）Tendency selection coefficient

The preference coefficient is that when the vehicle arrives at the garage, it will tend to choose the location convenient for finding and access to the entrance and exit, in particular, it will tend to choose the center entrance. When more entrances and exits, this tendency to choose more obvious. We set the preference coefficient is C_k.

3.2 The Theoretical Analysis Process of the Number Service Model of Stacker

When the vehicle arrives at the garage, the actual queuing process is relative to the stacker, as shown in Figure 3-1.

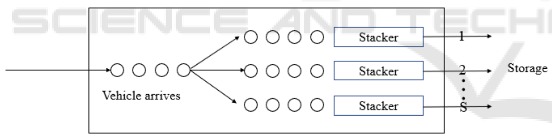

Figure3-1 The queueing process of stacking machine.

When the vehicle arrives, it is possible to choose a stacker exit and entry according to the actual situation. The reason for selection is different from driver's behavior and practice. Some drivers choose convenient access, and some drivers choose to enter the entry line with fewer queues.

We assign the probability that the driver tends to choose an entry and exit, assignment is C_k. $\sum_{k=1}^{S} C_k = 1$ .The vehicle receives the stacker service on the principle of first come and first served at the entry and exit.

According to the above discussion, we do research on queues at various entrances and exits.

Suppose that $N(t)$ is the number of vehicles at the K entry point.

$$P_n(t) = P\{N(t) = n\} \tag{3-1}$$

Where $N(t)$ ——Number of vehicles at the k-th entrance at time t（veh）；

$P_n(t)$ ——The probability of the nth car at the kth entrance and exit at time t.

In a very short time interval, there will be one of the following four situations at the garage exit of K garage. Firstly, there is no vehicle arrival and no vehicle service finished. Secondly, there is only the arrival of vehicles and no vehicle service finished; Thirdly, three is no car arrival and a car service finished. Fourthly, there is only one car arrival, and there is a car service finished.

（1）Firstly, there is no vehicle arrival and no vehicle service finished.

The probability of 0 of the vehicles arriving in a three-dimensional garage is:

$$e^{-\lambda\Delta t} = 1 - \lambda\Delta t + o(\Delta t) \tag{3-2}$$

The number of vehicles reaching the solid garage is 1, but the probability of not entering the K exit is:

$$\begin{aligned} &\lambda\Delta t e^{-\lambda\Delta t} \bullet (1 - C_k) \\ &= (1 - C_k)\lambda\Delta t \bullet [1 - \lambda\Delta t + o(\Delta t)] \\ &= (1 - C_k)\lambda\Delta t + o(\Delta t) \end{aligned} \tag{3-3}$$

No car service end probability is:

$$e^{-\mu\Delta t} = 1 - \mu\Delta t + o(t) \tag{3-4}$$

So the probability of no vehicles arriving and no vehicles being serviced is:

$$\begin{aligned} &[[1 - \lambda\Delta t + (1 - C_k)\lambda\Delta t + o(\Delta t)]][1 - \mu\Delta t + o(\Delta t)] \\ &= [1 - C_k\lambda\Delta t + o(\Delta t)][1 - \mu\Delta t + o(\Delta t)] \\ &= 1 - \mu\Delta t - C_k\lambda\Delta t + o(\Delta t) \end{aligned} \tag{3-5}$$

Where e ——natural logarithm, short-cut process 2.71828;

λ ——Vehicle arrival in unit time（pcu/h）；

Δt ——Tiny time intervals（s）；

$o(\Delta t)$ ——High order infinitesimal quantities of Δt ;

μ ——Average service time of stacker（s）;

C_k ——The probability of reaching the k-th entrance of the arriving vehicle.

（2）Secondly, there is only the arrival of vehicles and no vehicle service finished

At this point, the number of vehicles reaching the garage entrance and exit is 1, and the probability of entering the K exit is::

$$\lambda\Delta t e^{-\lambda\Delta t} \cdot C_k = C_k\lambda\Delta t + o(\Delta t) \qquad (3\text{-}4)$$

The probability that no car has finished service is:

$$e^{-\mu\Delta t} = 1-\mu\Delta t + o(\Delta t) \qquad (3\text{-}7)$$

The probability that only one vehicle will arrive and no vehicle service is completed：

$$\begin{aligned}&[C_k\lambda\Delta t + o(\Delta t)][1-\mu\Delta t + o(\Delta t)]\\ &= C_k\lambda\Delta t + o(\Delta t)\end{aligned} \qquad (3\text{-}8)$$

（3）There is no vehicle to arrive, only the probability of the completion of a vehicle.：

$$\begin{aligned}&\left[1\text{-}\lambda\Delta t\text{+}(1\text{-}C_k)\lambda\Delta t\text{+}o(\Delta t)\right] + o(\Delta t)\bullet\mu\Delta t e^{-\mu\Delta t}\\ &= \mu\Delta t e^{-\mu\Delta t} + o(\Delta t) = \mu\Delta t + o(\Delta t)\end{aligned} \qquad (3\text{-}9)$$

（4）There is a vehicle arriving and there is a probability of completion of a vehicle service.：

$$\left[C_k\lambda\Delta t\text{+}o(\Delta t)\right]\left[\mu\Delta t e^{-\mu\Delta t}\right]\text{=}o(\Delta t) \qquad (3\text{-}10)$$

According to the probability formula, the solution is:

$$\begin{aligned}P_n &= \frac{C_k\lambda_{n-1}}{\mu_n}P_{n-1} = \frac{C_k\lambda_{n-1}\cdots C_k\lambda}{\mu_n\mu_{n-1}\cdots\mu_1}P_0\\ &= \left(\frac{C_k\lambda}{\mu_n}\right)^n P_0 \qquad n\geq 1\end{aligned} \qquad (3\text{-}11)$$

And

$$\sum_{a=0}^{\infty}P_n = 1 \qquad (3\text{-}12)$$

$$\sum_{a=0}^{\infty}P_n = \sum_{n=0}^{\infty}(\frac{C_k\lambda}{\mu})^n P_0 = \frac{1}{1-\frac{C_k\lambda}{\mu}}P_0 \qquad (3\text{-}13)$$

$$P_0 = 1-\frac{C_k\lambda}{\mu} \qquad (3\text{-}14)$$

$$\rho_k = \frac{C_k\lambda}{\mu}\ P_0 = 1-\rho_k \qquad (3\text{-}15)$$

So

$$P_n = (\frac{C_k\lambda}{\mu})^n P_0 = (1-\rho_k)\rho_k{}^n \quad \text{n=0,1,2,}\cdots \qquad (3\text{-}16)$$

Where P_n ——The probability of having n cars at the garage entrance;

μ ——Stacker average service time（s）.

3.3 Basic Parameter Index Analysis of Model

According to the above model analysis can be obtained as follows:

（1）Average number of vehicles at the k-th entrance (including service vehicles)

$$\begin{aligned}\overline{n_k} &= \sum_{n=0}^{\infty}nP_n = \sum_{n=0}^{\infty}n(1-\rho_k)\rho_k{}^n\\ &= (1-\rho_k)\rho_k\sum_{n=0}^{\infty}nP^{n-1}\\ &= (1-\rho_k)\rho_k\frac{d}{d\rho_k}\sum_{n=0}^{\infty}\rho_k{}^n\\ &= (1-\rho_k)\rho_k\frac{d}{d\rho_k}(\frac{1}{1-\rho_k})\\ &= (1-\rho_k)\rho_k \cdot \frac{1}{(1-\rho_k)^2} = \frac{\rho_k}{1-\rho_k}\end{aligned} \qquad (3\text{-}17)$$

（2）Average queue length at the k-th entrance

$$\begin{aligned}L_q^{(k)} &= \sum_{n=0}^{\infty}(n-1)P_n = \sum_{n=1}^{\infty}nP_n - \sum_{n=1}^{\infty}P_n\\ &= \frac{\rho_k}{1-\rho_k} - \rho_k = \frac{\rho_k{}^2}{1-\rho_k}\end{aligned} \qquad (3\text{-}18)$$

（3）Average waiting time

After a vehicle arrives at a garage, the waiting time before choosing the kth entrance to receive service is distributed between t+dt:

$$P(t < \text{w} < t+dt)\text{=}f\left(t\right)dt \qquad (3\text{-}19)$$

This probability value is the product of the following three case probabilities:

Before the vehicle arrives, there are n vehicles at the k-th entrance, and the probability is $P_n=(1-\rho_k)\rho_k^{\,n}$.

During (0,t) there is n-1 vehicle service over time,

Its probability is $\dfrac{e^{-\mu t}(\mu t)^{n-1}}{(n-1)!}$.

A car is being served in (t, t+) time. The probability is μdt for all n values from 1 to n, The above situation is established ,so：

$$\begin{aligned} f(t)dt &= \sum_{n=1}^{\infty}(1-\rho_k{}^{n})\rho_k{}^{n}e^{-\mu t}\frac{\mu t}{(n-1)!}\mu dt \\ &= \mu(1-\rho_k)\rho_k e^{-\mu t}\sum_{n=1}^{\infty}\frac{(\rho_k \mu t)^{n-1}}{(n-1)!}dt \\ &= \mu\rho_k(1-\rho_k)\rho_k e^{-\mu t}e^{\rho_k \mu t}dt \\ &= \mu\rho_k(1-\rho_k)e^{-\mu(1-\rho_k)t}dt \end{aligned} \tag{3-20}$$

$$f(t)=\mu\rho_k(1-\rho_k)e^{-\mu(1-\rho_k)t} \tag{3-21}$$

The distribution function for waiting time is：

$$\begin{aligned} P(\omega\le t) &= \int_0^t \mu\rho_k(1-\rho_k)e^{-\mu(1-\rho_k)t}dt \\ &= -\rho_k e^{-\mu(1-\rho_k)t}\Big|_0^t = 1-\rho_k e^{-\mu(1-\rho_k)t} \end{aligned} \tag{3-22}$$

The average waiting time is:

$$\begin{aligned} \overline{w} &= \int_0^{\infty} t\,dp(w\le 1) = \int_0^{\infty} t\cdot\mu\rho_k(1-\rho_k)e-\mu(1-\rho_k)t\,dt \\ &= \mu\rho_k(1-\rho_k)\frac{1}{\mu^2(1-\rho_k)^2} = \frac{\rho_k}{(1-\rho_k)\mu} \end{aligned} \tag{3-23}$$

Average parking time $\overline{d}$ ：

$$\begin{aligned} f(t) &= \mu\rho_k(1-\rho_k)e^{-\mu(1-\rho_k)t} \\ \overline{d} &= \frac{\rho_k}{(1-\rho_k)\mu}+\frac{1}{\mu} = \frac{1}{(1-\rho_k)\mu} \end{aligned} \tag{3-24}$$

At this point, we have obtained various queueing indicators at the k-th entrance. Here

$$\rho_k = \frac{C_k\lambda}{\mu} \tag{3-25}$$

Where λ ——Average rate of arrival at the entrance；

C_k ——The probability of reaching the k-th entrance of the arriving vehicle；

μ ——The average service time of the stacker（s）

ρ_k ——Service strength at the k-th entrance

Assuming that the average service time of the stacker μ is fixed at this time, as the arrival rate of the vehicle increases, the service intensity of the stacker becomes larger and larger, thus increasing the queue length at the k-th entrance and exit, and increasing the average delay of parking. Garage service is less efficient.

C_k is the propensity selection coefficient, that is, the probability that the arrival vehicle chooses the k-then trance. When the garage system reaches equilibrium, the vehicle arrives at the garage, and the driver tends to choose the equal opportunity for each exit. At this time, the queuing situation at each entrance and exit converges. In the balanced state, the service level of the entire service system can be reflected by the queuing situation at the k-then trance. At this time $C_k = n^{-1}$.

The queuing indicators in the garage system can be derived from the following formulas.

（1）Average number of vehicles in the system:

Set the number of vehicles at each entrance and exit at any time isX1、X2、X3,…,Xm, So the average number of vehicles in the system is：

$$\begin{aligned} \overline{n} &= EX = E(X_1+X_2+\cdots+X_m) \\ &= EX_1+EX_2+\cdots+EX_m \\ &= \overline{n_1}+\overline{n_1}+\cdots\overline{n_m} = \sum_{k=1}^{m}\overline{n_k} \end{aligned} \tag{3-26}$$

（2）Average queue length in the system:

$$\overline{L_q} = \sum_{k=1}^{m}\overline{L_q^{(k)}} \tag{3-27}$$

Queue length at each entrance:

$$\overline{L_q{}'} = \frac{1}{m}\overline{L_q} = \frac{1}{m}\sum_{k=1}^{m}\overline{L_q^{(k)}} \tag{3-28}$$

（3）Average waiting time：

For any vehicle entering the cubic garage system, the probability that its waiting time is less than t is given by Eqs. (3-29) and (3-30).：

$$P(w \le t) = \sum_{k=1}^{m} C_k P_k(w \le t) \tag{3-29}$$

$$w = \int_0^{\infty} t dp(w \le t) = \int_0^{\infty} t d\left[\sum_{k=1}^{m} C_k P_k(w \le t)\right] = \sum_{k=1}^{m} C_k \int_0^{\infty} t d(P_k(w \le t)) = \sum_{k=1}^{m} C_k \cdot w_k \tag{3-30}$$

（4）Average parking time is

$$d = w + \frac{1}{\mu} = \sum_{k=1}^{m} C_k \bullet w_k + \frac{1}{\mu} \tag{3-31}$$

It can be seen from the above formula, When $C_k = n^{-1}$, The queue status of the entire system can be represented by the queue status of any entrance. However because the driver of the vehicle tends to be selective, C_k does not equal n^{-1}, but is a constant different from n^{-1}. Drivers will always tend to choose entrances and exits that are easy to access from the road into the garage area and are convenient for parking and picking up.

3.4 Considering the User Tolerance Optimization Model

The service level of the stereo garage is mainly reflected by the objective indicators of average waiting time and average queue length, but for the same queue length and parking waiting time, the severity of anxiety of different groups of people is different. Tolerance time varies with individual differences and cannot be determined by a fixed length of time criterion.

User tolerance time is not the same for different types of parking garages, It is shown in table 3-1 below.

Table3-1 The user tolerance time of garage for different use.

Different types of parking garage	Tolerance of parking queuing users
Residential parking garage	Residential community parking garage, when residents need to go home parking needs can not be replaced, so parking queues endure a long time.
Office parking garage	The parking garage in the office area solves the need for parking for users to work. It is irreplaceable, and parking queues take longer.
Hotel parking garage	The hotel-type parking garage solves the problem of the user's leisure demand parking, which is not necessarily more optional, so the parking queues endure shorter time
Commercial parking garage	The shopping mall type parking garage solves the user's shopping needs parking, which is more selective and highly replaceable. Overall, the parking queues tolerate shorter times
Medical parking garage	Medical parking garage to solve the user's request for medical parking, urgent and necessary, irreplaceable, parking queue to endure longer
Traffic parking garage	Traffic hub parking garage to solve user travel needs, the only and necessary, irreplaceable parking queues to endure longer

Assume that the longest average waiting time tolerated by the user is $\overline{w_r}$, and the longest average queue length that can be tolerated is $\overline{L_r}$. When the following conditions are satisfied, the optimal number of stackers can be obtained.

$$\begin{cases} \rho_k = \dfrac{C_k \lambda}{\mu} < 1 \\ \overline{w} = \dfrac{\rho_k}{(1-\rho_k)\mu} < \overline{w_r} \\ \overline{L_q} = \dfrac{\rho_k^{\,2}}{1-\rho_k} < \overline{L_r} \end{cases} \tag{3-32}$$

Find satisfaction

$$s^* = \max\left\{ s \middle| \rho_k = \frac{C_k \lambda}{\mu} < 1; \overline{w} = \frac{\rho_k}{(1-\rho_k)\mu} < \overline{w_r}; \overline{L_q} = \frac{\rho_k^{\,2}}{1-\rho_k} < \overline{L_r} \right\}$$

this is the optimal number of stackers.

4 INFLUENCE FACTORS AND INDICATORS OF STEREO GARAGE VEHICLES ACCESS SPEED

In order to optimize the access speed of stereoscopic garage vehicles, the following two methods can be used to reduce the average waiting queue length and the average waiting time.

（1）Only adjust the number of stackers s.

（2）Improve the stacker service speed μ and adjust the number of stacker s in combination.

Assume that the vehicle arrival rate during a leveling period of a certain garage is $\lambda = 60veh/h$,the peak vehicle arrival rate is $\lambda = 90veh/h$,According to design requirements, the average time t for the stacker to complete a car access is 75s.That is $\mu = 75s$ .When there are two stackers, s=2, the index parameters of the three-dimensional garage are shown in the following Table 4-1.

Table 4-1 The number of stackers s = 2 when the three-dimensional garage index table.

λ (veh/h)	ρk	Lq(veh)	W(s)	d(s)	λ (veh/h)
60	0.63	1.04	125.00	200.00	60
65	0.68	1.42	157.26	232.26	65
70	0.73	1.96	201.92	276.92	70
75	0.78	2.79	267.86	342.86	75

During the peak period $\lambda = 60veh/h$, the average parking queue length $L_q = 1.04veh$ and the average waiting time for cars are $w = 125s$ With the increase in the number of vehicles arriving, it is close to the peak, $\lambda = 80veh/h$ .At this time, the average parking queue lengthis $L_q = 4.17veh$, the average waiting time for parking is $w = 375s$ .At this time, the queue length exceeds the design specification of the three-dimensional garage $L_q \le 4$. When the vehicle reaches peakis $\lambda = 90veh/h$ .At this time, the average parking queue length is $L_q = 14.06veh$, the average waiting time for parking is $w = 1125s$. The average waiting time and the average queue length are far beyond the tolerance of customers. The service level of the three-dimensional garage is low, and the normal operation of the garage can no longer be guaranteed.

When the stacker crane service speed is increased by 2%, 4%, and 8%, the index parameters of the three-dimensional garage are shown in table 4-2 below. LetR be the rate of decrease in waiting time from the original speed.

When the number of unused stackers is calculated by the model, the average waiting time for the car and the average car waiting for the captain. The index parameters of the three-dimensional garage when the stacker number is s=3 and s=4 are shown in the following Tables 4-2 and 4-3.

Table 4-2 List of indicators for improving the service speed of the s=2 stacker crane.

μ increase by 2%			μ increase by 4%		
Lq (veh)	W(s)	R	Lq (veh)	W(s)	R
0.97	116.18	7.06%	0.90	108.00	13.60 %
1.31	144.95	7.83%	1.21	133.71	14.97 %
1.79	184.02	8.87%	1.63	168.00	16.80 %
2.50	240.10	10.36%	2.25	216.00	19.36 %
3.64	327.41	12.69%	3.20	288.00	23.20 %
5.69	482.09	16.82%	4.82	408.00	29.60 %
10.39	831.12	26.12%	8.10	648.00	42.40 %

μ increase by 8%		
Lq(veh）	w（s)	R
0.83	93.35	25.32%
1.11	113.98	27.52%
1.50	140.62	30.36%
2.07	176.33	34.17%
2.94	226.71	39.54%
4.42	303.13	47.69%

When s=2, s=3, s=4, μ original speed and s=2, μ increase speed by 2%, 4%, and 8% respectively, wait for the captain to draw a map as the vehicle arrival rate changes, as shown in Figure 4. -1 shows.

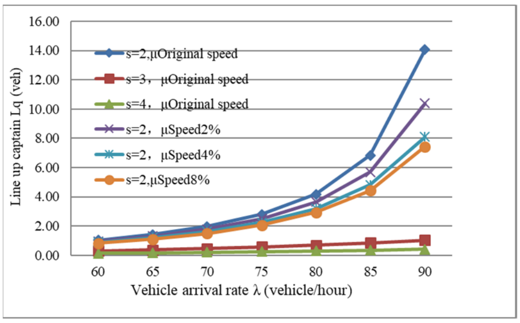

Figure 4-1 Relationship between arrival rate and waiting captain.

When s=2, s=3, s=4, the average waiting time of the car when the original speed and the speed of µ increase by 8% are plotted as a function of the vehicle arrival rate, as shown in Fig. 4-2.

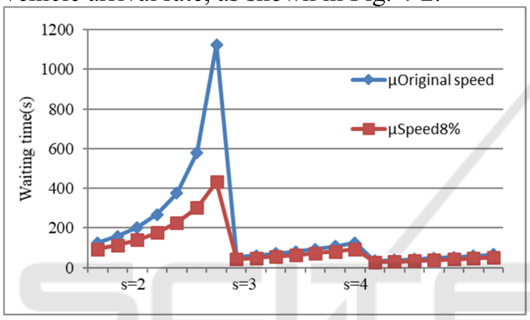

Figure 4-2 The relation schema between arrival rate and queue size.

When s=2, s=3, s=4, when the original speed of µ and the speed of µ increase by 8%, the average waiting distance of the car is plotted as the change of the vehicle arrival rate, as shown in Fig. 4-3.

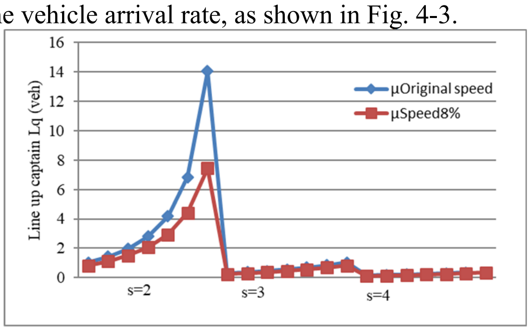

Figure 4-3 stacking machine number is not waiting for the captain change map.

By analyzing the data in Tables 4-3 , as shown in the data changes in Figure 4-2, Figure 4-3, when the number of stackers s = 2, the vehicle arrival rate is between During the change, by increasing the service speed of the stacker, the stacker crane's access efficiency can be significantly improved. The average waiting time and the average waiting team captain are all greatly reduced, and the service level can also meet the customer tolerance. At this time, increasing the number of stackers and optimizing the access speed is not as obvious as improving the service speed of the stacker. That is, there is no need to increase the number of stackers, improve access efficiency, and reduce energy consumption. When the arrival rate of the vehicle changes from time to time, the optimization effect of only increasing the service speed of the stacker on the access speed is not obvious. The average waiting time and the average waiting time for the team leader are too long, the service level is low, and the user cannot satisfy the user. demand. Therefore, increasing the number of stackers at this time optimizes the access speed, which can significantly increase the access speed and service level of the stereo garage vehicles. The increase in the service level of the two stackers is not obvious, so only one stacker is needed.

Due to the fact that the three-dimensional car garages are mostly built in areas such as hospitals and shopping malls where the traffic volume is relatively large, it is recommended to use three stacker cranes in actual operation. During the peak period of non-traffic, two stacker cranes work and fine-tune the stacker cranes. The service speed µ, the level of service can meet most of the vehicle arrival rate, stereo garage can be effectively run, when the traffic peak period, when the three stacker crane work at the same time, to ensure that the three-dimensional garage operates at a higher level of service . The third stacker can be used for inspection when idle. This will not only optimize the access speed of the three-dimensional garage, improve the service level of the garage, but also reasonably save energy consumption, but also ensure the rational operation of the mechanical stacker.

5 CONCLUSIONS

This article first analyzes the factors affecting the access speed of the stereoscopic garage, and determines the index of the access speed of the stereo garage. Then it establishes a model of the number of stereo garage stackers with reference to the selection coefficient. Under the condition of customer tolerance, the optimization of the quantity model of the stacker was optimized. Finally, the vehicle access speed of the stereo garage is optimized by changing the number of stackers and configuring the service efficiency of the stacker.

REFERENCES

1. Zhou Qicai, Pei Ning, XiongXiaolei. Discussion on Parking Garage Service Model and Efficiency Based on Queuing Theory[J]. China Journal of Construction Machinery, 2005 (2): 161-164.
2. Jiang Daijun. Research on the queuing and location optimization of roadway stacking type three-dimensional garage[D]. Chongqing University, 2014.
3. Zhou Xuesong, Tian Mi, Ma Youjie, et al. Research on Optimized Control Strategy of Intelligent Stereo Garage Access Vehicle[J]. Manufacturing Automation, 2008, 30(10): 29-34.
4. XU Gening, CHENG Hongmei, CHEN Yanwei. Optimizing the Principle of Accessing and Dispatching for Stereoscopic Garage Vehicles Based on Queuing Theory [J]. Hoisting and Transport Machinery, 2008 (5): 50-55.
5. Zhou Zhiyong, Chen Jun, Wang Wei. The acceptance condition of parked vehicles based on queuing theory[J]. Journal of Southeast University(Natural Science), 2006, 36(4): 638-642.
6. Zhou Qicai, XiongXiaolei, Ren Jianqiang, et al. Characteristic Analysis and Fluency Calculation of Stereoscopic Parking System [J]. China Civil Engineering Journal, 2005 (1): 41-45.
7. Li Jianfeng, Duan Wenjun, Fang Bin, et al. Optimization of Access Parking Dispatching Based on Improved Genetic Algorithm[J]. Control Engineering, 2010, 17(5): 658-661.
8. Xi Zhenpeng. Analysis of the Access Policy of Stereoscopic Garage Based on Queue Theory [J]. Forum on Industry and Technology, 2011, 12: 81-82.
9. Potrc,T.Lerher, J. Kramberger, and M.Sraml. Simulation model of multi-shuttle automated storage and retrieval systems. Journal of Materials Processing Technology,2004: 236-244
10. Motoji Yamamoto, Yoshiaki Hayashi and Akira Mohri, Garage parking planning and control ofcar-like robot using a real time optimization method[C] Proceeding of the 2005 IEEE International ConferenceonAssem Task Plan,July19-21,2005,Canada,2005:248-253.
11. Perry R F, Hoover S F, Freeman D R. Design of an Automated Storage/Retrieval System Using Simulation Modeling[J].Institute of Industrial Engineers. ICAW Proceedings,1983: 57-63.
12. Jung S,Moon B R. Toward Minimal Restriction of Genetic Coding and Crossovers for the 2nd Eunclidean TSP . IEEETrans on Evolutionary Computation, 2002, 6 (6) : 557-565.