Improving the efficiency of technical service enterprises at the expense of specialization, power and their location

Subochev O.[1], Sichko O.[2], Pohorelov M.[3], Solodovnyk D.[1]
[1]Engineering and Technology Faculty – Dnipro State University of Agriculture and Economics, Ukraine, e-mail: subochev.alex@gmail.com,
[2]Automotive Engineering Faculty of – National Transport University, Ukraine, sae@ua.fm
[3] Technological faculty - Donbass State Pedagogical University, Ukraine, texfak@gmail.com

Abstract: *Were selected queuing systems with different load, queue length and type of mutual assistance for the calculation of technical and economic indicators of technical service enterprises. The models of functioning A, B, C are given, which mainly reflect the properties of the internal environment of technical service enterprises. For the form of labor organization (model B), partial mutual assistance between the performers is provided, a mathematical model with a limited queue length is adopted. Optimization of the capacity of technical service enterprises is expressed in determining the number of service posts. The dependence of the level of competitiveness of technical service enterprises of the average and maximum possible queue length, the expected cars is obtained. When observing the structure of technical service in Dnipro, changes in the number of technical service enterprises were obtained by type of work performed, depending on the years of work. It has been substantiated that the criterion for choosing the type of specialization, location and capacity of service enterprises is the payback period of capital investments. It was optimized selection of a service company for forecasted demand, accommodation and specialization in a competitive environment.*

Keywords*: SERVICE ENTERPRISE, PLACEMENT, ENTERPRISE POWER, SPECIALIZATION, MUTUAL ASSISTANCE.*

1. Introduction

Technical service is an intensively developing industry. The success of the industry is limited, and there are too many shortcomings today. Success is due to the efforts of employees, and shortcomings - objective or subjective factors. These factors are reflected both in society as a whole and in technical service as a component of the social and economic system of society - the real state and the ratio of each of the factors. In general, there is a situation when the set of factors and the state of each of them are limited rather than conducive to the development of technical service [1].

A peculiarity of technical service enterprises operation (TSE) for maintenance and repair of cars at present in Ukraine is the presence of enterprises of different sizes and forms of ownership, which use a significant range of rolling stock. An important issue under these conditions is to determine the optimal way to organize service production depending on the number of units of rolling stock and operating conditions [2, 3].

Formed in the early 90's spontaneous road transport market is becoming more civilized every year, established permanent links between its participants. In connection with the growth of purchasing power of the population there is a steady increase in demand for new and used cars, which, in turn, leads to an increase in the market of services for car maintenance and repair [4].

About 10% of TSE specialize in servicing only foreign-made cars, they also include official dealers of vehicle manufacturers [5].

2. Problem statement

The constant growth of the car fleet has led to an increase in production capacity, i.e. has led to an increase in the number of technical service enterprises. At the same time, customer requirements are increasing. That is, customers of technical service enterprises give preference to those market participants who offer the necessary services and ensure high quality of their performance, in accordance with international standards [6, 7].

In this regard, there are new trends in the placement of TSE within cities. Previously, repairs of trucks and municipal buses were performed on their own production base and the established service enterprises were located in fairly small farms with one workplace [5].

Currently, construction is expanding, using the concentration and specialization of production, concentrating industrial facilities, trade in the central and adjacent areas of cities. This relocation of potential customers has led to a change in the location of new technical service enterprises [8].

3. Research results

To calculate the technical and economic indicators of service enterprises, it is necessary to have their characteristics as queuing systems (QS). These studies considered the possibility of the existence of 4 types of competition: acute, moderate, weak and zero.

Mathematical models of open QS with limited queue length for three forms of labor organization are selected:

A - without mutual assistance of performers;

B - with partial mutual assistance of performers;

C - with the full mutual assistance of performers.

These models of operation A, B, C, mainly reflect the properties of the internal environment of TSE, which can be adopted in one or another form workers' work organization at the maintenance and repair posts of cars, gas stations and parking lots. Meanwhile, there is a correlation between the forms of labor organization and the level of competition.

Let's consider at the first stage of the model of operation of the technical service enterprise in the absence of mutual assistance between the performers. After solving the differential equations of the state of the system, the following characteristics were obtained:

Probability that all posts are free:

$$P_0 = \frac{1}{1 + \sum_{k=1}^{n} \frac{\psi^k}{k!} + \frac{\psi^k}{n!} \sum_{s=1}^{m} \left(\frac{\psi}{n} \right)^s}$$

Probability that all areas of posts are occupied by service:

$$P_n = \frac{\psi^n}{n!} \cdot P_0 = \frac{\frac{\alpha^n}{n!}}{\sum_{k=1}^{n} \frac{\alpha^k}{k!} + \frac{\alpha^n}{n!} \psi \frac{1-\psi^m}{1-\psi}}$$

The probability that all posts occupied by the service in the queue is equal to the applications:

$$P_{n+m} = \frac{\psi^m}{n!} \left(\frac{\psi}{n} \right)^m \cdot P_0 = \psi^m \cdot P_n$$

According to initial conditions, if there are a valid number of applications m in the queue, the car leaves the enterprise, so:

$$P_{DEN} = P_{n+m}.$$

The average number of posts occupied by the service:

$$M_{SP} = \sum_{k=1}^{n} k \cdot P_k + n \sum_{k=1}^{m} P_{n+k} = n\psi \left(1 - \psi^m P_n \right)$$

The average number of applications in the queue

$$M_Q = P_n \psi \frac{1 - \psi^m \left[n(1-\psi) + 1 \right]}{(1-\psi)^2}$$

The number of cars that left the queue

$$\lambda_0 = \lambda \cdot \psi^m \cdot P_n$$

Assuming in these statements $m = \infty$ the allowable number of applications in the queue is unlimited, we obtain formulas that allow you to calculate the performance of the TSE, operating in the absence of competition. Conversely, $m = 0$, the characteristics of service companies operating in conditions of fierce competition, when the car in the absence of vacancies immediately leaves the enterprise.

For the form of labor organization (model B) provides for partial mutual assistance of performers, a mathematical model with a limited queue length is also adopted, in which workers can be grouped by 1 person in one perm (Fig. 1).

Thus, with weak competition, when the level of capacity utilization is high, it is more legitimate to use model A, which corresponds to the form of labor organization without mutual assistance to the performers.

With average competition, when the load level is quite low, there is the possibility of occasional mutual assistance between performers. This pattern of interaction of performers in stochastic flows of requests and decisions is more legitimately approximated by model (B) by mathematical expressions of QS with partial mutual assistance between performers (Fig. 1).

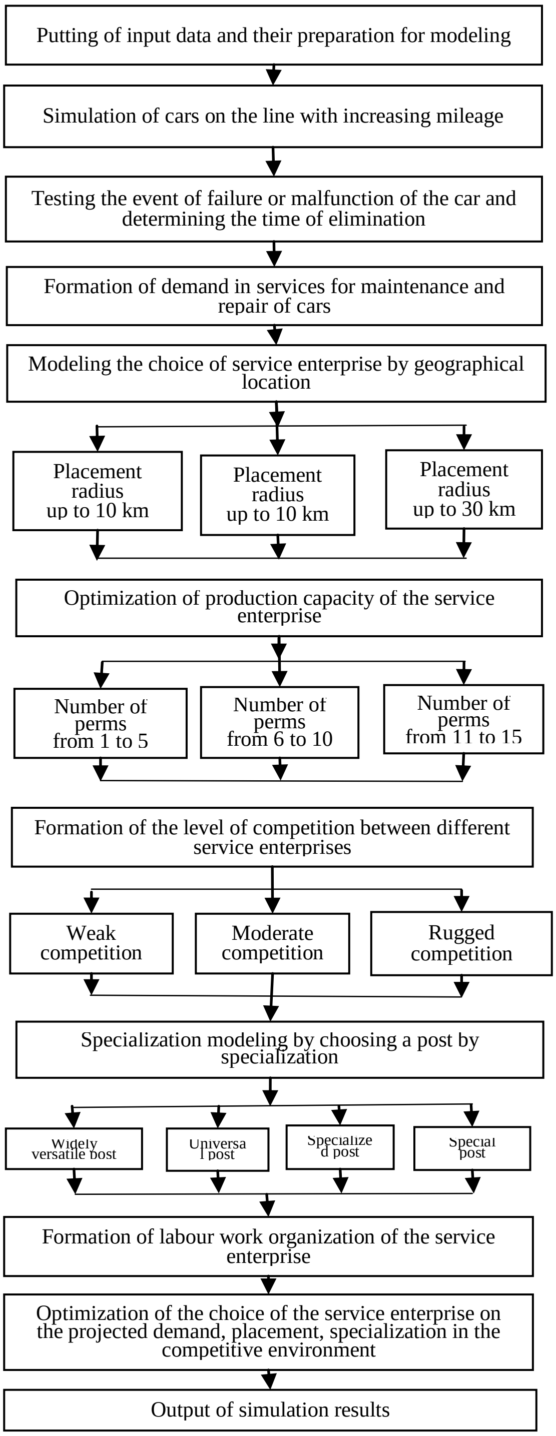

Fig. 1. *Algorithm at the technical service enterprise on the forecasted demand, placement, specialization in the competitive environment*

The third model of service enterprises (model C), in which full mutual assistance between performers is possible, is typical for small-scale production (small service stations, gas stations, parking lots, car washes, etc.), as well as high cost of car maintenance, foreign cars, trucks, etc.

Optimization of the road technical service enterprises has been reduced to determining the number of perms.

The number of current repair perms is determined by the classic deterministic formula:

$$n_{CR} = \frac{T_{CR}\varphi}{T_{SH} C_{SH} P_P \eta_{WT}},$$

T_{SR} - daily labor intensity of works, which reflects the estimated level of mechanization of works;

φ - coefficient of non-uniformity of capacity loading according to standards;

T_{SH} - duration of work shift;

C_{CH} - number of work shifts per day;

P_P - number of workers in the perm;

η_{WT} - working time utilization rate.

The value T_{SR} indirectly estimates the impact of the productivity of technological equipment due to the known adjustment factor depending on the scale of production.

You can determine the required number perm at a normalized value of the load factor, which takes into account the stable nature of production processes, but does not reflect the cost components of production efficiency.

The number of current repair perms without a load unevenness factor, which is equal to the inverse of the power load factor, is a common parameter:

$$\psi = \frac{\lambda}{\upsilon} = \lambda \cdot t_{SER}$$

From the fact that the parameter is included in the formulas of the theory of queuing, as one of the main initial parameters, there is an opportunity to move to capacity optimization at the design stage of the service enterprise. However, when designing a service enterprise, the values are determined much more difficult due to the presence of a large number of enterprises in one car service network.

Technical service enterprise income per day:

$$I_{TSE} = \lambda_{SER} \cdot C_{EV} = \lambda_{\text{вх}} \left(1 - P_{DEN}\right) C_{EV},$$

λ_{SER} - number of services;

C_{EV} - the average cost of one car maintenance;

λ_{IF} - input flow of applications.

At the same time, it should be considered that a highly skilled worker helps to increase the input flow of applications λ_{IF}. The same effect has technological equipment, which may not always increase productivity, but increases the prestige of the enterprise, and, consequently, competitiveness.

In both cases, the average length of the queue of cars waiting for service increases, so that a smaller number of cars from the number received by the service enterprise, goes to the competitor. In addition, the flow of incoming applications increases λ_{IF}. To make optimal decisions in both cases, it is necessary to identify the relationship between these parameters and the intensity of the incoming flow of applications λ_{IF}. This problem can be solved by conducting an experiment at existing enterprises.

To determine the optimal parameters of service enterprises, a universal and effective method of finding the extremum is adopted - the method of dynamic programming.

The essence of the method of dynamic programming is that the optimal solution has the property that whatever the initial state and the solution at the initial moment, the subsequent solutions must be the optimal solution for the state resulting from the first solution.

It is advisable to take into account that each time the value of the load factor ψ associated with other parameters changes:

$$\psi_0 = \frac{\lambda_{IF} \cdot T_{CR}}{\upsilon n} = \frac{\lambda_{IF} \cdot t_{mp}}{T_{WT} \cdot P_p \cdot \delta_{IQ} \cdot n}$$

Naturally, when changing one of the parameters $T_{WT}, P_P, \delta_{IQ}, n$ it is necessary to calculate the new (predicted) ψ , and then the probability of departure of the car P_{DEN} according to the formulas of queuing in the appropriate forms of labor organization.

The greatest tension arises in the "young" suburbs of the city, where there is a significant need for road transport that connects the peripheral areas with the center, and the increase in maintenance capacity traditionally lags behind these needs. In this regard, there is a task to identify and overcome imbalances in the development of urban transport.

During the observations on the structure of service enterprises in Dnipro city, changes in the number of service enterprises by types of work performed depending on the years of work were obtained (Fig. 2; Fig. 3). This technique allows you to choose the type of specialization, location and determine the optimal capacity of the service company at the design stage of the service company.

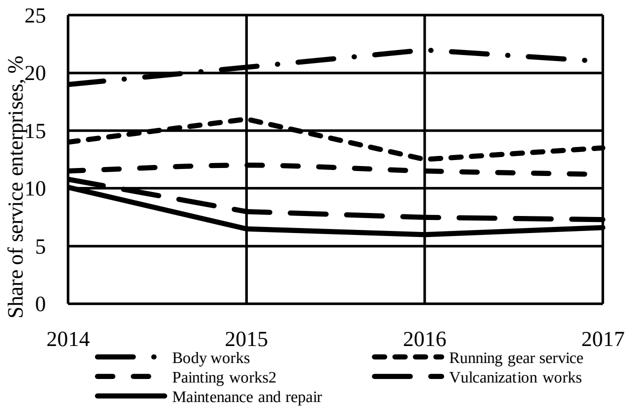

Fig. 2. *Change in the structure of service enterprises in Dnipro city by years of operation*

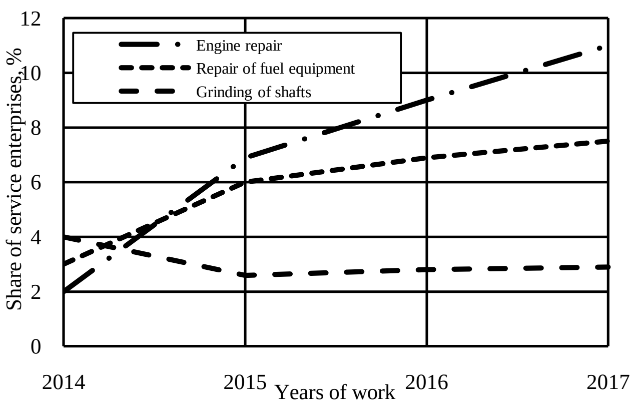

Fig. 3. *Distribution of service enterprises with complex repairs in Dnipro city by years of operation*

At the decision of the specified task conducting on the basis of the full and incomplete information on the operating enterprises of a network of technical service is provided.

Incomplete information is a large amount of input data on the characteristics of the service company throughout the technical service network of the city.

The influence of economic factors in the form of initial capital investments on the growth of the number of service enterprises is especially significant on the example of enterprises for grinding shafts. Due to the fact that for this type of work there is no need to build a production building and the main costs associated with the purchase of process equipment, relocation of equipment located in small rooms, did not require significant capital investment. This fact explains the fact that most of the enterprises of this profile of the entire car service network are located in the central part of the city. Approximately the same picture occurs for companies specializing in the repair of the chassis.

Complete information is based on the same data on the characteristics of service enterprises in one or more randomly selected neighborhoods of the city - the expected locations of the projected enterprises.

The approximate values of the service enterprise load factors of the local or general network of technical service for each specialization are calculated. From all types of specialization, the three with the largest average values of the load factor of the designed enterprises are selected.

If the calculations are carried out throughout the car service network of the city, then for each of the 3 best specializations are calculated forecast values of load factors for 3 companies in 3 districts of the city.

The final choice of the type of specialization, location and optimal capacity of the projected enterprise is made in the calculation and comparative analysis of the projected technical and economic indicators of the three enterprises.

Examining the experience of formation and development of production structures of road transport, we can conclude that the combination of the latter is not the only acceptable. A significant proportion of freight road transport service enterprises specialize in some activities, outsourcing others to third economic agent market participants.

In the process of modeling the dependences of the average length of the queue M_Q of cars, the probability of servicing P_{SER} cars depending on the number of working perms at different capacity utilization of service enterprises, different queue restrictions and types of mutual assistance between performers (Fig. 4; Fig. 5).

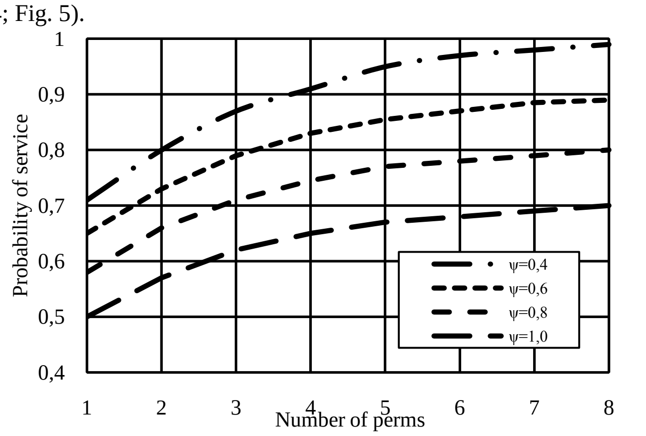

Fig. 4. *Change in the probability of car maintenance depending on the number of perms at different load factors of the service enterprise in the absence of queues (m=0) and the lack of mutual assistance between the performers*

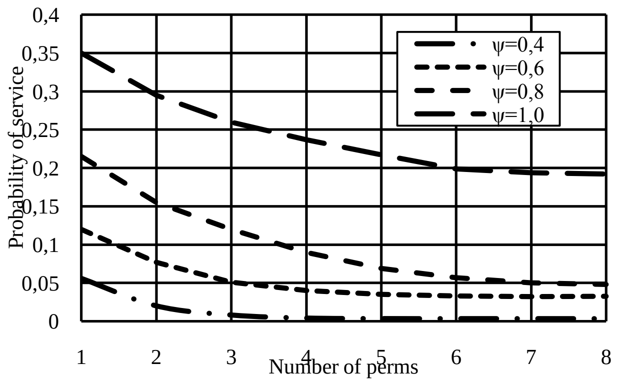

Fig. 5. *Change in the average length of the queue of cars depending on the number of posts n at different load factors of the service enterprise ψ and the lack of mutual assistance between the performers*

Based on the simulation results, the following conclusions are drawn:

The criteria for the level of competition in the car service network are the average M_Q and maximum possible m length of traffic waiting for service.

The average number of posts in the car service network of small towns ranges from 1 to 2, and the number of performers is 2-3 people.

According to the results of modeling the indicators of the service enterprise in the range of real values of the load factor ψ = 0.4 - 0.8, the probability of service depending on the maximum possible length of the queue ranges from 0.2 to 0.98 at ψ = 0.4 and 0.73 - 0.94 at ψ = 0.8 for n = 3.

As the number of posts increases, the possible service in the range ψ = 0.4 - 0.8 increases: so when n = 1 and ψ = 0.6 in the absence of a queue, it is equal to 0.76, and when n = 3 P_{SER} = 0.81. However, the specific flow density decreases.

With an average load ψ = 0.6, the probability of service depending on the maximum length of the queue varies between 0.81 - 0.97, i.e. about 16% of customers can leave the queue.

4. Conclusion

1. The network of enterprises of technical service of cities is a few dozen subnets of equal number of specializations for a certain technological cycle.
2. The technique of experimental establishment of indicators of capacity of set of operating posts of technical service on factor of loading and average length of cars allowing to cover all network of technical service is developed.
3. Mathematical models, adopted as basic, reflect the main factors of the external and internal environment of enterprises and allow to determine the performance of the service enterprise as a queuing system at the design stage.
4. Forms of labor organization and the level of competition of the service enterprise depends on the values of load factors: at high values there is weak competition and lack of mutual assistance, at low load there is fierce competition and full mutual assistance of performers.
5. The criterion of optimality in the creation of new service enterprises is the profit and payback period of capital expenditures.
6. The proposed set of analytical models will reflect the main factors of the internal and external environment of service enterprises, as well as the mathematical model with limited duration and partial interconnection of performers is universal, i.e. at L = 1 the model approximates the lack of mutual assistance, and at L = n - full mutual assistance.
7. The proposed algorithm for adapting the generally accepted regulatory framework for the formation of the capacity of service enterprises, which allows calculations to take into account the impact of major operational factors on the daily program.

5. Literature

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