Study of the operation of taxi cars in an emergency situation

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Abstract. This paper examines the transportation work of taxi companies operating in the city of Ruse in an emergency situation caused by the COVID-19 epidemic when the number of requests for taxis decreased by 60%, about 30% of drivers stopped working due to reduced workload. The aim of the present study is to identify changes in their work intensity. The taxi operating system is modelled as a queuing system with failures with non-stationary incoming flow of requests and a variable number of service channels. After collecting and processing statistical information about the received requests, the incoming flow is modelled as a periodic nonlinear function. The main parameters of the study are: density of failures, average number of taxi cars occupied per day and intensity of serviced requests. The object of the study is a full working day of 24 working hours, taking into account the reduced intensity of transportation work. Even at the highest peaks the load coefficient is below 0.1, which means that in the intervals with the highest load, the service occupancy is below 10% of those working at the moment. In the interval from 0:00 h to 7:00 h a load factor slightly above 0.04 is observed. An application has been created in the environment of MATLAB.

1. Introduction
In the late 2019, the first case of a coronavirus called SARS-CoV-2 was identified in Wuhan, central China. This happened after many people developed pneumonia in December for no apparent reason and the treatment of which is not affected by traditional methods. Almost all countries in Europe, North America, Asia-Pacific reported new cases of 2019-nCoV [1]. The incubation period of the virus is between 2 and 14 days, but it is transmitted before the onset of symptoms, as well as a few days after cure. This has led the governments of almost all countries to take various measures to reduce the infection by reducing social contacts and increasing the distance between people. Such measures to distance and limit social contacts in order to limit and slow down the spread of the COVID-19 epidemic have major economic and financial implications and should be the subject of research.

The COVID-19 coronavirus pandemic and the measures taken to curb it have reduced both private and urban passenger journeys, including taxis.

Analysis of data in the city of Ruse shows about six times a decrease in travel by urban passenger transport during the state of emergency.

The number of requests for taxis decreased by 60%. This affects the organization of work in dispatching points and taxi companies. The number of employees in the control points decreases by 50%. About 30% of drivers stop working due to reduced workload. Passengers are mainly transported under contracts with corporate clients. All operating vehicles are equipped with protective Plexiglas transparent partitions between the front and rear seats, with the aim of separating passengers from the driver as the best precaution against contamination with COVID-19. All preventive measures against...
infection have been taken for the drivers - equipment with masks and gloves, and treatment of taxis with disinfectants [2, 3].

The purpose of the present study is to establish the change in work intensity in the emergency imposed by COVID-19, to determine the main parameters of taxi activity in emergency situations and to determine the load factor of a car for a day. The created model makes it possible to simulate different variants of work organization. This will allow you to calculate the load factor of a server per day for these options. Thus, it will be possible to choose the option that will satisfy the management of the company to the maximum.

2. Literature review
Restrictions imposed in some cities on evening and night travel have further limited the work of taxi companies.

In recent years, the development of road transport is happening at a very fast pace. Due to its good technical and operational qualities – being faster and more flexible - it does not require in certain cases special road conditions. It turns out to be more convenient for a number of shipments. This predetermines its rapid development, which in turn leads to an increase in traffic motor vehicles. In a state of emergency, the pace of this process is greatly reduced.

An important characteristic of the transport flow is the intensity of traffic. It represents the number of cars that have crossed a section of road per unit time [4]. The intensity of movement changes during the hours of the day, week, month and year. The traffic on the street network of a city depends on the number of vehicles in motion, the territory of the city, the density of the street network and how the connections between the traffic and pedestrian flows on one or several levels are made [5].

Due to the sharply reduced intensity of traffic on the transport network, many problems arise related to the organization, management and safety of traffic. These problems are of different nature and complexity [6].

There are a total of about 2,800,000 vehicles registered in Bulgaria, which are roughly divided into the following groups [7]:
- light passenger – 2,200,000;
- minivans and vans incl. minibuses – 400,000;
- light goods up to 3.5 tons – 50,000;
- public transport buses – 6,000.

Passenger taxi transport is an integral part of the public transport system in the modern city. It has a number of advantages over the mass urban transportation of passengers between different areas of the city - non-connection with a pre-established route network (i.e. the ability to perform transport on routes freely chosen by passengers), the ability to perform transport "from door to the door", 24 hours a day and others.

The need for taxis arises when, as a result of the growth of cities, the distance between the center and its outskirts exceeds the so-called "pedestrian zone". It is usually estimated as the time for walking from the outskirts to the city center. This necessitates the study and research of passenger flows served by taxi.

Renting a taxi can be done at:
- the street,
- taxi ranks, through a control room and
- with mobile application.

Renting a taxi directly from the street is the least used case by passengers.

Using a taxi rank to rent a taxi is more reliable for the passenger than the first method. The taxi ranks are a special area with places for approaching and waiting for taxis and passengers. They are in places close to the places of occurrence of requests for taxi services (stations, ports, shopping malls, theaters). The taxi rank is equipped with a distinctive sign and is remotely connected to the central dispatching point or taxi station for submission and management of the execution of requests for taxi transport. Taxi ranks are also located on the streets, squares of cities, where there is a large flow of passengers and in places with a low degree of passenger flow. In terms of operation and technology,
the taxi ranks meet the expectations that the time for renting a taxi is less than the time for renting a taxi on the street. Observations show that the use of a taxi service from the taxi rank is more than 60% of all possibilities.

The main technological problem of the organization in the two considered forms of renting a taxi is that the passenger and the free taxi have different locations. As a result, time and resources are wasted. This is the reason for the introduction of the technology for pre-rental of a taxi on request [4]. Crucial to the introduction of this technology on the market is the availability of an affordable connection. The accessibility of the connection for passengers is based on modern communication connections. For taxi transport, the accessibility of the connection is based on the possibility to use modern communication and information systems.

The purpose of the study is to determine the main parameters of taxi activity in emergency situations and to determine the load factor of a car for a day.

In the European Union, over 60% of the population lives in cities. Just under 85% of the European Union’s gross domestic product is generated in cities. Taxis are an important part of the urban transport system in modern cities. As of January 2020, 151 companies are registered in the Municipality of Rousse with a permit for taxi activity. The total number of taxis operating on the territory of the Municipality of Rousse is 597. The average number of taxis in a company is 3.95 cars, and the number of taxis per 1000 people is 4.18.

For the city of Ruse the number of companies which use autonomous radiofrequency communication systems is 4, indicated in table 1.

Table 1. Taxi companies for the city of Ruse with autonomous radiofrequency communication systems to 30.03.2020.

| №  | Company                     |
|----|-----------------------------|
| 1  | Taxi 2222 – to4nite          |
| 2  | 8806 - taxi 6               |
| 3  | Orion Taxi 8800             |
| 4  | Milanov Taxi 8111           |

At the same time, the number of trips with clients in emergency situations in most companies has decreased by nearly 60%. Table 2 shows the number of calls received by 4 taxi companies in the city of Ruse for the period 13.04.2020 - 17.04.2020.

Table 2. Number of applications received by dates in 4 taxi companies in the city of Ruse for the period 13.04.2020 - 17.04.2020.

| Date       | Taxi 2222 – to4nite | 8806 - taxi 6 | Orion Taxi | Milanov Taxi 8111 |
|------------|---------------------|---------------|-------------|-------------------|
| 13.04.2020 | Day shift: 368      | Night shift: 162 | Day shift: 72 | Night shift: 113 | Day shift: 59 | Night shift: 75 | Day shift: 58 | Night shift: 51 |
| 14.04.2020 | Day shift: 344      | Night shift: 118 | Day shift: 75 | Night shift: 63 | Day shift: 57 | Night shift: 41 | Day shift: 44 | Night shift: 43 |
| 15.04.2020 | Day shift: 369      | Night shift: 96 | Day shift: 90 | Night shift: 51 | Day shift: 71 | Night shift: 32 | Day shift: 42 | Night shift: 28 |
| 16.04.2020 | Day shift: 341      | Night shift: 109 | Day shift: 72 | Night shift: 74 | Day shift: 60 | Night shift: 47 | Day shift: 43 | Night shift: 31 |
| 17.04.2020 | Day shift: 353      | Night shift: 106 | Day shift: 57 | Night shift: 69 | Day shift: 57 | Night shift: 43 | Day shift: 36 | Night shift: 33 |

№ of cars | 112 | 84 | 56 | 49
The table shows that on average one car for "Taxi 2222 - to4nite" has about 3.2 calls per taxi during the day shift and 1.05 calls during the night shift. For "8806 - taxi 6" this number is respectively - about 0.9 calls for day shift and about 0.8 calls for night shift. For Orion Taxi - 1.1 calls per day and 0.85 for the night shift and for Milanov Taxi 8111 - about 0.9 calls for the day shift and about 0.8 calls at night. This shows that with an 8-hour work shift, most of the time the cars stay in taxi ranks waiting to be hired by a customer or move through the streets of the city in waiting for an order. The table shows that in the conditions of implementation of emergency measures, the calls have decreased by almost 60% and the number of cars by almost 30%.

To describe the mode of operation of a taxi company, considered as a queuing system, it is necessary to know the characteristics of the incoming flow of orders, considered as a stochastic process, the intensity of service, the maximum allowable queue length and the number of service units [8-10].

For the incoming flow of taxis we can make the following prerequisites:
- ordinary flow – the probability of entering two or more taxi cars for an elementary time interval is infinitely small compared to the probability of entering only one taxi car, this means that cars arrive in singles, not in pairs, triples, at the same time.
- flow without consequences – the number of taxis entering the system for a time interval $\Delta t$ does not depend on how many cars have already arrived, i.e. does not depend on the prehistory of the studied phenomenon (the flow without subsequent action (Poisson flow)).
- stationary / non-stationary flow – for sufficiently long periods of time - 1 month, 6 months, 1 year, etc. with certain conditions, stationarity of the incoming flow can be assumed, i.e. the probability of a certain number of taxis appearing in a given, sufficiently large time interval depends only on the length of this interval. In the general case at arbitrary periods, the flow is non-stationary. This stands out well for a period of 1 working day (24 hours).

3. Materials and methods
For the intensity of service, it was found out that the service time of an order is a relatively constant value and is 8.5 min. in time intervals $7^00h - 10^00h$ and $16^00h - 19^30h$, and during the rest of the day it is 5.5 min. The number of service channels (servers) during the day is variable. It is also known that at a time when all servers are busy, the received order is rejected. To study the operation of the system, it is necessary to find the probability that there are currently a number of vehicles in the system with the server running

$$P_k(t)=?, \ k=0,n, \ t \in [0, T], \ 26 \leq n(t) \leq 120, \ (1)$$

where one full working day of 24 hours is taken for a unit period. The beginning of the working day coincides with the astronomical beginning of the day (0 hours and 0 minutes), the end of the working day, with the end of the astronomical day (24 hours and 0 minutes).

For the model such as a queuing system, the following can be summarized: a non-stationary flow of requests with density arrives at a queuing system with serving channels. The service time of the request is a random variable with an indicative distribution and a parameter that is a partially constant function [11, 12]. The number of service channels also changes around the clock, i.e. An order that arrives at the time of busy channels leaves the system as unserved, i.e. failure system.

The specified defining system is of type (M / M / n) in non-stationary mode, with a variable number of channels. To describe a system of this type, the following system of Kolmogorov differential equations (Erlang-Kolmogorov) is valid [13,14]:
\[
\frac{dP_0}{dt} = -\lambda(t)P_0(t) + \mu(t)P_1(t) \\
\frac{dP_k}{dt} = \lambda(t) - (\lambda(t) + \kappa(t))P_k(t) + \mu(t)(k+1)P_{k+1}(t) \\
\frac{dP_n}{dt} = P_{n-1}(t) - n(t)\mu(t)P_n
\]

where \(n(t)\) – number of running servers currently \(t\), \(P_k(t)\) – the probability that \(t\) currently has a \(k\) client in the system (\(k\) servers are occupied), \(\lambda(t)\) – the current flow rate at the moment \(t\), \(\mu(t)\) – the service speed of a server at the moment \(t\).

### 4. Results and Discussion

The data on the received requests (by hours) for 24 hours during one week are given in table 3.

| Table 3. Number of requests in the interval from 31.03 to 06.04.2020. | 31.03.2020 | 01.04.2020 | 02.04.2020 | 03.04.2020 | 04.04.2020 | 05.04.2020 | 06.04.2020 | Average value |
|---------------------------------------------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|---------------|
| hour                                                                 |             |             |             |             |             |             |             |               |
| 00-01                                                             | 16          | 14          | 16          | 16          | 30          | 37          | 16          | 20.71         |
| 01-02                                                             | 12          | 14          | 12          | 12          | 21          | 10          | 21          | 15.85         |
| 02-03                                                             | 7           | 8           | 8           | 8           | 18          | 23          | 7           | 11.28         |
| 03-04                                                             | 10          | 8           | 8           | 8           | 16          | 18          | 8           | 10.85         |
| 04-05                                                             | 9           | 8           | 10          | 9           | 13          | 15          | 6           | 10.00         |
| 05-06                                                             | 10          | 11          | 12          | 12          | 17          | 20          | 14          | 13.71         |
| 06-07                                                             | 24          | 24          | 24          | 25          | 18          | 20          | 29          | 23.42         |
| 07-08                                                             | 41          | 45          | 47          | 48          | 29          | 20          | 52          | 40.28         |
| 08-09                                                             | 55          | 57          | 54          | 45          | 31          | 23          | 63          | 46.85         |
| 09-10                                                             | 51          | 53          | 55          | 54          | 40          | 29          | 58          | 48.57         |
| 10-11                                                             | 51          | 48          | 51          | 47          | 42          | 31          | 58          | 46.85         |
| 11-12                                                             | 48          | 50          | 42          | 43          | 38          | 31          | 46          | 42.57         |
| 12-13                                                             | 43          | 38          | 42          | 43          | 37          | 25          | 40          | 38.28         |
| 13-14                                                             | 49          | 43          | 46          | 45          | 38          | 37          | 51          | 44.14         |
| 14-15                                                             | 43          | 44          | 37          | 40          | 37          | 32          | 43          | 39.42         |
| 15-16                                                             | 43          | 38          | 46          | 51          | 31          | 32          | 46          | 41.00         |
| 16-17                                                             | 47          | 41          | 36          | 49          | 34          | 32          | 44          | 40.14         |
| 17-18                                                             | 47          | 47          | 43          | 47          | 40          | 33          | 44          | 43.00         |
| 18-19                                                             | 40          | 38          | 38          | 47          | 40          | 34          | 38          | 39.28         |
| 19-20                                                             | 29          | 36          | 40          | 48          | 45          | 30          | 32          | 37.14         |
| 20-21                                                             | 30          | 32          | 32          | 41          | 43          | 29          | 26          | 33.28         |
| 21-22                                                             | 26          | 27          | 29          | 39          | 42          | 24          | 24          | 30.14         |
| 22-23                                                             | 22          | 26          | 24          | 36          | 38          | 25          | 24          | 27.85         |
| 23-24                                                             | 20          | 20          | 20          | 34          | 40          | 27          | 27          | 26.85         |

For modeling it is expedient to choose a relatively elementary function having periodicity. This is appropriate given the daily fluctuations. To approximate the average values of the received applications for a period of 24 hours, the method of least squares was used. The model should be as simple as possible, but should reflect the most characteristic behavior of the real flow. The following trigonometric order (Fourier series with 7 terms) is chosen as a model, linear with respect to the required coefficients:
\[ \lambda(t) = a_0 + a_1 \cos \left( \frac{2\pi t}{24} \right) + b_1 \sin \left( \frac{2\pi t}{24} \right) + a_2 \cos \left( \frac{4\pi t}{24} \right) + b_2 \sin \left( \frac{4\pi t}{24} \right) + a_3 \cos \left( \frac{6\pi t}{24} \right) + b_3 \sin \left( \frac{6\pi t}{24} \right) \]  

(3)

where \( \lambda(t) \) – the approximate current flow rate, \( t \), \( a_{i}, i=0,3, b_{j}; j=1,3 \) – coefficients of the approximating function.

Figure 1 shows the average data of the inflow for one day of 24 hours for one week and the density of the inflow approximated using the method of least squares.

![Graph of the inflow density approximated using LSM (Least squares method) and observed average inflow data for one day of 24 hours during one week.](image)

Figure 1. Graph of the inflow density approximated using LSM (Least squares method) and observed average inflow data for one day of 24 hours during one week.

The coefficients \( a_0, a_1, b_1, a_2, b_2, a_3, b_3 \) calculated according to LSM, as well as their confidence intervals are given in table 4. All coefficients are statistically significant (confidence intervals do not contain 0). The coefficient of determination is also statistically significant, which means that the chosen model is adequate.

| Value of the coefficients in the model | Confidence interval of the coefficients, guaranteed with probability \( \gamma = 0.95 \) |
|----------------------------------------|--------------------------------------------------|
| \( a_0 = 32.16 \)                     | \( (31.21; 33.11) \)                              |
| \( a_1 = -12.9 \)                     | \( (-14.24; -11.56) \)                            |
| \( b_1 = -7.73 \)                     | \( (-9.07; -6.39) \)                              |
| \( a_2 = 1.07 \)                      | \( (0.12; 2.01) \)                               |
| \( b_2 = -7.34 \)                     | \( (-8.64; -6.002) \)                             |
| \( a_3 = 3.79 \)                      | \( (2.45; 5.13) \)                               |
| \( b_3 = 2.29 \)                      | \( (0.95; 3.64) \)                               |
It is known about the speed of service that during the busiest part of the day, it takes about 8.5 minutes between the service of one request, i.e. for one hour the average speed of service is $\frac{120}{17} = 7.0588$ requests per hour, and during the rest of the day, the requests are served for 5.5 minutes, i.e. the speed is $\frac{120}{11} = 10.909$ requests per hour.

\[
\mu(t) = \begin{cases} 
\frac{120}{11}, & 0 \leq t < 7 \\
\frac{120}{17}, & 7 \leq t < 11 \\
\frac{120}{17}, & 10 \leq t < 16 \\
\frac{120}{17}, & 16 \leq t < 19.5 \\
\frac{120}{11}, & 19.5 \leq t \leq 24 
\end{cases} \tag{4}
\]

Statistics for one week on the number of servers running during the day are given in table 5.

Table 5. Number of servers running during the day for the interval 31.03 to 06.04.2020.

| Hour | 31.03. 2020 | 01.04. 2020 | 02.04. 2020 | 03.04. 2020 | 04.04. 2020 | 05.04. 2020 | 06.04. 2020 | Average value |
|------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|---------------|
| 00-01| 22          | 28          | 27          | 24          | 53          | 63          | 27          | 34.85         |
| 01-02| 21          | 31          | 21          | 27          | 31          | 52          | 21          | 29.14         |
| 02-03| 12          | 14          | 10          | 9           | 36          | 37          | 16          | 19.14         |
| 03-04| 19          | 7           | 9           | 17          | 29          | 27          | 9           | 16.71         |
| 04-05| 17          | 11          | 19          | 16          | 21          | 37          | 16          | 19.57         |
| 05-06| 13          | 14          | 25          | 26          | 29          | 41          | 27          | 25.00         |
| 06-07| 41          | 52          | 52          | 36          | 31          | 36          | 51          | 42.71         |
| 07-08| 71          | 76          | 80          | 82          | 43          | 30          | 90          | 67.42         |
| 08-09| 99          | 103         | 96          | 88          | 53          | 36          | 109         | 83.42         |
| 09-10| 93          | 92          | 96          | 106         | 66          | 50          | 101         | 86.28         |
| 10-11| 94          | 88          | 81          | 86          | 70          | 58          | 102         | 82.71         |
| 11-12| 80          | 85          | 72          | 81          | 61          | 49          | 81          | 72.71         |
| 12-13| 76          | 61          | 66          | 72          | 62          | 34          | 73          | 63.42         |
| 13-14| 80          | 70          | 83          | 77          | 59          | 58          | 95          | 74.57         |
| 14-15| 71          | 79          | 61          | 69          | 68          | 57          | 77          | 68.85         |
| 15-16| 75          | 65          | 81          | 94          | 56          | 58          | 80          | 72.71         |
| 16-17| 89          | 71          | 61          | 85          | 60          | 57          | 79          | 71.71         |
| 17-18| 79          | 89          | 77          | 86          | 69          | 57          | 78          | 76.42         |
| 18-19| 72          | 68          | 63          | 73          | 67          | 60          | 62          | 66.42         |
| 19-20| 49          | 63          | 73          | 83          | 83          | 51          | 60          | 66.00         |
| 20-21| 58          | 63          | 60          | 68          | 74          | 55          | 47          | 60.71         |
| 21-22| 41          | 44          | 58          | 62          | 70          | 36          | 43          | 50.57         |
| 22-23| 39          | 49          | 40          | 64          | 72          | 46          | 45          | 50.71         |
| 23-24| 37          | 39          | 27          | 60          | 69          | 44          | 48          | 46.28         |

Given the statistics, the number of running servers is approximated integer. The length of the time intervals in which the change in the number of servers is more dynamic are shorter (a shorter time interval of 1 hour cannot be taken due to the specifics of statistical measurements), those in which the dynamics is more small are longer.
Figure 2. Graph of the average number of measured working taxis (servers) during the day and graph of the function $n(t)$, integer approximating this number.

The computational features related to system (2) are the following:

- large dimension system (in general);
- the system is of the "stiff system" type (rigid system of equations);
- the number of equations is variable, in different intervals of integration.

This can be summarized as: a system with a variable number of solid, differential equations with a large dimension [15]. Special numerical methods have been developed to overcome these difficulties. A Matlab program has been developed to solve system (2), using the built-in "solver" ode15s, implementing the Geer method [16]. When entering $\lambda(t), \mu(t), n$, the application returns a numerical solution of $P_k(t)$. The accuracy is artificially increased compared to the default for the solver – from $10^{-6}$ to $10^{-9}$ for absolute error and from $10^{-3}$ to $10^{-5}$ for relative error [20]. The integration interval is divided into sub-intervals $t_0, t_1, \ldots, t_{i-1}, t_i, t_{i+1}, \ldots, t_N$, so that $[t_i, t_{i+1}]$, $\mu(t)$ and $n(t)$ are constants in each sub-interval.

$$n(t)=\begin{cases} 35, & 0\leq t<1 \\ 29, & 1\leq t<2 \\ 18, & 2\leq t<5 \\ 25, & 5\leq t<6 \\ 43, & 6\leq t<7 \\ 80, & 7\leq t<11 \\ 71, & 11\leq t<18 \\ 64, & 18\leq t<21 \\ 49, & 21\leq t<24 \end{cases} \tag{5}$$
The initial state of the system $P_k(t_0)$ is unknown. It is known that this type of processes are stable and after a long time enter a regular mode of operation. Therefore, can be take any initial state. The values of $P_k(t)$, at the end of the time interval $[t_{i-1}, t_i]$, become initial values for the subinterval $[t_i, t_{i+1}]$. If for a given time interval there are more equations than the previous interval, then for the initial conditions of these equations are take the zero value. The integration of the system in the interval needs to be done not once, but many times, and after each integration the values at the end of the period become the initial values for the next integration. Thus, the probability functions $P_k(t)$ begin to trend to their regular values. After several integrations, it was found out that only after 5-6 periods functions $P_k(t)$ enter a regular mode (for two adjacent periods, they remain the same). The accuracy is also increased here as the integration is done for 20 periods, as the difference of all $P_k(t)$ in the last and penultimate period is less than $10^{-8}$ for each $t$.

Table 6 shows the time intervals $[t_{i-1}, t_i]$, the values of the function $\mu$, as well as the number of service channels $n$ in the given interval.

| Interval of time in the day $[t_{i-1}, t_i]$ | Average value of service speed $\mu$ | Average number of service servers $n$ |
|-------------------------------------------|------------------------------------|-------------------------------------|
| [0,1]                                     | 120/11                             | 35                                  |
| [1,2]                                     | 120/11                             | 29                                  |
| [2,5]                                     | 120/11                             | 18                                  |
| [5,6]                                     | 120/11                             | 25                                  |
| [6,7]                                     | 120/11                             | 43                                  |
| [7,11]                                    | 120/17                             | 80                                  |
| [11,16]                                   | 120/11                             | 71                                  |
| [16,18]                                   | 120/17                             | 71                                  |
| [18,19.5]                                 | 120/17                             | 64                                  |
| [19.5,21]                                 | 120/11                             | 64                                  |
| [21,24]                                   | 120/11                             | 49                                  |

Figure 3 shows the probabilities of having a certain number of cars in the system for one day. It can be seen that the probability of having less than five requests is the highest during most of the day. In the intervals from 9:00 h to 11:00 h and from 16:00 h to 20:00 h the probability of having between 6 and 15 requests is the highest. Throughout the day, the probability of having more than 16 requests at a given time is practically equal to 0.

The graph in figure 4 shows the average number of taxis occupied by customers for a period of 24 hours. There are two peaks, the larger one is between 8 and 11 o'clock, and the smaller one is between 16-19 o'clock. The smallest peaks are in the interval 3-4 o'clock in the morning.

Figure 5 shows the load factor of a server (taxi) during the day. It can be seen that even at the largest peaks the coefficient is below 0.1, which means that in the intervals with the highest load, the server occupancy is below 10% of those working at the moment. In the interval from 0:00 h to 7:00 h a load factor slightly above 0.04 is observed.

Even at the highest load peaks, it can be seen that the state of emergency has a serious impact on the operation of taxis.
Figure 3. Probabilities to have between 0 and 10, 11-21 and over 22 service requests for a period of 24 hours, respectively.

Figure 4. Average number of occupied servers (taxis) for a period of 24 hours.
5. Conclusion
1. On average, one car for "Taxi 2222 - to4nite" company has about 3.2 calls per taxi during the day shift and 1.05 calls during the night shift. For "8806 - taxi 6" this number is respectively - about 0.9 calls for day shift and about 0.8 calls for night shift. For Orion Taxi - 1.1 calls for day and 0.85 for night shift and for Milanov Taxi 8111 - about 0.9 calls for day shift and about 0.8 calls for night.
2. With an 8-hour work shift, most of the time the cars stay in taxi ranks waiting to be hired by a customer or move on the streets of the city in search of an order.
3. In a state of emergency, applications have dropped by almost 60% and the number of used taxis by nearly 30%.
4. There are two peaks in the number of occupied cars, the largest is between 8 and 11 o'clock (around 7 o'clock), and the smaller is between 16-19 o'clock (around 18 o'clock). The smallest peak is in the interval 3-4 o'clock in the morning (average below one).
5. The load factor of a taxi during the day at the highest peaks is below 0.1, which means that in the intervals with the highest load, the occupancy of the servers is below 10% of those currently working. In the interval from 0:00 h to 7:00 h a load factor of slightly above 0.04 is observed.
6. The present study makes it possible to establish the change in the intensity of work in the emergency situation imposed by COVID-19 and to determine the basic parameters of taxi activity in emergency situations and to determine the load factor of a car for one day.
7. The created model makes it possible to simulate different variants of work organization. This will allow for calculation of the server load factor per day for these options. Thus, it will be possible to choose the option that will satisfy the company's management to the maximum.

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