PLANNING NUMBER OF OPERATORS IN CALL CENTRE USING INFINITE-SOURCE QUEUING MODEL WITH VARYING DEMAND INTENSITY

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Abstract

The article deals with the possibility of application of infinite-source queuing model in the organization, which provides a non-stop paid telephone information services to the public. Recently, more and more emphasis has been placed on building specialized centres that will be maximally tailored to the customer requirements. The implementation of these activities often requires high costs. Models of queueing theory are usually employed to determine the specific characteristics of the operator (service) system or to find the optimal performance of the system or number of operators.

The basic problem of the surveyed call centre is to plan the number of operators per shift, possibly up to per an individual hour of the working day. The number of operators depends on the accuracy of customer demand forecasts. For this purpose, the available data were analysed and their systematic use was proposed in order to improve the short-term forecast of customer demand. The problem of taking mechanical conclusions from hypothesis tests without deeper substantive analysis is also discussed. To solve the problem, a variable demand model was constructed, including a proposal for financial calculations to optimize the number of operators per shift, which may be a real benefit in similar situations.

Keywords: Call centre, infinite-source, queuing model, staffing problem

1. INTRODUCTION

A queuing system can be described by the flow of customers that enter a system for service, possibly form one or more queues, if service is not available soon, get served and leaving the system. [1] Number of models has been applied in various mass-service systems. Queueing models are useful for developing rules-of-thumb and intuition, or practically supporting design and control. [8] Typical application of queueing models is to help solving staffing problem in a service system. Theoretical standard models are mostly based on a number of simplifying assumptions, in particular concerning the distribution of probabilities of arrival intervals and customer service times. The basic model is, for example, usually based on the assumption that the arrival intensity rate of the customers (the mean number of occurrence of the service requirements per chosen unit of time) is constant over the entire monitoring period.

In practice, however, we often encounter cases where the assumption of a constant customer arrival rate is not met and within the monitoring period, we detect less or more significant fluctuations in the arrival intensity of the customers depending on the different time periods of the monitored period. The effectiveness of such planning is then dependent on the accuracy of short-term forecasts of demand for call centre services. For their determination, a number of predictive methods can be used, the accuracy of which depends, in particular, on the nature of available data on demand (e.g. degree of aggregation) and their evolution over time, i.e. on the existence of a trend and seasonal component in historical time series. [9]

In cases of time varying demands, theoretical queuing models need to be developed and adapted to the specific conditions of the given situation. Such queuing models were created, for example, by Agnihothri and Taylor (1991) in solving the staffing problem in the hospital under conditions where the pattern of calls was the same for each day but differed in the rate of calls during various times of the day. [1] The effort to apply and develop models of queues is testified by the fact that they are still dealt by a number of professional publications such as, Green [4] who describes use of queuing models also in health systems to increase effectiveness of emergency department, or Gillard [6] who solves staffing problem using finite-source queuing model, or Whitt [11] who discusses both old and new ways to cope with time varying demand using queuing models etc.

This paper deals with staffing problem in the conditions of current call centre. In call centres today, a contact with customers could be made not only by the telephone, but also using email, web chat etc. There could be multiple requirement classes of customers, operators could possess different call handling skills and interactive voice response could be incorporated into the system. [5] A review of the literature on workforce planning problems incorporating skills with managerial insights is given for example by Brueckera [2]. To solve staffing problem handling with different skills of employees could be solved with use of different mathematical models such as integer linear programming that is described, for example, in [7] and also with different queuing models, see for example Green [3] who reviews queueing-theory methods for setting staffing requirements.

The initial situation of the problem described in this paper was defined by the diploma thesis [10] that analysed operation activities of one Czech call centre, which provides paid information services 24 hours a day and 7 days a week. The basic issue of operational call centre control is to plan the number of operators per shift of a business day. The objective of this paper is to analyse available data and suggest their systematic use for the planning of operators for individual days of the planning month, for individual shifts and hours of each day and with doing that to add case study solving this problem to queueing literature.

The number of operators is apparently dependent on the accuracy of customer demand forecasts, and therefore, this demand was first analysed to improve the short-term forecast of customer demand. The analysis was based on the hypothesis that the intensity of demand fluctuated in individual hours of the working day, that it differs in each day of the week, and finally it may also be the result of a medium-term demand trend over several weeks, months and years. In order to plan number of operators for individual shifts (hours) every day, queuing models were used under certain simplifying assumptions, specifically the Erlang model was applied and time varying demand was discussed.

2. RESULTS OF INITIAL ANALYSIS

The process of planning the number of operators per shift for the next month must be finished 14 days before the end of the month. Manager of call centre uses historical data on the number of calls, number of customers waiting for connections, abandoned calls, and the length of calls, all broken down by hours and days in several years. Three types of business analyses that differ in the time horizon and the type of data processed are used for shifts planning. In the first analysis, short-term historical data are processed for each day of the week over the last 6 weeks. Specifically, these are the number of active operators, the number of calls served and the number of calls cancelled. Based on this data, the number of calls for next period is estimated, determined empirical distribution of calls during the day and converted to the number of operators. In the second analysis the data of demand recorded in the previous year are analysed. These data are cleared by so-called negative (negative article) or positive (advertising) influences. In the third analysis, there are comments on the specific events in the planned month that could affect the planning of shifts, e.g. change of time, holidays, planned advertising campaigns, etc. The planning process is influenced by efficiency-driven regime; rather lower number of operators on shifts is usually planned. In the cases of higher customer demand, extra shifts are introduced, specifically shifts for part time workers, which may be shorter than 8 hours, and thus better cover fluctuations in demand throughout the day. For control purposes the company uses a goal of having no more than 20% of the calls waiting more than 20 seconds before reaching an operator or being abandoned.

For the purpose of analysing the trend of customer demand for company information services over the course of the month, data for three months were processed. This period is sufficient for analysing the medium-term trend of customer demand for information services. **The analysis dealt first with the distribution of the**

demand intensity for each day of the week and then with the mutual comparison of the demand for individual days of the week. Weekdays differ from weekend days but individual weekdays have an average on the same level of demand, and similarly, weekend days do not differ between both days. The exception was national holidays. These circumstances need to be taken into account for estimation of the number of calls for the next month The analysis showed that the total number of requirements in the analysed period under review is relatively stable in the medium term and the average values of demand over the analysed period can be used for demand forecasts in the next month.

Next, **an analysis of the demand distribution over the individual days was carried out**. It was based on the hypothesis that the intensity of the demand fluctuates strongly over each day (24 hours), but that there is also a typical distribution of relative frequencies for each day of the week. For the purpose of this analysis, one hour was chosen as the basic time unit. For each day of the monitored period, the actual frequency distribution of the number of calls requested $f_{d,i}$ (d = 1, 2, … 7 day of the week; i = 1, 2, … 24 hours per day) was also determined, broken down by hourly intervals.

To test the hypothesis on the randomness distribution of calls on each day of the week, chi-squared test was chosen. Since the distribution of calls over the course of the day does not refer to any theoretical probability distribution, for the purposes of the test, the distribution of the average values of the calls was calculated according to the following equation (1), where j = 1, 2, … k days of monitored period:

$$f_{d,l} = \sum_{j}^{k} f_{d,i,j} / k \qquad (1)$$

This distribution of the average frequencies can be considered as a typical distribution for the relevant day and can serve, on the one hand, for comparison with the actual frequency distributions on the individual days of the reference period, on the other hand as well as the anticipated frequency distribution for the plan for the next month. None of the chi-quadrate tests demonstrated a 95% statistically significant difference between the actual distribution of relative frequencies on days and the typical distribution of average relative frequencies in the days of the referenced period. For the practical application of compiling the operator plan, it would be more appropriate to choose the one year long referenced period, and to use the rolling average method to keep every month plan up to date.

Finally, a quantitative analysis of the relationship of the demand frequencies distribution among weekdays was made and a company hypothesis that the demand distribution within days is similar among weekdays, but is significantly different on Saturdays, Sundays and holidays was verified. The validity of this hypothesis was verified by the analysis using the results of the previous step, namely the relative distribution of the average values for each day of the week. The analysis of demand distribution on weekdays, see results in **Figure 1**, showed a high degree of consistency and confirmed the hypothesis that the distribution of relative customer demand frequencies is similar in individual business days. At the same time it confirmed a different character from the days of rest, see **Figure 2**.

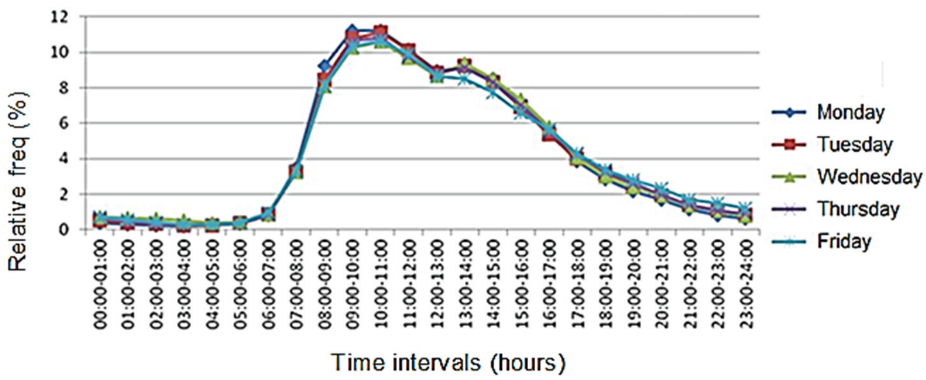

Figure 1 Empirical distribution of demand from Monday to Friday

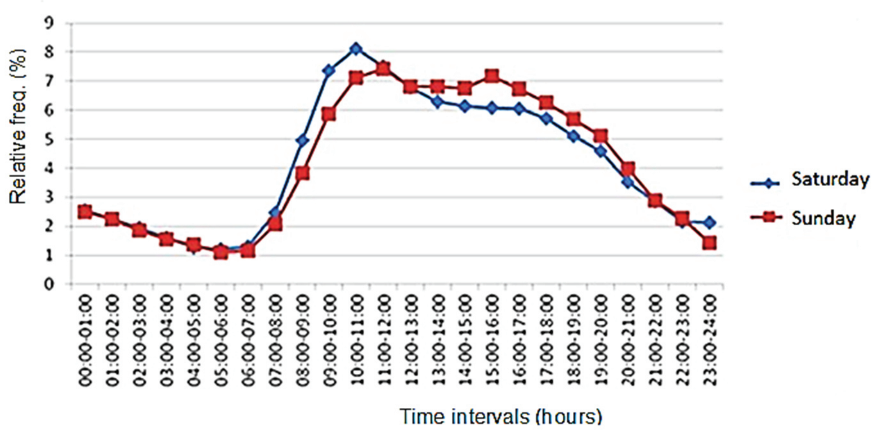

Figure 2 Empirical distribution of demand on weekends

3. PLANNING A NUMBER OF OPERATORS

The frequency distribution of calls at hourly intervals cannot be directly used to plan the number of operators because operators cannot be deployed and recall from the process based on an hour interval but by shifts whose shortest duration is 4 hours. If a frequency distribution analysis of calls is used to plan the number of operators within the day, it would be appropriate to use a four hour time interval for the base unit. Even in this case, a good match test can be used to test the consistency or difference of the individual distributions. However, the conclusions of the test should be evaluated with caution. For example, we are testing compliance with the frequency distribution for Monday and Tuesday in the surveyed period.

Table 1 Ch-squared test for empirical distribution of Monday and Tuesday calls

Time interval	*Frequencies Monday*		*Frequencies Tuesday*		
From-to (hours)	ni	Pi	ni	Oi	χ^2
0 - 4	156	0.0100	191	131	27.11
4 - 8	755	0.0483	618	636	0.49
8 - 12	6530	0.4178	5321	5497	5.65
12 - 16	5273	0.3374	4383	4439	0.71
16 - 20	2259	0.1445	1960	1902	1.79
20 - 24	657	0.0420	685	553	31.46
Total	15630	1.0000	13158	13158	67.20

The average values $f_{d,l}$, calculated according to formula (1), are used as the frequencies n_i. This is the typical distribution of call frequencies for all Mondays and Tuesdays in the given period. In column p_i, the relative frequencies for Monday are calculated and in the column o_i the expected frequencies of calls on Tuesday are calculated if the both distributions were exactly the same. In the last column of **Table 1**, the test criteria χ^2 are calculated. Because the critical value of χ^2 for 5 degrees of freedom equals 11.07, we reject the 95% nil hypothesis on the conformity of the two distributions. But if we look more closely at the **Table 1**, we find that a substantial part of the value of the test criterion is the value at boundary intervals, i.e. at night time, when the frequency of calls is significantly lower than at other intervals. For example, if we tested the match only for the interval from 4 to 20 hours, we would get the value of the test criterion χ^2 = 8.63. At the same time, the critical value for 3 degrees of freedom equals 7.81, suggesting that the result of the test is approaching the zero hypothesis rejection of the conformity of both distributions. In the example above, it is obvious how problematic the mechanical conclusions from the tests can be without deeper analysis. In order to estimate the number of operators required for the planned four-hour shifts, the forecast of the number of calls on the given day and interval can be used and divided by the number of calls served by one operator. The basis for this standard is the time-to-call standard for one operator. This standard is determined on the basis of a statistical evaluation of the average duration of a call by one operator and includes legal breaks for rest and lunch.

4. APPLICATION OF QUEUE MODEL FOR THE STAFFING PROBLEM

In addition to the above procedure, the application of queue theory models described in the literature can be considered. We have restricted attention to special case with the single-skill operators that could be after proper training obtained in real conditions. The usually used model is M/M/s queue with parameters λ, μ and s: the primitives are the arrival process (assumed Poisson at a constant rate λ), the service times (assumed exponentially distributed with mean μ^{-1}), and the agents (s of them). When attempting to apply the model, the questions about the assumptions had to be discussed. Whereas the arrival rate during whole day is time-varying, we tried not to use simplification with only one parameter λ for a whole day, but we divided arrivals into shorter intervals of a day that are better characterized by its parameter lambda, so we decided to build separate models for each interval. Another questioned assumption was the exponential distribution of service times. When considering non exponential distribution of service times Erlang loss model could be used, considering no waiting line. This could be applied for quality-driven call centre and also helping to serve impatient customers who would be abandoned.

There are two ways to model this system: first, we need to vary the number of operators, and then use the model to describe the individual states of the given system at a given number of operators, as shown in the **Table 2**. Or, the second way, to determine the required percentage of requests lost, which must not be exceeded and determine the corresponding number of required operators in the system. It is clear from **Table 2** that with 50 operators and above the call centre is able to process about 80% of the customer requirements.

Table 2 Erlang Loss Model of call centre

Number of operators	50	55	60
Outputs: Summary measures			
Percentage of requests lost	19.42%	13.08%	7.79%
Entering arrival rate	1154.0	1244.7	1320.4
Expected number in system	46.7	50.4	53.5

5. CONCLUSION

Adding operators has also been subjected to cost optimization. Consideration was given to the direct costs of the wages of their operators and to the loss of unrealized calls. Operator use is estimated at 80% and should include both legal breaks and breaks when the operator waits for the client. If predicted input values in our calculation were close to real values, it would be advantageous to have 1 operator more during the day (more precisely between 9 am and 5 pm), as the number of cancelled calls would decrease and the company's overall profit increase or to work with the flexible increase of operators for 4 hours shifts.

The paper deals with staffing problem in call centre, describes current planning process within the company, analyses time varying demand of customers, suggests its use for better operators planning per shifts with dividing 8 hours shift into 4 hours shifts. Also possibilities of queuing models application have been considered. An analysis of the initial situation showed that the basic problem of the simple application of queue theory models is the distribution of the intensity of demand during individual days, the differences in this division in individual days of the week and, finally, the effect of the medium-term trend on clients' demand for these services. It was necessary to construct a model with varying demand intensities and to combine it with other statistical procedures.

Authors are aware that more complex models could be applied and that a lot of simplifications were made. For the future, it could be considered to change assumption of homogenous caller and to deal with their segmentation into groups, also homogeneity of operators should be considered, namely when hiring more part time workers or to consider specialization of few operators according customers segments. Models could be also not discrete but applying demand as function of time.

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