DISCRETE EVENT SIMULATION – MODEL OF A CALL CENTER IN SIMUL8 SOFTWARE

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ABSTRACT

Simulation modelling is usually used when mathematical models and calculations are hard to apply on a system with stochastic behavior. This contribution deals with the application of simulation program SIMUL8 to the analysis of a call center. The main aim is to create a model based on the real data and afterwards to conduct two experiments to see the impact of changes on the functionality of the call center and on the number of customers lost. More suitable software can be used for the analysis of call centers. Because of our good experience we decided to use SIMUL8.

INTRODUCTION

In case of real systems that cannot be studied and analyzed using standard analytical tools, computer simulation is applied. Due to probabilistic and dynamic aspects of processes, a realization of experiments with the simulation model helps the decision-maker implement the improvement solution. In the paper, the call center system of the real company is analyzed. Mehrotra and Fama (2003) analyzed operations to increase demand for the call center service. They simulated the different scenarios with the right levels of cross-training to meet service level goals with the current staffing levels. Van Buuren et al. (2015) presented a detailed discrete event simulation model for call centers of emergency medical services. Their model includes two classes of centralists: call takers and dispatchers. The model discriminates between multiple types of applicants which differ in priorities. The model was made for general emergency medical services call centers, but it can also be used for other applications such as firefighter call centers. Mathew and Nambiar (2013) offer a straightforward tutorial on modelling call centers using discrete event simulation with MS Excel-based input and reporting. Ibrahim et al. (2016) provide a literature survey of modeling and forecasting call center arrivals. Call centers with uncertain non-stationary arrival rate and flexibility are analyzed in detail by Liao et al. (2012). Munoz and Brutus (2013) deal with the question of trade-offs in a call center. Kuncová and Wasserbauer (2007) created a simulation model for the optimization of the number of helpdesk's operators, and for the optimization of the operator's working time.

In the following text we present the simulation model of a call center in the real company. As many authors show (e.g. Banks 1998; Montevecchi et al. 2007), simulation experiments representing different scenarios have significant meaning for a company's decision making.

In the paper, we offer two experiments aimed at changes in the number of customers (acceding to a new advertisement) and in the number of operators (based on the closure of one call center building). The main aim is to analyze the impact of these changes on the percentage of lost customers and on the operators' utilization. The information obtained from call center staff says that the current percentage of lost customers is around 1-2% and the company accepts a maximum of 5% of unserved customers.

SIMUL8

SIMUL8 is a software package designed for Discrete Event Simulation or Process Simulation and developed by the American firm SIMUL8 Corporation (www.simul8.com). The software started to be used in 1994, and every year a new release has come into being with new functions and improved functionality. A visual 2D model of an analyzed system can be created by placing objects directly on the screen. SIMUL8 belongs to the simulation software systems that are widely used especially in industry (Greasley 2003). This software is suitable for discrete event simulation. Model of a call center as a set of activities of calling and answering can be taken as a typical discrete event simulation model. SIMUL8 uses 2D animation only to visualize the processes, but for the given problem, this view is sufficient. It is similar to SIMPROCESS, which is also aimed at the discrete event simulation (Dlouhý et al. 2011), but we decided to use SIMUL8 because of the easier way of queue modelling.

Pisaniello et al. (2018) used SIMUL8 to develop the simulation model of the call center in the children's hospital. On the case study, they demonstrate the meaning of the application of validation and verification

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techniques as the most critical aspects of the simulation modelling process.

Similarly, Vermeulen (2017) shows the exiting application of SIMUL8 to call center staffing and performance in the video presentation.

Fousek et al. (2017) tried to find out the total time needed for the increased production given by the new contract and also to show the bottleneck of the production system.

SIMUL8 main components

SIMUL8 operates with 6 main parts out of which the model can be developed: Work Item, Work Entry Point, Storage Bin, Work Center, Work Exit Point, Resource (Concannon et al. 2007).

Work Item: dynamic object(s) (customers, products, documents or other entities) that move through the processes and use various resources. Their main properties that can be defined are labels (attributes), an image of the item (showed during the animation of the simulation on the screen) and advanced properties (multiple Work Item Types).

Work Entry Point: an object that generates Work Items into the simulation model according to the settings (distribution of the inter-arrival times). Other properties that can be used in this object are batching of the Work Items, changing of the Work Items! Label or setting of the following discipline (Routing Out).

Storage Bin: queues or buffers where the Work Items wait before the next processes. It is possible to define the capacity of the queue or the shelf life as time units for the expiration.

Work Center: main object serving for the activity description with the definition of the time length (various probabilistic distributions), resources used during the activity, changing the attributes of entities (Label actions) or setting the rules for the previous or following movement of entities (Routing In / Out).

Work Exit Point: an object that describes the end of the modeled system in which all the Work Items finish its movement through the model.

Resource: objects that serve for modelling of limited capacities of the workers, material or means of production that are used during the activities.

All objects (except resources) are linked together by connectors that define the sequence of the activities and also the direction of movement of Work Items.

After the system is modelled, the simulation run follows. The animation shows the flow of items through the system and for that reason the suitability of the model can be easily assessed. When the structure of the model is verified, several trials can be run and then the performance of the system can be analyzed statistically. Values of interest may be the average waiting times or utilization of Work Centers and Resources (Shalliker and Rickets 2002). SIMUL8 can be used for various kinds of simulation models (Concannon et al. 2007). The case studies can also be seen on the website www.simul8.com.

Our experience shows that SIMUL8 is easy to learn when only the main components are used (without the necessity to use Visual Logic with different programming functions). It can serve not only for the modelling of different services (Dlouhý et al. 2011) but also for the simulation of various production processes (Ficová and Kuncová 2013; Fousek et al. 2017).

PROBLEM DESCRIPTION

The main aim of this article is to create a simulation model of a call center of one unnamed telecommunications company and to test the influence of the number of customers' changes (increase) on the call center functionality. The type of the system can be described as an open queueing system with multiple parallel service lines and with an unlimited number of requests. In this case, however, classical mathematical models of queuing theory cannot be used to determine the average queue length nor the optimal number of call center operators since the system contains more variables than it is usual for the mathematical model. Therefore, it is preferable to use a simulation model, and discrete event simulation is a suitable solution to the problem.

In general, two kinds of requirements can enter a given call center. The first one is a customer (households, companies with a contract, companies without contract) requesting information; the second one is the called customer who has been chosen by the company itself for the questionnaire survey. In the case of customers calling to the call center, the inter-arrival times have a stochastic distribution (statistical analysis of the data revealed that the distribution should be exponential) with different parameters for each day period, whereas for customers who are called by the company the distribution can be taken as normal for the whole week. These customers are pre-selected for the given week by the company, and afterwards, the free operators could call them to ask for an opinion on the product or fill out a questionnaire.

Data for the simulation model was obtained on the basis of monthly traffic monitoring and discussions with call center staff. A more detailed description of data collection can be found in Klímová (2019).

CALL CENTER DATA

The objective of the simulation is to model the real call center with a defined number of operators for each day period and afterwards to describe the impact of selected changes on the operation of this call center (also called "Infoline"). A call center is usually a group of employees that obtain the requirements of the customers and try to solve them. The requirements are reported by telephone/mobile phone. In the selected call center 3 groups of customers usually call to ask for any advice or information. The first type of customers can be described as individuals or households and it is unimportant whether they have a contract with the company or not. The other two types of customers are companies: both companies belonging to customers, i.e. with a valid contract, and other companies that do not yet have a contract. The call center has 3 buildings (called Infoline 1, Infoline 2, Infoline 3) where the workers/operators answer the customers' questions or call to customers.

Table 1 summarizes necessary information about the intervals between customer calls in each time window. Distributions' fittings were tested in Crystal Ball to find the estimations of parameters (detailed data analysis is presented in Klímová, 2019). For the inter-arrival times' generation, the exponential distribution is used. Three different types of customers contacting the call center can be identified: individual customers or households (we call them B2C), companies that already have a contract (B2B) and companies without any contract (other). Data analysis of the call lengths showed that even for this case, the exponential distribution should be used to generate the time length of each call. The number of the customers called by the call center can be estimated as a random variable from the normal distribution with the mean value equal to 200 and standard deviation equal to 20. The average length of the call can be estimated by exponential distribution with the mean value equal to 416 seconds (nearly 7 minutes).

Table 1: Mean value of exponential distribution of inter-arrival times in seconds

Time of the day	B2C	B2B	Other	Call length
8:00-12:00	5.9	6.3	5.9	338
12:00-16:00	6.0	6.4	6.1	340
16:00-21:00	14.6	16.4	14.8	286
21:00-7:00	155	193	188	181

Table 2: Number of operators on infolines during a working day

Time of the day	Infoline 1	Infoline 2	Infoline 3
7:30-9:00	90	74	28
9:00-12:00	120	88	38
12:00-16:30	140	88	45
16:30-20:00	70	32	22

The analyzed call center has more buildings where all the operators work. For the purposes of the simulation model, four daily time windows (see Table 2) with different numbers of employees on three workplaces (infolines) were identified, followed by the emergency team, which is used to strengthen the standard daytime and nighttime capacity of the call center (see Table 3). The most numerous is the Infoline 1 team, where the temporary workers work, which is also reflected in staff turnover and work efficiency.

Table 3: Number of operators on emergency line during a working day

Time of the day	Emergency line
1:30-7:30	5
16:30-19:30	6
19:30-1:30	10

MODEL IN SIMUL8

The simulation model was developed in SIMUL8 software. The main entity (Work Item Type) that moves within the system is the customer, with the Type label indicating the customer (Type = 1 for the B2B customer, Type = 2 for the B2C customer, Type = 3 for other customers). Based on the data in Table 1, the new named time dependent distribution (see Figure 1) consisting of inter-arrival times distributions for all time windows had to be created for each type of the customer. Figure 2 shows the settings for the "other" customers and Figure 3 the settings of one new named distribution as a part of the time dependent distribution. Similar types of named distributions were prepared for inter-arrival times of customers B2B and B2C.

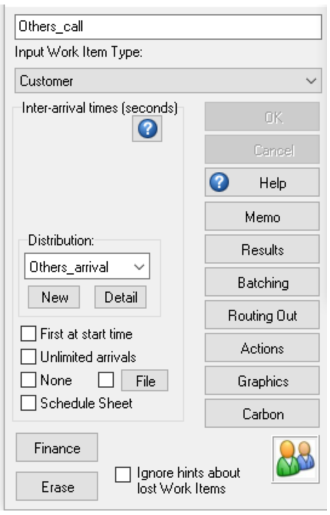

Figure 1: New distribution usage for the inter-arrival times of "other customers"

Aside from the customer calls, there should also be calls to customers done by an operator. According to the information of the call center's workers, the number of selected customers should be around 200 per week – it can be estimated by a normal distribution with the mean value equal to 200 and standard deviation equal to 20. For the model we defined the generation of these called customers once a week in the beginning – that is why the interarrival time was set as a fixed value equal to the length of the simulation run (1 week = 5 working days = 120 hours = 432000 seconds) – see Figure 4. The call is usually made when the operator is not busy. He/she then chooses a pre-selected customer and conducts an interview with him/her. Based on real data, it was estimated that the length of this interview could be approximated by an exponential distribution with a mean value of 416 seconds.

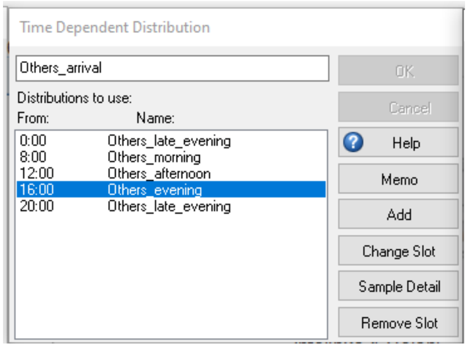

Figure 2: Creation of new time dependent distribution

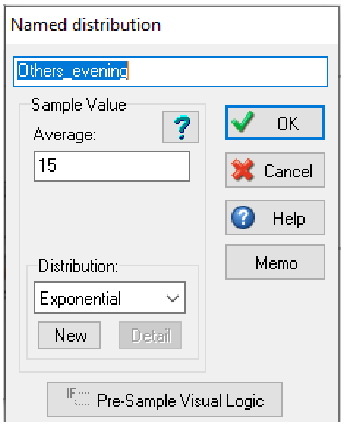

Figure 3: Creation of new named distribution

As the generation of customers is separated into 3 different inputs and so we do not have to distinguish them with different entity names, but it would be suitable for the results' description. In this situation, the program prefers to create labels in which this distinction can be made. Label Type1 was used to monitor the number of customers served by type (see Figure 5). Each customer has been assigned a unique number identifying the customer group (1 for B2B, 2 for B2C and 3 for other).

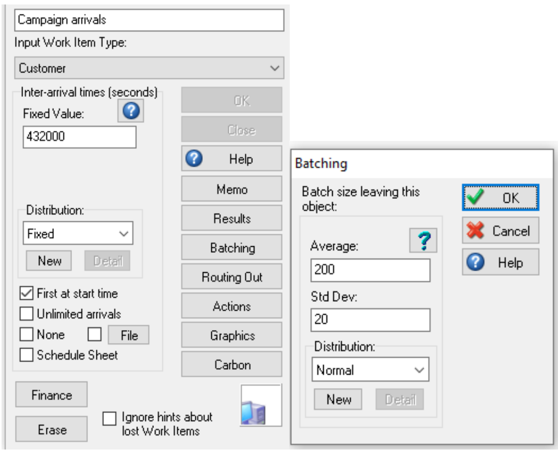

Figure 4: Settings of the generation of pre-selected customers for a call

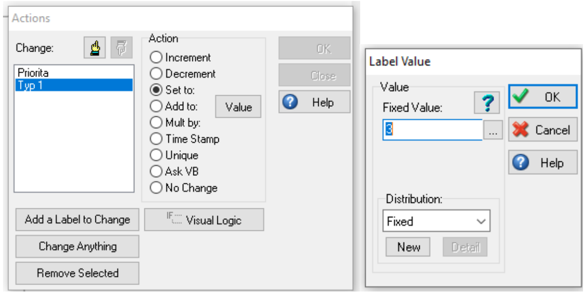

Figure 5: Label settings for each type of customer

After receiving calls, the customer is redirected to a free operator, first to Infoline1, then to Infoline2 or Infoline3, at night to Emergency calls. A minimum of 8 seconds elapses from the call to the connection. If no operator is free, the customer waits on the line. The customer's patience while waiting may vary, but it has been inferred from the experience of the company's employees that after about 200 seconds of waiting, the customer hangs up. Therefore, the queue parameters were set as follows: a minimum wait time of 8 seconds and a maximum patience of 200 seconds (see Figure 6). After 200-second waiting time expiration, the customers renege (see Figure 7).

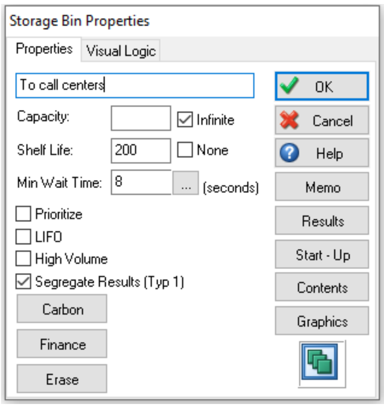

Figure 6: Queue to operators' settings

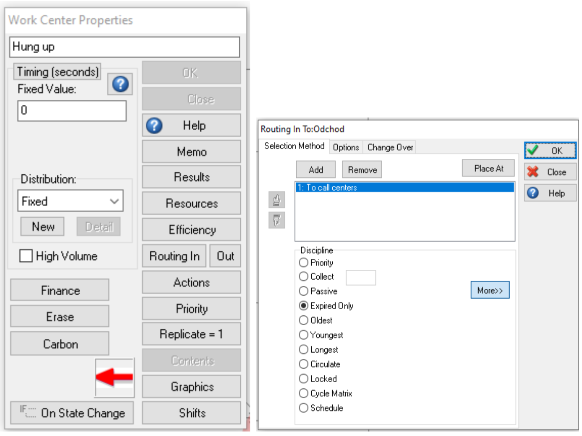

Figure 7: Early exits settings

Based on the data from Table 2 and Table 3 the shifts with a different number of operators were created for each Infoline (see Figure 8).

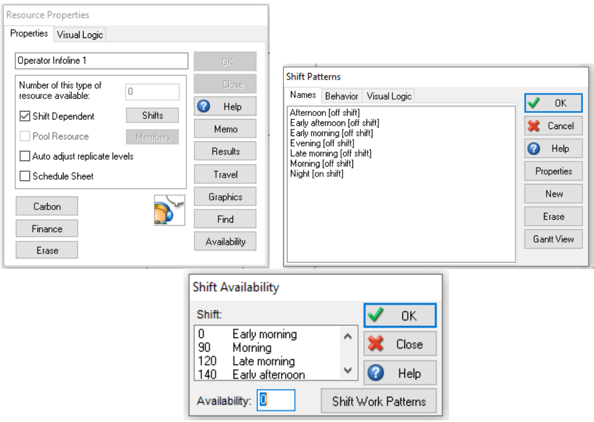

Figure 8: Shifts settings (Infoline1)

The setting of the number of operators is different for the campaign, i.e. for calls to customers by the call center. Here all operators from Infoline1, Infoline2 and Infoline3 could be used if they are currently free. In SIMUL8 a pool resource is selected (Figure 9). Work centers that require a pool resource can be given any resource from the list of members.

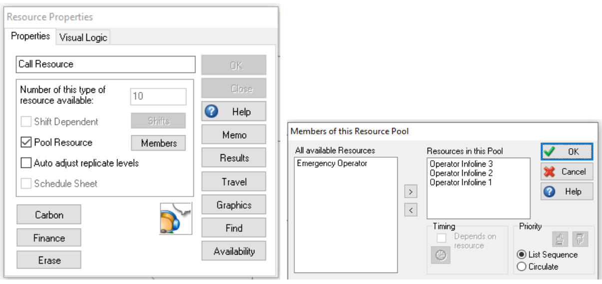

Figure 9: Pool resource settings

The whole model with 3 customer entrances, 1 calls to customer, 3 infolines, 1 emergency calls center, 1 campaign center, 1 exit for served customers and 1 exit for those who hung up early (see Figure 10).

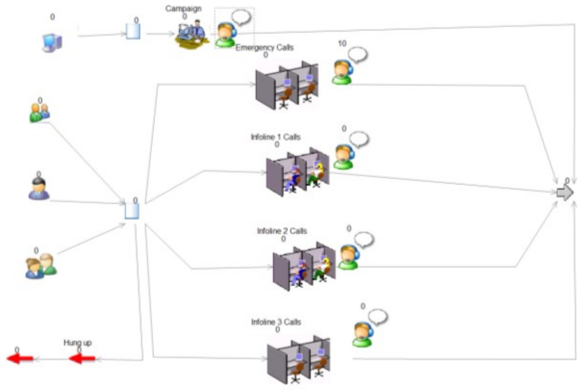

Figure 10: Final model in SIMUL8

Finally, the run settings are necessary to make. The model was tested on the simulation time of 5 days run, 24 hours per day. First, the warm-up period was set to 1 day but the results showed that it is not necessary to set a warm-up as it has no influence on them.

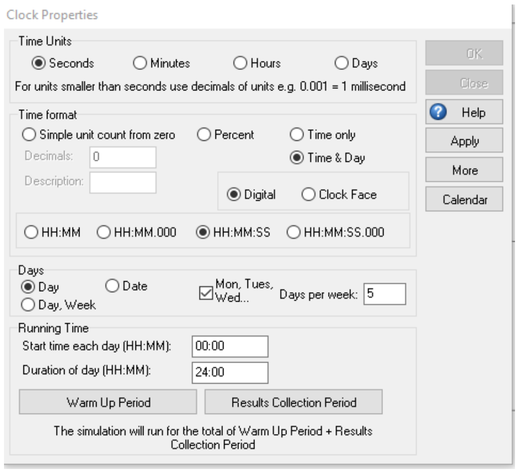

Figure 11: Simulaton model run settings

RESULTS

After 1 run (5 days experiment) more than 87000 of customers were served, and only 1187 customers (1.34%) were lost (see Figure 12). The results (see Table 4, Table 5) corresponds with information and data obtained from call center workers (expected hang ups were about 1-2%).

The operators' usage for all infolines is high enough, but it corresponds with the information we have from the call center workers. Every available operator is used every day (Table 5) and its number corresponds to fluctuations in incoming calls. Figures 13, 14 and 15 illustrate the number of busy operators during 5 days on Infoline1, Infoline2 and on Emergency calls.

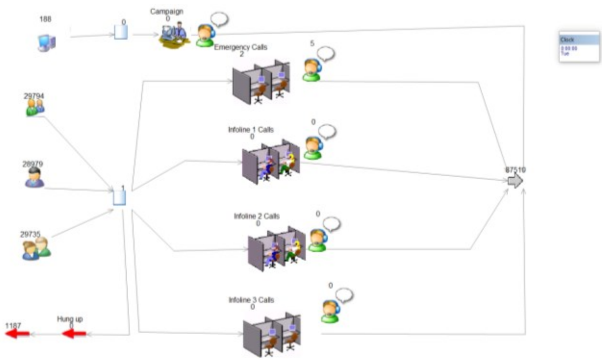

Figure 12: Five days simulation run results

Table 4: Customers generated and lost

Customer	No. of generated	lost (%)
B2B	28979	397 (1.37)
B2C	29735	427 (1.44)
other	29794	363 (1.22)
Pre-selected calls	188	0

Table 5: Operators' usage

Operator	% usage	Avg.no. of used operators	Max. no. of used
Infoline1	82	49.1	140
Infoline2	85	32.2	88
Infoline3	87	16.6	45
Emergency	61	2.8	10

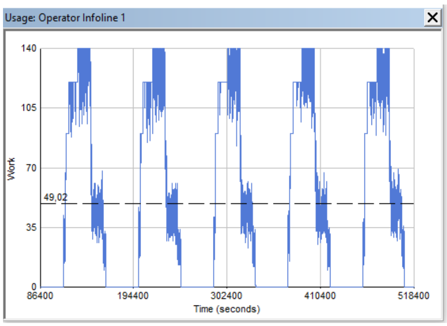

Figure 13: Infoline1 operators' usage

The maximum number of waiting customers was 127 (see Figure 16), but on average only 7.5 customers were waiting with an average waiting time of 36.7 seconds. About 64% of waiting calls were connected till 10 seconds (see Figure 17).

The maximum was higher on the first observed day (see Figure 16) because some operators were used for campaign and calls to selected customers. A campaign with 188 called customers with a maximum of 20 operators was handled during the first day of the simulation. In this situation, the campaign calls could be spread out over multiple days, but the impact on operators' usage is small, so there is no problem managing the campaign on any day.

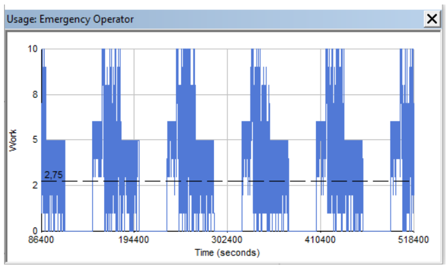

Figure 14: Emergency operators' usage

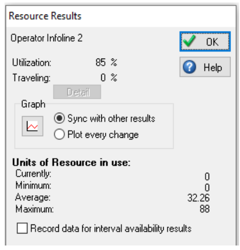

Figure 15: Infoline2 operators' usage

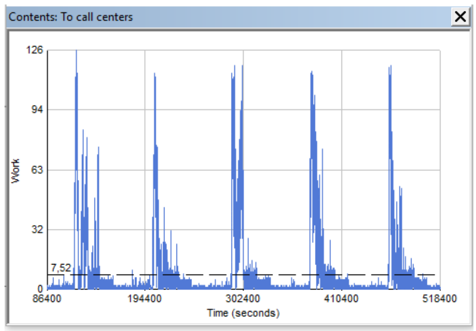

Figure 16: Number of customers in a queue to operators

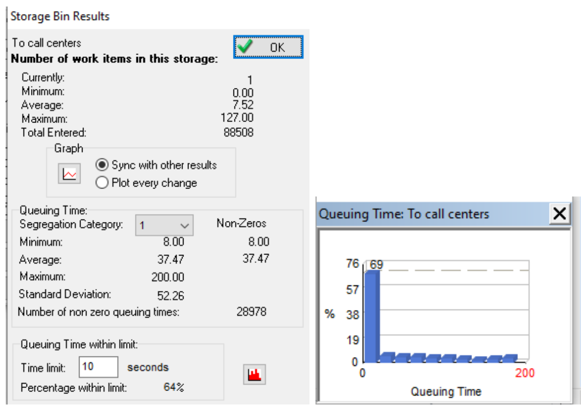

Figure 17: Queue to operators results

EXPERIMENTS WITH MODEL

Since the simulation model was validated and corresponded to reality, it could be used for experiments. There were two types of changes. The first experiment was to test how the percentage of lost customers will be affected by the introduction of new advertising spots on a new product. The second experiment concerns the analysis of the call center operation during the reconstruction of one of the buildings, i.e. of the number of the operators' decrease.

The first experiment assumes adding new calling customers based on the advertisement action. For this type of arrivals, a new time dependent distribution was created with seven time slots and two probability distributions (exponential) related to the scheduled launch of the ads (see Table 6).

Table 6: New customers – inter-arrival times distributions

Day time	**Distribution (avg. time in seconds)**
8:00-10:30	Exp(45)
10:30-11:00	Exp(8)
11:00-14:00	Exp(45)
14:00-14:30	Exp(8)
14:30-20:00	Exp(45)
20:00-20:30	Exp(8)
20.30-21:00	Exp(45)

In the second experiment, we tested the closure of one call center building. It was a reconstruction of Infoline3. Operators cannot move to other buildings because these info lines are all in relatively remote locations. As a result, there is no activity at Infoline 3 throughout the week.

In both experiments, 10 trials (10 weeks) were tested. Average results of all trials and both experiments are summarized in Table 7. The usage of operators in both experiments increased as expected (except of Emergency where no additional calls were set). The number of waiting customers to be served has also increased and so has the average waiting time. The percentage of lost customers in the first experiment was about 3.5% which can be accepted by the call center, but in the second experiment, it is 11.2% which is very high.

Table 7: Results of experiments

Simul. object	Experiment 1	Experiment 2
Infoline1 usage	85%	89%
Infoline2 usage	88%	90%
Infoline3 usage	88%	0%
Emergency usage	64%	64%
Max. queue length	148	134
Avg. waiting time (seconds)	73.7	136.1
Lost customers	3516	9894
% of lost customers	3.5%	11.2%

The call center could be successful in the case of a promotional event with minimal impact on operators' usage and with acceptable impact on the percentage of the customers lost. In the case of short-term closure of Infoline3, the impact on lost customers would be more significant and unacceptable for the company. It is, therefore, necessary to consider not to close one building as a whole and attempt reconstruction while maintaining partial operation.

CONCLUSION

The aim of the contribution was to demonstrate the applicability of SIMUL8 on the call center modelling. The model was based on available information given by employees of the call center. The simulation model should have shown the impact of an increasing number of customers and a decreasing number of operators. First, the impact of a promotional event was tested to monitor the utilization of operators. Second, a short-term closure of one infoline was examined to analyze the number of lost customers. While the first strategy seems to be suitable for the human resource management, the second one is not quite acceptable because of too high percentage of the customers lost. Although the situation was slightly simplified, the model corresponds with the real situation and proves a possibility to satisfy increased demand (number of calls) and problems when one part of the call center is closed. We verified that for this type of the real system analysis, a simulation model is the suitable tool to indicate the impact of planned changes in the system processes.

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