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Discrete event simulation applied to the software testing in a bank

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Abstract

In a bank or a similar organization offering e-services, there is constant pressure to innovate existing products, create new services or implement regulatory requirements. Each delivered software should be tested to detect and remedy supply deficiencies. The aim of the paper is to describe the software testing process in a bank and afterwards prepare the simulation model, based on real data, to estimate the appropriate number of human resources during the given process and to suggest changes in the process leading to higher efficiency. SIMUL8 software, as one of the discrete event simulation software type, was chosen for modelling and simulation purposes. The result showed not only the recommended number of employees but also the necessity of the changes in the process itself.

Keywords: Discrete even simulation, process modelling, software testing, SIMUL8.

1. Introduction

In today's world, banks have become leaders in offering electronic services (e-services). The use of IT in banking sector began in 1990s' when some American banks launched their e-banking services. But changing socioeconomic trends and advances in self-service technologies have enabled a vast number of people to access banking services and have forced banks to improve the e-services (Keskar and Pandey, 2018).

With an increasing variety of e-services currently offered by larger banking organizations, more complex software providing e-services is highly required. Software testing has emerged as a distinct and critical component in software development (Yang et al. 2011). Complex solutions require to verify their functionality by performing functional tests. These tests are usually performed by testing teams, a workforce that needs to be managed in time to deliver a project properly. Proper allocation of testing resources is crucial for a successful testing phase in which all delivery insufficiencies should be detected and fixed (Janitor, 2018). In this specific case of the banking organization, the testing phase is followed by the process of delivery acceptance, which is based on the success of testing. This is one of the most crucial milestones, and problems arising from an inability to accept delivery in time can cause severe issues affecting continuous operation, project planning and resource management of an organization. Impact of these problems could be lowered by appropriate management of the testing related resources. Simulation offers a way to model testing process which can be used to provide appropriate resources allocation. The model can be further tested for the impact of changes in the mapped process.

In the following text, a similar problem as in Madadi et al. (2013) is solved via a simulation model. First, we present the creation of the simulation model of the software testing in a bank. Second, several scenarios are tested to find out the optimal number of team members and testers for software testing process in a bank. Finally, a few recommendations for the bank managers are mentioned to improve the testing process itself. Since the simulation is not used in a given bank, it is also one of the goals to show the advantages of simulation modelling for the process analysis.

2. State of the art

A lot of studies are usually aimed at the analysis, whether electronic services have a positive effect on the banks' performance or not – according to Alomari et al. (2018), there is no global agreement on the effect of e-banking services on the banks' profitability. On the other hand, IT development is necessary for the customers, as nowadays e-services and e-commerce are very popular and widespread over the world. Berger and Mester (2003) or Sundas et al. (2017) proved the influence of new technology on the higher profits of banks.

For the analysis of the processes in a bank, a simulation model can also be used. Sarkar et al. (2011) applied simulation to the optimal utilization rate of counters. Pei (2008) aimed at the reduction of the service time of a bank's tellers by a motion study. Das and Bhar (2018) used system dynamics for manpower planning. Madadi et al. (2013) created a simulation model in WITNESS software to improve the average utilization rate of counters and average waiting time that customers have to spend in the queue in a bank. All these analyses were aimed at higher customer satisfaction or bank processes optimization.

Simulation modelling itself is a technique for imitation of the reality to study the modelled system or to find a solution to a problem (Banks 1998). Several types of software are available for the simulation model and the choice depends on the software knowledge or on the way of the simulation time incorporation. When no time sequences are needed, Monte Carlo simulation application and software (such as Crystal Ball o @RISK) could be used, but in most cases, discrete or continuous simulation is more appropriate for modelling real-world situations. Discrete event simulation (DES) is suitable for dynamic, stochastic systems that change in a discrete manner (Banks et al., 2004). DES is common for models of economic and business processes, such as production and manufacturing systems (Fousek, Kuncova and Fabry 2017; Masood, 2006), call centres or emergency medical services (Van Buuren et al., 2015; Mathew and Nambiar, 2013), queuing and shops functioning (Kuncova and Skalova, 2018) or different scenarios and company strategies (Montevechi et al., 2007).

The process of building a simulation model is usually divided into several steps (Dlouhy et al., 2011; Sharma 2015):

- problem formulation
- objectives settings
- decision about the model type
- conceptualization of the problem
- data collection
- software selection
- building a simulation model
- verification and validation of the model
- model testing and change of inputs
- results description
- documents or reports creation

3. Materials and Methods

The main aim of this contribution is to analyze the process of the software testing in a bank via a simulation model to find out the possible bottlenecks of the process, assess the number of employees involved and, based on the results, propose changes in the process that would serve management to increase the efficiency of the testing process itself. Data for the model were taken from the real-world banking scenario and also the authors' experience was incorporated. The given bank belongs to the biggest banks in the Czech Republic. The simulation model is created in SIMUL8 software. The results of the simulation model and simulation experiments should be in accordance with the acceptance criteria required by the bank's managers with the aim to minimize the number of testers. These acceptance criteria are:

- Pass rate (ratio of the successfully tested scenarios on all tested scenarios) at least 90%;
- Acceptance rate (implemented changes, solved defects) at least 80%.

3.1. SIMUL8 software

SIMUL8 as a software package designed for DES has been developed in 1994 by the American firm SIMUL8 Corporation (www.simul8.com). SIMUL8 belongs to the simulation software systems that are widely used in industry and available to students (Greasley 2003; Dlouhy et al., 2011). SIMUL8 uses 6 main parts out of which the model can be developed: Work Item, Work Entry Point, Storage Bin, Work Center, Work Exit Pont, Resource (Concannon et al. 2007; Fousek, Kuncova, and Fabry 2017). 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. When the structure of the model is verified, a number of trials can be run under different conditions. 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). Additionally, the Visual Logic, as a king of VBA programming, can be used to better specify the rules and conditions in the process.

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 and easy to use. It can serve not only for the modeling of different services (Dlouhy et al. 2011), but also for the simulation of various production processes (Fousek, Kuncova and Fabry 2017; Kuncova and Skalova, 2018).

3.2. Problem formulation and conceptual model

The constant need for product innovation, changes in legislative requirements and new directives made constant pressure to implement changes into the company's existing infrastructure. Most changes cannot be implemented without disrupting business processes. On the other hand, and especially when introducing new software, it is necessary to test it outside the real system. Several types of tests are used for testing the change or introduction of a new software product. In the given bank three main types of tests are used: penetration tests (to verify sufficient security against external attacks on the system), performance tests (verifying the performance of new hardware) and functionality test. The last type of tests is essential for the main bank processes as they verify that the new change/application correctly performs all tasks for which it is intended. The steps covered by a functionality test are the subject of research and simulation in this paper.

For each functionality test, a test scenario is specified as a sequence of steps the tester must take. Any error detected during the testing, known as a defect, is recorded in the system along with its priority. The priority is determined based on the urgency of its resolution and the potential impact on the operation of the organization.

All data, except for the working hours of repairs, were collected by one of the authors of this paper. Work repair times were retrieved from the bank database of the system for managing internal test scenarios and defects.

Data cover 82 previous bank projects (Janitor, 2018). The process of functionality testing covers 6 main activities described in Figure 1. After setting the test scenario, the testing process starts. When a defect is confirmed, a team (one of the three) is selected to correct the defect and then to implement the correction into the testing environment. A reassessment that the error has been corrected follows. If a defect has not been found and a pre-set test period has passed, the new application (software change) is accepted for inclusion in real operation.

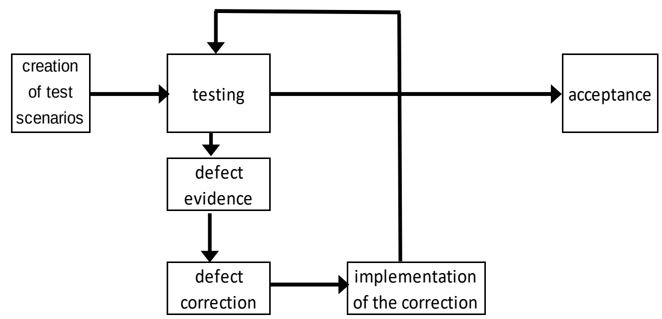

Figure 1. Conceptual model.

Based on these projects, it is evident that the proportion of defects changes over time. The testing period is 6 weeks. According to obtained data, it can be estimated that the defect priorities (given by the bank managers to each type of defect) differ in the 1.week and in the 2.-6.week (Janitor, 2018), as the first week is crucial for the defects with extremely high and very high priorities, that have to be solved immediately (that is why the probability of these findings is lower in the next weeks. Table 1 describes the percentages of each type of defects' priority.

Table 1. Defect priorities and probabilities.

Priority	1.week	2.-6.week
1 Extremely high	8.91%	5.70%
2 Very high	14.31%	11.23%
3 High	25.13%	28.52%
4 Medium	24.18%	24.87%
5 Low	12.20%	13.17%
6 Very low	15.27%	16.51%

3.3. Data Analysis

The data necessary for the simulation model was taken from the bank's database from 82 previous functionality tests. The detailed description of the data collection and the probability distribution estimations can be found in Janitor (2018). The main activities and the estimated probability distributions are in Table 2.

Table 2. Main activities and its duration in hours

Activity	Probability distribution
Test scenarios	Normal (0.17; 0.0425)
Testing	Lognormal (0.14; 0.21)
Defect evidence	Normal (0.5; 0.125)
Defect correction	Lognormal (2.74; 2.54)
Implementation	Normal (0.1; 0.025)
Hotfix	Normal (3; 0.75)

Test scenarios are input for testers. The tester follows the steps defined in the test scenario and compares the expected result with the current result. If the tester finds a problem (the probability is about 80% during the first 2 weeks testing and about 73% during the next 4 weeks testing), he/she registers it as a defect. According to the priority attributes, defect is moved to the appropriate solver. These solvers can be divided into 3 basic research teams: Front-End (FE) team, Back-End (BE) team and Integration (INT) team. Probability of initial assignment to the research team is 50% for FE, 25% for BE and 25% for INT. The duration for this activity is estimated by the lognormal distribution with a minimum of 0.5 hour.

The defect need not necessarily be resolved by the first team to which it was passed. Research team verifies whether an error has actually occurred or provides another required information for defect resolution. If the error occurs on another system or the given solver does not have enough information to verify the error, the solver converts the defect to one from other possible research teams. The probabilities for each phase of a defect solution are in Table 3. When a defect is repaired more than 10 times, the probability of being solved in the given team is 98% and 1% in each of the other teams.

Table 3. Probabilities to reassign the defect

Defect solution cycle	1.assigned team probability	Other 2 teams (together) probability
1	31%	34.5% (69%)
2	66%	17% (34%)
3	80%	10% (20%)
4	87%	6.5% (13%)
5	92%	4% (8%)
6	94%	3% (6%)
7	95%	2.5% (5%)
8	96%	2% (4%)
9	97%	1.5% (3%)
10	98%	1% (2%)

To deploy changes at any time during working hours would make the environment unpredictable and make it impossible to do any planning for the testing. That is why only Thursdays were selected for the deploying changes.

On this day, all the accumulated defect repairs move to the test environment, and during this day, the environment is not available for other tests. A particular case are priority 1 defects that block the testing process. For such defects, there is the possibility of accelerating the implementation to a test environment called hotfix.

After the patch is deployed, the tester repeatedly performs a test scenario including all its steps, the process is called retest. The following procedure is the same as the previous one. If the test fails again (avg. probability is about 29%), there is a defect reopened. If the test was successful, the test scenario is successfully tested, and in the case, the priority 1 defect unlocks the part of the test scenarios that was blocked by the defect.

For each test period (6 weeks) usually 500 tests are made.

3.4. Simulation Model Creation

According to the conceptual model and the information obtained from a bank and described above, the modeling SIMUL8 was created (see Figure 2). There is no generation of the test as the fixed number of 500 cases to be tested is given – and put in the first queue. Several changes brought about by the process characteristics and procedures applied in the program were necessary to make. First, the test and the retest were separated into two different activities (because of the different probabilities in the first pass and the next ones). Second, the activities "unlock" and "hotfix" were used for the implementation only on Thursdays which blocks the other test (except defect with priority 1 which must be implemented immediately).

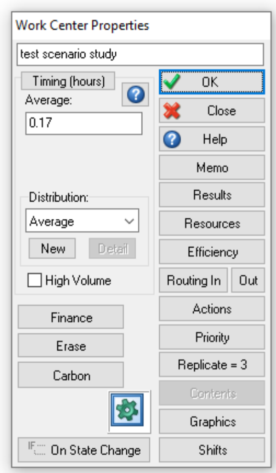

Figure 3. Settings of the duration of an activity.

For each activity, the duration was set according to the Table 2. In SIMUL8 the normal distribution with the standard deviation equal to ¼ of the mean value is called "Average" distribution (Figure 3). The lognormal distribution with a minimum of 1 minute was used for the testing activity. According to the probabilities to reassign the defect in Table 3 it was necessary to use the Visual Logic to set the rules of changes in the probabilities (Figure 4).

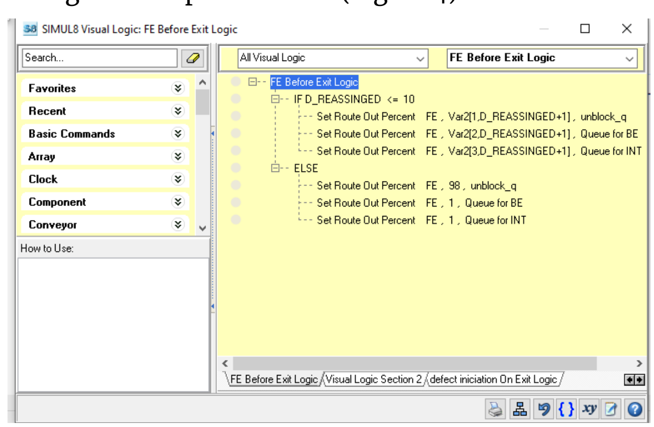

Figure 4. Visual Logic usage to change the probabilities of the team selection

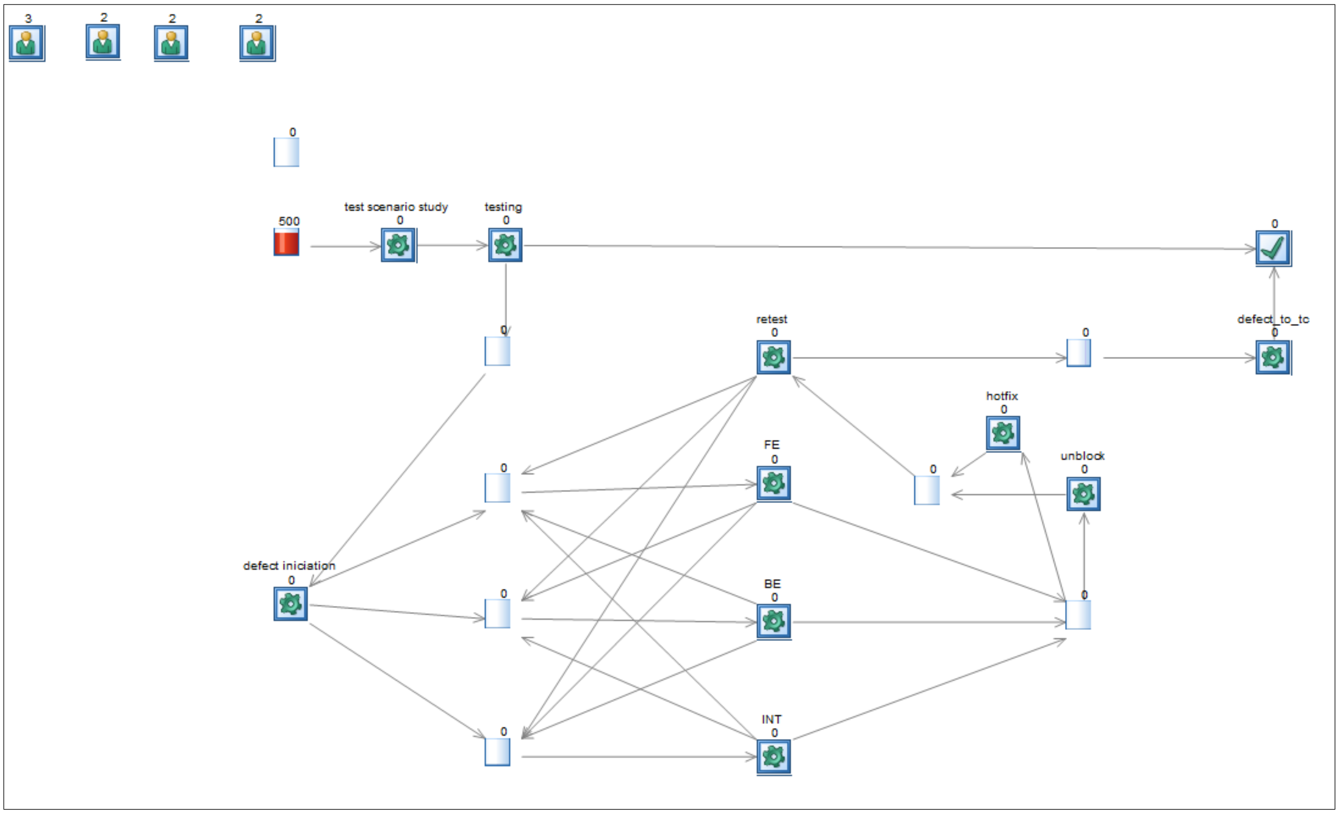

Figure 2. Model in SIMUL8

4. Results and Discussion

The main aim of the simulation was not only to create the model but also to test the influence of the number of testers and teams to the pass rate given by the ratio of pass test to all tests during the 6 weeks' period of testing.

First, it was necessary to verify and validate the model. Verification was done based on the knowledge of the process of testing. For the validation, data from the bank database was used for the comparison with the model results. Figure 5 describes the comparison of the duration of testing – the blue line shows the real data; the red line is taken from the SIMUL8 model results.

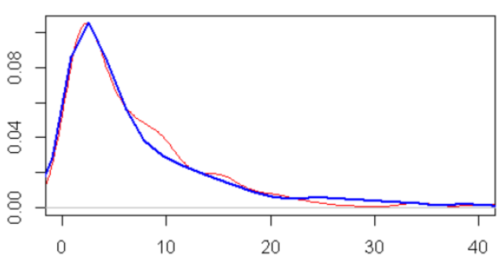

Figure 5. Validation of the model

When the model was validated, several scenarios were tested with a different number of testers and teams and the results were compared. The availability of testers and teams was set to 70%. The trial of 100 simulation runs was tested with a different number of testers and teams (Table 4). First (model 1) with a minimum number of resources (1 tester, 3 teams), second (model 2) with 3 testers, third (model 3) with two times more teams and in model 4 with 4 testers. The main aim was to have the pass rate on 90% at least and the acceptance rate (implemented changes, solved defects) on 80% at least.

Results of all tested scenarios are presented in Table 4. It is clear that to meet the aim, the number of testers should be 3 or 4 for the pass rate (but better 4), and 6 teams for the acceptance level.

Figure 6 shows the usage of the testers during the 6 weeks (240 hours). It is evident that in the second part of the testing period not all testers are used. That is why it is possible to have 4 testers for the first 3 weeks and 3 testers for the last 3 weeks. This change in the model showed the same pass rate (99%) and nearly the same – but acceptable – acceptance rate (88%). The testers' usage was a little bit higher (58%) – but 15 man-days could be saved.

Another aspect that is necessary to consider is the queue length. Each of the three teams has to solve several defects during 6 weeks (240 working hours) and it is essential to solve all defects during this time period. Simulation results of the queues (Figure 7 and 8) show that the maximum queue length is lower than 5% of problems and there is no queue at the end of the 6 weeks' period.

Table 4. Results of experiments 4 models

	Model 1	Model 2	Model 3	Model 4
testers	1	3	3	4
teams	3	3	6	6
Pass rate	43%	89%	98%	99%
Accepted	0%	8%	70%	90%
Tester util.	74%	61%	62%	54%
FE team util.	80%	96%	89%	87%
BE team util.	72%	93%	82%	80%
INT team util.	72%	92%	79%	78%

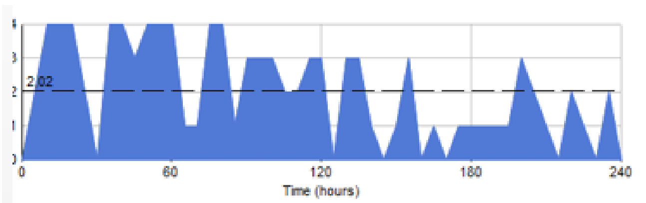

Figure 6. Testers usage

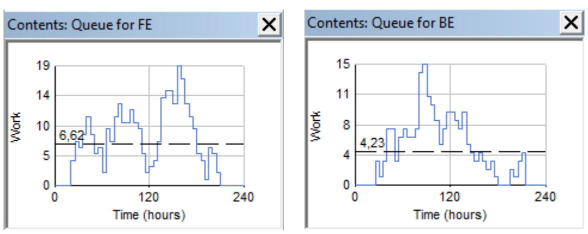

Figure 7. Queues for teams FE and BE

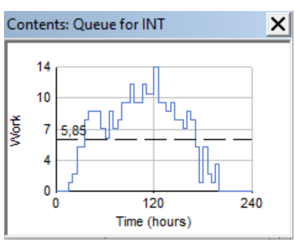

Figure 8. Queues for teams INT

So far, the bank's managers have deployed the number of testers rather ad-hoc according to what the testing situation looked like, i.e. they increased the number of testers when problems in queues accumulated. The simulation experiments' results showed the minimal number of testers that are necessary to work in the process so as to meet the acceptance criteria.

The last experiment was connected with the day for the deploying changes. As it was mentioned above, only Thursdays were selected, when all the accumulated defect repair moves to the test environment, and during this day, the environment is not available for other tests. In our experiments, we tried to test whether the results are different when Tuesdays, Wednesdays or Thursdays were selected. The main results are summarized in Table 5. Based on these results, Tuesdays cannot be recommended for the deploying changes and the acceptance rate is lower than 0.8. The current scenario with Thursdays is better in the pass rate, but when Wednesdays should be selected, the acceptation rate could be higher.

Table 5. Results of experiments

	Tuesdays	Wednesdays	Thursdays
Pass rate	0.97	0.97	0.99
Accepted	0.71	0.90	0.88
Tester util.	58.6	58.1	58.6
FE team util.	80.2	80.3	80.6
BE team util.	78.4	78.3	78.4
INT team util.	87.6	87.3	88.2

5. Conclusions

Banks pay special attention to the quality of services, including e-services. That is why it is necessary to thoroughly analyze all processes and monitor its' quality and functionality. On the other hand, the main aim of the existence of a bank is to make a profit. Thus, it is important to balance the quality and the cost of services. Customer satisfaction is one of the main factors that influence the success of a bank. The functionality of e-services is crucial for bank managers to satisfy customers' needs.

Similar to the work of Madadi et al. (2013), an attempt was made to improve the e-service quality of a branch of a bank by constructing a computer-based simulation model. The main aim was to analyze the software testing process via a simulation model in SIMUL8 and to find out the minimal number of testers and teams to meet the required pass rate and acceptance rate. Because of the specific conditions and probabilities, it was necessary to create a model in SIMUL8 based not only on the conceptual model but also with the Visual Logic usage.

The simulation results showed that the model corresponds with real data and the number of testers should be 4 for the first part of the testing and 3 for the second part when 2 research teams of each type are necessary (6 teams together). Another recommendation, based on the results of the model, is to consider changing the day to implement the deploying changes as the acceptance rate could increase a bit.

This study has a few limitations that could set the direction for future research. The simulation model is partly based on the experiences of one author and on the opinions of bank managers. For future experiments, newer information and data should be factored in.

We can conclude that also for the case of the software testing in a bank, discrete event simulation is a good tool to analyze the process and SIMUL8 is suitable software for that kind of modelling and analysis. Although only one main process was tested, a simulation model for the analysis can be recommended to the bank for other analysis. This research could help the bank to increase its quality of processes.

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