

Teaching Simulation for Management Students in LMS

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Abstract. The aim of the paper is to present the role of modelling and simulation in education of future managers. The text reflects the experience that students can learn better when they solve real practical problems. Some of the managerial problems include stochastic variables, and experiments with these models are known as stochastic simulation. The paper presents and focuses on a decision model for a selection of a mobile phone tariff. Since ICT is widely and effectively used in the process of simulation, the paper also presents particular practical steps how to prepare and how to analyse a selected model in MS Excel. All steps are implemented at LMS system. Based on the described method, the paper formulates several recommendations in the area of the model theory and the decision support teaching that can be used in higher education of managers.

Keywords: Computer supported teaching · Decision support · LMS · Simulation

1 Introduction

With regard to the managerial practice, a model can be considered as simplified representation of a real object/organization of their interest, see [9]. Models are usually used to study properties of the given organizing processes in two ways: either to reveal the effect of different policies impact on that organization, or to investigate possible improvements in the organization, see [1]. Typical models constructed by business analysts are used in decision support systems and for comprehension of business rules. Decision support systems can be considered as a part of business analytics component of business intelligence, see [11]. Since a lot of variables within the considered model can have a probability character, computer simulations are widely used to study their properties. In this paper we would like to show that the process of developing of a simulation model is a complex one which uses knowledge and findings from different areas. There are a lot of pedagogical challenges linked with potential ways of explaining the main ideas of modelling and simulation to learners. Firstly, students should be aware of the following essential steps of simulation: (a) formulation of the problem – defining of the problem, acquiring of input data, developing of a simulation model, (b) solution of the problem - running of the computer simulation model including its testing, (c) interpretation of the obtained results – statistical processing and analysing of output data. All these parts of the simulation process are quite complex and long-lasting. Therefore, it is not sufficient to build up only a theoretical framework, but it is also necessary to focus on practical solutions to problems. Moreover, there are a lot of

different approaches how to simulate a given problem, and students should learn which approach is just the best one in the given situation, [9]. Since students usually positively appreciate when a real problem is being solved or when a model is based on real data, we agree with [6, 7] that it is desirable to use models where real data are available. We think that, apart from solutions of simple problems, students should solve more complex problems in their seminar projects. Therefore the aims of this paper are: (a) to introduce a step by step implementation of key learning outcomes (LO) into teaching of the subject called “Stochastic modelling and data”, which is offered at our institution; all steps are also implemented at Blackboard Learn LMS (BbL) that is used at our university, (b) to introduce quite a simple but non-trivial model that solves a decision problem when implemented in MS Excel; the main focus will be given on a case study of a decision problem of a small entrepreneur that compares two different mobile phone tariffs and selects the better one, (c) to show that the process of developing a simulation model is complex and that it involves and applies knowledge from different areas of the curriculum, (d) to show that a statistical analysis of output data is necessary for finding a solution of the problem, (e) to present the students’ attitudes and opinions concerning each stage of the developing of the simulation model.

2 Methods and Material

The learning objective of the subject “Stochastic modelling and data”, which is divided into several modules, is as follows: At the end of the course the student will be able to construct a simulation model for a given managerial problem and to provide an analysis of its solution. In the framework of the seminars in this subject students work out and submit their seminar project. The principal steps of the modelling process are well known, see [9]. They can be briefly presented through the following instructions: analyze and formulate the problem; formulate the model; solve the model or make simulations; verify, interpret and analyze the model’s solution; report and present the model. These steps will be introduced as LO of the teaching/learning process in this paper, see [4]. At the end of the course which has been chosen for this case study students were supposed to evaluate the difficulty of each step of their solution process, this evaluation was made through answering the questions included in a short questionnaire.

Since spreadsheets are one of the main tools for modelling in business and management, see [2, 3, 8, 10], the considered model is implemented in MS Excel. Our approach is based on that one used in [1]. When a problem contains at least one variable that exhibits a probability character, the Monte Carlo simulation can be applied. This method of simulation is based on generation of multiple random trials to determine the observation sufficient for finding of the expected value of the output variable. The process can be described in the following steps: First, we find a probability distribution for each parameter that can be represented by a random variable. Secondly, we use a random numbers generator and simulate values from the probability distribution for each random variable. Finally, we repeat the process for series of trials that are usually called replications. Let us remark that symbol $N(\mu, \sigma^2)$ denotes the normal distribution with the mean μ and the variance σ^2 , and the symbol $R(a, b)$ denotes the uniform distributions

(discrete) between the lower limit a and the upper limit b . MS Excel has two functions to produce random numbers. The function = RAND() produces a (continuous) uniform distribution between 0 and 1. The function = RANDBETWEEN(a ; b) provides a (discrete) uniform distribution between a and b . If we want to use the normal distribution, we have to convert the uniform distribution that is available. One of the possible ways is the following one: Let's remind that function NORM.INV is the inverse of the NORM.DIST function and that it calculates x variable given probability p . It can be used in the following way: = NORM.INV(p ; μ ; s), where μ is the mean and s is the standard deviation of the considered normal distribution. Functions RAND() and NORM.INV can be combined to calculate a random number from a normal distribution. The resulting formula is = NORM.INV(RAND(); μ ; s).

2.1 LMS Section - Assignments and Tasks

The following problem was assigned to students as their seminar project: an entrepreneur wants to compare his potential costs linked with different phone tariffs. He makes the decision between two possibilities given by the mobile phone operator that are described in Table 1.

Table 1. Selected mobile phone tariffs (source: https://www.t-mobile.cz/dcpblic/Cenik_sluzeb_T-Mobile.pdf)

Tariff	Monthly fee in CZK	Free credit in minutes	Extra free credit in minutes, calling inside T-Mobile	Price in CZK per minute, calling inside the company	Price in CZK per minute	Price per 1 SMS in CZK
Plus 250	250.00	58	25	0.30	4.30	1.00
Plus 450	450.00	136	45	0.30	3.30	1.00

2.2 LMS Section - Input Data, Data Understanding and Data Preparation

During the process of preparation of the input data, the following LO can be considered: A student gathers the input data, makes a simplifying assumption and determines the variables and units of the given problem.

To be able to calculate the costs of phone calls per month, one needs data that are related to the length of calls. For different entrepreneurs we find different input data, and therefore we can gain different results. These data can be collected from the entrepreneur's records taken from his/her former phone calls invoices. The particular approximations of data used in our paper are introduced in Table 2.

Table 2. Random variables of the model and their distributions (source: own observations)

Variable	Distribution
Length of calls inside the company/minutes	$T_1 \sim N(180, 900)$
Length of calls inside T-Mobile/minutes	$T_2 \sim N(80, 400)$
Length of calls outside T-Mobile/minutes	$T_3 \sim N(50, 100)$
Number of text messages (SMS)	$X \sim R(0, 50)$

2.3 LMS Section - Model

At the stage of formulation of the model, the following LO can be considered: A student establishes relationships among variables and determines equations and functions for them.

Suppose that FC_i is the fixed monthly fee for using mobile phone tariff i , $i \in \{250, 450\}$, where $i = 250$ represents the tariff Plus 250, and $i = 450$ represents the tariff Plus 450. Further, suppose that MC_i are the variable costs of mobile phone calls inside the company, VC_i are the variable costs of mobile phone calls outside the company. Finally, suppose that XC_i are variable costs of text messages (SMS). The total costs TC_i of the services paid are the sum of the fixed costs and the variable costs, which can be formally written as

$$TC_i = FC_i + MC_i + VC_i + XC_i, \tag{1}$$

where $i \in \{250, 450\}$. First, let us consider the variable costs of mobile phone calls outside the company. Since there are free minutes available in this tariff mode, it is necessary to determine the total time T_i , $i \in \{250, 450\}$, that has to be charged in this mode. Further considerations presented in the text are related to the tariff Plus 250 only. Similar considerations can be obviously applied to the tariff Plus 450. According to Table 1 the time T_{MOB} that has to be paid for calling inside T-Mobile is

$$T_{MOB} = \begin{cases} 0, & T_2 \leq 25, \\ T_2 - 25, & T_2 > 25. \end{cases} \tag{2}$$

Similarly, the total time T_{250} that has to be paid for calling outside the firm is

$$T_{250} = \begin{cases} 0, & T_{MOB} + T_3 \leq 58, \\ T_{MOB} + T_3 - 58, & T_{MOB} + T_3 > 58. \end{cases} \tag{3}$$

The above given relations (2) and (3) can be simplified and summarized as follows

$$T_{250} = \max\{0, \max\{0, T_2 - 25\} + T_3 - 58\}. \tag{4}$$

In the same way we could find

$$T_{450} = \max\{0, \max\{0, T_2 - 45\} + T_3 - 136\}. \tag{5}$$

Now we can express the relation for the total costs. According to (1) and Table 1 we can write

$$TC_{250} = 250 + 0.3 \cdot T_1 + 4,3 \cdot T_{250} + 1 \cdot X \quad (6)$$

and similarly

$$TC_{450} = 450 + 0.3 \cdot T_1 + 3,3 \cdot T_{450} + 1 \cdot X. \quad (7)$$

Relations (6) and (7) represent the model of our problem. Although we have found simple expressions for the total monthly costs of calls, we could realize that both quantities TC_{250} and TC_{450} are random variables. When we want to characterize them better, we need to carry out simulations.

2.4 LMS Section - Model Implementation and Simulation

At the level of the implementation of the simulation model we can state the following LO: Students are able to use MS Excel to prepare computations with the given formal model.

We do not present all details of this step here. First, it is necessary to record the input variables given in Table 1. Next we record all parameters of the random variables given in Table 2. The formulas used are summarized in Table 3.

Table 3. Formulas specification for input variables

Description	Cell address	Formula
Length of calls inside the company	H5	=NORM.INV(RAND()); \$H\$2; SQRT(\$H\$3))
Length of calls inside T-Mobile	I5	=NORM.INV(RAND()); \$I\$2; SQRT(\$I\$3))
Length of calls outside T-Mobile	J5	=NORM.INV(RAND()); \$J\$2; SQRT(\$J\$3))
Number of text messages	K5	=RANDBETWEEN(\$K\$2;\$K\$3)

After having prepared all necessary input data, we can proceed to construct a simulation model. Using (6) and (4) we gain the costs of calls and texting with the tariff Plus 250, and similarly, using (7) and (5), we gain the costs of calls and texting with the tariff Plus 450. The formulas used are summarized in Table 4. The formulas in Table 4 use both absolute and relative addresses of some cells. The absolute addresses are used because formulas will be used for replications of the model, and at each step of replication it is necessary to refer to the same input values. Such constant values in the given tariff are: monthly fee, unit prices and number of free minutes, see Table 1. On the other side, relative addresses are used because the formula contains references to random

variables that will be freely changed at each replication. Such variables are related to times given in Table 2. Since the constructed simulation model is quite compact, the replications can be performed by copying the model several times. To finish the simulation, the number of replications has to be determined.

Table 4. Formulas specification for output variables

Description	Cell address	Formula
Costs of Plus 250	L5	=B\$5 + B\$8*H5 + B\$9*MAX(0; MAX(0; I5-B\$7) + J5-\$B\$6) + B\$10*K5
Costs of Plus 450	K5	=D\$5 + D\$8*H5 + D\$9*MAX(0; MAX(0; I5-D\$7) + J5-\$D\$6) + D\$10*K5

The simplest way how to find this number is as follows. The number of replication can be determined in such a way that the relative error of the mean $E(TC_{250})$ of total costs is less than 2 %. Since the margin of the error e for 95 % confidence interval is approximated by

$$e = 1.96 \frac{\delta}{\sqrt{n}}, \tag{8}$$

where δ is the standard deviation and n is the sample size (in the context of simulation it is the number of replications), see [5], the relative error can be estimated as $e/\mu \leq 0.02$. Using the given relations, the number n of replications can be estimated as

$$n \geq \left(1.96 \cdot \frac{\delta}{0.02 \cdot \mu} \right)^2. \tag{9}$$

The unknown values of standard deviation and means can be approximated from the first 100 replications of our model, for instance. In this way it was found that $\mu \approx 540$, $\delta \approx 90$. Using these values and (9) we find that $n \geq 267$. Particularly the number $n = 350$ of replications has been selected.

2.5 LMS Section - Analysis and Interpretation

At the stage of analysing the output data we can consider the following LO: A student applies principles of statistical inference for the output data, analyses them and identifies the potentially best managerial solution. Within the environment of BbL system students then debate the economic effects linked with different solutions of the given managerial problem.

Here we mainly concentrate on comparison of two means: $\mu_1 = E(TC_{250})$ and $\mu_2 = E(TC_{450})$. Since the two considered tariffs, i.e. the tariff Plus 250 and the tariff Plus 450, are different, our research hypothesis is that $\mu_1 \neq \mu_2$. This means that the null and the alternative hypotheses are $H_0: \mu_1 = \mu_2$ and $H_A: \mu_1 \neq \mu_2$. The test will be conducted with the significance level $\alpha = 0.05$. The simulation has been designed in such a way

that both values TC_{250} and TC_{450} are computed simultaneously, so the test for paired samples can be used, see [5]. The basic visual characteristic feature of the data analysis is given by box and whisker plots, see Fig. 1.

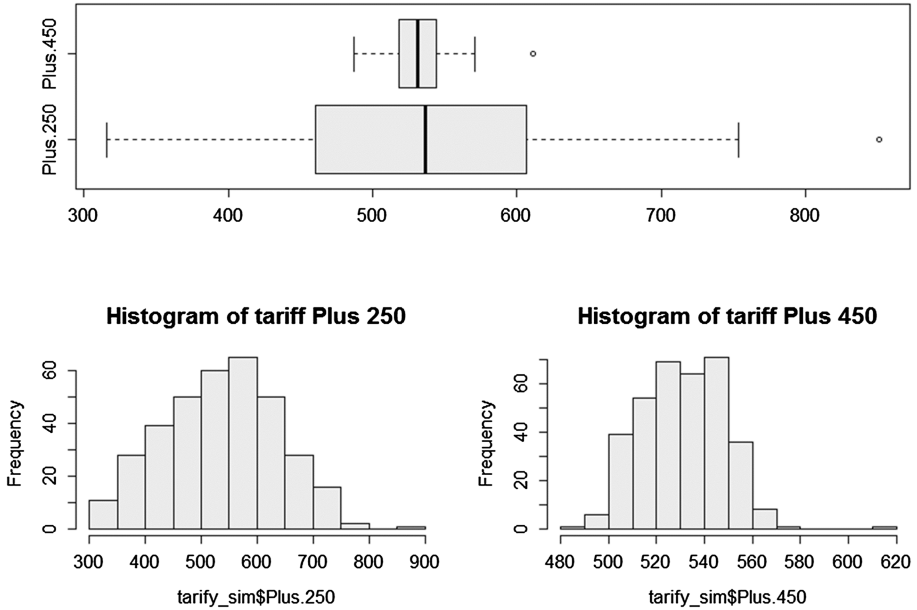


Fig. 1. Box and whisker plots and histograms of data obtained by simulation.

Let $d = TC_{250} - TC_{450}$ be the difference between the costs of calls with the tariff Plus 250 and the tariff Plus 450. Using the replications data of the given simulation model, it was found that the average \bar{d} of the difference d is $\bar{d} = -2.07$ and its standard deviation is $s_d = 97$. The critical value t_{crit} of the rejection region is a quantile of Student’s t -distribution. For two tailed test, $\alpha = 0.05$ and $n - 1 = 349$ degrees of freedom, where n is number of replications, it has been found that $t_{crit} = t_{1-\alpha/2}(n - 1) = 1.97$. This value can be found by function $T.INV(0.975;349)$ in MS Excel.

The test statistics is calculated using the following formula

$$t = \frac{\bar{d} - \mu_d}{s_d} \cdot \sqrt{n} = \frac{-2.07 - 0}{97} \cdot \sqrt{350} \doteq -0.4. \tag{10}$$

Due to $|t| < t_{crit}$, we do not reject the null hypothesis. This observation allows us to formulate a conclusion. Based on the input data and on the simulation data, no sufficient statistical evidence exists to conclude that there is a difference between the tariff Plus 250 and the tariff Plus 450. It has to be notified that this result is strongly dependent on the input data given in Table 2. Students should be aware of the fact that working with different input data could bring a different result.

3 Results and Discussion

The essential principles that students of management courses can learn about stochastic simulation in the process of working out their projects were introduced and summarized in this paper. These steps are implemented within the Blackboard Learn system as sections of a module. Having submitted their project in the winter term of academic year 2014/15, the students were asked to answer a few questions in a short questionnaire that was distributed them by BbL system. Some of the results are presented below (a reduced analysis was made). The first question was: What was the most difficult part in developing of the simulation model? 86 students formed the group, 73 answers were gathered. It was found that the distribution for the given question can be characterized as follows: 4.1 % of the students - understanding of the problem, 10.9 % of the students - analysis of the input data, 38.3 % of the students – the model formulation itself, 15.1 % of the students – the implementation of the model, 8.4 % of the students - the simulation itself, 20.5 % of the students – the statistical analysis of the output data, 2.7 % of the students – reaching the decision. From this survey it is clear that in the opinion of our students the most difficult part of the solution is the part where it is necessary to establish relationships among variables and some mathematical relations have to be used. This part of construction of the model is the most critical because students of economics and management often avoid mathematical concepts. We have found that this aversion can be partly overcome when students work with a real problem and real data. This is in accordance with [7]. Quite surprising is the fact that students do not consider the part of preparation and analysis of input data as difficult as it is usually considered, see [1, 11]. We think that the main reason is that the input data were partly given in the assignment of the problem. Another difficult part of the modelling seems to be statistical analysis of the output data. We think that this finding corresponds with the general aversion of students of economics and management to quantitative methods, see [4]. The students also stated that the own implementation of the simulation model in MS Excel was fairly difficult. This is the reason why we deal with this problem in detail in this paper. This issue is quite new for students and we agree with [1] that it is necessary to extend the competences of students in using MS Excel in different areas. In this case we partly modify the approach for Monte Carlo simulation given in [2]. The case study was presented in a detailed way because we want to show how complex the problem of simulation is and which steps are relevant for developing a useful model. A possible way how to simulate a random variable with normal distribution in MS Excel was presented, this simulation allows us to solve a wide range of problems.

Another question that students were asked in the final questionnaire was: Were you interested in the result and impact of the decision made in connection with the given problem? It was found that 67 % of students were interested in the result. Thus we think that solving real problems can motivate our student effectively. These real problems can also support our students' ability to think about and consider the given problem in many different ways. Working on their practical projects, the students can propose different approaches how to reach solutions. They can work in teams and discuss different ideas, which can support their team co-operation. In our practice we have found that the process in which students work out their projects and work with real data is very useful for them

as future managers. Working on projects, students learn how to collect data, how to analyze them and how to approximate them. They also learn how to prepare and how to formulate a model for a practical problem and finally how to prepare a computer simulation that enables them to provide an experiment with the given model. During most parts of their work students use ICT. With the help of the simulation model, they can find different phenomena and qualities of the model. These findings do not differ from the findings made by [6], who studied some issues from the sphere of science.

Finally we would like to discuss some advantages of using learning outcomes (LO) that were used in the teaching module. We proposed a concise formulation of LO, which turns the decision about the education strategy away from a teacher to a learner, and tends the orientation of education on its (measurable) outputs as the education purpose, see [4, 12, 13]. Another question the students were asked in the final questionnaire about LO was: Have you found that LO helped you to understand the process of developing a simulation model? The positive answer was stated by 61.6 % of students. We therefore agree with [4] that LO can enhance learning. LO usually provide relevant information about the content to be learned and also about the way in which the student will demonstrate his/her knowledge. It means that if the student has a set of LO he/she can make better choices about study methods and content emphasis. Moreover, LO can also help teachers and instructors to better design and implement their educational intention within BbL system. With LO teacher can better plan and manage their instructions, manage learning or facilitate evaluation activities.

4 Conclusion

Managers and their decisions can be successful only if they work with correct and relevant information. Because it is not possible to implement an experiment with institutions that are to be managed, it is necessary to provide artificial experiments within an appropriate model. This is the way how simulation models are introduced into managerial work. Since we are aware of this reality, we intend to prepare students of management courses in modelling and simulation.

Each model can be enriched, modified and particularized in many ways. The model that was presented in this paper can be also modified, and instead of the monthly costs of phone calls we could compute e.g. the annual costs. Moreover, the statistical analysis can be enriched and can focus on describing of another feature of the output data, for instance that of mapping the difference in the variety of the output data distributions. All these modifications can be discussed with our students. Since modelling and computer simulation provides a useful methodology of the experimental research in the current management and in the university education as well, we would like to aim at the methodological issues in future papers. The intention is to present more detailed description of how to use simulation in business problems and transfer them to our students by BbL LMS.

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