

# USING OF STOCHASTIC SIMULATION FOR MODELING OF COMPANY SALES PLAN IN MS EXCEL

Šárka Michalcová

VŠB – Technical University of Ostrava, Faculty of Economics

***Abstract:** Current real business processes are affected by a series of complex interactive and interdependent elements with probabilistic and dynamic characteristics. In this case it cannot be used mathematical methods with the exact analytical solutions for analysis of business processes and one of the alternatives is using of simulation. It is a very useful tool which can serve for modeling of the complex processes and for carrying out experiments with them.*

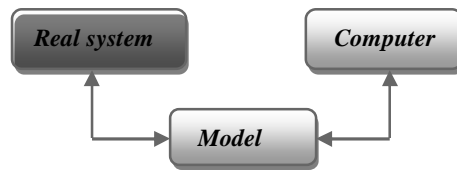
*This article discusses using of stochastic simulation to generate a variable demand for the products of certain virtual manufacturing and commercial company. Presented simulation includes process from stochastic behavior of anonymous demand for finished products of the company through the creation of binding orders and through the distribution channels of finished goods (distribution warehouse, company shop, direct customers). The results of stochastic simulation serve as a basis for subsequent use of descriptive statistics and statistic inference methods. Own simulation was performed by the Monte Carlo method and by using of widely available software MS Excel.*

***Keywords:** Sales plan, Confirmed and Fejected Orders, Computer Simulation, Stochastic Simulation, Planned and Variable Demand, Distribution Function, Probability Distribution, Linear Regression, Monte Carlo Method, Random Variable, Random Numbers, Stochastic and Dynamic System, Arithmetical Mean, Standard Deviation, Point and Interval Estimate*

## 1. Introduction

Computer simulation is a modern tool for analysis of complex manufacturing, supply, communication and other business processes. Simulation is a method that allows to managers to predict behavior of the system under the changing of external and internal conditions, to optimize business processes in relation to specified criteria (profit, costs, reliability). A considerable advantage of simulation is the fact that everything takes place only in a computer model without necessary interventions into the operation of the company. It is possible to explore alternative changes in the system through the simulation, to verify the impacts and consequences of these changes and select a solution which is the most suitable for a given situation. Computer simulation is a tool that is usable to all levels of the company: for management decision support of strategic importance, for design and production planning, for quality assurance and for operative decision making at the workshop level. [10]

Computer simulation can be characterized by three elements – the real system, model, computer and by two relationships – modeling and simulation [13] as can be shown in the following schema (*Fig. 1*).



***Fig. 1: Three elements and two relationships in process simulation***

Source: Křupka, Kašparová, 2009

It happens very often that we cannot solve the problem only by a mathematical model in complicated situations and it is necessary to find a solution of this situation by a simulation. Computer simulation is the only possibility of analysis and problem solution in these cases. Dynamic model is solved by a stochastic simulation which is known as Monte Carlo method at literature. This method looks for a solution of probability tasks by using many times repeated random experiments. Options of its use are wide and very diverse.

A typical feature of the Monte Carlo method is that in solving of the problem we create the sequence of random variables with a given probability distribution. In practice, these variables are usually described either by some empirical distribution function which has based on observations of random variables in the past or by continuous or discrete theoretical probability distribution. To create a sequence of random variables it is necessary to obtain the numerical realization of the input random variables - random numbers. Generation of these random numbers with a defined probability distribution is usually done in two steps. First, it is generated a primary sequence of random and mutually independent numbers with uniform distribution on the open interval (0, 1). Each number has the same probability of occurrence. A sequence of numbers with desired probability distribution is created by an appropriate transformation subsequently.

The RNG (Random Number Generators) are a normal part of spreadsheets and in the Czech version of MS Excel it can be used for generation of random numbers functions RAND(), RANDBETWEEN or complex tool RNG.

Intricate stochastic and dynamic systems are represented very often in economic reality and they cannot be solved by analytical procedures. Major application areas in which simulation methods are used: queuing systems, production systems optimizing, financial planning, supply management processes etc. Models which are characterized by a relationship between input and output data are indicated by abbreviation RIRO (random in, random out). [10]

When demand is not constant in observing periods (weeks, months), it is possible to use options in MS Excel to obtain an estimate of variable order in a certain time horizon. One way how to estimate demand is its generation by a given probability distribution. We can use for example the triangular distribution which has a trivial

expression of the probability density function and it may be suitable for demand estimating (for relatively easy specification of parameters without historical data but on the basis of experience and knowledge of relevant staff). It was used a normal probability distribution for generating of demand in the following stochastic model. This probability distribution is characterized by two parameters (arithmetical mean and variance) which were set at the beginning of simulation deterministically.

## **2. Problem formulation – model description**

### **2.1 Company strategies and methods used in the production – capacity planning and planning of sales**

#### **1st strategy:**

Capacity production schedule of finished products is framed always for 6 weeks in advance and is based on the actual (but random) gradual filling of the plan in individual weeks in advance (from 6. to 1. week, 0. already not). The random confirmed orders are added up gradually and so the capacity plan increases and reaches the maximum of an actual value at the first week in advance. The advantage of this strategy is that capacity plan is accurate because it corresponds to actual orders in the first week and therefore there are no losses from rejected orders and no losses from “overproduction” to the warehouse. On the other hand, the losses evolve from the disproportions between well-timed and accurate purchase of certain materials (it should be solved by maintaining of higher safety stock). Sometimes it also does not manage timely the preparation of production according to production plan.

#### **2nd strategy:**

Capacity production plan is fixed definitely in the 6th week in advance based on experience, knowledge of statistic methods (regression analysis) and data from the previous year. The advantage of this method is that although it has been created a “static” plan in sufficient advance, there may incur losses from rejected orders due to the adoption of a “soft” plan (undervalued capacity plan). Conversely, if set too “hard” capacity plan (i.e. expected plan was overvalued and thus higher than the actual demand for the current week), then will be losses from the temporary “overproduction”. It is projected as “the production to warehouse” which leads to a temporary increase of the stock level of finished goods in a warehouse. This strategy is applicable when the losses from rejected orders or the losses from “overproduction” to warehouse are not large and acceptable. In practice, there usually exist ways how to solve this dilemma by additional managerial interventions into already accepted capacity plan. Regression analysis can be used for creation of point or interval estimates to determine the optimal planned capacity of orders.

#### **3rd strategy (mixed):**

This strategy is a compromise between those two above mentioned. This compromise allows (after adoption of foreseeable capacity plan) to change fixed plan additionally. However, this situation may have an influence on preparation of production and material ordering. In particular, in this strategy is used the possibility to

move orders of category B (below) to subsequent weeks. Thanks to the moving of certain parts of the received orders is recorded an effect of increased continuity of adopted capacity schedule. It increases productivity and thus reduces relatively some types of costs and it goes to economies of scale.

Used categories of orders (sorted by priority):

- A: order cannot be moved to the following week (i.e. must be delivered in requested term);
- B: order may be moved to the next week but only once (after the first move will be changed the priority from B to A);
- C: individual contract (requires a specific material with a long delivery time ) and must be planned as a whole.

## **2.2 Management of customer orders**

A certain manufacturing and trading company has issued directions of managing director for sales department staff which contained these following rules (*The internal regulations for order management*):

The company customers (private persons, dealers, supermarkets, restaurants, hotels etc.) can order products according to printed catalogs, video offers on the internet or by personal inspection of the exhibit products at company shop that is placed at the distribution warehouse. Incoming orders of customers (written, e-mail, faxes, phones) are checked by a responsible worker and then are stored in so called ORDERS file, in which are constantly updated (changes, rejection, cancellation). Individual orders can come without limitation also a few days before their execution, but the term when order may be confirmed to customer, is established firmly. This is *6 weeks before its realization*. Customers are familiar with this stipulation. All formally correct orders that were received to this deadline are confirmed back to customer bindingly. The customer may, however, to withdraw from it even after order confirmation, but he cannot withdraw without some sanctions from a certain date (usually 1 week before the start of production).

In case when the order will come after the term of internal closing date (i.e. *6 weeks before the realization*) it can be confirmed if and only if the capacity does not exceed the plan of distribution for the desired week of implementation. Otherwise the orders will not to be confirmed and the customer is informed about it. Unconfirmed but still valid order can be realized additionally in originally requested term as far as there will be so called *free stock* in the sales warehouse at the time of realization. This will be reserved for the customer preferentially before so called *direct sales* from the distribution warehouse to random customers.

If it has not been possible up to now unconfirmed order to cover from free inventory in the warehouse in the term of required realization then the order is rejected and cannot be met in the requested term. The customer is informed about this fact immediately and at the same time it is given him a possibility to transfer his orders to the nearest next term in which it could be possible to confirm his order.

Another option for unsatisfied customer demand is direct sale from the free distribution warehouse inventory (from the company shop that is a part of the distribution warehouse). This form of sale for immediate customer does not require a formal order but on the other hand it is uncertain in majority of cases due to unpredictability of the emergence of free stocks. This form of sale is intended for those potential customers who do not plan their demand in advance and accordingly for wider public. This situation is the most often associated with a personal inspection of the exhibited products at the company shop.

### **2.3 Sales plan – verbal description**

Sales plan is compiled every week on basis of received orders and statistic forecasts with regard to marketing surveys, seasonality and trends in demand (including trends, fashion or demographic influences) and also with regard to the nature of the economic cycle in which the economy is just located. The time horizon of the plan is for 6 weeks in advance – in usual (the  $n$ -th) week will be included newly the sixth ( $n+6$ ) week as the sum of orders that are recorded for the sixth week. This value (here designated as  $x_6$ ) enters into a simple statistic regression model which provides an output value (here labeled  $y$ ). This output value is a result of statistical regression that is obtained on the basis of recorded values of orders from past 52 weeks (i.e. the previous year).

It means that orders that are determined for the  $n$ -th week and which arrived subsequently in weeks  $n-5, n-4, n-3, n-2, n-1, n$  (i.e. after regular internal closing date in week  $n-6$ ) are recorded but they do not enter into the consumption plan for the  $n$ -th week. Plans remain fixed for weeks  $n-5, \mathbf{K}, n$  overwhelmingly. These orders, however, can be continuously confirmed to customers when there is a free capacity until the limit of production plan for the  $n$ -th week.

Changes in already approved production plan may be accepted only exceptionally as a result of a higher management decision. They are such as the following situations: a) the strategic necessity to fulfill increased demands of an important customer (e.g. dealer) or b) unexpectedly large decline in demand compared with the production plan (this situation would lead to an excessive growth of inventories of finished products in the warehouse). These special cases are dealt with the specific managerial interventions into already accepted production and sale plan. These activities are not a subject of our research in the simulation model.

## **3. Problem solving – simulation model in MS Excel**

### **3.1 Demand generation**

In stochastic models where demand is characterized by certain fluctuations, the demanded amount can be approximated by a normal distribution with the given arithmetical mean and standard deviation. This probability distribution has been selected in our model to estimate the input parameters that were subsequently used for demand generating in each week. There is a function  $NORMINV(p, \bar{x}, s)$  in Excel for

these purposes, where  $p$  is probability that is given by a generated random number  $RAND()$ ,  $\bar{x}$  is mean value and  $s$  is a standard deviation. Specially, to generate probability demand in our model, it has been used the following formula:

$$= WHEN(NORMINV(RAND();\bar{x};s) > 0; NORMINV(RAND();\bar{x};s); 0)$$

Values of generated random demand are in columns I – O (values  $x_6, \mathbf{K}, x_1$ ) in the Excel table on the following page. (Fig. 2)

### 3.2 Linear regression in simulation model

Values of the predictable demand were generated in 52 rows (i.e. for 52 weeks) and these data were used to calculate the linear regression coefficients (for a functional description of a linear dependence). The recommended production capacity (plan of finished products) is calculated according to equation of the regression line  $\hat{y} = ax_6 + b$

where  $a = \frac{Cov(x_6, y)}{s_{x_6}^2}$  and  $b = \bar{y} - a\bar{x}_6$  ( $\bar{y}$  is mean value of variable  $y$  and  $\bar{x}_6$  mean value of  $x_6$ ). [9]

Covariance is a measure of simultaneous variability of two characters and it is calculated according to the formula: 
$$Cov(x_6, y) = \frac{\sum_{i=1}^n x_{6i} y_i - n\bar{x}_6 \bar{y}}{n}$$
. The measure  $s_{x_6}^2$  is the variance of character  $x_6$ .

To calculate the covariance and variance we can use Excel built functions COVAR and VAR.



These formulas are used when  $x_6$  is independent variable and y dependent variable. Statistic dependence between these two characters can be illustrated also by regression line where y is independent variable and  $x_6$  is depended on it. Both regression lines pass through so called central point whose coordinates are mean values of both

$$\hat{y} - \bar{y} = \frac{Cov(x_6, y)}{s_{x_6}^2} \cdot (x_6 - \bar{x}_6) \quad \text{and}$$

$$\hat{x}_6 - \bar{x}_6 = \frac{Cov(x_6, y)}{s_y^2} \cdot (y - \bar{y})$$

where  $s_y^2$  is a variance of character y.

Their Fig. (Fig. 3) recalls open scissors which we call the correlation scissors.



**Fig. 3: Associated linear regression from one simulation run**

Source: Michalcová, 2010

### 3.3 Confidence bands in regression analysis

Regression analysis can be used to determine the optimal capacity of the planned orders. For each regression value  $\hat{y}_i$  we can determine the confidence interval. By identifying of these intervals for all values of processed area we obtain so-called confidence bands (two branches of a hyperbola around the regression line). The confidence interval for  $y_i$  of regression line for a given value  $x_i$  is:

$$\left( \hat{y}_i - t_{1-\frac{a}{2}}(n-2) \cdot s_{y \cdot x} \cdot \sqrt{\frac{1}{n} + \frac{(x_i - \bar{x})^2}{\sum_{i=1}^n (x_i - \bar{x})^2}}; \hat{y}_i + t_{1-\frac{a}{2}}(n-2) \cdot s_{y \cdot x} \cdot \sqrt{\frac{1}{n} + \frac{(x_i - \bar{x})^2}{\sum_{i=1}^n (x_i - \bar{x})^2}} \right),$$

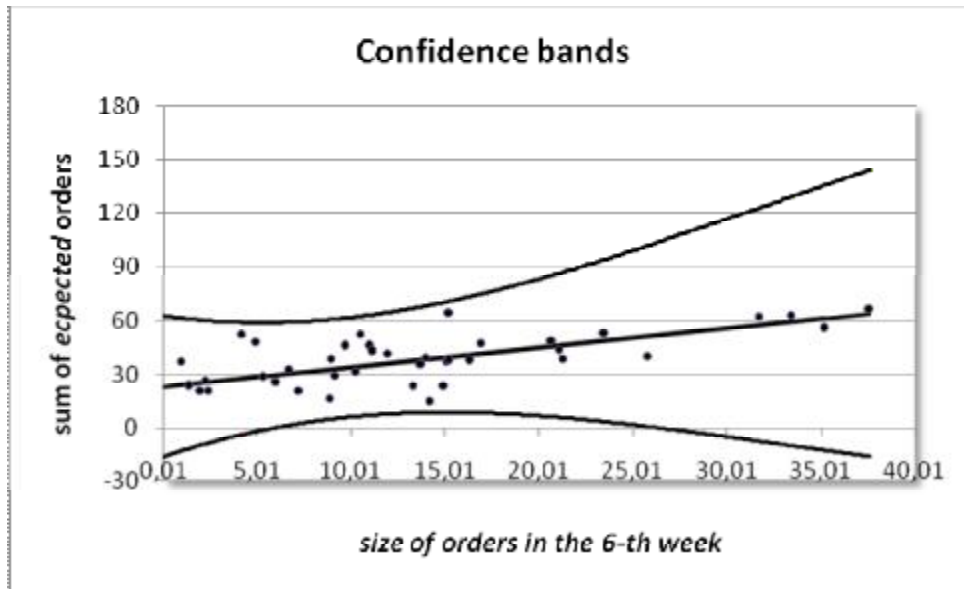
n is a number of values, t is a critical value of Student t – distribution with n-2 degrees of freedom, a is a level of significance,  $s_{y \cdot x}$  is so called rezidual variance.



Formula for calculating of rezidual variance:

$$s_{y \cdot x} = \frac{\sum_{i=1}^n (y_i - \hat{y}_i)^2}{n - 2}$$

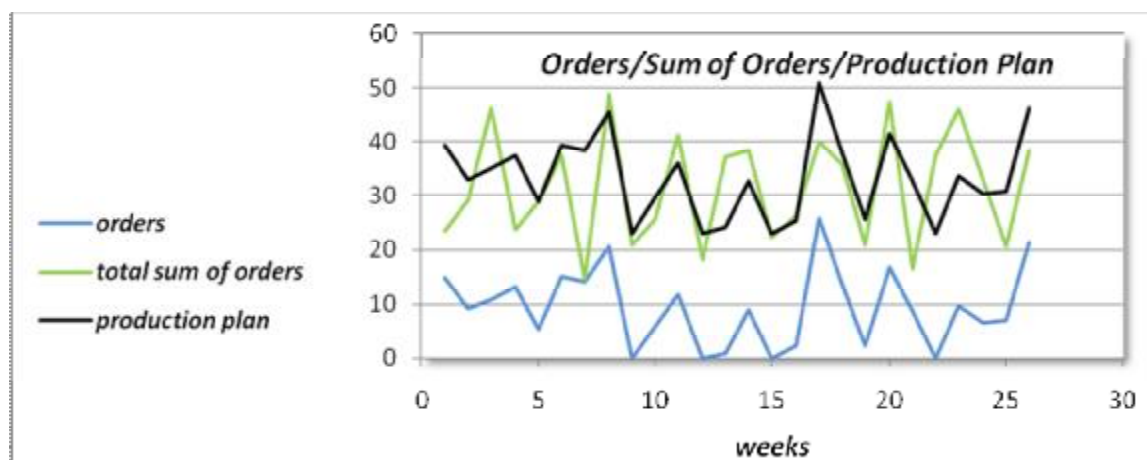
The following Fig. shows the confidence bands from one simulation run for  $n = 52, a = 0,05$ . (Fig. 4)



**Fig. 4: Confidence bands from one simulation run**

Source: Michalcová, 2010

Graphic development of orders  $x_6$ , total sum of orders (sum of plannable demand)  $y$  and production plan (according to linear regression  $\hat{y} = a \cdot x_6 + b$ ) shows the following Fig. (Fig. 5):



**Fig. 5: Graphic development of orders, sum of orders and production plan for 26 weeks**

Source: Michalcová, 2010

## Sales plan in MS Excel

Model of sales plan builds on the above values - i.e. predictable demand and production plan of finished products by a simple linear regression. Indicators such as: production plan, planned final state of stock of finished products in the warehouse, losses of stocks for orders, losses of stocks for direct customers and rejected orders, total sale were imputed by a trivial way – by using balance equations and logical function WHEN. These indicators are listed in rows 2– 17 (Fig. 6).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	
1	SALES PLAN (deliveries from the production to the warehouse, distribution and sale)																
2	Serial number of the week						1	2	3	4	5	6	7				
3	Planned demand (total confirmed orders from customers)						56,0573	36,7983	14,2528	22,1185	13,1225	28,4165	26,1931				
4	Unplanned demand (shop)						0,9533	1,37157	0	0	0	6,2137	7,00643				
5	Production plan (regression)						48,0094	34,6043	23,3115	32,7229	26,8597	41,5055	42,2077				
6	Differences (planned demand - production plan)						8,0478	2,19396	-9,0587	-10,6044	-13,7372	-13,0891	-16,0146				
7	Increases of stocks in the warehouse						48,0094	34,6043	23,3115	32,7229	26,8597	41,5055	42,2077				
8	State A (t) = State (t-1) + Additions (t)						48,0094	84,6043	28,8115	41,7816	46,5218	74,9058	82,4884				
9	Losses A of stocks in the warehouse (for orders)						48,0094	34,6043	14,2528	22,1185	13,1225	28,4165	26,1931				
10	State B (t) = State (t-1) + Additions (t) - Losses A (t)						0	0	9,0587	19,6631	33,4003	46,4894	56,2903				
11	Losses B of stocks in the warehouse (for free sale)						0	0	0	0	0	6,2137	7,00643				
12	State C (t) = State (t-1) + Additions (t) - Losses A (t) - Losses B (t)						0	0	9,0587	19,6631	33,4003	40,2757	49,2839				
13	Planned final state of stocks of finished products in the warehouse						initial stock	0	0	0	9,0587	19,6631	33,4003	40,2757	49,2839		
14	Rejected orders						8,0478	2,19396	0	0	0	0	0				
15	Sales for orders						48,0094	34,6043	14,2528	22,1185	13,1225	28,4165	26,1931				
16	Free sale						0	0	0	0	0	6,2137	7,00643				
17	Total sale						48,0094	34,6043	14,2528	22,1185	13,1225	34,6302	33,1995				

Fig. 6: Indicators of sales plan

Source: Michalová, 2010

## 4. Simulation model and analysis of results

### 4.1 Analysis of results

All of the above values were calculated using only by a single realization of the simulation run. When there are random variables in input characteristics, outputs are random variables too. The result of analysis is either some point or interval estimate. Therefore one simulation run is not sufficient to estimate output characteristics of modeled system. The simulation must be seen as a computer statistical experiment. [10]

With the determination of interval estimates based on data from the simulation model are linked certain problems because these data are usually unsteady (data distribution changes over time). Since consecutive processes interact we must not forget the problem of autocorrelation. Strategy how to deal with this problem depends on the type of simulation. Our type of simulation is called the *simulation with the final horizon*. [10] We assume that we know the initial state of the system and the rule for the end of simulation in this case. Simulation was ended in a predetermined time (52 weeks) in the given model.

## 4.2 Simulation with the final horizon and statistic inference

The problem of autocorrelation is solved by repetition (replication) of simulation run in the case of simulation with the final horizon. Determination of the interval estimate is not based on the original data but on the average values which are established from each individual simulation run. This procedure is known as the replication method. [10] To get a number of independent observations, simulation must be repeated in a sufficient number. There were made 40 replications in our model and the arithmetical mean  $\bar{y}$  was calculated from these values. Let us suppose that we want to estimate the mean value of random Y. We receive an estimate of the mean

$$\bar{y}_i = \frac{1}{n_i} \sum_{j=1}^{n_i} y_{ij}; i = 1, 2, \mathbf{K}, k$$

value of quantity Y from each replication by: , where k is a number of replications,  $y_{ij}$  is the  $j$ -th value of Y in the  $i$ -th replication,  $n_i$  is a number of observed values Y in the  $i$ -th replication. Furthermore we calculate a point estimate

$\hat{m}_y$  of mean by  $\hat{m}_y = \bar{y} = \frac{1}{k} \sum_{i=1}^k \bar{y}_i$ , where k is a number of replications. The danger of autocorrelation already does not exist because it goes on the point estimate on the basis of independent values. We determined a confidence interval by formula:

$$\bar{y} - \frac{s}{\sqrt{k}} t_{\frac{a}{2}}(k-1) < m_y < \bar{y} + \frac{s}{\sqrt{k}} t_{\frac{a}{2}}(k-1) \quad (*)$$

t is a value of t - distribution,  $t_{\frac{a}{2}}$  is a critical value of t - distribution,  $a$  is a level of significance and  $s$  is a sample variance of average. Sample variance was calculated

according to  $s^2 = \frac{1}{k-1} \sum_{i=1}^k (\bar{y}_i^2 - \bar{y}^2)$ . Observations (which are obtained by the replication method) satisfy the condition of independence and can be also used to obtain confidence interval of variance of sample mean.

The following table (Table 1) shows the results of 40 simulations. Critical value of t - distribution is determinate with confidence coefficient  $1-a=0,95$  (level of significance  $a=0,05$ ).

**Table 1: Results of 40 simulations in Excel**

<i>arithmetical mean</i>	<i>standard deviation</i>	<i>critical value of t - distribution</i>	<i>confidence interval for predictable demand</i>
27,14	0,859596	2,0227	(27,0954; 27,1846)

Source: Michalcová, 2010

There were used the following functions in Excel to calculate the values in the table: AVERAGEA for arithmetical mean calculation, STDEV for standard deviation calculation, TINV for calculation of critical value of t – distribution and confidence interval is calculated by formula (\*).

## 5. Conclusion

In cases when demand is stochastic variable influenced by different seasonal fluctuations, demographic changes, market turbulence, fashion etc. we can take advantage of its generation on the basis of chosen probability distribution. Statistic methods (descriptive statistics methods, statistic inference methods) can be used to analyze the results of stochastically many times repeated simulation of the given ordering sub-model of manufacturing and commercial company. There was demonstrated a simple regression model in this article which provided output values (variable demand) based on data (recorded values of orders) from the past 52 weeks. It is actually a transformation of random demand to a company production plan which is important for example for ordering materials etc. Instead of simple regression analysis can be used multiple regression analysis which has a chance of more accurate forecasts of values  $y$  obtained from the set of all values  $x_6, \mathbf{K}, x_1$  in the range of 52 weeks for the previous period. It can be also used a method of simple or multiple time series to detect trends in demand etc.

This article is not focused only statistically but may serve as a basis for the trivial use of existing methods for the analysis of the real situation. Its triviality is also in using of widely available spreadsheet MS Excel. Of course, we can use for the analysis of business processes some of the specialized software (ARENA, SIMUL8, WITNESS), but it may not always be available.

It has been used popular and widespread program MS Excel to create a model. It is obvious that when we make the more simulation runs, we get the more accurate results of simulation. It would be time consuming to implement e.g. 1000 simulations “manually” in a spreadsheet. Stochastic simulation can be supplemented by programming of simulation cycles using Visual Basic programming language that is included with Excel.

### References:

- [1] KVANLI, A. H., GUYES, C. S., PAVUR, R. J. *Introduction to business statistics*. 2. vydání. St. Paul: WEST PUBLISHING COMPANY, 1989. 899 s. ISBN 0-314-47148-0.
- [2] GROS, I. *Kvantitativní metody v manažerském rozhodování*. 1. vydání. Praha: Grada Publishing, a. s., 2003. 432 s. ISBN 80-247-0421-8.
- [3] RADHACRIHNA, C. R. *Lineární metody statistické indukce a jejich aplikace*. 1. vydání. Praha: Academia Publishers, 1978. 668 s. ISBN 104-21-852.
- [4] PERNICA, P. *Logistický management*. 1. vydání. Praha: RADIX, spol. s r.o., 1998. 664 s. ISBN 80-86031-13-6.
- [5] ŠŤASTNÝ, Z. *Matematické a statistické výpočty v Microsoft® Excelu*. 1. vydání. Brno: Computer Press®, 1999. 254 s. ISBN 80-7226-141-X.
- [6] WISNIEWSKI, M. *Metody manažerského rozhodování*. 1. Vydání. Praha: Grada, 1996. 507 s. ISBN 80-7169-089-9.

- [7] ORVIS, W. J. *Microsoft Excel pro vědce a inženýry*. 1. vydání. Praha: Computer Press, 1996. 498 s. ISBN 80-85896-49-4.
- [8] BASL, J., TUMA, M., GLASL, V. *Modelování a optimalizace podnikových procesů*. 1. vydání. Západočeská univerzita v Plzni, 2002. 140 s. ISBN 80-7082-936-2.
- [9] KŘUPKA, J., KAŠPAROVÁ, M. *Modelování v kostce pro Matlab a Simulink*. 1. vydání. Univerzita Pardubice, 2009. ISBN 978-80-7395-162-7.
- [10] BASL, J., BLAŽÍČEK, R. *Podnikové informační systémy*. 2. vydání. Praha: Grada Publishing, a.s., 2008. 283 s. ISBN 978-80-247-2279-5.
- [11] HRADECKÝ, P., MADRYOVÁ, A., TURČAN, M. *Pravděpodobnost*. 2. vydání. Ostrava: VŠB – Technická univerzita Ostrava, 2004. 177 s. ISBN 80-248-0679-7.
- [12] DOLEŽALOVÁ, J., PACELKA, L. *Pravděpodobnost a statistika*. 1. vydání. Ostrava: VŠB - Technická univerzita Ostrava, 2005. 176 s. ISBN 80-248-0948-6.
- [13] HENDL, J. *Přehled statistických metod zpracování dat*. 2. vydání. Praha: Portál, 2006. 583 s. ISBN 80-7367-123-9.
- [14] DLOUHÝ, M., FÁBRY, J. et.al. *Simulace podnikových procesů*. 1. vydání. Brno: Computer Press, a. s., 2007. 201 s. ISBN 978-80-251-1649-4.
- [15] HUŠEK, R., LAUBERT, J. *Simulační metody*. 1. vydání. Praha: SNTL ALFA, 1987. 352 s. DT 310.116.1/075.8.
- [16] HARRINGTON, H., TUMAY, K. *Simulation Modeling Methods to reduce risks and increase performance*. 1<sup>st</sup> edition. New York: McGraw Hill, 2000. 379 s. ISBN 0-07-027136-4.
- [17] WOCANNOT, T. H., WOCANNOT, R. J. *Statistika pro obchod a hospodářství*. 1. vydání. Praha: VICTORIA PUBLISHING a.s. 891 s. ISBN 80-85605-09-0.
- [18] UNČOVSKÝ, L., ČEMICKÁ, K.: *Stochastické procesy a modely*. 1. vydání. Rektorát Vysoké školy economickej v Bratislave, 1992. 220 s. ISBN 80-225-0340-1.
- [19] ZEIGLER, B., PRAEHOFER, H., KIM, T. G. *Theory of Modeling and Simulation, Integrating Discrete Event and Continuous Complex Dynamic Systems*. 2<sup>nd</sup> edition. London: Academic Press, 2000. 510 s. ISBN 0-12-778455-1.
- [20] TOŠENOVSKÝ, J., DUDEK M. *Základy statistického zpracování dat*. 1. vydání. Ostrava: VŠB – Technická univerzita Ostrava, 2006. 82 s. ISBN 80-248-0006-3.

**Contact address:**

RNDr. Šárka Michalcová  
VŠB – Technical University of Ostrava  
Faculty of Economics  
Sokolská třída 33  
701 21 Ostrava 1  
Email: [sarka.michalcova@vsb.cz](mailto:sarka.michalcova@vsb.cz)  
Phone: 59 732 2165