Monte Carlo Cost Simulation in the Supply Chain in E-business

Monte Carlo simulacija troškova u opskrbnom lancu kod e-poslovanja

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Summary

This paper is focused on the possibility of using the costs simulation in supply chain, which are on relative high level. In the first part we focus on the theoretical basis of supply chains in E-business and the possibilities of using Monte Carlo simulation. In the second part we focus on the costs simulation in the supply chain in the company of machine industry. In the past, this company used traditional forms of communication and management within the supply chain. With the development of the company and modern technologies it plans to use various forms of E-business. Before it, we have to analyze the costs that will be spent on supply chain management, if we use E-business solutions. Our goal is to determine the costs using Monte Carlo simulation, which must necessarily be spent on business activities in the supply chain management using E-business.

KEY WORDS
supply chain
cost
Monte Carlo simulation

Sažetak

Ovaj članak koncentriran je na mogućnost korištenja simulacije troškova u opskrbnom lancu, koji su na relativno visokoj razini. U prvom dijelu koncentriramo se na teoretsku bazu opskrbnog lance kod E-poslovanja i mogućnost korištenja Monte Carlo simulacije. U drugom dijelu, koncentriramo se na troškove simulacije u opskrbnom lancu kompanije u proizvodnji strojeva. U prošlosti je ova kompanija koristila tradicionalne oblike komunikacije i menadžmenta u opskrbnom lancu. S razvojem kompanije i modernim tehnologijama planiramo koristiti različite oblike E-poslovanja. Prije toga moramo analizirati troškove koji će se utrošiti da bi se opskrbio lanac menadžmenta, ako koristimo E-poslovna rješenja. Naš cilj je odrediti troškove koristeći Monte Carlo simulaciju, koja se mora utrošiti na poslovne aktivnosti u opskrbnom lancu koristeći E-poslovanje.

KLJUČNE RIJEČI
opskrbni lanac
trošak
Monte Carlo simulacija

INTRODUCTION / *Uvod*

Supply chain management refers to the management of materials, information, and funds across the entire supply chain, from suppliers through manufacturing and distribution, to the final consumer. It also includes after-sales service and reverses flows such as handling customer returns and recycling of packaging and discarded products. In supplay chains the most important element is the transportation system. Shipping by trucks, ships, trains and airplanes should be influenced with e-business more and more. Especially it has significant impact in shipping of different container contingents with the same transportation mean.

In contrasts to multiechelon inventory management, which coordinates inventories at multiple locations of a single firm, or traditional logistics management. Supply chain management involves coordination of information, materials, and financial flows among multiple firms.

Supply chain management has generated substantial interest in recent years for a number of reasons. Managers in many industries now realize that actions taken by one member of the chain can influence the profitability and the cost level of all other in the chain. (Pyke, Johnson, 2011)

Manufacturer-oriented supply chain systems are concerned with the effective management of the flow and storage of goods in the process from the procurement of raw materials from the suppliers to the delivery of finished goods to the customers. Here the flow refers to transporting materials and the storage refers to holding inventory. (Dong-Ping Song et al, 2013) One of the key challenges in supply chain management is how to appropriately tackle and respond to a variety of uncertain factors such as supply uncertainty and disruption. (Lu, Huang, & Shen, 2011; Snyder et al., 2012)

Research in supply chain management has identified twelve distinct management areas that are associated with the subject.

The twelve categories we define are

- location,
- transportation and logistics,
- outsourcing and logistics alliances,
- sourcing and supplier management,
- marketing and channel restructuring,
- inventory and forecasting,
- service and after sales support,
- reverse logistics and green issues,
- product design and new product introduction,
- information and electronic mediated environments,
- metrics and incentives,
- global issues. (Pyke, Johnson,2001;Ganeshan, Jack, Magazine, Stephens, 1999; Johnson, Pyke, 2000)

Then we focused mainly on costs related with these activities: transport, reverse logistics, inventory, marketing, information sources, outsourcing.

E-business is a modern tool to minimize costs in supply chain. These costs represent the cost cathegory which are the highest part of company´s budget. Following the framework of Lee and Whang (2002), we divide the various forms of e-Business applications into three categories – e- Commerce, e-Procurement, and e-Collaboration. e-Commerce helps a network of supply chain partners to identify and respond quickly to changing customer demand captured over the Internet. e-Procurement allows companies to use the Internet for procuring direct or indirect materials, as well as handling value-added services like transportation, warehousing, customs clearing, payment, quality validation, and documentation. e-Collaboration facilitates coordination of various decisions and activities beyond transactions among the supply chain partners, both suppliers and customers, over the Internet. (Johnson, Wang, 2002)

E-Commerce has had a profound impact on the supply chains of many products. Manufacturers of physical products have also turned to the Internet as a direct channel of distribution. The direct channel poses a different set of decisions and challenges from those in the existing “bricks-and-mortar” retail channel. These two channels differ in customer types, operations of order fulfillment, cost structure, profit contributions, priority in rationing, logistical requirement, expectations of service quality, degree of market segmentation, access to demand/ supply information, and returns policies. (Johnson, Wang, 2002)

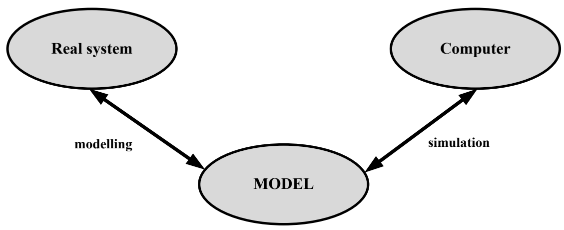
Modern manufacturing requires flexibility due to stiff competition, fast changing customer preferences, shortening product life cycle and product variety proliferation. Along with dynamic capacity allocation, efficient material procurement forms a pillar to support flexible manufacturing. The Internet again offers a natural platform to facilitate efficient procurement as numerous buyers and sellers find each other and transact according to some pre-specified protocols (governed by the marketplace or traders’ internal rules). While e-Procurement is the mirror image of e-Commerce, they have many different aspects. For example, e-Commerce often faces a large number of individual consumers, while e-Procurement usually involves dealings with companies.

While e-Commerce and e-Procurement have captured most of the business press headlines over the past five years, the promise of e-Collaboration may be far greater. We define e-Collaboration as business-to-business interactions facilitated by the Internet. These interactions go beyond simple buy/sell transactions and may be better described as relationships. These include such activities as information sharing and integration, decision sharing, process sharing, and resource sharing. Lee and Whang (2002) provide this taxonomy of e-Collaboration and link the idea to earlier research in supply chain management. (Johnson, Wang, 2002)

We are focusing on the possibility of simulation of supply chain costs in E-business in this paper. There is a sign that potentially applicable instruments to solve such problems are simulation methods. Term „simulation“, if appropriate expression „modelling and simulation“ is based on rather a simple idea – it arises from a direct imitation of analysed real or projected system. This term covers a complex of activities connected with model construction of real (e.g. economic) systems and their „simulation“ on a computer. From the above results that the main elements of simulation access are following:

- real system,
- model,
- computer.

There are certain relationships between the three basic elements. The one so – called modelling, which is a relationship between real system and its model; the second one – simulation, which is a relationship between computer and model. Schematically:



Source: KLIEŠTIK, T., Investment management - Tangible Investments“, EDIS: Publishers, Žilina 2008, 132 pp., ISBN 978-80-8070-949-5.

Figure 1 Diagram of simulation model

Slika 1. Dijagram simulacijskog modela

Real system presents that part of the real world (e.g. transportation enterprise, national economy, etc.) which is the object of our concern. Real system in this diagram is a data resource about behaviour – behaviourism data.

Model is a certain formal construction (mathematical, logical and so on) which in a certain way represents the real system, that is, it provides data of the same character as the data generated by real system. However the model itself does not generate data in a proper sense of the word, we talk about data „generated by model“, eventually about „ model behaviour“, since the model is based for instructions, if appropriate for programme, in pursuance of which computer generates data. A particular form of rules, on the basis of which model acts (i.e. generates data), is called model structure.

As seen in picture 1, i. e. – there arise very important conclusions for assessment of simulation model from two relationships between the three elements. Relationship between real system and model concerns model validity, i.e. how truly or exactly given model represents real system. Model validity is measured by degree of concordance between data generated by real system and data generated by model. (Klieštik, 2013)

FEATURES OF MONTE CARLO SIMULATION / *Značajke simulacije Monte Carlo*

The fundamental characteristic of simulations is the information usage from the complete distribution of the input variables. The indicators of project effectiveness are calculated according to this distribution. In this case, the values of input variables are derived from the defined distribution.

Monte Carlo simulations are used for a simulation (imitation) of real systems and in comparison to standard scenario analysis take account of the randomness and uncertainty of variables entering these systems. (Boďa, Kanderová, 2012) Monte Carlo method is used to quantify the likely and deterministic tasks based on multiple repeated random experiments. We construct probabilistic task with identical solution to the original task. The final solution has a probabilistic character.

Monte Carlo simulation was employed for forward propagation of the aleatory type input uncertainties

- Gela,
- R. Garga,
- C. Tongd,
- M. Shahnama,
- C. Guenther (Gel, et al., 2013)

The Monte Carlo method can be used to address any mathematical problem or model that is too complex, time consuming, or resource intensive to solve analytically. Instead of tackling the numerical problem directly, Monte Carlo allows the researcher to obtain an approximation of the solution through setting up an experiment of statistical sampling. As the name indicates, the method borrows from games of chance such as those played at the famous casinos of Monte Carlo in Monaco. The Monte Carlo method relies on realizations (draws) from a probability density function. Ideally, to correctly apply the Monte Carlo method and obtain valid results, the sampling method employed should be completely random. The number of realizations has to be sufficiently large to accurately represent the distribution of the input variables. (Ratick, Schwarz, 2009)

The computer simulation Monte Carlo is a mathematical-statistical method of risk measurement of individual variants. It is used when there are multiple risk factors that affect the performance of investment projects.

To facilitate the MCMC analysis, a statistical model was generated in order to implement a Bayesian approach. Bayesian modeling draws from two types of knowledge to derive model parameter estimates: prior knowledge, as described in initial parameter distributions, and information that can be deduced from measured data, if appropriately analysed. (Bernillon, 2000, Gel, 2013)

Markov chain Monte Carlo (MCMC) methods have been an important algorithm in various scientific fields (Liu, 2011, Robert,Casella, 2004). MCMC methods can generate samples that follow a target distribution by using a simple proposal distribution. However, in sampling from a complex distribution such as a multimodal one, the standard MCMC methods produce samples that theoretically converge to the target distribution but practically do not. The produced samples can be trapped in a local mode for an extremely long period. (Araki, Ikeda, 2013)

METHODS / *Metode*

The essence of Monte Carlo simulation is to generate a large number of scenarios and criteria values conversions for each scenario. Simulation outputs can be displayed in numeric or graphical form.

We apply Monte Carlo simulation to supply chain costs of a company in this paper.

One of the Monte Carlo simulation´ s parts is the sensitivity analysis, which allows calculate the sensitivity of the selected project financial criteria to possible changes in the values of risk factors that affect this criterion. With this analysis we can determine how are the costs of supply chain, as an evaluation criterion, influenced by the sensitivity of quantity, selling price or cost. Risk factors, where changes in the selected criteria are small are less important, and vice versa. The advantages of sensitivity analysis are simplicity and graphical clearness. On the other hand, the main disadvantage is ignoring the different rates of uncertainty of the individual factors.

Monte Carlo can by divided into several steps, according to Souček. First four steps represent the simulation preparation and the last one simulation performance:

1. Investment project model design and processing in a computer program
2. Identification of key risk factors
3. Determination of likelihood distribution of factors
4. Determination of statistical dependence of risk factors
5. Simulation performance and interpretation of simulation results (Souček, Fotr, 2005)

By creating the project model it is important to consider the level of detail of the model, which is intended to represent a compromise between simplicity and credence of the project. It is important to recognize the complexity of relationships between costs of supply chain, as an evaluating criterion, and various risk factors. Souček highlights to keep the principle that all input variables of the model (risk factors) should form a separate, distinct part of the model. (Souček, Fotr, 2005)

Risk factors represent the input variables of the financial model, which significantly affect the simulation output uncertainty in the form of evaluation criteria. Key risks are those that are sensitive to even the smallest changes in inputs of a simulation and are uncertain. To determine this sensitivity we use the already mentioned sensitivity analysis. It is recommended to start with a larger number of factors and according to simulation results try to minimize them.

Because we used the Normal distribution we determine the parameters of this distribution, which are subsequently converted. In this case, we chose the following:

- Modus
- Median
- The standard deviation
- The arithmetic mean
- Lower and upper quartile

The arithmetic mean is calculated as follows:

$$\bar{X} = \sum_{i=1}^{k} x_i . f_i \quad (2)$$

Where:
xi – interval mean value
fi – relative occurrence frequency

The mode is the value of symbol X, which occurs in particular empirical set most frequently. In the frequency distribution lines it is that value xi, which comes with the highest absolute or relative frequency. This value does not have to be represented by the distribution exactly, because multiple values can occur with the same highest frequency. (Cisko, Klieštik, 2009)

$$\hat{x} = a + h.\frac{d_0}{d_0+d_1} \quad (3)$$

Where:
a – lower limit of modal interval
h – interval range
d_0 – the difference between modal and previous interval frequency
d_1 – the difference between modal and next interval frequency

Medianis the fair value $\tilde{x}$, which divides an identified set of values x_1, x_2, ..., x_n arrangedin ascending order of size into twoequal-sizedparts. Medianbasic advantageis that it is not affected by the extreme values. (Cisko, Klieštik, 2013)

$$\tilde{x} = a + h\,.\frac{0.5-F_{\tilde{x}-1}}{f_{\tilde{x}}} \quad (4)$$

Where:
a – lower limit of median interval
h – interval range
$F_{\tilde{x}-1}$ – relative cumulative frequency of previous interval
$f_{\tilde{x}}$ – absolute frequency of median interval

The standard deviation is the square root of the variance and expresses the dispersion of the values around the mean. It represent show these values differ from the mean value. Because the dispersion is calculated in the squareunits of measure, it cannot be logically interpreted. That is why we try to get a degree of variability, which is expressed in the original units of measurement. (Cisko, Klieštik, 2009)

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2 . p_i} \quad (5)$$

Where:
n – total number of units,
xi – individual selection units,
pi – occurrence likelihood of i - event
$\tilde{x}$ – arithmetic mean

Lower quartile divides the unit set so that the value of variable x of quarters of units is lower or equal to the first quartile and the value of the variable x of three-quarters of units is higher or equal to the first quartile.

$$\tilde{x} = a + h\,.\frac{0.25-F_{\tilde{x}-1}}{f_{\tilde{x}}} \quad (6)$$

$$\tilde{x} = a + h\,.\frac{0.75-F_{\tilde{x}-1}}{f_{\tilde{x}}} \quad (7)$$

Where:
a – lower limit of median interval
h – interval range
$F_{\tilde{x}-1}$ – relative cumulative frequency of previous interval
$f_{\tilde{x}}$ – absolute frequency of median interval

RESULT AND DISCUSSION / *Rezultat i rasprava*

The first step in supply chain costssimulation is to define the basic kind of supply chain const. Monte Carlo simulation is applied to an enterprise which operates in the field of mechanical engineering and industrial engineering. In this case, costs of supply chain will be consisting of:

Transport costs
€ 18 500 with probability 0.31
€ 25 500 million with probability 0.50
€ 20 125 million with probability 0.19

Inventory costs
€ 36705 with likelihood 0.2
€ 27 850 with likelihood 0.55
€ 28 600 with likelihood 0.25

Reverse logistics costs
€ 10 000 with likelihood 0.4
€ 12 000 with likelihood 0.35
€ 15 000 with likelihood 0.25

Information costs
€ 1585 with likelihood 0.30
€ 3590 with likelihood 0.40
€ 4578with likelihood 0.30

Outsourcing costs
€ 30 080 with likelihood 0.28
€ 23 980 with likelihood 0.42
€ 40500 with likelihood 0.30

Marketing costs
€ 28 050with likelihood 0.28
€ 50 990 with likelihood 0.42
€ 40 050 with likelihood 0.30

We used MS Excel to simulate individual fundaments that influence the result. Each characteristics is simulated on 1 000 repetitions.

Table 1 Transport costs simulation examination

Tablica 1. Ispitivanje simulacije transportnih troškova

	A	B	C	D	E
1	Transport costs	Likelihood	Cumulative likelihood	Random number	Simulated transport costs
2	18500	0.31	0.31	=RAND()	
3	25500	0.5	0.81	=RAND()	
4	20125	0.19	1.00	=RAND()	

Source: Self processed

Simulated transport costs are calculated via the function:
=IF($D2<=$C$2;$A$2;IF($D2<=$C$3;$A$3;$A$4)) (1)

Information, outsourcing, marketing, inventory and reverse logistics costsare simulated in a similar way.

The operating result is simulated as the last one. Total simulated supply chain costs are expressed as a sum of individual simulated costs.

Table 2a Simulated input values – costs, quantity, price

Tablica 2a. Vrijednosti simuliranog inputa troškovi, količina, cijena

Simulated transport costs	Simulated information costs	Simulated outsourcing costs	Simulated marketing costs
20125	3590	40500	28050
25500	4578	40500	50990
2 5500	3590	23980	40050

Source: Self processed

Table 2b Simulated input values – costs, quantity, price

Tablica 2b. Vrijednosti simuliranog inputa troškovi, količina, cijena

Simulated inventory costs	Simulated reverse logistics costs	Simulated total costs of supply chain
36705	12000	155055
27850	12000	150478
28600	12000	147390

Source: Self processed

Then we determined the most appropriate statistical distribution - Normal Gaussian distribution, which allows us to statistically process the results for the simulated supply chain costs. Values of simulated supply chain costs are divided into intervals from - ∞ to ∞, the interval range is 10 000.

Table 3 Normal distribution of simulated supply chain costs

Tablica 3. Normalna distribucija troškova u simuliranom opskrbnom lancu

	A	B	C
1	Lower interval limit	Upper interval limit	Occurrence frequency
2	0	100 000	0
3	100 000	110 000	1
4	110 000	120 000	85
5	120 000	130 000	134
6	130 000	140 000	244
7	140 000	150 000	278
8	150 000	160 000	178
9	160 000	170 000	74
10	170 000	180 000	6
11	180 000	190 000	0
12	190 000	∞	0

Source: Self processed

The following tables show the calculation of statistical characteristics of Monte Carlo simulation. In addition to absolute frequency detected by a computer simulation, we calculate the relative, absolute cumulative and relative cumulative frequency. The indicator mean was calculated as the conjunction of relative frequency and mean value. The resulting average supply chain costs are quantified as the sum of all partial averages. In our case, the average supply chain costs are € 140 730.

The probability that the company will generate the loss in particular period is 0.1.

Table 4a Simulation result – arithmetic mean

Tablica 4a. Rezultat simulacije aritmetička sredina

	C	D	E
Class	Absolute frequency	Relative frequency	Cumulative absolute frequency
1	0	0	0
2	1	0,001	1
3	85	0,085	86
4	134	0,134	220
5	244	0,244	464
6	278	0,278	742
7	178	0,178	920
8	74	0,074	994
9	6	0,006	1000
10	0	0	1000
11	0	0	1000
Total	1000	1,0000	x

Source: Self processed

Table 4b Simulation result – arithmetic mean

Tablica 4b. Rezultat simulacije aritmetička sredina

F	G	H
Cumulative relative frequency	Mean value	Arithmetic mean
0	95000	0
0,001	105000	105
0,086	115000	9775
0,22	125000	16750
0,464	135000	32940
0,742	145000	40310
0,92	155000	27590
0,994	165000	12210
1	175000	1050
1	185000	0
1	195000	0
x		140730

Source: Self processed

Modal interval was defined in Class 6, in interval from 140 000 to 150 000. It was calculated via the formula 3.

$$\hat{x} = 140\ 000 + 10000.\frac{(0.278 - 0.244)}{(0.278 - 0.244) + (0{,}278 - 0{,}178)}$$

The calculation shows that the most frequent value of the simulated supply chain costs are **€ 142 537.**

Building on the characteristics of the median as the middle value of the character of a statistical set, median interval is in Class 6.

$$\tilde{x} = 140000 + 10000\,.\frac{0.5 - 0.464}{0{,}278}$$

The mean value of simulated supply chain costs was determined on the level of **€ 141 294**.

Lower quartile distributes the statistical set in the ratio of 0.25 to 0.75. Based on this definition, the lower quartile interval is represented by the Class 5.

$$\tilde{x} = 130000 + 10000\,.\frac{0.25 - 0.467}{0.278}$$

With the like ihood of 0.25, the simulated supply chain costs will be lower than **€ 122 302** and with 0.75 the simulated supply chain costs will be higher than **€ 122 302** €.

A similar procedureis applied to determine the upper quartile; its interval will be the Class 7.

$$\tilde{x} = 150000 + 10000\,.\frac{0.75 - 0.742}{0.278}$$

With the likelihoodof 0.75, the simulated supply chain costs will by lower than **€ 143 884** and with 0.25 the simulated supply chain costs will be higher than **€ 143 884.**

Table 5 Simulation result – standard deviation

Tablica 5. Rezultat simulacije - standardna devijacija

	I	J
Class	Dispersion	Standard deviation
1	0	0
2	10805602,5	3287,188
3	1103691213	33221,85
4	2058722735	45373,15
5	4377995010	66166,42
6	5760605495	75898,65
7	4218707245	64951,58
8	1989090585	44599,22
9	181551615	13474,11
10	0	0
11	0	0
Total	19701169500	140360,9

Source: Self processed

To determine the extent of variability of simulated supply chain costs we used standard deviation and we built on the formula No. 5. The actual supply chain costs value may differ from the average value of ± € 140 360,9.

CONCLUSION / *Zaključak*

Modern technologies now largely simplify the operation of several business areas. In this paper we assessed the costs of functioning of the supply chain in E-business. We focused on an enterprise of machine industry, which is currently using traditional form of supply chain and in the future would like to implement E-business into its management. Currently, the supply chain costs represent an average of € 327 000. In case if the enterprise implement E- business the average costs of supply chain would fall to a level of € 142 537. In addition, by the use of Monte Carlo simulations we also identified risk rate increase / decrease in supply chain costs, which the company wouldtake in case if E-business implemented into supply chain. Costs of supply chain with implemented E-business could differ from the average of ± € 140 360. In conclusion, our study is the recommendation for the implementation of E-business in supply chain in the selected company.

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