SIMULATION IN INVENTORY MANAGEMENT

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Abstract: In this paper inventory management is analyzed as an organic part of the supply chain managing process. In today's competitive economic environment traditional inventory policies should be improved. Simulation models enable a priori managing and analyzing variety of possible results and implication of selected inventory policies. The model presented in this paper uses the Monte Carlo simulation method and variables taken as random, in order to depict a harmonization and integration of dynamic quantitative analysis and theoretical, qualitative concepts of inventory management.

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Supply chain management

Business practice today is much different than it was 10 or 15 years ago. Globalization, permanent changes at the stock market, mergers and acquisition of companies, e-business, outsourcing are just a few phenomena that characterize contemporary economy. In this situation it is not easy to provide a desired product at the right time, place and quantity while maintaining an acceptable level of cost. Continuous changes force company to readjust business policies and keep or obtain competitive advantage through some new management concepts. Supply chain management is relatively new business philosophy, based on the ideas of logistics management, which tend to optimize physical, financial and data flows between all parts of the supply chain system, from primary producer to final consumer. The main goal of supply chain management is maximization of total value based on synergetic effects.

Different types of mathematical models and modeling techniques can be used for managing and analyzing supply chain. First, there are descriptive models that modeling practitioners develop to better understand functional relationships in the company and the outside world. Descriptive models include:

- forecasting models that predict demand for the company's finished products, the cost of raw materials, or other factors, based on historical data;
- cost relationships that describe how direct and indirect costs vary as functions of cost drivers;
- resource utilization relationships that describe how manufacturing activities consume scarce resources;
- simulation models that describe how all or parts of the company's supply chain will operate over time as a function of parameters and policies.

Other huge group of models is called normative models, that modeling practitioners develop to help managers make better decisions. Those models are also known as mathematical programming models or optimization models. In this paper a simulation model in inventory management is presented on the concrete example.

Inventory Management

Inventory management is a very important part of supply chain, because it provides a flexibility and certainty to production and sales activities. Beside advantages in holding inventory, other side of a coin is that it can become very costly segment of a supply chain. Inventory management problems are characterized by holding costs, shortage costs, replenishment delays and probabilistic demand distributions for products. Inventory costs are just one group of total supply chain costs and they encompass ordering costs, holding costs and shortage costs (that occur if demand exists, but the product is out of stock).

Models for optimizing inventory management decisions that take these factors into account have been proposed and applied for over 60 years. Recently, attention has focused on creating business processes that reduce or eliminate inventories, mainly by reducing or eliminating the uncertainties that make them necessary. Models for optimizing inventory policies for individual items use methods from statistics and applied probability theory. As such, they are very different in form from deterministic optimization models, which broadly consider products, facilities, and transportation flows in analyzing resource acquisition and allocation decisions. Inventory models involve parameters and relationships such as variances of market demands and delivery times and their impact on stock outages, which are not easily represented in optimization models. For this reason, incorporating inventory decisions in supply chain optimization models is difficult. Nevertheless, depending on the scope of the analysis, acceptable approximations of inventory costs can be developed.

The deterministic inventory models are limited because they treat all parameters relating to future operations as certain. The major sources of uncertainty include demand over the delivery lead time and the length of the lead time. Demand uncertainties are a reality that most companies must accommodate in managing their supply chains, thus probability inventory models are more suitable. The extended models employ concepts and constructs from probability theory. A random variable X can assume more than one value with an associated probability. We write $P(X = x)$ to denote the probability that X assumes the specific numerical value x. Such probabilities lie between 0 and 1. A probability density function describes the values of X where it takes on positive probabilities and the values of these probabilities. In the simple case when the probability density function for the random variable X takes on a finite number of values, say $X=x_1$ with probability p_1, $X=x_2$ with probability p_2 and so on until $X=x_n$ with probability p_n, its expected value, denoted by $E(X)$ is given as

$$E(X) = p_1 x_1 + p_2 x_2 + ... + p_n x_n \quad (1)$$

$$p_1 + p_2 + ... + p_n = 1.$$

Monte Carlo Simulation

When we use the word simulation, we refer to any analytical method meant to imitate a real-life system, especially when other analyses are too mathematically complex or too difficult to reproduce. A Monte Carlo method is a technique that involves using random numbers and probability to solve problems.

The Monte Carlo method is just one of many methods for analyzing uncertainty propagation, where the goal is to determine how random variation, lack of knowledge, or error affects the sensitivity, performance, or reliability of the system that is being modeled. Monte Carlo simulation is categorized as a sampling method because the inputs are randomly generated from probability distributions to simulate the process of sampling from an actual population. So, we try to choose a distribution for the inputs that most closely matches data we already have, or best represents our current state of knowledge. The data generated from the simulation can be represented as probability distributions (or histograms) or converted to error bars, reliability predictions, tolerance zones, and confidence intervals.

Monte Carlo simulation is a versatile method for analyzing the behavior of some activity, plan or process that involves uncertainty. If you face uncertain you can benefit from using Monte Carlo simulation to understand the impact of uncertainty, and develop plans to mitigate or otherwise cope with risk.

Simulation in managing meat inventory

In order to present the practical usage of simulation models, we present a model that describes inventory management in a butcher. Our client is a successful local businessman who would like to open a butcher in a couple of months and he has no experience in this type of business. He is interested in projection of inventory costs that may occur in, since the capital he would like to invest is limited.

By analyzing accurate trends at the local meat market and comparing with the historical data collected by The Statistical Office of The Republic of Serbia, some basic assumptions were defined. Model manages inventory of four kind of meat (lamb, beef, pork and chicken) and beginning variables per type are: demand per day, purchase price, delivery time, sales per day and percentage of low quality meat. Beginning inventory level, ordering costs, holding costs, shortage costs and capital costs are also defined. Initial assumptions of a model that presented in a following table are extracted from stated data.

TABLE 1 – INITIAL ASSUMPTIONS OF THE MODEL

Meat	Optimal order quantity (kg)	Expected daily demand (kg)	Expected delivery time (days)	Expected demand during delivery time (kg)	Safety stock (kg)	Reorder point (kg)
Lamb	350.68	50.75	4.9	248.68	101.5	350.17
Beef	854.41	199.0	3.3	656.7	398.0	1054.7
Pork	1350.93	490.0	2.1	1029.0	980.0	2009.0
Chicken	739.93	161.0	2.9	466.9	322.0	788.9

Optimal order quantity is calculated by the following relation:

$$q^* = \left(\frac{2KD}{h}\right)^{1/2}, \quad (2)$$

where D represents the demand, K - fixed ordering or setup cost that occur whenever a replenishment order of any size is placed and h cost per unit-year of holding inventory.

Expected values are calculated as a sum product of the value of variable and belonging probability, as shown in relation (1). Level of safety stock is determined as a product of the expected daily demand and the highest deviation in delivery time. Reorder point presents a sum of expected daily demand during delivery time and safety stock.

Simulation model uses random number generator and probability distributions to determine input variables for a single iteration. Results of Monte Carlo simulation are used to define a daily beginning and ending inventory level. By analyzing changes in daily inventory levels together with trends of other variables, we can get some information about different types of costs. Model contains information about ordering costs per meat type, holding costs (20-30% of ordering costs) and shortage costs. When the sum of stated costs surpasses the amount of disposable capital, investor should provide additional financial resources and new capital costs may occur. Further cost analysis is based on aggregate costs function, determined as a sum of inventory and capital costs. Standard deviation, absolute error and required number of iterations on a 95% confidence interval, are calculated from information about projected costs obtained by simulation model.

$$\sigma = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2} \quad (3)$$

$$N = \left(\frac{3\sigma}{\varepsilon}\right)^2 \quad (4)$$

Further analysis obtains approximation of this empirical distribution to a normal distribution. By comparing the indicators and the curve shape with the characteristics of normal distribution we can conclude that the data are not normally distributed and that left asymmetry exists.

TABLE 2. CHARACTERISTICS INDICATORS OF A MODEL

Indicators	Values
Standard deviation (σ)	127942.8
Absolute error 5% (ε)	11628.24
Number of iteration (N)	1200
Average costs	232067.9
Median	216868.1
Skewness α_3	0.4569
Kurtosis α_4	2.4302
Jarque-Bera statistic	57.9926

It means that in the most cases the level of total costs is below the average and the most frequent amount of cost is about 100000 Dinars. From the economical point of view we can conclude that acquisition of all types of meat at the same time, which can lead to a high cost level and capital shortages, is pretty rare. But if it happens, one of the ways to solve the situation is to open a credit line at a bank that has the most suitable interest rates. It provides a significant level of flexibility to the investor, so he can easily readjust the business activity considering demand oscillations and market changes.

In a certain number of cases disproportion between the amount of meat in stock and demand level can be found, due to differences in customer's needs, inventory level in a butcher and activities of suppliers. In that situation shortage costs may appear. Total probability that demand will be unsatisfied is 2.52%, separately by meat type: lamb 4.58%, beef 0.25%, pork 2.42% and chicken 2.83%. Those percentages are relatively low, except in a case of lamb meat. Probably the investor should consider other suppliers or different acquisition policies together with improvements in logistics and transportation of lamb meat.

Conclusion

The presented model shows how simulation model can be used to help managers and investors in complex situations. This model can be extended by testing various scenarios and finding the most suitable one together with capturing all other parts of what-if analysis. Modeling provides valuable support for decision making process in nowadays turbulent business world, so harmonization and integration of dynamic quantitative analysis and theoretical, qualitative management concepts is absolutely necessary and unavoidable.

References

Chopra, S., Meindl, P., 2004. Supply Chain Management: Strategy, Planning and Operation, Pearson Education International, New Jersey.

Kiš, T., Čileg, M., Vugdelija D., Sedlak O., 2005. Kvantitativni metodi u ekonomiji, Ekonomski fakultet, Subotica.

Letić D., Jevtić V., 2001. Operaciona istraživanja, Tehnički fakultet Mihajlo Pupin, Zrenjanin.

Shapiro F., 2001. Modeling the Supply Chain, Duxbury Thomson Learning, Pacific Grove, CA.

Stojković, M., 2001. Statistika, Ekonomski fakultet, Subotica.

Vunjak M., 2005. Finansijski menadžment, Ekonomski fakultet Subotica.