The Use of Penalty Functions in Logistics

Upotreba penalty funkcija u logistici

Jozef Gajdoš
University of Economics in Bratislava
Slovakia
e-mail: jozef.gajdos@euke.sk

Luboš Socha
Technical University Košice
Slovakia
e-mail: lubos.socha@tuke.sk

Bohuslava Mihalčová
University of Economics in Bratislava
Slovakia
e-mail: bohuslava.mihalcova@euke.sk

UDK 658:343.53
Pregledni rad / *Review*
Rukopis primljen / *Paper accepted*: 28. 11. 2013.

Summary

This article is aimed at the management of interrelated subsystems, through the penalty functions in logistics systems. We compared the results obtained using simulation models on the examples three types of models (production model, supply model and model sales) with use penalty function for their connection with results achieved when optimizing the system as a whole.

KEY WORDS
penalty functions
model
simulation
costs

Sažetak

Tema ovoga rada je menadžment međusobno povezanih po-sustava kroz penalty funkcije u logističkim sustavima. Autori su usporedili rezultate dobivene upotrebom simulacijskih modela na primjerima tri tipa modela (proizvodni model, model nabave i model prodaje) i upotrebom penalty funkcije kako bi ih povezali s dobivenim rezultatima u optimizaciji sustava u cjelini.

KLJUČNE RIJEČI
Penalty funkcije
model
simulacija
troškovi

INTRODUCTION / *Uvod*

Market and competition create pressure on enterprises to increase utilization of existing resources, reduce costs and optimize overall system management. This pressure increases during economic recession. As shown by the results of a survey of the economic crisis in 2008, which in July 2008 performed by Ernst & Young and the Economist Intelligence Unit, 87% of respondents, the main activity of firms in recession reported revenue optimization and cost reduction. One possibility to improve the situation in terms of costs in the enterprises is an application of exact methods, which should serve as a means of support for managerial decision making.

The paper based on the fundamental philosophy of modern Complexity Theory. Application of Complexity Theory into the economy is the application complexity of scientific problems, as a result of the state of human knowledge, into economic thought. There is no generally valid definition for the complexity of economic systems. The complexity of the economy is built on the foundations that draw inspiration from areas such as behavioural economics, institutional economics and evolutionary economics. Proponents of complexity economics argue that economic systems not having a 'natural' tendency to reach equilibrium.

Current research in the field of economic systems, and the possibilities his prediction and management, points to the fact that economic systems are really complicated, with changing patterns of quantitative and qualitative relations. The complexity of managing a system as a whole raises the need for its decomposition into mutually affecting subsystems. This article is aimed at the management of interrelated subsystems, through the penalty functions in logistics systems.

LOGISTICS AND LOGISTICS COSTS / *Logistika i troškovi logistike*

To the paper we need to specify the logistic area. We come out from the concept of logistics comprehension, where logistics is understood as integrated planning, execution and audit of material flow and appropriate flow of information. These flows are flows from contractor to enterprise, within enterprise and from enterprise to customers. Kortschak's [3] definition is appropriate here: Logistics is a "knowledge about co-ordination of active and passive elements of enterprise, leading to the lowest costs in time, to the flexibility improvement and adaptability of enterprise to the changing general economic conditions and buyer's market". Objects of interest are manufacturing stocks, semi products and finished products. Logistics fulfils several functions. One of them is optimisation of costs.

Logistics costs are associated with the logistics system functioning. These costs are direct by proportional to the rate of consumer satisfaction. Deficit costs are arising as a consequence of insufficient consumer´s satisfaction (penalty, loss of consumer). The level of cost is indirectly proportionate to consumer's satisfaction.

The results of researches focused on the share of logistics costs on total costs of enterprise in the last decade are very different. Logistics costs represent from 10 percent to 15 percent of total costs included in the price of the final product [2]. In the automotive industry logistics costs are supplied parts, the starting materials and their subsequent distribution to the production line about 10 percent of the total cost of the car or truck. Results of findings from particular enterprises are shown in Table 1.

Table 1. The share of logistics costs on total costs of enterprise
Tablica 1. Udio troškova logistike u ukupnim troškovima poduzeća

Types of enterprise (country)	The share of logistics costs on total costs of enterprise (resource)	Author of research (year)
Industrial plant (Germany)	7,00 percent (www.wuerth-phoenix.com/fileadmin/downloads/pdf_Presse/Kernaussagen_zur_Trendstudie_Logistik.pdf)	Straube, F., Pfohl, H.Ch. (2008)
Agricultural enterprise (unspecified country)	42,20 percent (http://ageonsearch.umn.edu/bitstream/24562/1/pp05wa01.pdf)	Wajszcuk, K. (2005)
Department store (Germany)	14,00 percent (Hellfrich, 2002)	Hellfrich, Ch. (2002)
Automotive enterprise (Germany)	8,20 percent (http://logistics.de/logistik/scm.nsf/798DAEFC66DF332DC12574A900397E27/SFile/baumgartner.pdf)	Baumgartner, H. (2002)
Logistics enterprise (Singapore)	17,47 percent (http://epubl.ltu.se/1402-1617/2006/217/LTU-EX-06217.pdf)	Frőlderberg, A. (2005)

*S*ource: own processing

The main factors that influence different understanding of logistics costs can be considered:

1 The differing analytical breakdown logistics costs;

2 Responsibilities logistics managers;

3 Changing priorities in assessing logistics costs.

In this paper we start from the breakdown of logistics costs as related to performance.

METHODOLOGY - MODELS AND USE OF PENALTY FUNCTIONS / *Metodologija – Modeli i upotreba penalty funkcija*

The shape of the model depends on organisational structure and management system of enterprise. Our approach came out of classical hierarchy structure. Our example of models includes activity connected with delivery, production and sales, includes price and material costs. Philosophy of the approach comes from the dominant position of the only subsystem, to which the others are subordinated. All models are based on the alternative production options, taking into account changing market prices. Used as operational research methods based on the use of linear programming problems. A basic characteristic of the system is economic result. Economic result is seen as the difference between profit and cost of production, storage and expedition. In developing individual models are used different types of objective functions: the profit function (production model), the cost function (model inventory and model sales) and the penalty function (conflict situations). Variable is the production plan (production volumes by product type during one time period).

PRODUCTION MODEL / *Proizvodni model*

The aim of enterprise, contribution to profit maximisation is modelled by function

$$\max z(\overline{x}) = \sum_{i=1}^{m}\left(p_i - \sum_{j=1}^{n} a_j p'_j - \sum_{k=1}^{r} b_k w_k\right) \times x_i \quad (1)$$

$$\sum_{i=1}^{m} b_{ik} x_i \leq b_k^H \qquad k = 1,2,\ldots r \qquad (2)$$

$$x_{s} \leq x_i \qquad i = 1,2,\ldots,m \qquad (3)$$

$$x_i \geq 0 \qquad i = 1,2,\ldots,m \qquad (4)$$

wherex_i^H is the top limit of production facilities given by the production technology,

x_i is the quantity of product i amount per one period,

a_{ij} is the standardised consumption of material j per product i,

p_i is the price of product i,

pj´ is the price of material j,

wk is the wage rate profession k,

r he number of types of professions involved in the production,

bik is labour intensity of the product i in the profession k,

bkH is the upper limit of working time profession k.

SUPPLY MODEL / *Model nabave*

The function of total costs C (T_s) is

$$C(T_s) = \frac{c_{sA} + b_{sA} w_s}{T_s} + T_s \sum_{j=1}^{n} \frac{\lambda_j}{2} c_{sj} + w_s \sum_{j=1}^{n} \lambda_j b_{sj} \quad (5)$$

,

$$\frac{b_{sA}}{T_s} + \sum_{j=1}^{n} \lambda_j b_{sj} \leq b_s^H \qquad (6)$$

$$T_s > 0 \qquad (7)$$

where

λ_iC (T_s) are total costs of supply,

Ts is the delivery cycle,

csA are acquisition costs of one supply,

csj are unit costs connected with storage of material j per one period,

is the need of material j per one period,

bsA is standard performance is a warehouseman in equipment deliveries,

bsj is working standard for handling of one unit material j,

ws is the wage rate warehouseman,

bsH is the upper limit of working time profession warehouseman.

Table 2. Test the consistency of the means of economic result

Tablica 2. Test konzistencije prosječnih vrijednosti ekonomskog rezultata

Comparison of Means
t tests to compare means

Null hypothesis: meanl = mean2	Assuming equal variances	Not assuming equal variances
(1) Alt. hypothesis: meanl NE mean2	t= -4,00275 P-value= 0,0000626394	t= -4,00275 P-value= 0,0000626394
(2) Alt. hypothesis: meanl > mean2	t= -4,00275 P-value= O,999969	t= -4,00275 P-value= 0,999969
(3) Alt. hypothesis: meanl < mean2	t= -4,00275 P-value= 0,0000313197	t= -4,00275 P-value= 0,0000313197

Source: own processing

Table 3. Test the consistency of the standard deviations of economic result

Tablica 3. Test konzistencije standardnih devijacija ekonomskog rezultata

Comparison of Standard Deviations
Economic result 1 Economic result 2
Ratio of Variances = 1,04443
F-tests to Compare Standard Deviations

Null hypothesis: sigmal = sigma2	F	P-value
(1) Alt. hypothesis: sigmal NE sigma2	1,04443	0,492248
(2) Alt. hypothesis: sigmal > sigma2	1,04443	0,246124
(3) Alt. hypothesis: sigmal < sigma2	1,04443	0,753876

Source: own processing

Table 4. Test the consistency of the medians of economic result

Tablica 4. Test konzistencije srednjih vrijednosti ekonomskog rezultata

Comparison of Medians
Median of sample 1: 94276,3
Median of sample 2: 116052,0
Mann-Whitney (Vilcoxon) W tests to compare medians
Average rank of sample 1: 943,486
Average rank of sample 2: 1057,51

Null hypothesis: medianl = median2	W	P-value
(1) Alt. hypothesis: medianl NE median2	557014,0	0,0000100906
(2) Alt. hypothesis: medianl > me	557014,0	0,999995
(3) Alt. hypothesis: medianl < median2	557014,0	0,00000504528

Source: own processing

Table 5. Test the consistency of the standard deviations of economic result

Tablica 5. Test konzistencije standardnih devijacija ekonomskog rezultata

Variance Check		P-value
Cochran's C test	0,510865	0,492248
Bartlett's test	1,00024	0,492247

Source: own processing

MODEL SALES / *Model prodaje*

The function of total costs C_e (T_e) is

$$C(T_e)=\frac{c_{eA}+b_{eA}w_e}{T_e}+T_e\sum_{i=1}^{m}\frac{x_i}{2}c_{ei}+w_e\sum_{i=1}^{m}x_i b_{ei} \tag{8}$$

$$\frac{b_{eA}}{T_e}+\sum_{i=1}^{m}x_i b_{ei}\le b_e^H \tag{9}$$

$$T_e>0 \tag{10}$$

where

$C(T_e)$ are total costs of sales,

T_e is the expedition cycle,

c_{eA} are distribution costs connected with one expedition,

c_{ei} are unit costs connected with storage of product i per one period,

b_{eA} is standard performance is a salesman in equipment expedition,

b_{ei} is working standard for handling of one unit product i,

w_e is the wage rate salesman,

b_e^H is the upper limit of working time profession salesman,

x_i is the product i amount per one period.

The problem is interconnection models. In case capacity problems we used penalty functions. Substitute objective function minimizes the loss of deficit (f.e. penalties). For example in case of capacity problem in supply penalty function is

$$\min\ \delta(\overline{x}_s)=\sum_{i=1}^{m}d_i(x_i-x_{si}) \tag{11}$$

$$x_{si}\le x_i \qquad i = 1, 2, \ldots, m, \tag{12}$$

$$\frac{b_{sA}}{T_s}+\sum_{j=1}^{n}b_{sj}\sum_{i=1}^{m}x_{si}a_{ij}=b_s^H \tag{13}$$

$$x_{si}\ge 0 \qquad i = 1, 2, \ldots, m, \tag{14}$$

where d_i is the penalty for non-delivery of one unit of product i to customer,

a_{ij} is the standardised consumption of material j per product i,

b_{sA} is standard performance is a warehouseman in equipment deliveries,

b_s^H is the upper limit of working time profession warehouseman,

b_{ij} is working standard for handling of one unit material j,

T_s is the delivery cycle,

x_i is the optimum amount of the product i from the optimal production program which not respecting storage capacity limitation,

x_{si} is the amount of the product i capable of supplying process.

RESULTS / *Rezultati*

Simulation models are processed by EXCEL 7.0 software. Varying input parameters are the selling prices of finished products. We generated 1,000 entries with a normal distribution and a standard deviation of size 30 percent of the mean value. We compared results of models with use penalty function and results of complex models which included the same parameters. We used parametric tests, considering sample size, and nonparametric tests, considering of the outcome of the tests of normality. The results of parametric tests are in Table 2 and Table 3. The results of nonparametric tests are in Table 4 and Table 5.

From Table 2 shows that, on the significance level 0,01, may be accepted third alternative hypothesis: mean of economic result in model with use penalty functions is worse than the mean value of economic result in the complex model. From Table 3 shows that between models are not statistically significant differences among the values of variances. Nonparametric testing should confirm the results of the parametric tests.

Results of Mann-Whitney test for the null hypothesis of identity medians in Table 4 show that, on the significance level 0.01 may be accepted third alternative hypothesis: economic result in model with use penalty functions is worse than economic result in the complex model.

CONCLUSION / *Zaključak*

Results of tests showed that mean values of economic result are higher in the optimization model as a whole, but for the dispersion and the standard deviation statistically significant differences are not. The problem is that economic systems are really complicated. Often is unrealistic their optimization as a whole. In case their decomposition to subsystems occurs problem their subsequent interface. Use of the penalty functions is one option to solve this problem. We showed example for exploitation of the penalty function on the particular model.

Results of statistical tests confirmed the general conclusions of the theory of cybernetics. Nevertheless, we believe that penalty functions have the potential to solve the questions of modern Complexity Theory.

REFERENCES / *Literatura*

[1] Arthur, W. B. – Durlauf, S. N. – Lane, D. A. 1999. The Economy as an Evolving Complex System II. In: Santa Fe Institute, Studies in the Sciences of Complexity Proceedings vol. XXVII. Reading: Addison-Wesley, 1999.

[2] EC DG Enterprise & Industry. 2008. ICT and e-Business Impact in the Transport and Logistics Srvices Industry – Study report. In The European e-business Market W@tch – Studies. [cit. 2009.02.20.] http://www.ebusiness-watch.org/studies/sectors/transport_services/transport_services.htm

[3] Kortschak, B. H. 1993. Úvod do logistiky. (Co je logistika?). Praha: BABTEXT, 1993. ISBN 80-85816-06-7.

[4] Kováč, V. - Gazda, V. – Gazda, J. 2012. Cognitive radio networks – basic approach and elementary terms. In: National and Regional Economics 9: zborník z medzinárodnej konferencie: 26th - 27th September, 2012, Herľany, Slovakia. Košice : TU, 2012 s. 249 - 256. ISBN 978-80-553-1215-6.

[5] Luenberger, D. G. 2005. Linear and nonlinear programming. New York: Springer Science, Business Media, 2005. ISBN 978-14020-7593-3.

[6] Tsoukalas, J. D. 2005. Modelling Manufacturing Inventories. Workiong paper No. 284. London: Bank of England, 2005. <Pogreška! Referenca hiperveze nije valjana.publications/workingpapers/wp284.pdf > ISSN 1368-5562.

[7] Weigel, A. P. – Liniger, M. A. – Appezeller, Ch. 2009. Seasonal Ensemble Forecasts: Are Recalibrated Single Models Better than Multimodels? In: Monthly Weather Review, Volume 137 Issue 4, April 2009. p. 1460-1479. ISSN 1520-0493.