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EVOLUTION OF THE TOTAL LOGISTICS COSTS CONCEPT

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ABSTRACT. The article considers the evolution stages of the total logistics cost concept; an interrelations of TLC and EOQ models has been analyzed. The author presented analytical approaches to determine a value of total cost, as well as an integral criterion for logistics systems' functioning, based upon package treatment of the total costs value and service level.

Key words: Total Logistics Cost model (TLC), logistics cost, service level, Economic Order Quantity (EOQ) model.

INTRODUCTION

According to research by various authors [Barykin 2007, Lukinski 2008, Dolgov 2004, etc.], one may state that costs-in-full dependence was covered in Ford Harris's work 'How Many Parts to Make at Once', 1913 [Operations ..., 1990], by way of:

$$y = \frac{1}{240 * M}(cx + s) + \frac{s}{x} + c \qquad (1)$$

where M is product consumption per month, in units;

c - a unit cost;

s - costs related to order management;

x - target order quantity, in units.

The work by Lukinski [2008] shows that value 240 in the formula (1), includes (2*12)/J, where J is a share in cost per unit as for production c, accounted for storage expenditures. In the mentioned work by F. Harris, value J = 0.1. Having finished necessary manipulations, it is easy to get the formula to calculate the economic order quantity, which according to present-day ideas is represented by way of:

$$x = \sqrt{\frac{2 * 12 * M * s}{J * c}} \qquad (2)$$

Thus, the first reference to 'total costs' equation (Total Logistics Costs, the TLC) and actually to the EOQ model, dates to 1913. At that two components have been considered, i.e. order management costs (C_3) and production storage costs (C_x):

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$$C_{\sum} = C_з + C_х \quad (3)$$

It must be emphasized that Ford Harris developed the formula for economic order quantity to estimate in-process inventory. For historical reasons, the economic order quantity model and the EOQ formula, called Wilson Formula, appeared between 1916 and 1934, when he published his article in The Harvard Business Review. Therefore some specialists consider that the formula (2) should be called Harris-Wilson Formula.

Moreover, according to the work by Bukan and Kenigsberg [1967], "having acted in-dependently", between 1915 and 1922, several American scientists „invented the formula for the most economic order quantity that minimized total product storage costs for cases, when demand was known and invariable."

We believe that to identify directions for further research and improvements to a logistics toolkit, we need to describe the evolution of one of fundamental concepts in logistics theory that is the total cost concept.

CO-EVOLUTION OF THE CONCEPT OF TOTAL LOGISTICS COSTS AND EOQ-MODEL

Summarizing above-mentioned reasoning, one may conclude that the first stage in the TLC and EOQ models development dates to 1913-1940 (Table); there are no essential differences between components of the TLC and EOQ models; their structure of elements is limited, while interrelations and mutual influence between elements of the models are not taken into consideration.

The second stage covers the period between 1940 and 1970. As far as logistics evolves, methodological approaches to cost analysis change: one may observe a move from isolated study of measures to rationalize distribution and production sphere to total costs accounting.

According to Lukinski [2008], in that time (1951) the work by K. Arrow, T. Harris and J. Marschak appeared, giving a mathematical analysis of the simple inventory control model, while in 1953, T. Whiting developed a probability version of the model [Hadley and Whiting, 1969]. Research made led to the new version of the total costs equation that might be presented by way of:

$$C_{\sum} = C_к + C_з + C_х + C_д \quad (4)$$

where $C_к$, $C_з$, $C_х$, $C_д$ are correspondingly costs for purchasing, ordering, inventory storage and shortage costs.

At the same time, one should mention that some references related to inventory control, present the dependence (3) by way of:

$$C_{\sum} = C_з + C_{хт} + C_{хс} + C_д \quad (5)$$

where $C_{хт}$, $C_{хс}$ are storage costs for running and reserve inventory correspondingly.

Benchmarking study of (3), (4) and (5) models shows as follows: firstly, in the evolution process, a number of entered types of expenses increases; secondly, one may observe a difference between the second-generation models (second stage), e.g. in the formula (4), there are purchasing costs $C_к$, while in another one (5), those costs are not entered, although instead of total storage costs (Formula (4)), costs to store running and reserve inventory are introduced (Formula (5)); thirdly, a range of costs traditionally related to transportation, is not entered in dependencies (4) and (5), presenting main types of costs.

Let' look at the EOQ model. Two summands $C_з$ and C_x (for dependency (5) - C_m) can be evidently identified from each total costs dependency, and considered as constituents within the formula (3), it means getting back to the EOQ model's first stage. Nevertheless, a fundamental distinction of the second stage EOQ model is that it introduces the concept of 'inventory control strategy'.

Several strategies for inventory control are known to exist and based upon two models, i.e. a periodic one (a fixed interval between orders T and a variable delivery quantity S_i) and of critical levels (in particular, one critical level ('reorder level', the ROP) and the constant delivery quantity S_0. The second strategy has got another name, i.e. with a fixed order quantity (the FOQ).

Consideration of the inventory control strategy results in appearance of additional variable τ, lead time, in models. For example, for the fixed order quantity model, it is embodied in the value of 'reorder point' or 'order level' R. In presence of two variables, order quantity S and reorder point R, one need to draw a system of equations to identify their optimal values:

$$\begin{cases} \dfrac{\partial C_{\Sigma}}{\partial S} = 0 \\ \dfrac{\partial C_{\Sigma}}{\partial R} = 0 \end{cases} \qquad (6)$$

Having been transformed, these dependences are written in the following form [Taha 2005] for the inventory control strategy, the *FOQ*:

$$\begin{cases} S^* = \sqrt{\dfrac{2A(C_0 + C_\partial F(S,R)}{C_x}} \\ \int\limits_{R^*}^{\infty} f(S)dS = \dfrac{C_x S^*}{C_\partial A} \end{cases} \qquad (7)$$

where $F(S,R) = \int\limits_{R}^{\infty} (S-R) f(S) dS$.

For a standard law with density function f (S) in an explicit form it is impossible to identify optimal values of S* and R*, hence the numerical algorithm submitted by D. Hadley and T. Whiting is applied [Hadley and Whiting 1969].

Thus, for the second stage of the evolution in the total logistics cost model, sophistication of the model is characteristic in view of a number of its constituents and a diversity of applied calculation methods that in its turn is caused by development in the methodology of inventory control in logistics systems.

The third stage (1970-until present) is described with rapid developments in the theory of logistics and supply chain management. Along with that, in actually functioning commercial systems, one may observe that market relations are getting more sophisticated, competition is getting stronger, that inevitably result in a necessary increase in customer service quality. Establishing an integral criterion for efficient functioning of the logistics system that takes into account an amount of total logistics costs, on the one hand, and a level of customer service on the other hand, is a unique feature of the given stage of the evolution within the considered concept. Formally, the given criterion can be written by way of the equations system as follows:

$$\begin{cases} C_{\sum}\ (C_i, S_0 < P) \to \min \\ SL(C_{\sum}\ , S, P_i) \to \max \end{cases}$$

where SL is service level, or demand satisfaction coefficient.

Structure sophistication of the total logistics costs model, on the one hand, and a need in applying integral criteria to assess efficiency of logistics systems functioning, on the other hand, at the first glance point out that the interrelation between the EOQ model and that of total logistics costs gets weaker (Table). Although it is not always true. A further analysis lets identify the interrelation and mutual influence between elements of considered models. For example, costs for purchasing inventory holdings are not taken into account within the EOQ model, while a contrary situation appears in case of purchasing goods with a discount; in general, transportation costs are not included into the EOQ model, but costs related to failed delivery risks are covered within the model.

Table 1. Main stages in development of total logistics costs concept
Tabela 1. Główne etapy rozwoju koncepcji kosztów całkowitych logistyki

Stage	Official representation of the model	Overall procedure for solving
First stage (1913-1940) Components of the total logistics cost model are independent	$C_{\sum}\ = C_з + C_x$	$Q = \sqrt{\dfrac{2AC_з}{C_x}}$
Second stage (1940-1970) Between the model components takes into account the relationship of inventory management strategies	1) $C_{\sum}\ = C_к + C_з + C_x + C_д$ 2) $C_{\sum}\ = C_з + C_m + C_c + C_д$	For example, for the strategy with a fixed order quantity $\begin{cases} \dfrac{\partial C_{\sum}}{\partial S} = 0 \\ \dfrac{\partial C_{\sum}}{\partial R} = 0 \end{cases}$
Third stage *(1970 until present)* Relationship and interaction of logistics key indicators (KPI), the total costs and service level	$C_{\sum}\ = C_к + \boxed{C_з + C_x + \boxed{C_c + C_д}^{\mathrm{II}}}^{\mathrm{I}} + C_л$ *I level* *II level* (C_m $C_{xp.}$ $C_{xp._1}$ $C_{xp._2}$ *III level* (C_m – transportation costs)	$\begin{cases} C_{\sum}\ (C_i, S_0 < P) \to \min \\ SL(C_{\sum}\ , S, P_i) \to \max \end{cases}$ Hence $\begin{cases} \dfrac{\partial C_{\sum}}{\partial S} = 0 \\ \dfrac{\partial C_{\sum}}{\partial R} = 0 \\ \dfrac{\partial SL}{\partial P_i} = 0, i = 1,..., n \end{cases}$

CONCLUSIONS

Thus, one needs to mention a range of important directions for advanced research. Firstly, in a domain of logistics commercial provision one needs to develop further a set of methods to estimate elements of the logistics costs system. Secondly, as far as the model gets more complex in its structure, a problem of search for criteria to group elements of the model is getting relevant to assess functioning of logistics systems in their various configurations, implemented logistics technologies and applied integration methods. Thirdly, we need further study of interrelations and mutual dependencies.

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EWOLUCJA KONCEPCJI CAŁKOWITYCH KOSZTÓW LOGISTYCZNYCH

STRESZCZENIE. Praca przedstawia etapy ewolucji koncepcji całkowitych kosztów logistycznych. Analizie poddano zależności między modelami TLC oraz EOQ. Autor przedstawił analityczne podejście określania wartości kosztów całkowitych, jak również kryteriów funkcjonowania systemów logistycznych, opierając się na zintegrowanym ujęciu wartości kosztów całkowitych oraz poziomu obsługi.

Słowa kluczowe: model całkowitych kosztów logistycznych (TLS), koszt logistyczny, poziom obsługi, model ekonomicznej wielkości zamówienia (EOQ).

ENTWICKLUNG DES KONZEPTS DER GESAMTEN LOGISTIKKOSTEN

ZUSAMMENFASSUNG. Der Artikel präsentiert die Etappen der Entwicklung des Konzepts der gesamten Logistikkosten. Die Beziehungen zwischen TLC und EOQ-Modelle wurden analysiert. Der Autor präsentiert einen analytischen Ansatz zur einem Wert der Gesamtkosten sowie integralen Kriterien für die Arbeitsweise von Logistik-Systemen, die auf einer integrierten Behandlung der Gesamtkosten und Service-Level basiert.

Codewörter: Modell von gesamten logistischen Kosten (TLC), logistische Kosten, Service Level, Modell der ökonomische Bestellmenge (EOQ).

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