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Economic-Mathematical Modeling of Logistic Coordination of Financial Flows in Cities and Metropolitan Areas

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ABSTRACT

The article is devoted to the formation of economic-mathematical model of logistic coordination of financial flows in cities and metropolitan areas. Efficient implementation of logistic coordination is impossible without using of economic-mathematical models, which allows us to define optimal scenario for certain system functioning. The research objective is to establish efficient economic-mathematical model for logistic coordination of financial flows in city (metropolitan area). The author reveals the essence, objectives and priorities of the financial logistics coordination. The model of logistic coordination of financial flows in cities and metropolitan areas, based on the Black-Scholes model, is proposed. The use of the proposed measures implementing financial coordination of logistics software subsystems enable cities and metropolitan areas with financial resources as well as distribution of financial resources to enhance the economic component of sustainable development. Due to the defined model's parameters, local self-government bodies can adopt decision on permission for certain activity, that allow to involve additional financial flows to the city (metropolitan area) and thus to provide sustainable development of cities (metropolitan areas).

JEL Classification: O18, R48.

Keywords: Economic-mathematical modeling, model, financial logistics coordination.

1. INTRODUCTION

While providing of sustainable development of city (metropolitan area) demand in logistic coordination of financial flows is appeared. Implementation of the efficient logistic coordination of the urban financial flows will allow to accumulate sufficient amount of financial resources that is very important on background of decentralization reform in Ukraine. Also, strong demand in logistic coordination of financial flows is arisen from city (metropolitan area) constructed as combination of basic subsystems, that consume resources, and supporting subsystems, that transfer resources through the basic ones. The city as a logistics system is characterized by a system of input and output flows that occur through the consumption of the socio-ecological and economic resources, the availability of internal and external environment in which there are basic stages of the logistics process: procurement - production-distribution-consumption that actually confirms the position to review the city as a logistics facility (Gerasymchuk Z. V.& Averkyna M. F., 2014) [1]. The city as any logistics system is adaptive, open to interaction with the environment is organized, structured economic system consisting of interconnected and interacting participants, united unity of purpose and economic interests, and which is established to optimize the resources used in economic flows. But efficient implementation of logistic coordination is impossible without using of economic-mathematical models, which allows us to define optimal scenario for certain system functioning.

2. BRIEF LITERATURE REVIEW

Theoretic and methodical aspects in logistic systems coordination is presented in papers of N. Volosnikova (2013) [2], Z. Gerasymchuk (2011) [1], V. Livshyts (2007) [3], O. Moroz (2008) [4]. Modeling aspects in logistic systems is presented in papers of R. Rezende Amaral (2014), El-H. Aghezzaf (2014) [5], Jeffrey C. Brinkman (2016) [6], Vincencza Chiarazzo (2014) [7], Luigi dell'Olioa (2014) [7], Ángel Ibeasa (2014) [7], Michele Ottomanellib (2014) [7], Mohammed Aljoufie (2014) [8], S. Tirumalachetty (2013) [9], K. Kockelman (2013) [9], B. Nichols (2013) [9], K. Doi (2012) [10], M. Kii (2012) [10], Z. Rainbekov (2016) [11], B. Syzdykbaeva (2016) [11], A. Baimbetova (2016) [11], Z. Rakhmentulina (2016) [11].

Rodrigo Rezende Amaral, El-Houssaine Aghezzaf (2014) [5] considers a two-tiered system and proposes a two-layered optimization model for the urban freight transport, taking delivery time-widows and traffic conditions into account, as well as the replenishment of satellite warehouses and coordination of both flows. Jeffrey C. Brinkman (2016) [6] develops a spatial equilibrium model of urban structure that includes both congestion costs and agglomeration externalities (estimate the structural parameters of the model by using a computational solution algorithm and match the spatial distribution of employment, population, land use, land rents, and commute times in the data.). Vincencza Chiarazzo, Luigi dell'Olioa, Ángel Ibeasa and Michele Ottomanellib (2014) [7] implemented modeling the effects of environmental impacts and accessibility on real estate prices in industrial cities. Presented hedonic Multiple Linear Regresion models (MLR) to estimate real estate price variation in metropolitan areas as a result of changing environmental and accessibility conditions. Mohammed Aljoufie (2014) [8] developed a dynamic model to compare the ability of different approaches to depict the impact of land use changes on transportation and vice versa. The model was applied in the city of Jeddah (Saudi Arabia) over the course of 20 years. S. Tirumalachetty, K. Kockelman, B. Nichols (2013) developed a microsimulation model to predict greenhouse gas emissions in the city of Austin (Texas, USA) [9]. K. Doi et. al., analyzed public transport and strategies in place for the use of urban land for the year 2030 in all urban areas in Japan, a total of 269 [9]. The model also included the financial balance between the working of the public transport systems and the benefits for the users. Z. Rainbekov, B. Syzdykbaeva, A. Baimbetova, Z. Rakhmentulina (2016) [11] outlined key factors of development and main elements of logistics infrastructure are, their impact on different areas of regional economy is evaluated.

Despite significant scientific achievements in the field of sustainable development of the city (metropolitan area), insufficient attention is attracted to implementation of the logistic coordination of financial flows in connection with methods of economic-mathematical modeling.

3. THE PURPOSE

The research objective is to establish efficient economic-mathematical model for logistic coordination of financial flows in city (metropolitan area).

4. RESULTS

For establishing efficient economic-mathematical model it is necessary to define content of financial logistic coordination. We treat financial logistic coordination as involvement of financial resources to certain subsystems of the city (metropolitan area) which are most advantageous for rational consumption of the social-ecological-economical resources, its reproduction, reaching the social-ecological-economical safety as well as increasing logistization level. Also, shortage of external resources consumption by subsystems of the city (metropolitan area) and maximal providing them with internal resources, belong to the aims of financial logistic coordination

The next tasks of financial logistic coordination are treated as basic:

1. Providing city (metropolitan area) with necessary financial resources. It includes: estimating of requirements in financial resources, selection of the supplier of the financial resources, preparation of the plan for strategical activities' funding aimed for sustainable development of the city (metropolitan area).
2. Distribution of the financial resources in the city (metropolitan area) that provides establishing system for finance resources distribution, determination of basic directions for financial resources forming and usage, estimation of financial possibilities to prospective investments into strategical activities, reaching of financial transparency for investors in the city (metropolitan area).
3. Establishing sound financial cooperation between the municipal budget, banks, suppliers, customers and other business of the city and metropolitan area that allows Department of Finance to optimize payments between them.

In order to achieve efficient logistic coordination of financial flows in the city (metropolitan area) will be reasonable:

1. to organize local tenders bidding procedures for choosing an actors who will be capable to fund certain events necessary for city (metropolitan area) e.g. building and reconstruction of the objects in municipal property;
2. to create local financial organizations e.g. banks, insurance companies, that allows to involve financial resources to cities and metropolitan areas;

3. to establish investment trusts with depreciation charges of municipal entities. It allows to concentrate resources for investments intended for large-scale rotation of the worn equipment in the basic and supporting urban subsystems.
4. to establish local mutual-aid funds in order to fulfill needs of citizens, city and metropolitan areas. These funds should be created within self-government authorities which have to control financial flows.
5. to provide efficient control for financial flows in the city (metropolitan area). Activity of financial control authorities should be aimed for prevention and early disclosure of illegal and ineffective activities with local funds, in due time elimination of disclosed problems, damage mitigation and punishment of offenders.
6. to create real-time accounting system, especially weekly designing of municipal (metropolitan area) budget. It enables more transparent consumption of financial resources by all participants.
7. to stop funding of insignificant programs i order to support more important programs aimed for sustainable development of the city (metropolitan area);

whereas, financial flows are defined by volume, cost and direction, pricing is basic for financial logistic coordination. Financial resources are formed with significant impact of the financial relations between municipal subsystems or homogenous subsystems in the cities joined by metropolitan area. In order to achieve efficient logistic coordination of financial flows in the city (metropolitan area) it will be reasonable to support more important programs aimed for sustainable development of the city (metropolitan area). The estimation of program's priority should be performed on the basis of Black-Shoels optimization model [12], because it defines current cost of the bid for certain good or service (*e.g. transportation service*) is defined as

$$C(S,t) = SN(d_1) - Ke^{-r(T-t)}N(d_2) \tag{1}$$

where,

$$d_1 = \frac{\ln(S/K) + (r + \sigma^2/2)(T-t)}{\sigma\sqrt{T-t}}; \tag{2}$$

$$d_2 = d_1 - \sigma\sqrt{T-t}; \tag{3}$$

$C(S, t)$ – cost of the applicant bid in moment "t" till the end of the option term (e.g. competitive tender for public transportation);

S – cost proposed by the project contractor (e.g. transfer cost: (1) within city – UAH 3; (2) between cities — UAH 40);

$N(x) = \frac{1}{2\pi}\int_{-\infty}^{x} \exp(-z^2/2)\,dz = \frac{1}{2}(1 + erf(x/\sqrt{2}))$ – standard cumulative function of normal distribution (probability of deviation to be lesser under standard normal distribution);

K – cost, consumers are ready to pay (e.g. transfer cost: (1) within city – UAH 2, 5; (2) between cities – UAH20);

r – risk-free interest rate (30%);

T − t − time to termination of competitive tender;

σ − income volatility.

"Greeks" of this model allow to estimate sensibility of pricing to factors put in model. In particular, a new interpretation of the Greeks on the proposed model is offered by author.

"Delta" $\Delta = \frac{\partial C}{\partial S}$ − price sensitivity to the transfer cost proposed by transport operators of the city (metropolitan area). If this parameter is closer to zero than transfer cost is lesser influenced by transportation operators position and prising is efficient and reasonable;

"Vega" $\text{Vega} = \frac{\partial C}{\partial \sigma}$ − price sensibility to volatility. With increasing of this parameter the bigger amount of non-transparent components are included to the price.

In ideal circumstances "Delta" and "Vega" should be equal to zero.

In the Black-Shoels optimization model analytic formulas for every "Greek" are provided. They enable analytic analysis of the pricing efficiency for given indicators and further pricing optimization.

Let's substitute values for Central Volyn sub-region (Lutsk and Rivne are treated as metropolitan area because of the guidebook Spatial Development in Ukraine: development of agglomerations and subregions, p. 51-53, Metropolitan area Lutsk − Rivne is included in Central Volyn sub-region) to the mentioned formula:

- option period (T) – 1 year;
- cost of the bid (cost of the ticket in one-way calculation Rivne-Lutsk) from certain transport operators and their ratio UAH 20−10%, UAH 30−40%, UAH 40−20%, UAH 35−30%)
- cost of the bid – UAH 25.

Based on the proposed data, all the necessary parameters of the model, and the optimal value proposition, to be established by the local government, are set (Table 1).

Table 1
Calculated parameters for Black-Shoels model for Central Volyn sub-region

Model parameter	*Unit*	*Value*
Risk-free interest rate	%	30
Average cost of the bid	UAH.	32,5
Dispersion	Non-dimensional value	0,029586
Income volatility (*σ*)	%	17, 2
C (S,t)	UAH	31,16

Author's calculations

As result of calculation, we have received optimal transportation cost for intercity transportation Rivne-Lutsk in one-way mode, that can be adopted by local government at UAH 31,36. The fact that this cost is less then weighted average one (32,5 UAH) means that hidden factors are available in pricing. Therefore it should be strict control of the intercity transportation cost in metropolitan area.

Substituting values for Lutsk to the mentioned formula are obtains:

- option period (T) – 1 year;
- cost of the bid (cost of the ticket in one-way calculation Rivne-Lutsk) from certain transport operators and their ratio UAH 2,6−10%, UAH 3,0−40%, UAH 2,5− 20%, UAH 2,8−30%)
- cost of the bid – UAH 2,0.

Based on the proposed data, all the necessary parameters of the model, and the optimal value proposition, to be established by the local government, are set (Table 2).

Table 2
Calculated parameters for Black-Shoels model for Lutsk

Model parameter	*Unit*	*Value*
Risk-free interest rate	%	30
Average cost of the bid	UAH	2,8
Dispersion	Non-dimensional value	0,004847
Income volatility (*σ*)	%	6,92
C (S,t)	UAH	1,32

Author's calculations

As result of calculation, we have received optimal transportation cost for public transport in one-way mode at UAH 1,32. Also due to economic content of the model we can observe speculative position of transport operators (excessive profit receiving) because of significant fluctuation between cost of proposal and real cost defined with the Black-Scholes model.

The use of the proposed measures implementing financial coordination of logistics software subsystems enable cities and metropolitan areas with financial resources as well as distribution of financial resources to enhance the economic component of sustainable development.

5. CONCLUSIONS

Due to the defined model's parameters, local self-government bodies can adopt decision on permission for certain activity, that allow to involve additional financial flows to the city (metropolitan area) and thus to provide sustainable development of cities (metropolitan areas).

Proposed model shows the real cost of services in terms of supply and demand. We found that prices are overcharged in twice by local self-government bodies (price exceeds net cost but is lower than the actual current prices). Therefore, due to the proposed model economically reasonable price can be not only proposed, as well as evaluation model of local self-government bodies' transparency.

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