MATHEMATICAL MODELING OF PROBLEMS OF OPTIMAL PLACEMENT OF ONLINE STORES

Problems of optimal allocation of resources arise in different industries and different areas of human activity. Many theoretical and practical problems of optimization in their formulation are reduced to continuous problems of optimal partitioning (ORM).

In particular, according to a national survey of Ukrainian Internet audiences recently published in electronic media, there are about 8 million regular users of the global network in Ukraine, among them the most active are residents of large cities, youth and high-income people. That is why it would be extremely unwise to ignore the consumer demands of this audience, without trying to satisfy at least some of such requests directly on the Internet. In order to implement this idea in practice, online stores will be useful, the estimated turnover of which, according to analysts, only in the domestic segment of the World Wide Web this year will reach 1 billion dollars.

In the process of moving from the primary source of raw materials to the final consumer, material flow can accumulate in the form of stocks in a particular section of the logistics chain. Because of this, there is an objective need for specially equipped places for their storage, and in addition, the implementation of important logistical operations, such as sorting, assembly, packaging and more. This role is performed by various compositions.

The warehouse network is one of the elements of the logistics system, which provides a balance of interests of all market participants and creates a modern system of goods movement, focused on meeting the needs of end users.

Today Ukraine needs to create an extensive and territorially balanced warehouse network, as there is currently a significant territorial unevenness of its development.

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In a given region it is necessary to place \( n \) warehouses of online stores in order to optimally distribute consumer demand for food and industrial products. Introducing restrictions on the total
capacity of warehouses, the problem of placement-partition is reduced to a continuous linear multi-product problem of optimal division of the set into subsets with the location of their centers under constraints.

Mathematical model. It is necessary to divide the set of consumers into their service areas

$$\bigcup_{j=1}^{N} \Omega_j = \Omega, \quad j=1,M,$$

$$\text{mes}(\Omega_j \cap \Omega_k) = 0, \quad i \neq k, \quad i,k = 1,N, \quad j=1,M$$

and place these warehouses in the area $$\Omega$$, minimizing the functionality of the total cost of storage of goods and their delivery to the consumer:

$$F \left( \{ \Omega_1^j, \ldots, \Omega_N^j ; \ldots ; \Omega_1^M, \ldots, \Omega_N^M \} \cup \{ \tau_1, \ldots, \tau_N \} \right) =$$

$$= \sum_{i=1}^{N} \sum_{j=1}^{M} \left\{ \int_{\Omega_j} c^j(x,y,\tau_i) \rho^j(x,y) dxdy + \varphi_i^j \left( \int_{\Omega_j} \rho^j(x,y) dxdy \right) \right\}$$

where $$\rho^j(x,y)$$ — the density with which the demand for the $$j$$-th type of goods in the region $$\Omega_j$$; $$(x,y)$$ — coordinates of the consumer’s location; $$\tau_1, \ldots, \tau_N$$ — points of possible placement of warehouses; $$c^j(x,y,\tau_i)$$ — the cost of transporting a unit of production from the warehouse to the consumer with coordinates $$(x,y)$$; $$\varphi_i^j(Y^j)$$ — the dependence of the cost of storage of products of the $$j$$-th type of goods on the capacity of the $$i$$-th warehouse $$Y^j_i$$ and is determined by

$$Y^j_i = \int_{\Omega_j} \rho^j(x,y) dxdy$$

the formula

The capacity of the $$i$$-th warehouse for all types of goods is determined by the total demand of consumers, which belong to $$\Omega_j^i$$ and should not exceed the existing capacity, defined by the relevant restrictions:

$$\sum_{j=1}^{M} \int_{\Omega_j^i} \rho^j(x) dx = b_i, \quad i = p+1,\ldots,N \quad \sum_{j=1}^{M} \int_{\Omega_j^i} \rho^j(x) dx \leq b_i, \quad i = 1,\ldots,p$$

The conditions for solving the problem are fulfilled:

$$S = \int_{\Omega} \sum_{j=1}^{M} \rho^j(x,y) dxdy \leq \sum_{i=1}^{N} b_i, \quad 0 \leq b_i \leq S, \quad i = 1,\ldots,N$$

Therefore, the presented problem is a linear continuous multiproduct problem of optimal division of a set into $$\Omega \in E^n$$ its non-intersecting subsets $$\Omega_1^1, \ldots, \Omega_N^1; \ldots; \Omega_1^M, \ldots, \Omega_N^M$$ (among which there may be empty ones) with the location of the centers of these subsets with constraints in the form of equalities and inequalities.

The constructed mathematical model is considered in various modifications and numerically investigated with the help of software implementation of algorithms, which are developed on the basis of the theory of optimal partitioning.