# Nonlinear Optimization Logistic Model in the Problem of Cargo Transportation

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We would like this task to be solved simultaneously in the context of minimizing the target function of costs and maximizing the total profit from the sale of the all products. However, it has been repeatedly shown that the problem has no solution in such a formulation. Therefore, we will fix the level of income from the sale of all products, considering it parametrically set. Then we have the following problem

$$\begin{cases} C = \sum_{i,j=1}^{n} c_{ij} x_i x_j \to \min, \\ \sum_{i=1}^{n} m_i x_i = M, \\ \sum_{i=1}^{n} x_i = N, \; x_i \geq 0, \end{cases} \qquad (1)$$

where $M$ is the parameter.

It is required to solve the problem for each parameter value from its definition area.

**Corner Point method**

We introduce the concept of corner points for the problem (2). There are two points $X^1 = (x_1^1, \ldots, x_n^1)$ and $X^2 = (x_1^2, \ldots, x_n^2)$ that deliver a local minimum to the problem (2) at the values $M_1$ and $M_2$ of parameter $M$. If a point $X^*$ that is a linear combination of points $X^1$ and $X^2$

$$X^* = \alpha X^1 + (1-\alpha)X^1, \forall \alpha \in [0,1] \quad (2)$$

also delivers a local minimum to task (1) for the parameter value

$$M^* = \sum_{i=1}^{n} m_i \left( \alpha x_i^1 + (1-\alpha) x_i^2 \right), \quad (3)$$

then the points $X^1$ and $X^2$ are called “corner points”.

To solve (2), it is necessary to proceed to the quadratic programming problem

$$\begin{cases} F = \sum_{i,j=1}^{n} c_{ij} x_i x_j - \lambda \sum_{i=1}^{n} m_i x_i \to \min, \\ \sum_{i=1}^{n} x_i - N = 0, \\ -x_i \le 0,\ i = \overline{1,n}. \end{cases} \qquad (4)$$

where $\lambda$ is a parameter. The problem (4) is solved by the method of indefinite Lagrange multipliers with restrictions of the type of equalities and inequalities, where the Lagrange function will take the form

$$\Lambda = \sum_{i,j=1}^{n} c_{ij} x_i x_j - \lambda \cdot \sum_{i=1}^{n} x_i \cdot m_i + \gamma_0 \cdot \left(\sum_{i=1}^{n} x_i - N\right) - \sum_{i=1}^{n} \gamma_i \cdot x_i \ , \qquad (5)$$

$\gamma_0, \gamma_1, \ldots, \gamma_n$ are the indefinite multipliers.