Methodology for substantiating optimal location of oil storage, supply and transportation facilities in agricultural and industrial companies of Kostanay Region, Kazakhstan

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Abstract. This article proposes a methodology for substantiating an optimal location of oil storage facilities in agricultural and industrial companies, for estimating a consumption of fuel and greases, a placement of reserves and their operational distribution in the company. This approach allows reducing costs on providing consumers with petroleum products and saving fuel and oil when operating motor vehicles and tractors.

1. Introduction
In recent years, a mainstream of agriculture concentration and cooperation has been the establishment of inter-farms to mechanize agricultural works and regional agricultural and industrial companies responsible for the management of various farms, their motor vehicles and tractors, oil depots, oil storages, tank trucks and refueling facilities.

The concentration of agricultural machinery and material and technical facilities in inter-farms and regional companies makes a more efficient use of motor vehicles and tractors and allows their efficient management and controlling spare materials and technical means (petroleum products, spare parts, etc.).

A timely supply of high-quality petroleum products to motor vehicles and tractors of farms represents a burning issue which needs a conceptual solution. The latter is related to the development of maintenance programs; their management is based on unifying and coordinating information relevant for economic processes of a maintenance company. An analysis of processes results in a certain option for the development of a service product. In most cases, a decisive role in designing technical service programs is played by traditional methods of analysis focused on experience and intuition of maintenance company managers. In other words, a decision-making process, i.e. a choice of one of the possible actions hardly involves special research methods, since situations are very simple and management of maintenance companies has enough traditional knowledge and skills. However, sometimes situations are so difficult that there are doubts whether chosen solutions are correct. In such cases, it is necessary to apply techniques of formalized description and analysis of situations. Here is an approximate (and rather arbitrary) sequence of such an analysis:

- developing a model process or operation, e.g. as mathematical description;
- analysis of uncertainties and goal formalization, establishment of a target function and particular efficiency criteria;
- developing centralized management to process available or received information;
- solution to optimization related problems.

Any agricultural company should have oil storage, supply and transportation facilities to store, supply and transport petroleum products.

A rational structure of oil storage, supply and transportation facilities in an agricultural company is established depending on specific operating conditions of motor vehicles and tractors, state of roads, distance from the place where machines are operated to oil storage and filling points and other local features. Choosing a scheme for constructing and organizing oil storage, supply and transportation facilities, it is necessary to
have a proper balance between delivery, storage and refueling capacities of oil products and maintenance means of motor vehicles and tractors to ensure an efficient use of equipment.

Centrally solved issues of delivery, storage, accounting the consumption of fuel and greases, placement of reserves and their operational distribution in the company are relevant for an entire administrative region, they allow reducing costs on providing consumers with petroleum products and saving fuel and oil when operating motor vehicles and tractors.

When agricultural and industrial companies and their subdivisions operate in such conditions, it is necessary to clarify the procedure of supplying fuel and greases to motor vehicles and tractors, locate oil storages and filling stations, taking into account bases of oil-supplying companies, an average distance to oil depots, oil storage facilities and oil-supplying companies. The problems above can be solved with the methodology described below intended to substantiate an optimal placement of oil facilities both in one company and in an administrative district on the whole.

Large volumes of consumed petroleum products, e.g. an average-sized company needs annually up to 600 tons of diesel, 400 tons of gasoline and 500 tons of diesel oil, as well as a significant share of expenditures on oil storage, supply and transportation (20%) in mechanized works, give grounds to claim the solution to this problem is of national economic relevance.

2. Materials and Methods

The proposed methodology for substantiating optimal placement of oil facilities is a step forward of methodological foundations developed in [2, 3, 4, 6] and focused on optimizing work parameters of an agricultural machinery maintenance station. The operation of oil facilities is similar to that of an agricultural machinery maintenance station. Therefore, basic work parameters of these branches are identical.

These include the following points:
1. An average distance of transporting oil products from storages and supply centers to farms and consumers (working groups, brigades, etc.) or to subdivisions in the administrative region.
2. An annual throughput of an oil storage or filling center (working groups, brigades, etc.) or to subdivisions in the administrative region.
3. Total, reduced monetary costs on storages, stations, tanker truck and other stationary equipment, t/year, which makes it possible to determine a necessary oil container capacity in m³.

3. Results and Discussion

In this connection, the target function to provide a solution to the considered problem from the standpoint of national economic efficiency is stated in the following expression suitable to the most generalized organization of oil facilities:

\[ C = B_{mech} \cdot (A_{rep.mech} + E_t) + B_g \cdot (A_{rep.g} + E_t) + \sum_i C_j + \sum m \cdot \rho \cdot P_f + \sum m \cdot \rho \cdot P_f + \frac{M_{sw} \cdot k_f \cdot \beta a}{N_l \cdot L_{av}} \rightarrow \min \]  

(1)

where \( B_{mech} \) – balance price (value) of construction, tank and other equipment of oil facilities, ruble.
\( A_{rep.mech}, A_{rep.g} \) – a coefficient of annual expenditures on renovation of constructions (buildings and structures) and equipment of oil facilities, 1/year;
\( E_t \) – a linear density of fuel and greasing materials, t/km (an amount of oil products (ton) per one km of an average distance of their transport to consumers; it is calculated according to the formula (t/km):

\[ N_l = \frac{Q_v \cdot d}{L_{av} \cdot d} \]  

(2)

where \( Q_v \) – a need of a department (other subdivision) in fuel and greasing materials, t/year;
\( \sum C_j \) – a sum of standardized operation costs of oil facilities (salaries of employees of oil storages, warehouses and centers with all charges, expenditures on repair of construction and installation units, repair and maintenance of reservoirs and equipment, electric power supply, etc.);
\( \sum m \) – total reduced costs on transportation of oil products with a variety of technical means (tank trucks, refilling machines, etc.) per one unit of transport work, ruble/t.km;
\( \mu_{f.g} \) – a coefficient taking into account losses of fuel and greasing materials when transported per one ton-km, t/t-tm, (1/km);
\( P_f \) – price (cost) of one ton fuel and greasing materials, ruble/ton;
\( \delta l, f \) – a share of fuel losses when loading and unloading per 1 ton;  
\( C_{m}, \) – capacity of \( m \) fuel, \( m^3; \)  
\( \rho f \) – a fuel density, t/m\(^3\);  
\( K_{e,t} \) – a fuel evaporation coefficient calculated as a share of evaporating fuel in a total annual throughput of oil facilities 1/year;  
\( K_{c.f.t} \) – a frequency of tanks circulation for a particular fuel, 1/year;  
\( M_{s.w} \) – a number of service workers of oil storage, center or station, man.  
\( K_l \) – an efficiency coefficient of labor resources, ruble/man year;  
\( \alpha \) – a coefficient purposeful employment of service workers within a year.

The function of specific total reduced costs for maintenance and troubleshooting of motor vehicles and tractors in a subdivision (ruble/ man hour):

\[
C = \frac{bb \cdot (A - \text{rep} \cdot b + \text{En}) + B_g \cdot (A - \text{rep} \cdot e + \text{En})}{NL \cdot \text{Lav.}} + \frac{F_y \cdot \Sigma \text{Cj}}{NY} + \frac{Za \cdot \text{av.} \cdot m \cdot \text{Lav}}{NY} + \frac{\Sigma f \cdot M_w \cdot \gamma w}{NL \cdot \text{Lav.}} + \frac{dav \cdot F_y}{NY} + \\
(3)
\]

Taking a first derivative to \( L_{av.} \) from expression (3) and equating it to zero, we obtain a formula for estimating a minimal average distance of oil products transport from oil storages to a consumer (km):

\[
L_{av.}^{opt} = \left( \frac{b_{\text{mech.}} \cdot (A - \text{rep} \cdot \text{mech.} + \text{En}) + B_e \cdot (A - \text{rep} \cdot e + \text{En}) + M_{s.w.} \cdot K_f \cdot \beta_{av}}{NL \cdot (2dav + E \cdot m \cdot f_{g} \cdot E_{f}} \right)^{1/2} \\
(4)
\]

If we know \( L_{av.}^{opt} \) we can determine an optimal (annual) throughput of oil storage, center, station or mobile refuel capacity according to the formula (t/year):

\[
Q_{\text{year}}^{opt} = N_1 \cdot L_{av.}^{opt} \\
(5)
\]

Substituting \( Q_{\text{year}}^{opt} \) into (3), we obtain minimal (optimal) total reduced costs on storage, transport and loading and unloading works per 1 ton of fuel and greasing materials.

A volume of tanks for storing a production fuel stock is calculated in a percentage of annual demand, taking into account various monthly fuel consumption and using the formula [5] (m\(^3\)):

\[
G = \frac{Q \cdot E_{\text{max}}}{100 \cdot \gamma \cdot m^3} \\
(6)
\]

where \( Q \) – a fuel consumption, t;  
\( E_{\text{max}} \) – a maximal amount of fuel in % of annual consumption;  
\( \gamma \) – a fuel density, t/m\(^3\) (for diesel – 0.82) [5];  
\( m \) – a coefficient of tanks filling, \( m = 0.95 \) [5].  
\( E_{\text{max}} \) depends on the maximal coefficient of various monthly fuel consumption \( K_{\text{max}} \).

\[
K_{\text{max}} = \frac{Q_{\text{max.m}}}{Q_{av.m}}, \\
(7)
\]

where \( Q_{\text{max.m}} \) – a maximal monthly demand of diesel, kg;  
\( Q_{av.m} \) – an average monthly demand of diesel, kg.

An estimated volume is smoothed to values of standard tanks.

The described methodology makes it possible to analyze the existing organization of oil storage, supply and transportation at various production levels via comparing optimal work parameters with those really available in a company subdivision, as well as to select standard designs of oil depots in specific production conditions.

4. Conclusion

A distinctive feature of these techniques is the use of linear density of process labor intensity or an amount of fuel and grease or other units per one kilometer of an average transportation distance and characterizing the spatial difficulty degree of the process.

The use of linear density as a main design parameter simplifies optimization calculations, and improves their accuracy when taking into account specific field and road conditions of production units.
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