EXAMINING THE EFFECT OF PRODUCTION CONDITIONS AT TERRITORIAL LOGISTIC SYSTEMS OF MILK HARVESTING ON THE PARAMETERS OF A FLEET OF SPECIALIZED ROAD TANKS

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At present, Ukraine faces the unresolved problem of food security. When this country joined the World Trade Orga-
ucts and has specific requirements to its harvesting. At the same time, these requirements lead to a change in the systems of milk production. Small-scale privately-owned farms that produce more than 80% of the total milk production in Ukraine do not ensure the quality regulated by the EU standards. They are forced to cooperate in order to form family dairy farms. To this end, the State has developed a number of programs that promote such efforts of milk producers. At the same time, neglected are the logistic systems of milk harvesting at the territory of separate administrative districts, whose parameters greatly affect quality of the raw milk for the production of dairy products.

To create efficient logistics systems for milk harvesting at the territory of separate administrative districts, it is necessary to apply specific methods and models. Such methods and models must take into consideration both the features of production conditions for milk harvesting (the presence of family dairy farms, geographical location, condition of the road network, etc.) and its seasonality. This largely defines the parameters for the fleet of specialized vehicles (SV) milk harvesting, as well as the modes of their operation over a calendar year.

2. Literature review and problem statement

Paper [1] proposed an approach for planning the operation of a fleet of vehicles when servicing sea ports. Studies [2–5] address the improvement of efficiency of a fleet of vehicles based on different criteria (cost, impact on the environment, etc.). Works [6–8] take into consideration special features of using freight vehicles during cargo transportation. However, applying the reported research results in order to define parameters for a fleet of specialized vehicles employed in logistics systems of milk harvesting (LSMH) is impossible, because they do not imply the use of quality criteria for the delivered cargo, as well as the time, which are characteristic of perishable cargoes that include milk.

It is proposed in papers [9–11], in order to define the indicators of employing freight vehicles, to model the use of these vehicles. The above methods and models imply specifying the deterministic indicators for the use of vehicles. It is not possible to apply the obtained research results for LSMH as they fail to take into consideration the changing volumes of milk harvesting over a calendar year, as well as conditions and peculiarities in the execution of transport operations.

Papers [12–14] propose to substantiate the need for vehicles taking into consideration the changing volumes of cargo transportation, and, as suggested in articles [15–17], taking into consideration the associated risk. However, the application of results, reported in these works, in order to substantiate the SV parameters for LSMH is impossible, due to the fact that they do not take into consideration the specific operational conditions for transportation processes in these systems. Specifically, they do not account for the peculiarities in the production conditions of milk harvesting that are specific for each administrative district of the state. In addition, they do not consider the seasonality of milk production and, accordingly, its harvesting, which greatly affect the efficiency of transportation processes [18, 19] and the quality of the delivered milk [20].

The adequate forecasting of production conditions and the representation of transportation processes in LSMH is only possible based on modeling [21, 22]. That requires undertaking a special research [20]. It is impossible, in the case of estimation of production conditions that are specific for each administrative territory, and without forecasting the seasonality of milk harvesting and the indicators of transportation processes, to adequately substantiate the effective parameters for a fleet of specialized vehicles (SV) in the respective logistics systems.

Scientific papers [23–25] partially consider production conditions of milk harvesting and prediction of its volumes. However, they address the procurement of milk from small-scale individual households [26, 27], which does not adequately represent conditions for milk harvesting from family dairy farms. In addition, they did not take into consideration the possibility to model transportation processes for each of the periods in the seasonal milk harvesting, which makes it impossible to adequately substantiate the parameters for a fleet of SV in LSMH.

The need in SVs for territorial LSMH is characterized by their number and the predefined brand, in order to ensure the delivery of the total amount of milk to dairy plants. The need in SV is affected by the production conditions in LSMH and the duration of implementation of transportation operations that change over a calendar year.

It is possible to explore the impact of changing production conditions over a calendar year on the need in SV for LSMH based on forecasting the volume of transportation operations to be performed. To this end, it is required to carry out a simulation modeling of transportation processes for each season in milk harvesting. Based on the simulation modeling, the trends in the change of indicators for using SV are established, and the need in them is determined for each of the periods in the season of milk harvesting [25].

Consider the peculiarities of territorial LSMH. They are characterized by changing production conditions that determine the changing need in SV over a calendar year. The characteristics of production conditions include the changing daily volumes of milk harvesting from each family dairy farm and the durations of periods during which these volumes remain constant. They predetermine the changing annual volume of transportation operations within LSMH. There is also a limited duration of transportation operations in LSMH. It depends on the technological requirements for milk harvesting that are regulated by the acting standards [25–27].

There is a set of family dairy farms within separate administrative territories, each of which has a daily output of milk production. The geographical location of these farms and the duration of operations related to loading and issuing forwarding documents affect the need in SV and the organizational modes of their utilization. Specifically, work of SV in LSMH can be performed over a single or several shifts. In this case, for the assigned production conditions and the makes of SV used, there is always the optimal organizational mode for transportation operations [25].

All the above-specified indicates that the efficiency of using SV within LSMH depends on the following components:

\[ E_{SV} = f(N_v, \xi, \lambda, O, P, Z). \]

where \( E_{SV} \) is the efficiency of using SV for LSMH over a particular period during the season of milk harvesting; \( N_v \) is the number of family dairy farms within LSMH; \( \xi \) is the geographical location of family dairy farms within an administrative territory; \( \lambda \) is the intensity of milk delivery from family dairy farms; \( O \) is the organizational mode of transportation operations; \( P \) are the acting regulations for
Control processes

harvesting and transportation of milk; \( Z \) are the parameters for a fleet of SV.

All components from expression (1) are interconnected; relations between them should be considered in models and methods that are used to substantiate the parameters for a fleet of SV in LSMH. These relationships could be elucidated only based on the simulation modeling of SV operation within LSMH.

The availability and geographical location of family dairy farms within territorial LSMH are substantiated based on known method [27]. The resulting information, as well as the topographic map of LSMH territory, are the basis for determining distances between the family dairy farms and a milk processing plant. The acquired data are entered to symmetrical matrix \( \xi \) of the shortest distances between the family dairy farms within a territorial LSMH, of dimensionality \( N_o + 1 \times N_o + 1 \):

\[
\begin{pmatrix}
0 & L_{11} & L_{12} & \ldots & L_{1n} \\
0 & 0 & L_{22} & \ldots & L_{2n} \\
\vdots & \vdots & \ddots & \ddots & \vdots \\
0 & \ldots & \ldots & 0 & L_{nn}
\end{pmatrix}
\]

(2)

where \( N_o \) is number of family dairy farms within a territorial LSMH, units; \( L_{ij} \) – is the distance between the first and the \( n \)-th family dairy farm, km.

In a given matrix (4), number one is assigned to the processing plant, other numbers – to family dairy farms in the increasing order of distances from them to the processing plant.

The volume \( Q_{dx} \) of milk harvesting within the assigned territory of LSMH on the \( j \)-th \( \xi \)-th day during a season is derived from formula:

\[
Q_{dx} = \sum_{x=1}^{N_o} Q_{dx}^x,
\]

(3)

where \( Q_{dx}^x \) is the amount of milk harvesting from the \( x \)-th family dairy farm on the \( j \)-th day, \( t \); \( N_o \) is the number of family dairy farms within the territory of LSMH, units.

The volumes \( Q_{dxj} \) of milk harvesting from the \( x \)-th family dairy farms on the \( j \)-day during a season of harvesting are forecast based on known technique [25]. The durations of operations in the transportation processes of LSMH are determined based on the production observation that implies time-keeping [18].

To study the influence of production conditions at territorial LSMH on the parameters of SV fleet taking into consideration the changing volumes of transportation operations over a calendar year, we apply the developed simulation model of milk production management, which includes a set of interrelated technical-technological and organizational-technical subsystems, each of which adds value [26]. The proposed simulation model is composed of the following modules:

1) compilation of initial data for modelling;
2) simulation at the level of specific processes and determining the functional indicators for SV along separate routes;
3) modelling at the generalized level and determining the systemic functional indicators for SV.

The result of simulation modeling of transportation processes is the determined rational delivery routes based on known method [20]. This method provides for the selection of routes to transport milk from family dairy farms to the processing plant based on three major rules that take into consideration effectiveness \( E_{CA} \) of using SV within LSMH and the fund of a working SV regulated by the acting standards.

That makes it possible to identify such indicators of using SV for LSMH as the distance \( L_{dxj} \) traveled along the \( j \)-th route on the \( j \)-th day of milk harvesting, the duration \( t_{dxj} \) taken to travel along \( \mu \) routes, the freight turnover \( W_{dxj} \) on \( \mu \) routes.

The specified parameters make it possible to determine the required number \( N_o \) of SV of the predefined make for the \( j \)-th day during a milk harvesting season:

\[
N_o = \frac{\sum_{\mu=1}^{\mu} t_{dxj}}{t_{dxj}}, \quad \text{units}
\]

(4)

where \( t_{dxj} \) is the time taken by SV to travel the \( \mu \)-th route on the \( j \)-th day during a milk harvesting season; \( h \); \( [t_{dxj}] \) is the regulated duration of SV operation during day \( j \); \( h \); \( n_o \) is the number of routes traveled by SV on the \( j \)-th day, pieces.

The results obtained from determining the required number \( N_o \) of SV of the predefined make for \( j \) days during a milk harvesting season underlie the graph demonstrating the need in them (Fig. 1).

![Fig. 1. Trends in a change in the need in SVs \( (N_o) \) of the predefined make over a milk harvesting season and the durations \( (t_{dxj}) \) of periods with a constant need in them: \( Q_{dxj} \) – daily volume of milk harvesting within a territorial LSMH; \( t_1, t_2, \ldots, t_n \) – duration of the 1st, 2nd, and \( n \)-th period of milk harvesting](image)

The number of periods \( n_o \) with a constant need in SV during a separate season of milk harvesting, and their duration \( (t_{dxj}) \), depend on:

\[
t_o(Q_{dxj}, q_t) = f(Q_{dxj}, q_t),
\]

(5)

where \( Q_{dxj} \) is the daily volume of milk harvesting within a territorial LSMH; \( t \); \( q_t \) is the load capacity of SV, \( t \).

With respect to the stated earlier, one can argue about the possibility to objectively determine the need in CA, as well the
modes of their use, based on taking into consideration the changing patterns in production conditions within LSMH. To this end, it is necessary to predict the changing volumes of milk harvesting over a calendar year and to model transportation processes for each period during a milk harvesting season. That would enhance the accuracy of determining the indicators for using SV in LSMH. In order to investigate the influence of changing production conditions on the need in SV, one should use a database that is compiled from different sources. These include: territorial maps (Google maps geodata), volumes of milk production at the territory of LSMH, chronometric data on the duration of transportation operations (speedometers’ readings, time taken to perform individual operations, statistical data form forwarding documents), reported data on the availability of freight vehicles in LSMH.

3. The aim and objectives of the study

The aim of this work is to investigate the impact of the changing characteristics of production conditions and the components of transportation processes on the need and the modes of using SV for LSMH.

To accomplish the aim, the following tasks have been set:

– to explore the changing production conditions during milk harvesting and the duration of execution of certain transportation operations;
– to define the indicators for using SV with respect to the changing production conditions during milk harvesting and the duration of execution of transportation operations;
– to substantiate the need in SV and the modes of their utilization over a calendar year.

4. Results of investigating the changing production conditions during milk harvesting and the duration of execution of separate transportation operations

We investigated production conditions during milk harvesting using the example of LSMH, which is limited to the territory of the Brodovskiy Region, Lviv Oblast, Ukraine. The processing plant is in the town of Brody, which is a structural subdivision of PAT “Brodovskiy ZSZM”. Based on official documents from PAT “Brodovskiy ZSZM”, it was found that the Brodovskiy Region has 24 communities hosting the family dairy farms that produce milk. They are shown in the diagram of the territorial LSMH in Fig. 2.

The family-owned dairy farms, which are located at the territory of separate communities of the territorial LSMH are assigned the numbers, starting with two, in the order of increasing distances from them to the processing plant. Given the data on the existence and territorial location of family dairy farms in Brodovskiy Region, and using the geodata from Google maps for this administrative region, we determined distances between the settlements hosting the family dairy farms.

Based on known procedure [20], we predicted a daily volume of milk harvesting from the family dairy farms at separate communities in Brodovskiy Region over a calendar year. That allowed us to obtain data for each of 24 communities within LSMH about volumes of milk harvesting for specific days over a calendar year (the sample size is $v_0=53\times24=1,272$) (Table 1).

We verified extreme values for a variation series of the volumes of milk harvesting for their belonging to the sample based on the Irvine criterion, and tested the vicinity of empirical and theoretical distributions based on criterion $X^2$ (Chi-square, by Pearson) [20]. Based on the mathematical processing of statistical data on the estimated daily volume of milk harvesting from family dairy farms at the territory of separate communities, it was found that there are two periods of milk delivery – intensive (weeks 17–43 over a calendar year) and non-intensive (weeks 1 to 16 and 44 to 53 over a calendar year). It was established for the intensive and non-intensive periods over a calendar year that the distributions of daily volume of milk harvesting from family dairy farms are described by laws of the Weibull distribution (Fig. 3, 4); their respective statistical characteristics are given in Table 2.
## Table 1

### Results of predicting the daily volumes of milk delivery from the family dairy farms at separate communities in Brodovskiy Region over a calendar year

| Week of year | Sniatyn | Yurivka | Polovetska | Yavorivka | Hryvne | Sobkivka | Zbahyts | Verbivka | Stud-Markova | Podhorska | Poduchivka | Kiselova | Palkivka | Polonova | Pidkopa | Galekha | Markovka | Bykivka | Verbyts |
|--------------|---------|---------|------------|-----------|--------|----------|---------|----------|-------------|-----------|-------------|----------|----------|----------|---------|--------|----------|----------|---------|--------|
|              |         |         |            |           |        |          |         |          |              |           |             |          |          |          |         |        |          |          |         |        |
| 1            | 3       | 3       | 4          | 5         | 6      | 7        | 8       | 9        | 10          | 11        | 12          | 13       | 14        | 15       | 16      | 17       | 18       | 19      | 20      |
| 2            | 3       | 3       | 4          | 5         | 6      | 7        | 8       | 9        | 10          | 11        | 12          | 13       | 14        | 15       | 16      | 17       | 18       | 19      | 20      |
| 3            | 3       | 3       | 4          | 5         | 6      | 7        | 8       | 9        | 10          | 11        | 12          | 13       | 14        | 15       | 16      | 17       | 18       | 19      | 20      |
| 4            | 3       | 3       | 4          | 5         | 6      | 7        | 8       | 9        | 10          | 11        | 12          | 13       | 14        | 15       | 16      | 17       | 18       | 19      | 20      |

### Daily volume of milk delivery to the separate points of its harvesting, liters
Continuation of Table 1

| Indicator | Equation | Statistical characteristics |
|-----------|----------|----------------------------|
| Volume of milk harvesting during intensive period, l | \( f(Q_i) = 1 \cdot 10^{-3} \left( \frac{Q_i - 509}{2457} \right)^{0.569} \times \exp \left[ - \left( \frac{Q_i - 509}{2457} \right)^{1.964} \right] \) | 2.716 | 266 |
| Volume of milk harvesting during non-intensive period, l | \( f(Q_i) = 7 \cdot 10^{-3} \left( \frac{Q_i - 46}{246} \right)^{0.646} \times \exp \left[ - \left( \frac{Q_i - 46}{246} \right)^{1.964} \right] \) | 1.429 | 136 |

Notes: \( \mu[Q_i] \) and \( \sigma[Q_i] \) are, respectively, the mathematical expectation and the standard root mean square deviation in the volume of milk harvesting over the i-th period, l; 509, 46 are, respectively, the minimum value of the estimated daily volume of milk harvesting from family dairy farms at the territory of separate communities during the intensive and non-intensive periods in a calendar year; 2,457, 246 is, respectively, the measure parameter for the intensive and non-intensive periods of using SV.

The main statistical characteristics for distributions of the estimated daily volume of milk harvesting from family dairy farms at the territory of separate communities in Brodivskyi Region for the intensive (Fig. 3) and non-intensive (Fig. 4) periods of using SV are as follows: the coefficient of variation is 0.63 and 0.62; a shape parameter is 1.56 and 1.64. The confidence interval is, respectively, 509...6,995 and 46...634 l. We have derived the estimated values for criteria \( X^2 \) compared with the tabular values \( \left( X^2 \right)^* \) for distributions of the estimated daily volume of milk harvesting from family dairy farms at the territory of separate communities during the intensive and non-intensive periods of using SV. They are, respectively, \( \left( X^2 = 0.71 \right) \times \left( X^2 = 4.6 \right) \) and \( \left( X^2 = 0.89 \right) \times \left( X^2 = 3.2 \right) \). That indicates that the theoretical curves in the Weibull distributions adequately reflect empirical data on the estimated daily volume of milk harvesting from family dairy farms at the territory of separate communities during the intensive and non-intensive periods of using SV.
Accordingly, the estimated daily volume of milk harvesting from family dairy farms, as well as the dependence of the total annual duration of SV operation on their load capacity [19], allow us to determine their number for a predefined make. For the further research we selected the SV Hyundai HD-65 STD+G6-OTA-3.9, which are used in the existing LSMH at Brodivskyi Region.

Based on timekeeping (using a stopwatch and by monitoring the SV Hyundai HD-65 STD+G6-OTA-3.9) of certain transportation operations, we determined specific duration of loading milk into SV, including the issuing of forwarding documents at separate family dairy farms. We similarly determined specific duration of unloading milk from SV at a processing plant and the average motion speed between the settlements within LSMH. The data on the duration of separate transportation operations, acquired experimentally, using the SV Hyundai HD-65 STD+G6-OTA-3.9, are given in Table 3.

The result of mathematical processing of the obtained experimental data (Table 2) is the constructed distributions of specific duration of loading and unloading the SV Hyundai HD-65 STD+G6-OTA-3.9. It has been established that they are described by laws of the Weibull distribution (Fig. 5).

Table 3

| Indicator                      | Quantitative value |
|-------------------------------|--------------------|
| Specific duration of loading SV, h/t | 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 |
|                               | 0.07 0.07 0.07 0.07 0.07 0.07 0.07 0.07 0.07 0.07 0.07 0.07 |
|                               | 0.08 0.08 0.08 0.08 0.08 0.08 0.08 0.08 0.08 0.08 0.08 0.08 |
|                               | 0.09 0.09 0.09 0.09 0.09 0.09 0.09 0.09 0.09 0.09 0.09 0.09 |
|                               | 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 0.1 |
|                               | 0.11 0.11 0.11 0.11 0.11 0.11 0.11 0.11 0.11 0.11 0.11 0.11 |
|                               | 0.12 0.13 0.13 0.13 |

Table 4

| Indicator                      | Equation | Estimates of statistical characteristics |
|-------------------------------|----------|------------------------------------------|
| Specific duration of loading SV, h/t | \( f(t) = 49,502 \left( \frac{t - 0.06}{0.036} \right)^{0.804} \times \) \( \exp \left[ -\left( \frac{t - 0.06}{0.036} \right)^{0.804} \right] \) | 0.092 0.018 |
| Specific duration of unloading SV, h/t | \( f(t_{\text{un}}) = 119,434 \left( \frac{t_{\text{un}} - 0.38}{0.015} \right)^{0.842} \times \) \( \exp \left[ -\left( \frac{t_{\text{un}} - 0.38}{0.015} \right)^{0.842} \right] \) | 0.052 0.008 |

The basic statistical characteristics for the distributions of specific duration of loading the SV Hyundai HD-65

![Fig. 5. Distribution of specific duration of loading milk to the road tanker Hyundai HD-65 STD+G6-OTA-3.9](image)

![Fig. 6. Distribution of specific duration of unloading of the road tanker HD-65 STD+G6-OTA-3.9 at a processing plant](image)
STD+G6-OTA-3.9 at family dairy farms and their unloading at a processing plant are, respectively, as follows: the coefficient of variation is 1.57 and 1.61; the measure parameters are 0.036 and 0.061; shape parameters are 1.66 and 1.8. Confidence interval is, respectively, 0.006...0.16 and 0.038...0.072 h/t. We have derived the estimated values for criteria $X^2$ compared with the tabular values ($X^*_T$). For the distributions of specific duration of loading, at family dairy farms and unloading at a processing plant, the SV Hyundai HD-65 STD+G6-OTA-3.9, they are, respectively, $\{X^2 = 1.92\} < (X^*_T = 7.78)$ and $\{X^2 = 0.81\} < (X^*_T = 6.25)$. This indicates that the obtained theoretical curves for the Weibull distribution adequately reflect the empirical data on specific duration of loading at family dairy farms, and unloading at a processing plant, the SV Hyundai HD-65 STD+G6-OTA-3.9.

Based on keeping the time of operations in the transportation processes of milk harvesting, which involves using the SV Hyundai HD-65 STD+G6-OTA-3.9, we acquired data on their technical motion speed ($V_p$). That allowed us to substantiate the theoretical law of the distribution of technical motion speed ($V_p$) of the SV Hyundai HD-65 STD+G6-OTA-3.9 (Fig. 7).

Fig. 7. Distribution of technical motion speed ($V_p$) of the SV Hyundai HD-65 STD+G6-OTA-3.9

By processing the obtained statistical data in a similar fashion, we have established that the technical motion speed ($V_p$) of the SV Hyundai HD-65 STD+G6-OTA-3.9 is represented by a theoretical law of the Weibull distribution, which is described by the following equation:

$$f(V_p) = 0.18 \left( \frac{V_p - 25.1}{10.315} \right)^{0.67} \times \exp \left[ - \left( \frac{V_p - 25.1}{10.315} \right)^{0.67} \right]. \quad (6)$$

The basic statistical characteristics for the distribution of technical motion speed ($V_p$) of the SV Hyundai HD-65 STD+G6-OTA-3.9 are as follows: the estimate of mathematical expectation is 34.15 km/h, the estimate of root mean square deviation is 5.05 km/h, the coefficient of variation is 1.55, the measure parameters and a shape parameter are 10.31 and 1.87. The confidence interval is 25.1...46.16 km/h.

We have derived the estimated values for criteria $X^2$ compared with the tabular values ($X^*_T$). For the distribution of technical motion speed ($V_p$) of the SV Hyundai HD-65 STD+G6-OTA-3.9, they are, respectively, $\{X^2 = 2.96\} < (X^*_T = 7.78)$. This indicates that the obtained theoretical curve for the Weibull distribution adequately reflects the empirical data on technical motion speed ($V_p$) of the SV Hyundai HD-65 STD+G6-OTA-3.9.

The obtained numerical values for the indicators of using SV to transport milk demonstrate the possibility to employ them in order to model transportation processes for each period of milk harvesting and to establish trends in a change in their functional indicators.

5. Results of determining the indicators of using specialized vehicles

In order to study the impact of production conditions within territorial LSMH on the need in SV over a calendar year, taking into consideration the changing volumes of transportation operations, we performed simulation modeling of the respective processes. The developed simulation model of transportation processes, which was reported in paper [20], was tested for adequacy based on the paired t-criterion. While checking its adequacy, we compared the experimental and simulated values for the duration of separate routes traveled by the road tanks SV Hyundai HD-65 STD+G6-OTA-3.9. It was established that the deviation of the derived quantitative values for the duration of separate routes based on the simulation of transportation processes from their values obtained experimentally does not exceed 3.7 %. This indicates the adequacy of the applied simulation model of transportation processes within LSMH.

That allowed us to determine the following parameters: a total number of completed routes ($N_r$); total distance ($L_r$) traveled by the SV Hyundai HD-65 STD+G6-OTA-3.9; duration ($t_r$) of utilizing the SV during milk delivery from family dairy farms to the processing plant; their cargo turnover ($W_r$); fuel consumption ($\psi_r$); need in SVs ($N_r$).

The result of simulation modeling of transportation processes within LSMH is the derived quantitative values for indicators of using the SV Hyundai HD-65 STD+G6-OTA-3.9. Based on these data, and by employing the statistical software Statistica, we built dependences of the estimation of mathematical expectation for the daily number of completed routes $M[N_r]$; traveled distance $M[L_r]$; duration of use $M[t_r]$ and cargo turnover $M[W_r]$ of the SV Hyundai HD-65 STD+G6-OTA-3.9 on the daily volume ($Q_d$) of milk harvesting. That allowed us to derive equations of the specified dependences, given in Table 5.

Table 5

| Indicator                                                                 | Equation                          |
|--------------------------------------------------------------------------|-----------------------------------|
| Estimate of mathematical expectation of the total daily number of completed routes $M[N_r]$, units | $\bar{N}_{\bar{X}} = -0.254 - Q_d - 0.633$, $r = 0.98$ |
| Estimate of mathematical expectation of the total daily mileage of $M[L_r]$, km | $\bar{M}_{\bar{L}} = 754.241 + 21.725 - Q_d - 156.577 - 9.69 - 10$, $Q_d - 1.51$, $Q_d + 9.365$, $q_r = 0.82$ |
| Estimate of mathematical expectation of the total daily duration of using SV $M[t_r]$, h | $\bar{M}_{\bar{t}} = 20.822 + 0.754 - 4.41 - 3 - 10$, $Q_d - 4.19 - 10$, $Q_d - 0.258$, $q_r = 0.86$ |

The dependences derived indicate that an increase in the daily volume ($Q_d$) of milk harvesting within the territorial LSMH leads to an increase in the estimates of mathematical
expectation of the total daily number of completed routes \( M[N] \) in line with a linear dependence. The mileage \( M[L] \) of road tanks and the duration \( M[r] \) of their utilization, when a daily volume of milk harvesting grows, increase according to the polynomial dependences of second power. In the obtained dependences, the correlation ratio is within 0.82...0.98, indicating a strong interrelation between the indicators of transportation processes and the daily volume \( (Q_d) \) of milk harvesting from family dairy farms within territorial LSMH.

The result of simulation modeling of transportation processes is the derived quantitative values for cargo turnover \( (W) \) of the SV Hyundai HD-65 STD+G6-OTA-3.9 for different values of daily volumes \( (Q_d) \) of milk harvesting from family dairy farms within territorial LSMH. Their respective dependence, constructed by employing the Microsoft Excel software, allowed us to establish that the achieved cargo turnover \( W \) changes partially discretely at an increase in the daily volume \( (Q_d) \) of milk harvesting from family dairy farms within territorial LSMH (Fig. 8).

Discrete character of the cargo turnover achieved by the road tankers Hyundai HD-65 STD+G6-OTA-3.9 is predetermined by a change in the technological need in their quantity (1 to 4 units) under condition of fulfilling the predefined amount of transportation operations.

6. Results of determining the need in specialized vehicles and the modes of their utilization

Based on the obtained quantitative values for the indicators of using the road tanks, we determined the need in them. Processing the data acquired by employing the Microsoft Excel software has allowed us to build a dependence of the estimates of mathematical expectation of the need \( M[N] \) in the road tanks Hyundai HD-65 STD+G6-OTA-3.9 on the specific day during a milk harvesting season (Fig. 9) and the dependence of need in them \( M[N] \) on the annual volume \( (Q_d) \) of milk harvesting (Fig. 10).

The dependences obtained indicate that the need in road tanks discretely changes over a calendar year, depending on a change in the volume of the completed transportation operations. Specifically, the estimate of mathematical expectation of need \( M[N] \) in road tanks depends on the annual volume \( (Q_d) \) of milk harvesting within the territory of LSMH. A growth of the annual volume \( (Q_d) \) of milk harvesting from 5 to 65 t leads to a discrete increase in the need in road tanks, from 1 to 4.

Based on Fig. 9, 10, one can argue that during the intensive period of transportation operations, which lasts from May to September with a single calendar year, transportation processes should be organized in two working shifts. In this case, the need in SV changes from 1 to 2 units. During the non-intensive period, which lasts from January to March and from October to December within a separate calendar year, transportation processes should be organized in a single working shift. The need in SV during this period varies from 2 to 4 units.

The application of the proposed approach to determining the number of SV for separate LSMH, as well as the modes of their utilization, ensures meeting the acting requirements to transportation processes, which largely affects the quality of the harvested raw materials and, accordingly, the quality of production of dairy products.

7. Discussion of results of studying the impact of production conditions on the need in specialized vehicles

The study that we conducted into the influence of changing production conditions and the components of transportation processes on the need in SVs are based on the approach that eliminates the disadvantages of the existing ones. Specifically, this approach takes into consideration the changing production conditions within LSMH and implies
the prediction of changing amounts of milk harvesting over a calendar year. A given approach implies taking into consideration the changing components of duration of transportation operations, as well as the simulation of transportation processes, in order to determine indicators for using road tanks. These indicators underlie our determining the need and modes of road tanks utilization over a calendar year.

The main disadvantage of the proposed approach and the conducted study is that it implies performing specific and labor-consuming experiments to determine the characteristics of production conditions and the components of transportation processes. However, in the future, development of a decision support system for LSMH will facilitate compiling a database and processing the results of experimental research into the changing production conditions and the components of transportation processes. In addition, the availability of such an information system would make it possible to accelerate a decision-making process on determining the need in, as well as the modes of utilization of, road tanks over a calendar year, and would improve their accuracy.

The results obtained when studying the changing volumes of milk harvesting allowed us to establish the existence and the duration of two periods of transportation operations that formed the basis for determining the modes of SV utilization. It was found that the duration of separate transportation operations that are described by laws of the Weibull distribution (Table 4), as well as the experimentally investigated trends of change in the volumes of milk harvesting for each community (Fig. 3, 4), are the initial data for simulating transportation processes within LSMH.

The simulation of transportation processes has made it possible to determine the indicators of SV utilization (Table 5). It was established that the turnover of SVs changes discretely from 820 to 4,610 t·km at an increase in the daily volume of milk harvesting from family dairy farms from 6 to 66 tons/day within territorial LSMH. Discrete character of the achieved turnover is predetermined by a change in the technological need in the number (1 to 4 units) of SV Hyundai HD-65 STD+G6-OTA-3.9 to perform the predefined volume of transportation operations.

The established trends in a change in the need in SVs (Fig. 9, 10) are the basis to substantiate the optimal utilization modes of these road tanks within separate territorial LSMH. The established durations of periods with the constant demand for SVs, shown in Fig. 9, allowed us to determine the duration of periods for the one-shift and two-shift organization of transportation processes within a calendar year. For the intensive period of transportation operations, which lasts from May to September within a single calendar year, transportation processes should be organized in two working shifts. For the non-intensive period, which lasts from January to March and from October to December within a separate calendar year, a one-shift work would suffice. The need in the SV Hyundai HD-65 STD+G6-OTA-3.9 over specified periods changes, accordingly, from 1 to 2 units and from 2 to 4 units. The results of our research underlie determining the cost-related indicators for transportation processes. They form the basis for planning the need in resources for the functioning of LSMH and are applied for designing the specified systems.

The study that we performed is useful for managerial staff that plan the operation of LSMH, as well as design them. The substantiated patterns of change in the need in SVs could speed up decision making and improve its accuracy. Further research in this field should be conducted to address the development of a decision support system for LSMH, which would make it possible to substantiate the need in SVs with various cargo capacity under different production conditions (separate regions of different countries). That would make it possible to optimize the SV parameters for separate territorial LSMH and to devise recommendations regarding their design.

8. Conclusions

1. The investigated production conditions of milk harvesting have allowed us to predict the changing volumes of milk harvesting over a calendar year and to establish the existence and duration of two characteristic periods while performing transportation operations. It was established that the intensive period of transportation operations lasts from May to September within a single calendar year, while the non-intensive period has two half-periods, which last, respectively, from January to March and from October to December within a single calendar year. The production experiments that we performed have made it possible to determine the duration of execution of transportation operations and to substantiate their distributions. It was established that specific durations of loading and unloading the road tanks SV Hyundai HD-65 STD+G6-OTA-3.9 are described by laws of the Weibull distribution.

2. Based on the examined changing production conditions for milk harvesting and the duration of execution of transportation operations within the specified administrative territory, we have performed the simulation of transportation processes. That has made it possible to determine the key performance indicators (number of routes traveled, duration of tank utilization, mileage, and cargo turnover) for using road tankers. It was established that they do change. An increase in the daily volume of milk harvesting within territorial LSMH leads to an increase in the estimates of mathematical expectation of the total daily quantity of routes traveled, in line with a linear dependence, while the mileage and duration of using the road tanks SV Hyundai HD-65 STD+G6-OTA-3.9 are described by the polynomial dependences of second power. The cargo turnover changes discretely from 820 to 4,610 t·km at an increase in the daily volume of milk harvesting from family dairy farms from 6 to 66 tons/day within the predefined territory, we have performed the simulation of transportation processes. In the derived dependences, the correlation ratio varies within 0.82...0.98, indicating a strong interrelation between the indicators for transportation processes and the daily volume of milk harvesting.

3. Based on the derived indicators for using the road tanks Hyundai HD-65 STD+G6-OTA-3.9, we determined the need in them for each period during a milk harvesting season. It was established that the need in the road tanks Hyundai HD-65 STD+G6-OTA-3.9 during the intensive and non-intensive periods of transportation operation varies from 1 to 2 units and from 2 to 4 units. During the intensive period, transportation processes should be organized in two working shifts, and during the non-intensive period, in one shift.

4. Further research should be carried out to address the development of a decision support system for LSMH. That would make it possible to assess the need in road tanks of various cargo capacity for the assigned production conditions (or regions in different countries), which forms the basis for the optimization of parameters for a fleet of road tanks for regions of different countries.
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1. Introduction

Transportation process plays an important role in forming the added value to goods, which necessitates the minimization of the negative impact of this process on the final price of a product. One variant to resolve this issue is to search for a rational mode of transportation or their combination [1, 2], which is an effective measure at the stage of trunk line (long-haul) transportation in the supply chain. Servicing the trunk line (long-haul) transporting flows requires the rational location of terminals with the appropriate handling capabilities [3, 4] and the description of a delivery