Technical-economical indicators in the sugar beet transportation management

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Abstract

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Work deals with the transportation and manipulation of sugar beet from storages to sugar refineries. The aim is evaluation of sugar beet transport organization and further transport suggestion and way of its organization in order to minimize transported material costs per unit. The aim attainment is reached by setting up mathematical model necessary for creating the lines for sugar beet transport and their comparison in term of unit costs is made. Result of this work is model of transportation process according to individual variants and object is vehicles efficiency determination, unit costs per ton of transported sugar beet, number of vehicles, number of cleaning loaders providing the adjustment of sugar beet transportation to sugar refinery absorptive capacity and the traffic situation in sub-region of the relevant sugar refinery.

Keywords: transportation; manipulation of the sugar; sugar beet transport; mathematical model

Progressing devastation of the environment doubtless belongs among the most serious problems of current life. Air pollution is also one of the factors. Transportation has a significant influence on the undesirable waste production, with approximately 13–20% share on the air pollution, depending on the motorization. Nowadays, it does not concern only pollution of the surroundings, it means the global damage of the environment.

According to Novák et al. (2009), transportation is an inevitable part of every production process that does not change product utility value, but increases the costs. In the conditions of Czech agriculture, approximately 35% of diesel fuel consumption is consumed for the manipulation, loading, reloading, storage and transportation and represents 50–70% of the variable costs (Syrový et al. 2008, Skalický 1994).

Considering the fact of 90% goods transportation is realized by vehicles consuming oil at present, it represents an enormous potential. Besides, there are many vehicles with diesel engine that could also use bio-oil. The amount of these vehicles is 15–40% in EU countries. Due to the intensive growth of the agricultural production and food overproduction, the governments of the economically and technically developed countries started to support farmers in the transition to oil crops growing suitable for the bio-oil production (Jablonický et al. 2009; Müllerová et al. 2009).

Effectiveness of using such machinery will definitely depend on the perfection of harmonization of technical, exploitative, efficiency and economical parameters of all elements integrated into the system of individual machine lines used in the mechanized systems of the specific products production.

Object of the work

Future development of the agriculture mechanization will be definitely connected with the more efficient technical means, higher utility value and

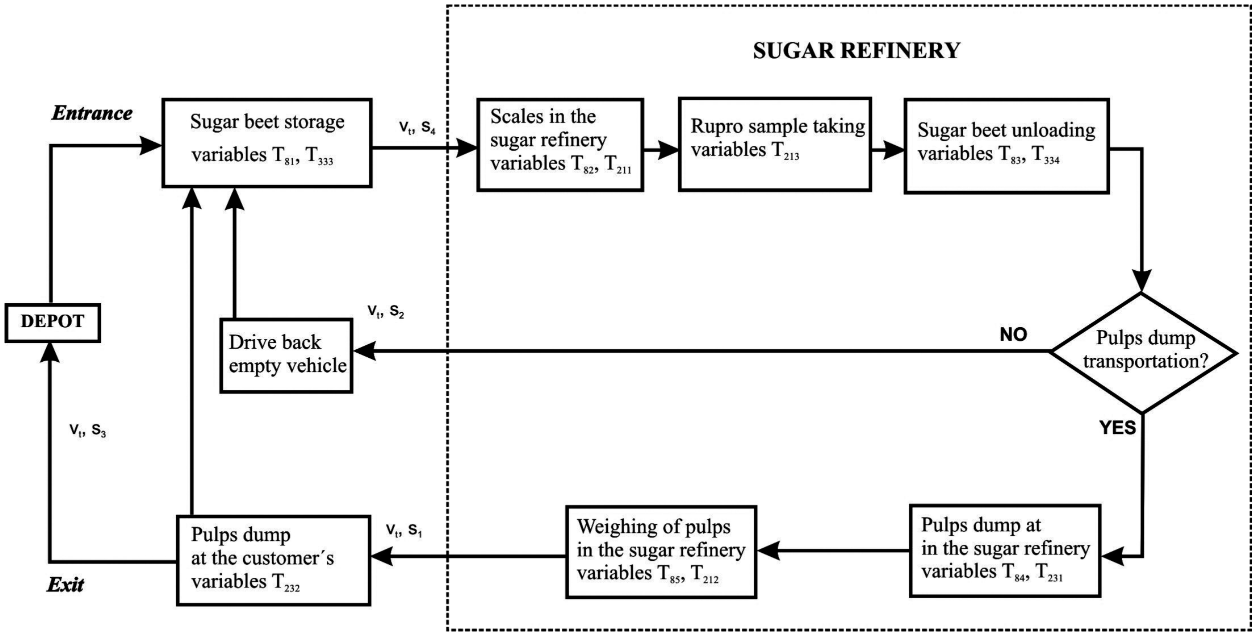

Fig. 1. Model of the material flow

technical level of which will be reflected in higher acquisition prices. Effectiveness of the sugar beet loading, cleaning and transportation turned to be a strong factor influencing production costs of sugar in the last years (Ružbarský 2002; Žitňák, Jech 2003).

Money is motive power of the world economy therefore result of this work is transportation systems with the lowest unit costs per transported material unit. It is necessary to realize, that the effectiveness of new and expensive transportation machinery resides in the high annual utilization. Annual utilization can be achieved only in the conditions of extra business utilization by the form of services. Efficiency is important in the agricultural transportation. High transportation efficiency is a guarantee of the costs per production unit decrement. Therefore it is necessary to analyze the basic factors influencing the efficiency of vehicles in agricultural companies.

Object of the project is:

a) to realize experimental measurements at sugar beet loading and evaluate the efficiency of selected cleaning loaders,
b) to realize experimental measurements at sugar beet transportation in the individual sugar refineries,
c) to evaluate measured results, propose the type of transportation and way of its organisation for the individual companies including the vehicles in order to costs per transported material unit decrement as possible.

MATERIAL AND METHODS

Object attainment is reached by a general scheme creation of the transport system optimization (Fig. 1). Using of machinery takes an important place among the factors influencing the efficiency of machinery sets. Therefore the objective machine evaluation during the work shift gets a great importance. A comparable time base, it means a certain obligatory division of the total machine operating time, is a condition of such evaluation. Method of time pictures according to STN 47 0120 (1987) is applied for accomplishing the comparable time base. Measured values are registered into observation form (Table 1). Following vehicles and cleaning loaders are used in experiments: Tatra 815 + PS2 17.12, Liaz 150 + PS2 17.12, Tatra 815 + NS2 29.23.20, Liaz 24 + NS2 29.21.20, loaders UNK 320, cleaning loader THYREGOD TR5 a self-propelled loader ROPA L8.828 (ROPA Fahrzeug- und Maschinenbau GmbH, Herrngiersdorf, Germany).

Evaluation of the service load of sets usage

Use of the service load of vehicles means the ability of vehicle to transport the weight of load equal to effective weight (load capacity, service load) of vehicle. This value is practically given by dimensions of the loading space and it is important in the agriculture because of mainly lighter materials transportation.

Table 1. Measured times at the sugar beet transportation

Name	Operation	Units
T_{11}	drive time to the pulp and sludge dump	min
T_{12}	drive time from the sugar beet storage to the sugar refinery	min
T_{211}	sugar beet weighing time in the sugar refinery	min
T_{212}	pulp or sludge weighing time	min
T_{213}	time of the sample taking – RIPRO	min
T_{221}	drive time from the pulp dump to the sugar beet storage	min
T_{222}	drive time from the sugar refinery to the sugar beet storage	min
T_{231}	pulp or sludge loading time	min
T_{232}	pulp or sludge discharge time	min
T_{233}	loading time at the sugar beet storage	min
T_{234}	sugar beet tilting time in the sugar refinery	min
T_3	time to prepare a machine for the operation	min
T_{421}	breakdown time during the drive from the pulp dump to the sugar beet storage	min
T_{422}	breakdown time during the drive from the sugar beet storage to the sugar refinery	min
T_{81}	downtime at the sugar beet storage	min
T_{82}	downtime before the weighing at the sugar refinery	min
T_{83}	downtime before the sugar beet tilting in the sugar refinery	min
T_{84}	downtime before the pulp or sludge loading in the sugar refinery	min
T_{85}	downtime before the pulp or sludge weighing	min
m_1	weight of the delivered sugar beet	t
m_2	weight of the pulp and sludge driven away	t
s_1	distance of the pulp dump from the sugar refinery	km
s_2	distance of the pulp dump from the sugar beet storage	km
s_3	distance of the sugar refinery from the sugar beet storage	km
s_4	distance of the sugar beet storage from the sugar refinery	km
v_t	technical speed of the set	km/h
	vehicle	type
	number of drives per total time of measurement	
T_s	total time of measurement	min

Attention is paid to weight of load (m, t) from the aspect of the loading capacity of vehicle (V, m^3) and bulk weight of load (ρ, t/m^3).

$$m = V \times \rho \times \lambda \quad \text{(t)} \qquad (1)$$

where:
λ – coefficient of the use of the loading capacity

By expressing the load weight (m) as a conjunction of service weight (N) and coefficient of weight usage (γ):

$$m = N \times \gamma \quad \text{(t)} \qquad (2)$$

The following cases may occur:

$\gamma > 1$, vehicle is overloaded,
$\gamma < 1$, service weight of the vehicle is not used,
$\gamma = 1$, vehicle is optimally used.

Characteristics of formalized model of the sugar beet transportation:

(1) acquiring data for the mathematical model:
 (a) using time pictures,
 (b) from the literature,
 (c) from the producers of vehicles,
(2) statistical evaluation of measured data,
(3) test of individual variables by the chi-square (χ^2) test with aim to determine distribution function for individual variables in the mathematical model.

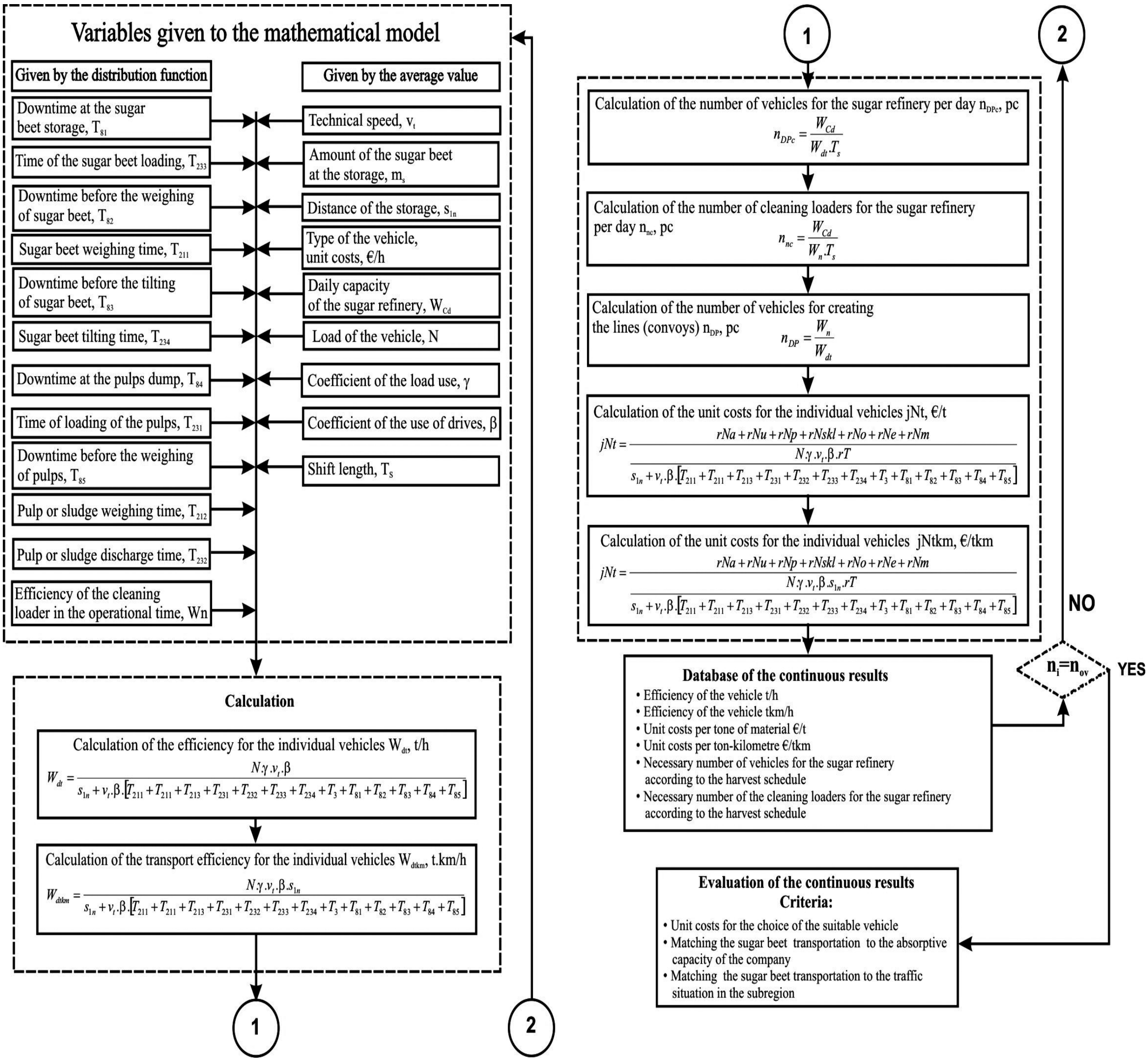

Fig. 2. Mathematical model of the sugar beet transportation from the storages to the sugar refinery

Table 2. Example of statistical evaluation of mathematical model results for unloading distance of 21 km and automobile Tatra 815 + trailer with cuttings transfer

	Efficiency MT v t/h with cuttings	Efficiency MT (t km/h)	Costs (€/t)	Costs (€/t km)
Average value	17.1435896	360.0153817	2.198782182	0.104704
Median	17.29174529	363.1266511	2.159314024	0.102824
Standard deviation	3.467286817	72.81302316	0.302168197	0.014389
Dispersion of selection	12.02207787	5301.736342	0.091305619	0,000207
Minimum	7.504521022	157.5949415	1.539930698	0.07333
Maximum	27.50594104	577.6247619	3.66998045	0.174761
Number of generated values	3,000	3,000	3,000	3,000

MT – means of transport

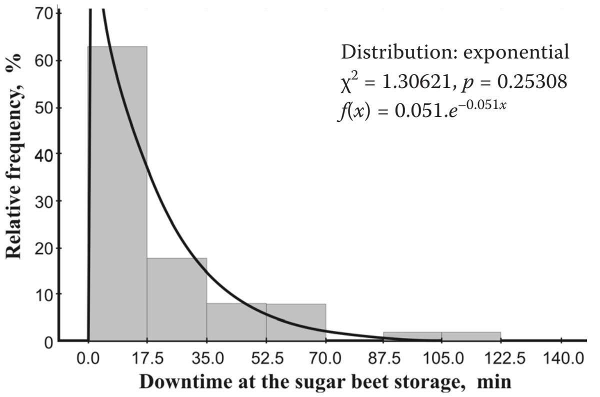

Fig. 3. Time T_{81} – downtime of the vehicles at the sugar beet storage (min)

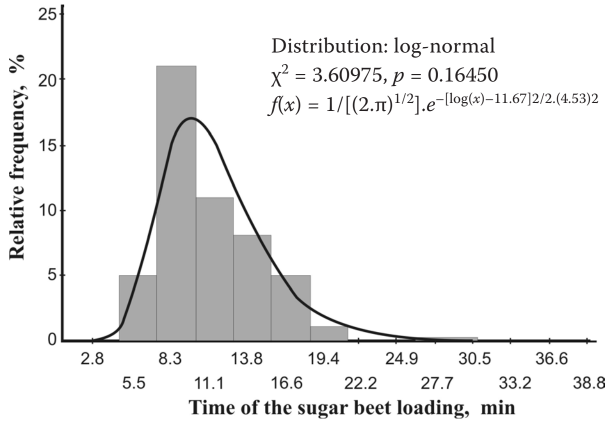

Fig. 4. Time T_{233} – loading of the sugar beet at the storage (min)

An exact criterion to qualify accordance of the theoretical division with the division of experimentally acquired data is χ^2 test. The χ^2 coefficient value is calculated and the higher value of criterion is, the less theoretical division suites the empiric division. Object of the test is to find a suitable theoretical model for our data from the list of divisions (beta, χ^2, exponential, F, gamma, logonormal, normal, uniform, Weibul's). Directly derived criterion from the χ^2 criterion is a significance level, when lower then 0.05, it indicates absence of good accordance. For the individual variables are calculated a χ^2 test criterion, significance level and showed an analytic expression of the function:

(1) graph of measured parameters by histograms translated by the distribution function,
(2) assignment of the distribution function to generator of the pseudo-random numbers,
(3) entering of random numbers to the mathematical model of the line for cleaning, loading and transportation of sugar beet roots,
(4) model of transportation process according to the individual variants with aim to determine the efficiency of sets t/h, transported sugar beet unit costs/t, number of vehicles, number of cleaning loaders.

MS Excel and StatGraphics software (Statpoint Technologie, Inc., Virginia, USA) is used for the graphical processing and mathematical-statistical evaluation of all results. Created mathematical model is used for the calculation of unit costs €/t and €/t km.

RESULTS AND DISCUSSION

Evaluation of time operation structure of the assessed transportation sets

We observed the sugar beet transportation from the storage to sugar refinery in the prolonged shifts for six days. For objective transport evaluation, we

Table 3. Example of statistical evaluation of mathematical model results for unloading distance of 21 km and automobile Tatra 815 + trailer without cuttings transfer

	Efficiency (t/km)	Efficiency (t km/h)	Costs (€/t)	Costs (€/t km)
Average value	16.05797328	337.2174	2.464586	0.11736123
Median	16.22257679	340.6741	2.436214	0.11601021
Standard deviation	3.037361604	63.78459	0.304809	0.014514737
Dispersion of selection	18.3340967	385.016	2.12112	0.101005705
Minimum	7.198806443	151.1749	1.805997	0.08599988
Maximum	25.53290315	536.191	3.927117	0.187005585
Number of generated values	3,000	3,000	3,000	3,000

took time pictures of all working operations connected with the transportation of sugar beet to sugar refinery including the transportation of the sugar beet pulps from sugar refinery, which serve for creation of the mathematical model of the transport system of sugar beet (Fig. 2). We tested individual variables by the χ^2 test with the aim to determine distribution function for the mathematical model.

Times measured at the sugar beet storage

Time measurement was done at the sugar beet storages. We registered downtimes of vehicles before the sugar beet loading and the loading time of transport sets to prepared table. In a period of time measurement for removal or reduction of the unwanted impurities (clay) in the transported sugar beet, sugar refinery was using the cleaning loaders Thyregod (Thyregod, Give, Denmark) and Holmer (Holmer, Schierling, Germany). Sugar beet roots are cleaned at the loading directly at storages. We tested the measured downtimes and loading time by the χ^2 test to determine the theoretical division of measured values probability. Further we calculated the average time of vehicle downtime before the loading (T_{81} = 19.99 min), average time of the loading of vehicle (T_{233} = 11.67 min). Downtime of vehicles before the loading is shown in Fig. 3. Measured values are expressed by histogram, theoretical division, χ^2 test value and significance level. Loading times of the transportation sets are shown in Fig. 4. Downtimes over the average were caused by the cleaning loader breakdowns and insufficient work organisation (the late arrival of cleaning loader to the storage created the long lines at loading place which caused the higher downtimes). Loading times over the average were caused by the breakdowns of cleaning loaders and insufficient efficiency of the front loader. It is important at the loading, that the line front loader + cleaning loader are efficiently synchronized. The higher soil humidity the more slips of the loader tires occur and its efficiency declines.

Times measured at the entrance to the sugar refinery

At the sugar refinery reception, we noted in the sense of methodology the downtime of transportation set before weighing, time of set weighing and time of sugar beet sample taking to the prepared table. Based on the measured times, we calculated the average downtime of the set before weighing, weighing time and time of the sample taking. We tested the measured values by χ^2 test.

Average downtime before weighing was T_{82} = 2.55 min. This time is technically necessary for replacement of vehicles on scale. Entry place of the sugar refinery was equipped with two parallel weighing scales. Downtimes over the average were caused by arrival of more than two vehicles at the same time.

Average weighing time was T_{211} = 1.93 min. Increased times were caused by delay of driver when taking the weighing ticket. Here, the time necessary for weighing of set could be shortened to the minimum by adequate technical solutions. Average time of taking the sample was T_{213} = 1.92 min. The time is necessary concerning technical side of taking the sample.

Sugar beet samples are taken from every storage, one sample from every fourth set. The sample is marked by bar code and together with the purchase ticket sent for the analysis.

Downtimes before the tilting and times of tilting the sugar beet can be reduced by the automatic opening side forms and creating the suitable conditions for drive-in and easy drive-out of vehicles.

Evaluation of the sugar beet roots transportation

Currently, costs of sugar beet roots transportation from the storages to the sugar refinery quantify the sugar refineries for thousands of €. For the costs causes of transportation increment can be considered the fuel price increment, road tax increment, road-toll implementation, insufficient use of the service load for vehicles etc.

Experimental basic variables influencing transportation process given by the distribution function as well as constants was acquired for creation of a probabilistic model of solution of the sugar beet transportation process from the storages to sugar refinery. Methodological procedure based on the results from field measurements with the following simulation of calculation by the mathematical model was used for the calculation. We will simulate the sugar beet transportation process by the generation of random numbers according to distribution functions. The result of generation of 3,000 values

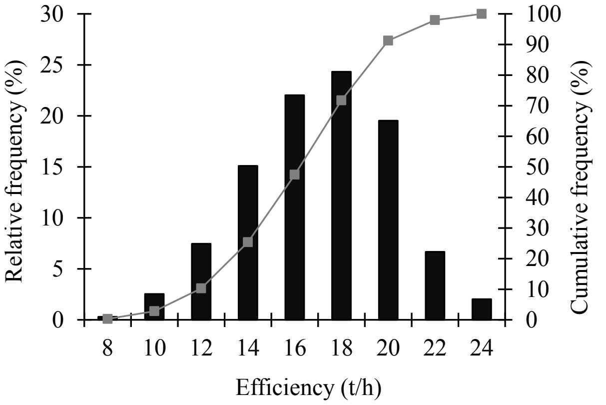

Fig. 5. Distribution of the efficiency of Tatra 815 + trailer at the distance of 21km

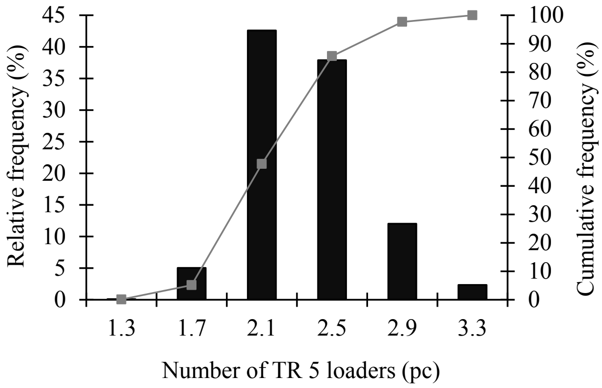

Fig. 6. Number of loaders necessary for loading at the capacity of the sugar refinery of 3,000 t/day

for every variable will be the efficiency of the set t/h, efficiency t km/h price per transported tone of sugar beet, number of loaders and vehicles.

Example of statistical evaluation of modelling results is in Table 2 and 3.

Example of graphical evaluation of modelling is on the Figs 5–7.

After modelling the efficiency parameters are mostly in range of 15–19 t/h. We can expect value 15.84 t/h calculated in the static model with the probability of 22%. Value calculated statically from the given variables and higher efficiency can by expected at 52.57% and the risk, that the efficiency will be lower is 47.43% (Fig. 5).

The most often values in Fig. 5 are in range of 15–19 pc. The value 15.5 calculated in the static model can be expected with probability of 21.2%. The value statically calculated from the given variables and the risk of higher number of vehicles can be expected at 77% and the lower number of vehicles can be expected at 23%.

The result of modelling need of loaders THYREGOD TR 5 for the sugar refinery with the capacity of 3,000 t daily at 12-hour transport is shown in Fig. 6. The most often value is in range of 0.8–2.3 pc.

At the suggestion of 2 pc the time of transport could be prolonged. In case of breakdown the sugar refinery would have to have further loaders as back-up.

One of the variables, which affect the line efficiency the most, is subservient load. Real service weight of vehicles and constructive service weight are compared for vehicles transporting the sugar-beet.

- Vehicle Liaz 150 with the semitrailer NS2 29.21.20, with the construction service weight of 21,000 kg, reached the real average weight of the transported load for observed period of 19,330 kg.
- Vehicle Liaz 150 with the trailer PS2 17.12, with the construction service weight of 21,250 kg, reached the real average weight of transported load for observed period of 20,900 kg.
- Vehicle Tatra 815 with the semitrailer NS2 29.23.20, with the construction service weight of 23,000 kg, reached the real average weight of the transported load for the observed period of 18,200 kg.
- Vehicle Tatra 815 with the trailer PS2 17.12, with the construction service weight of 27,750 kg, reached the real average weight of transported load for observed period of 22,870 kg.
- From the above mentioned the service weight usage of the vehicles was 84–97%. The amount of losses caused by the unused service weight in total measure represents not small financial losses for the sugar refinery.
- Service load usage can be realised only by the construction of the suitable extensions. Concerning the safety we should not forget safety nets.

On the other hand, from the factors analysis influencing the load of vehicles and use of the service weight at sugar beet transport follows that with the correct equipment for vehicle with extensions, some values will vary (e.g. specific weight of the sugar beet, coefficient of filling of the volume of extension, stand-by weight). Therefore it is necessary to substitute the method of correct vehicle load through the average specific weight and volume of extension by the method of indication and signalization of the limit vehicles load during the loading at sugar beet storage. It can be presumed,

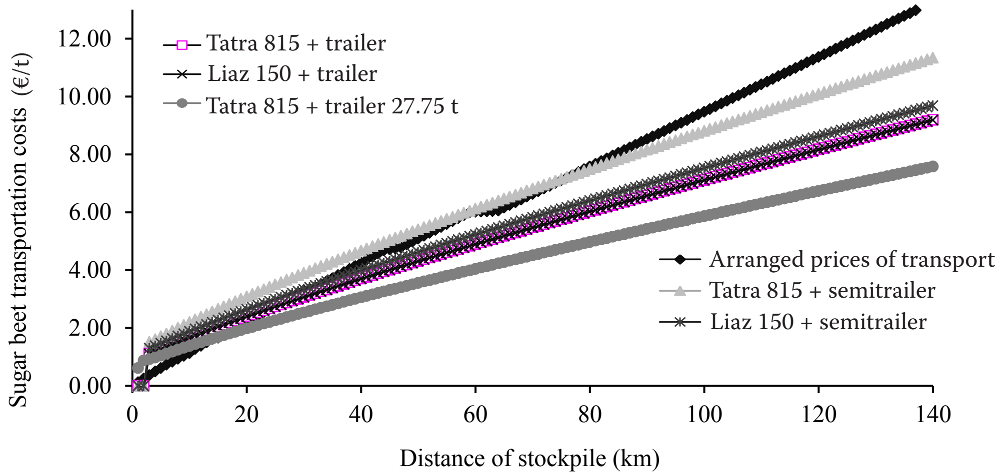

Fig. 7. Cost comparison with price list for sugar beet transfer

that by solving the sufficiently exact system of indication of the axles' vehicle load could be eliminated cases of insufficient load or overload of vehicle. For example, at drive with the 10% insufficient loading of the service weight 20 days of operation are lost from yearly labour fond of 300 days. For that reason we suggest to install sensors for registration of the vehicle load, e.g. companies Lodic, Global, Vibro-Meter, axles load gauge MZM. It is necessary for operator to be able of determination of the load weight directly at place.

Next part deals with the cost comparison for sugar beet transfer paid by sugar refineries according to contract additions and loads per ton of transferred material for individual set. Set Tatra 815 + PS2 17.12 with 100% usage of service weight 27.75 t was selected for comparison.

Monitored set Tatra 815 + trailer up to distance of 24 km has higher costs than work price is (Fig. 7); set Liaz 150 + trailer up to distance of 25 km, set Liaz 150 + semitrailer up to distance of 32 km, set Tatra 815 + semitrailer up to distance of 77 km, set Tatra 815 + trailer with 100% usage of service weight up to distance of 14 km.

Results suggest that the best unit cost for one tone of sugar beet transfer has the set Tatra 815 + PS2 17.12 and Liaz 150 + PS2 17.12 (Fig. 7). Of course Tatra 815 + PS2 17.12 has great reserve in usage of service weight about 17.59% but the usage of service weight of set Liaz 150 + PS2 17.12 can be lifted only to 1.65%. With respect to this remedy, the set Tatra 815 + PS2 17.12 with 100% usage of service weight 27.75 t according to the lowest costs per ton of transferred sugar beet can be considered for renewal of the machinery.

CONCLUSION

An important condition for effective usage of machine technique in agricultural operational processes is determination and rational number for assecuration of individual working operation. One of the methods that allows to determine necessary number of transport for assecuration of cleaning loader operation within transportation process is the method which uses the model of computer simulation of individual work on the line. On the basis of statistical analysis of measured values of transportation process we can state that it is a random process, which concludes more factors. Behaviour of these factors can be presumed only with some probability in operational conditions. Therefore the undesirable downtime of transport or cleaning loaders can occur at calculation of needed transportation according to average values of individual indicators. Process regularity can be shown within work simulation of gathering-transportation process on computer. Knowledge of this fact should be considered on the basis of real operational conditions.

The above mentioned results suggest that computer simulation is a suitable tool for real operational process examination and it can significantly contribute to its rationalisation and effectiveness.

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