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Chosen Problems in Agro Logistics - a Proposals to the Use of Selected Indicators

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ABSTRACT
The article presents examples of tools which can effectively contribute to, among others, better selection of machines and coordination of their performance and the mass transport stream. The following formulae can be useful in practice: the number of necessary machine units, mass flow, intake capacity of storage facilities, duration of the transport cycle, load capacity utilization rate and performance measure of means of transport (or a set of means of transport). Their use, according to the authors, will allow agricultural producers to minimise various kinds of risks which for many reasons are extremely high in this industry.
Keywords: exploitation, agricultural production, maintenance, manufacturing control

I. INTRODUCTION

The biological process of agricultural production is conditioned by the natural environment. It depends on locally occurring soil and climatic conditions. This means that certain technological activities must be conducted at particular times and they are restricted by the time available to perform them. Thus the technological process of agricultural production is not characterised by continuity typical of industrial manufacturing. In the periods of particular types of field work it is divided into separate, closed groups of activities – technological operations. The authors of this article present particular characteristics and difficulties in production management in agriculture, i.e. the challenges faced by agricultural producers. It was emphasised that an essential part of logistic activity on a farm is production logistics. The publication gives examples of tools which can efficiently contribute to, among others, better selection of equipment and coordination of their performance and the mass transport stream. The intention of the authors was attracting attention to the necessity to minimise various risks by agricultural producers, as for numerous reasons such risks are extremely high in this area of activity.

II. THE SPECIFICS AND THE DIFFICULTIES IN PRODUCTION MANAGEMENT IN AGRICULTURE

Family farms, which constitute the basic group of food producers in Poland, are characterised by a relatively small production scale, it is limited by workforce and the level of technological support for processes. Supplies for production are usually synchronised with their use in the production process. Meeting this condition requires IT connections between a farmer, a recipient and a supplier. The in-time delivery system defines general delivery conditions and delivery volume in particular months or decades of a year, it also specifies delivery dates for particular recipients. However, in agricultural production it is the production logistics to be of primary importance due to its particular dependence on the logistics of supplies and distribution. Production logistics has an internal nature and its role and functions are directly related to the process of making a product [7,9–12].

Obtained agricultural produce should meet certain defined quality conditions. The reason for this is the fact that for recipients (consumers) such produce usually makes food or an ingredient to make food. Additionally crops have to be collected when they are ripe, however, before any biological losses occur. Hence crop collection in the field and later storage are dependent on a few or sometimes more than ten-hour time regimes during which the collected crops have to be protected against biological self-destruction and the impact of harmful pathogens. Then the process of making reserves, related to the seasonality of the supply of agricultural produce, occurs. In other technological operations related to agricultural production, one hardly ever deals with developing stocks and their logistical control [6,13].

Nowadays a producer – farmer has to face the necessity to manage the logistics of production whose operating criterion is cost minimisation.

Production logistics encompasses the following tasks:

- production control and defining farm needs,
- planning the use of means of transport,
- defining machine workloads and controlling machine use,
- planning transport processes and produce storage,
- planning the location of stockpiles and storage facilities [1–5].

In agriculture production control most often means selecting production type depending on agricultural business trends, a production system and technology. Accepting particular technology results in the transfer of activities related to production logistics to a particular technological operation, e.g. cereal crops collection. The basis for planning this phase of production logistics must be determination of consecutive technological activities of the selected technological operation. A sample sequence of technological activities related to cereal crops collection is presented in Table 1.

Tab.1. A sample sequence of technological activities in cereal crops collection at four workstations

No.	**Technological activities (work functions)**	**Technical equipment**
I	**Farmland**	
1.1 1.2 1.3	Cutting and transport of cereal mass Separation and collection of grain Loading grain onto means of road transport	- combine harvester
II	**Road**	
2.1 2.2	Grain transport Gravitational unloading	- tractor or other means of road transport - means of transport
III	**Grain storage facilities**	
3.1 3.2 3.3 3.4 3.5 3.6	Accepting (making) grain supply Transport Initial cleaning of grain Transport Drying grain Storage of grain supplies	- receiving hopper in storage facilities - vertical elevator - corn cleaner initial cleaning (separator) - drag conveyor - drier - grain silos
IV	**Seed production facilities**	
4.1 4.2 4.3	Cleaning and separation of seed Chemical processing (seed pickling) Packaging – bagging	- complex seed cleaners - seed pickling machine - bagger, labeller

Source: Authors' own study

In the presented technological operation one can distinguish four workstations: farmland (I), road (II), storage facilities (III), seed production facilities (IV). Between the first three workstations (I-III) process pipelining conditions should be ensured. The obtained product is grain ready for distribution or a semi-product for seed production. At the next stage, the fourth workstation (IV), some part of collected and stored grain is processed. Production at this workstation is an assembly-line type of production, however, it does not have process pipelining connection with workstations I-III. Grain finally obtained from field production and stored grain (activity 3.6) is dedicated to market distribution either directly or after seed processing (activities: 4.1 – 4.3).

III. INDICES USEFUL IN AGRICULTURAL PRODUCTION

The measure of workload of farm equipment and means of transport used in farming is their working efficiency – W_{07}. When a leading activity performed by a leading machine is distinguished in a technological operation as well as activities performed by auxiliary technical equipment, a farmer (producer) should first optimise the number of necessary leading machines, while the number of auxiliary ones should be selected according to process pipelining rules. The goal of optimisation in the selection process of leading machines for particular activities and technological operations determines their number in such a way that the restrictions of the available time are met.

In the source literature [1,8] the availability time of subsequent periods of typical types of work in farming production is determined by the number of days in the range of $\{T_p - T_d\}$, where:

T_d – determines the boundary length of work time and the smallest number of units needed for timely performance of a task,

T_p – is time limit which when exceeded (shortened) will result in determination of a large number of machines whose use will generate excess costs of machine park maintenance.

IV. THE NUMBER OF NEEDED MACHINE UNITS

The optimum number units is the number corresponding with the time range T_p – T_d. Boundary numbers of necessary machines (i_a) can be determined by modifying formula (1) accordingly, by introducing the maximum availability time (T_d) to the algorithm one meets the requirement of minimisation maintenance and operational costs of machines.

$$i_{a\ (\min.)} = \frac{L}{W_{07} \cdot T_d} \tag{1}$$

where: i_a – number pf needed equipment units,
L – range of work to be performed, ha, Mg (tony), m^3,
W_{07} – daily operating efficiency of an equipment unit, ha, Mg, m^3/dn,
T_d – acceptable length of an agrotechnical period in available days.

V. MASS STREAM

The optimised number of leading machines in a technological operation should become the basis to determine their total efficiency $\sum W_{07}^{A}$ and subsequently the value of mass stream (M_z).

$$M_z = i_a \cdot W_{07} \cdot p \tag{2}$$

where: M_z – mass stream, Mg/h,
i_a – number of needed equipment units,
W_{07} – operating efficiency of a unit, ha/h,
p – crop of grain, straw, etc., Mg/ha.

VI. INTAKE CAPACITY OF STORAGE FACILITIES

The defined maximum value of the transport mass stream from a field to storage facilities can be an introduction to the determination of the necessary intake capacity of a storage facility. Assuming the model of quantity-based selection of technical factors in a technological operation, which guarantees the continuity of work of a leading machine (A), the relations between the capacity of machines and means of transport participating in the operation can be described in the following way:

$$\sum W_{07}^{A} \le \sum W_{07}^{B} \le \sum W_{07}^{C} \le \sum {}_{07}^{D} \ldots \tag{3}$$

where: $\sum W_{07}^{A}$ - sum of operating capacities of a group of leading machines,
$\sum W_{07}^{B}, \sum W_{07}^{C}, \sum W_{07}^{D}$ ... – sums of capacities of means of transport (B) and accompanying machines (C, D).

The selected machine or a group of machines, for which a producer should ensure the continuity of work is group "A", obtaining the total efficiency $\sum W_{07}^{A}$. It results from the above that the obtained efficiency level of means of transport and groups of accompanying machines depends on the efficiency of the group of leading machines. Hence to establish the number of means of transport (B) and accompanying machines (C)..., one can assume:

$$\sum W_{07}^{A} = \sum W_{07}^{B}, \tag{4}$$

$$\sum W_{07}^{A} = \sum W_{07}^{C} \text{, itd.} \tag{5}$$

$$\sum W_{07}^{A} = i_{at} \cdot W_{07}^{B}, \tag{6}$$

$$\sum W_{07}^{A} = i_{at} \cdot W_{07}^{C} \tag{7}$$

where: i_{at} – number of means of transport and accompanying machines.

Then the number of means of transport and accompanying machines ensuring technological continuity of the work of leading machines will be the result of the following formula:

$$i_a = \frac{\sum W_{07}^{A}}{W_{07}^{B(C)}}, \tag{8}$$

where: $W_{07}^{B(C)}$ - efficiency of a unitary machine, a measure consistent with the sum W_{07}^{A}, e.g. ha/h, Mg/h.

The efficiency result of means of transport in agriculture influences many various high variability factors. These are for example:

- type of transported load,
- load capacity of a load-carrying body,
- journey length and road quality,
- speed,
- unloading and loading efficiency.

VII. TRANSPORT CYCLE TIME

Means of transport operate by repeating a certain defined sequence of activities, called a transport cycle. The nature of the operation of means of transport and the above mentioned factors lead to difficulties in determining the efficiency obtained during a shift. Due to this the efficiency of means of transport should be calculated as the average efficiency of a single transport cycle. During a transport cycle a load is transferred from one storage place to another and in the basic perspective the cycle encompasses such activities as loading, journey with a load, unloading and a return journey without a load. Thus transport cycle time is the sum of amounts of time spent on performing the mentioned activities:

$$t_o = t_z + t_{p1} + t_r + t_{p2} \, [\text{h(min)}] \quad (9)$$

where: t_o – transport cycle time,
t_z, t_r – loading and unloading time,
t_{p1}, t_{p2} - time of journeys with and without a load.

The constituent times of a transport cycle can be established in minutes from the following formulae:

$$t_z = \frac{G_p \cdot 60}{W_{07z}}, \; t_{p1} = \frac{S \cdot 60}{v_1}, \; t_r = \frac{G_p \cdot 60}{W_{07r}}, \; t_{p2} = \frac{S \cdot 60}{v_2} \quad (10 - 13)$$

where: G_p – actual loading capacity, Mg,
W_{07z} ; W_{07r} – efficiency of loading and unloading, Mg/h,
S – transfer distance, km,
v_1, v_2 – journey speed with and without load, km/h.

VIII. LOAD CAPACITY COEFFICIENT

High differentiation of bulk density of loads transported in agriculture requires the application of the actual loading capacity G_p in calculations which refers to a transported material. Actual loading capacity is the product of the rated loading capacity of a mean of transport – G and the coefficient of its use – c. The load capacity coefficient c arises from:

$$c = \frac{V_p \cdot \rho}{G} \quad (14)$$

where: V_p – volume of a load-carrying body, m^3,
ρ – bulk density, Mg/m^3
G – load capacity of means of transport, Mg.

From the technical perspective stationary loading equipment belonging to the elevators and conveyors group are used mainly in storage areas and less frequently during field work. In the case of machines used for field work currently the loading function is included in harvesting machines' activity, e.g.: chaff cutter, combine harvesters, crop collecting trailers. One deals here with a continuous or batchwise way of loading crops on means of transport using these machines. Then the mass efficiency W_{07z} [Mg/h], resulting from multiplication of surface efficiency W_{07} [ha/h] by a crop – p [Mg/ha], e.g. grain, straw, soilage, allows to calculate the loading time - t_z. The ways of unloading means of transport in agricultural field transport largely depend on the mechanical properties of transported materials. One should distinguish here gravitational unloading bulk materials on a base or into a receiving hopper or mechanical unloading of materials of a larger size on a base or into a receiving hopper.

IX. MEANS OF TRANSPORT EFFICIENCY

Currently unloading means of transport is rarely limited to emptying a load-carrying body. Usually it is also connected with a transfer of goods to storage or processing facilities. Sometimes unloading of one piece of equipment is related to loading another one. In this case it is reloading and the time of unloading one machine remains equal to the time of loading the other one ($t_{r1} = t_{z2}$). This must be taken into account in the calculations of the unloading time – t_r. The equipment of means of transport with hydraulic actuators allows for quick gravitational unloading of load-carrying bodies (within minutes). However, this cannot be the basis for determining efficiency and unloading time – t_r. One should use here the efficiency of transfer to a technological line in storage facilities also referred to as intake capacity. For example, the calculated intake capacity (2) of storage facilities is 40 Mg/h, which allows to accept 8 Mg (ton) of load within 12 minutes which should be treated as the unloading time of means of transport - t_r. Assuming that in each transport cycle there is one or two loads of fixed size, the efficiency of means of transport can be described by the following formula:

$$W_t = \frac{G_p \cdot 60}{t_o} \text{ or } W_t = \frac{c_1 \cdot G + c_2 \cdot G}{t_o} \qquad (15 – 16)$$

where: c_1, c_2 – coefficients of load capacity utilisation for two different loads of means of transport, the other notation is the same as above.

X. PLANNING MEANS OF TRANSPORT UTILISATION

An analysis of the influence of the above mentioned factors of constituent times and the efficiency of a transport cycle and next a simulation of traffic constitute the basis for the selection of means of transport and planning their use. The influence of load capacity of means of transport on their efficiency should be analysed in correlation with the type of transported load. In consequence one does not consider the load-carrying capacity of means of transport but its actual load capacity - G_p. The dependence of the efficiency of means of transport on loading and unloading time indicates that reducing these times will result in efficiency increase which will be relatively higher at short distances. The selection and use of highly efficient means of transport used for loading and unloading reduces loading and unloading times and thus increases the efficiency of means of transport.

Analysing the influence of the speed of means of transport on their efficiency, one should observe a relatively smaller increase in transport efficiency at short distances. This rule justifies the use tractors travelling at lower speeds but characterised by relatively big traction force sile in field transport where there are changeable and difficult conditions. At longer distances the speed increase of means of transport results in a relatively large increase in transport efficiency. This justifies the use of vehicles in agriculture nearly only in supplies for production and produce distribution.

The basis for planning the use of means of transport should be a simulation of their traffic based on a prepared schedule. Such a schedule is presented in Fig.1 where one can see cyclical operation of means of transport in a time and path coordinate system.

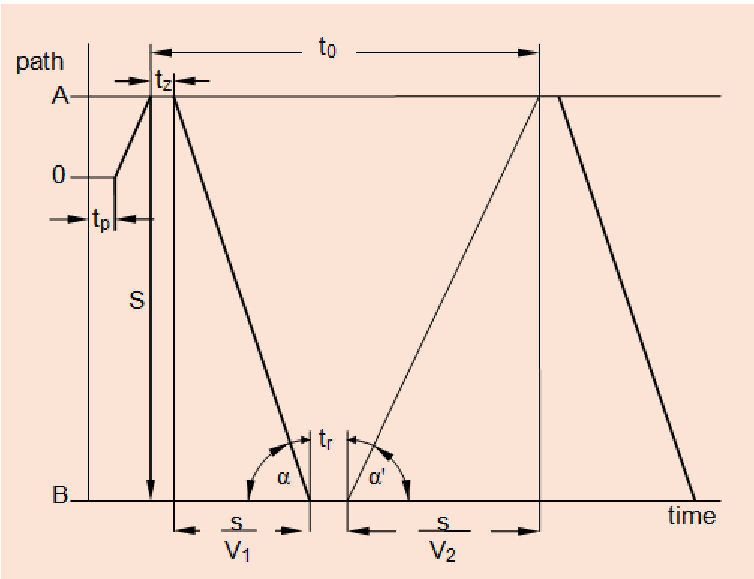

Fig. 1. A schedule of transport unit traffic: O – garage, A – loading, B – unloading, t_p – transport unit preparation, α – inclination angle of the line of unit traffic representation S, v_1, v_2, t_z, t_r – the same as in formulae 10 – 13. Source: [1]

The schedule represents time used for the following activities:

- unit preparation in the garage, G,
- journey to a loading place, G → A and loading,
- journey with a load (thick lines), A → B and unloading, journey without a load B → A (thin lines). The speeds of a transport unit represent the tangents of the inclination of traffic lines α and α':

$$tg\alpha = \frac{S}{\frac{S}{v_1}} = v_1 \text{ i } tg\alpha' = \frac{S}{\frac{S}{v_2}} = v_2 . \qquad (17 – 18)$$

The schedule shows that to enable proper, continues operation of loading equipment, one should first meet the utilisation condition of the formula $t_z \geq t_r$ and then ensure the number of means of transport resulting from the dependence:

$$i_t = \frac{t_o}{t_z} \text{ after meeting the condition } t_z \geq t_r. \qquad (19)$$

The cyclically repeated function of loading is usually performed by crop collection equipment. Hence according to the determined formula, one will calculate the numbers of means of transport necessary to ensure the continuity (pipelining) of machines used to collect e.g. grain and straw, roots and leaves of beetroots, potatoes, soilage and straw. However, to ensure the continuity of operation of unloading equipment, one should select the number of means of transport which would be equal to:

$$i_t' = \frac{t_o}{t_r} \text{ after meeting the condition } t_r \geq t_z \qquad (20)$$

where: i_t' – number of means of transport, t_o, t_z, t_r the same as in formula (9).

Thus the above formula will be used to calculate the number means of transport necessary in technological operations in which leading machines are used for unloading, i.e. in fertilisation, sowing and planting as well as in conservation by spraying.

Bibliography

[1]. Banasiak J (red. . Agrotechnologia. Warszawa-Wrocław: Wyd. Naukowe PWN; 1999.
[2]. Banasiak J, Bieniek J, Detyna J. Aktualne problemy użytkowania maszyn rolniczych. Eksploat. i Niezawodn. – Maint. Reliab. 2002; 2(14):63–72.
[3]. Baran J. Logistyka w przedsiębiorstwach agrobiznesu. Logistyka. 2013; (3).
[4]. Klepacki B. Agrologistyka – nowe wyzwania dla teorii i praktyki. Logistyka. 2011; 3.
[5]. Matulewski M. Modern logistic strategies in agriculture. Res. Logist. Prod. 2012; 2(3):295 – 302.
[6]. Mazurkiewicz D. Computer-aided maintenance and reliability management systems for conveyor belts. Eksploat. i Niezawodn. – Maint. Reliab. 2014; 16(3):377–382.
[7]. Mazurkiewicz D. Data mining - new concept in data processing. Eksploat. i Niezawodn. – Maint. Reliab. 1999; 2(2):24–30.
[8]. Pepliński B, Wajszczuk K. An Analysis of the Use of Means of Transport on Model Farms Producing Energy Crops. In: II-nd Domestic Scientific Conference AGROLOGISTYKA. Poznań:
[9]. Suchoń A. Wybrane instrumenty prawne rozwoju agrologistyki. Logistyka. 2012; 4.
[10]. Vellema S. Transformation and Sustainability in Agriculture: Connecting Practice with Social Theory. Wageningen Academic Pub; 2011. doi:http://dx.doi.org/10.3920/978-90-8686-717-2.
[11]. Wojciechowski A. Agrologistyka – nowy wymiar działań w logistyce. Logistyka. 2011; 3.
[12]. Wojtaszczuk K. Agrologistyka coraz bardziej popularna. Logistyka. 2012; 4.

[13]. Żak J. The methodology of the multiple criteria decision making/aiding in agrologistics. In: II-nd Domestic Scientific Conference AGROLOGISTYKA.