Influence of Management Automation on Managerial Decision-making in the Agro-Industrial Complex

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***Abstract*—The preservation and rational use of the grown harvest, obtaining the maximum product output from raw materials today is one of the most important state tasks. Automation of production processes is the main area in which production is currently advancing around the world. Everything that was previously performed by the person himself, his functions, not only physical but also intellectual, are gradually transferred to automation systems that perform technological cycles and exercise control over them. The purpose of the article is to analyze the effect of automation on the ability to store grain in elevators. The main research question is what factors should be considered when introducing an automation system into the grain storage process at elevators to improve the efficiency of process control at enterprises. To solve the question posed, a qualitative study was conducted using the method of an expert survey. The article reveals the factors that affect the quality of grain; the tasks implemented in the computerized process control system (CPCS) and management information and control system (MICS); the factors that hinder the grain elevator automation; the tasks solved by the automation of grain elevators in the framework of autonomous subsystems and integrated automatic control systems (ACS). It is concluded that the implementation of automation in the process of grain storage in elevators leads to an increase in grain quality, increased productivity, reduction or elimination of losses caused by theft and the peculiarities of grain storage, saving energy resources, minimizing the impact of the human factor, as well as the risks of accidents. At that, the inclusion of non-standard tools in the MICS and CPCS makes it easier to solve several current automation problems. Creating standard problem-oriented complexes of responsible decision-makers based on an integrated ACS, with the inclusion of certified object-oriented non-standard tools in their composition, is the most rational way to further improve the efficiency of the automated control system of the industry.**

Keywords*—Grain elevator; automation; grain quality; grain storage; grain drying; grain losses

I. Introduction

Storage of grain products without losses is of great national importance and serves to solve several strategic tasks, such as guaranteeing the country's food security, providing raw materials for the processing industry, strengthening the feed base of animal agriculture, and creating appropriate conditions for effective export-import. Grain storage is one of the main factors of stabilization and increase of grain production not only in Russia. In the context of the global logistics crisis, it is necessary for grain to be able to be stored for as long as possible, without the deterioration of the consumer characteristics of grain quality. To do this, it is necessary that during its production, technological processes are carried out at the highest quality level, even if the enterprise does not have significant labor and financial resources.

In the broad sense of the term, storage means a system of technical and technological, regulatory, and economic-legal measures aimed at extending the shelf life of grain and seeds [1]. Technical and technological measures include a network of granaries/elevators, and a set of processes for accepting grain, preparing it for storage, as well as the storage technology itself [1].

An important part of the storage system is grain elevators, which represent complexes of structures designed for receiving, cleaning, drying, processing grain, and shipping it to consumers. A grain elevator is a complex system with a large number of operations that require precise accounting and control.

It should be noted that in agricultural enterprises, where the shortage of highly qualified labor is most noticeable, there is a fairly high need for partial or complete automation of technological processes, which in the contemporary conditions is an integral part of rising the competitive advantage of the enterprise because it will allow competing quite successfully both on the domestic and the world market [2]. Thus, according to a study by the California Farm Bureau, more than 40% of farmers over the past five years have not been able to employ all the workers needed to grow the main crop. It was revealed that about 56% of farmers started using mechanization in the last five years, and of the total, more than half noted this was initiated by a lack of skilled labor [3].

However, according to the researchers [4], the construction of grain elevators primarily focuses on equipment, its efficiency, and cost, while automation of grain elevator operations, as a rule, is postponed, although, with its implementation, agricultural enterprises could have saved significant funds. Thus, the researchers [4] claim that the payback period of a fully automated newly built grain elevator is 1.5 years less than that of a similar non-automated grain elevator due to minimizing personnel costs, reducing energy consumption, and optimizing technological routes. At that, automation of an already operating grain elevator with a capacity of 40 thousand tons of one-time grain storage takes 3-4 months (from the programming process flows to the assembly of equipment and installing software).

Therefore, the grain elevator is the most relevant research object of automation systems in the industry.

II. Literature Review

According to the researchers [5] the grain quality and properties are influenced by various factors that need to be taken into account already at the growing stage, during harvesting, primary processing of grain, and subsequent storage. A detailed description of these factors is presented in Table I.

TABLE I. FACTORS AFFECTING GRAIN QUALITY

Stage	Factor
Grain cultivation	The quality of the seed grain, in particular, the sowing and varietal characteristics. Thus, the grain of different wheat varieties has different flour-milling and baking qualities; different varieties of corn differ in feed properties; varieties of barley have various brewing qualities; different varieties of rapeseed and soy differ in oil content and the like.
	Reducing infestation of fields and the impact of pests
	Application of mineral fertilizers
	Weather and climatic conditions. Thus, in the case of a large amount of precipitation, grain receiving plants receive highly moisture grain, which requires additional costs for drying. In dry years, during the grain maturation period the grain filling stage grows short reduced; in early frosts, grain is characterized by lower technological qualities and less resistance to storage.
Harvesting	Harvesting with a combine. In Soviet times, as a basis for solving grain quality issues, namely, drying, maturing in rolls, and the ability to start harvesting 6-7 days earlier, a separate combining method was used. But with high prices for fuel and lubricants, as well as in adverse weather conditions, a separate combining method is often economically inefficient and can lead to a significant loss of grain. Therefore farms often use the direct combining method. Currently, the energy component is the main criterion for choosing the grain harvesting method.
	Grain fractionation by moisture. If the grain was harvested in different weather conditions, it is advisable to carry out grain fractionation by moisture (dry, medium-dry, wet and sodden grain) to facilitate post-harvest processing and storage of grain, and reduce energy costs.
Post-harvest grain processing	Grain cleaning and drying allows bringing the grain to the requirements of regulatory documents in terms of the foreign matter and moisture content of grain for further storage in granaries or further processing.
Grain storage	Complete set for the quality of individual grain batches
	Disinfection against pests
	Required temperature and humidity (climate control) in the granary

Source: Compiled based on [6-9]

According to the researchers [10], the greatest influence on the grain quality has heat treatment, namely, grain drying, which, if the process is not properly conducted, downplays all measures to obtain a high quality of the crop.

At the present development stage of grain drying equipment, the convective drying method is most often used in continuously operating grain dryers of column, tower, vertical, and drum types. Also, for drying grain in small volumes, or grain for seed purposes, periodic grain dryers in a fixed layer or bunkers for venting grain are used [11]. The automation level of the drying process allows controlling and measuring the grain feed, level, moisture, and temperature, as well as heat carrier temperature in the grain dryer [12].

Recent practices in the field of automated process control systems make it possible to automatically predict the process of self-heating of grain, which is necessary to improve the efficiency of grain storage [12, 13].

However, the use of serial standard tools in automated enterprise control systems and automated process control systems of enterprises in the grain storage and processing industry has practically exhausted its potential [14, 15]. The inclusion of non-standard tools in standard automated enterprise management systems and automated process control systems makes it possible to simplify the solution of several topical automation problems [16, 17]. The creation of typical problem-oriented complexes of responsible decision-makers based on an integrated ACS, with the inclusion of certified object-oriented non-standard tools in their composition, is the most rational way to further improve the efficiency of the industry's automated control system [18, 19].

Thus, the issues of introducing control automation for grain storage at elevators relevant in Russia remain unresolved. They include factors constraining the automation of elevator operation and the possibility of creating an integrated ACS (ACS of technological processes and ACS of the enterprise).

The research hypothesis is formulated as follows. The implementation of automation in the grain storage process in elevators allows improving grain quality, increasing productivity, reducing or eliminating losses caused by theft and the grain storage peculiarities, saving energy resources, minimizing the impact of the human factor, and the risks of accidents.

The article reveals the factors affecting the grain quality; as well as the tasks implemented in the computerized process control system (CPCS) and management information and control system (MICS); the factors that hinder the automation of grain elevators; the tasks solved by the automation of grain elevators in the framework of autonomous subsystems and integrated automatic control systems.

III. Research Objectives

The following research objectives were set:

1) To determine the factors affecting the quality of the grain should be taken into account already at the stage of grain cultivation, harvesting, primary processing, and subsequent storage.

2) To determine the factors that hinders the complex automation of grain elevators.

3) To specify the tasks implemented in the CPCS and grain elevator MICS using standard and non-standard means.

4) To consider the tasks solved by the integrated ACS of the grain elevator, whose solution within the local subsystems is difficult or impossible.

The article consists of an introduction, a literature review, research methods, results, discussion, and conclusion.

IV. Methods

A. Research Design

To achieve the set goals, the following research methods were used in the article:

- Theoretical methods (generalization, analysis, and synthesis theoretical basis of the study). The theoretical basis of the study was grouped depending on the type of documents. The first group of sources of information consisted of studies devoted to the problem of grain quality and storage factors affecting it. The second group of information sources was devoted to the problem of automation of grain storage complexes. The considered sources of information were mainly articles from scientific peer-reviewed journals indexed in Scopus and Web of Science over the past 15 years (57 publications).
- Empirical methods (expert survey method) were employed to determine the factors that hinder the automation of grain elevators, as well as tasks implemented through CPCS and MICS, and solved using the integrated ACS of the grain elevator.

B. The Procedure and Research Tools

The expert online survey was held as part of the annual comprehensive monitoring of the development of agriculture in Russia in 2021. The annual comprehensive monitoring was supported by six universities (Dagestan Federal Research Center of the Russian Academy of Sciences, Kemerovo State University, Moscow Aviation Institute, Russian State Social University, Moscow Polytechnic University, and Russian State University of Tourism and Service). The selection criteria for the work of experts included experience in the field of agricultural automation for at least seven years, a position at a level below a middle manager in engineering companies engaged in the design and maintenance of elevators, as well as heads of agricultural enterprises, whose interests include the use of ACS of technological processes and ACS of the enterprise of the elevator.

The expert online survey was attended by 35 experts' distribution by status and length of service is presented in Table II.

The experts were asked several questions concerning the automation of the grain elevator performance:

1) What are the main deterrents to the automation of elevator operation?

2) What tasks are subject to automation in the first place in the ACS of technological processes and the ACS of the enterprise?

3) What tasks can be solved by the integrated ACS of the elevator?

All participants were warned about the purpose of the survey and the planning of the organizers of the study to publish the survey results in a generalized form.

TABLE II. Distribution of Experts by Status and Work Experience

Status	**Work experience**	**Number, persons**
Heads of engineering companies	7 to 12 years	9
	Over 12 years	10
Heads of agricultural enterprises	7 to 12 years	4
	Over 12 years	12

C. Statistical Analysis

During the mathematical processing of the research results, the percentage of expert mentions of the factors hindering the automation of grain elevators, as well as the tasks solved by the integrated ACS, was determined.

The ranking of the entire set of expert opinions consisted in their arrangement by each of the experts in the form of a sequence according to their decreasing preference.

At that, each of the opinions was evaluated by the rank (number) under which they were arranged in this sequence. The final rank represented the arithmetic mean of all the expert ranks in the sample of experts.

V. Result

According to experts, despite the huge potential opportunities of the current market, the provision of a variety of automation services, the complex automation of grain elevator operations is constrained by the following factors (Table III).

According to experts, these factors predetermine the situation in which solutions to automation problems are performed within the established document flow with the same automation functions and a simple transfer, as a rule, only the technical support of the ACS to a more modern level.

TABLE III. Factors hindering the grain elevator automation

Factors	%	Rank
Lack of objective knowledge about the potential capabilities of the ACS on the part of the customer; as a rule, decision-makers underestimate the importance of automation or, sometimes, have excessively high expectations	74.3%	1
The lack of subject orientation of developer enterprises and, as a result, the lack of knowledge about the subject area on the part of specialists of leading enterprises specialized in providing IT services (technologies) using standard design solutions	68.6%	2

Note: compiled based on an expert survey.

Initially, the experts considered standard already functioning CPCS and MICS. According to experts, with respect to the CPCS of the grain elevator, automation should concern tasks implemented using standard (SCADA) and non-standard tools. In the MICS, tasks are implemented, as a rule, using 1C (Table IV).

TABLE IV. TASKS IMPLEMENTED BY THE CPCS AND MICS

Means	List of tasks
CPCS	
Standard	Controlling grain movement routes (several hundred, sometimes thousands of input/output signals); weighing, dosing (usually implemented using strain gauges); management of aspiration, ventilation, i.e. typical CPCS tasks implemented using SCADA systems.
Nonstandard	Measuring the temperature field of grain storage array (several thousand control points); grain drying control (a few dozen of the input-output signals); measuring the grain humidity in the flow; continuous grain level measurement in silos, etc.
MICS	
Standard	Accounting, tax, production accounting; as well as issues, such as personnel, salary, warehouse, trade, etc., i.e. typical MICS tasks, which are implemented using the 1C complex
Nonstandard	Quantitative and qualitative analysis of grain and grain accounting, grain movement accounting, decision-making support systems, etc.

Note: compiled based on an expert survey

At that, in standard solutions, noted systems function locally, the CPS and MICS continue to remain autonomous and have no links. Meanwhile, according to experts, some automation tasks are successfully solved within the framework of autonomous subsystems.

However, the creation of an integrated ACS will allow solving problems that are difficult or impossible to solve within local subsystems (Table V).

TABLE V. TASKS SOLVED BY THE INTEGRATED ACS

No	Tasks	%	Rank
1	Grain drying in automatic mode	82.6%	1
2	Performing grain acceptance and shipment operations with a given performance	77.1%	2
3	Reducing or eliminating grain losses due to theft	71.4%	3
4	Eliminating losses caused by the grain storage peculiarities	62.9%	4

Note: compiled based on an expert survey

VI. DISCUSSION

Speaking about the automation of grain elevators in the framework of implementing autonomous subsystems, the majority of experts (82.6% of respondents) note that as a rule standard design solutions are developed by organizations that are official dealers of large developer enterprises. Thus, automated control systems are implemented using SCADA systems, which are collecting real-time information from remote points for processing, analyzing, and possibly managing remote objects. The requirements of real-time processing are determined by the need to deliver all the necessary events and data to the central interface of the operator (dispatcher). All contemporary SCADA systems include three main structural components:

- RTU (Remote Terminal Unit), which is the lower level of the CPCS: industrial computers, programmable logic controller (PLC).
- MTU (Master Terminal Unit), which is supervisory control center (upper level).
- CS (Communication System) [13].

The SCADA system solves the following main tasks: providing data exchange with controllers, terminal devices, and real-time data processing; visualization of the technological process progress on monitors and terminals; ensuring the storage of technical information in a real-time database; monitoring technological parameters; implementing warning alarm and alarm event protocol; generating reports on the progress of technological processes; providing data to external systems at the enterprise management level [14]-[16].

The characteristics of alternative SCADA systems are given in Table VI.

Free technical support is provided by the Russian company AdAstra Research Group LLC (TraceMode V6) – the only 100% Russian company in the SCADA systems market, as well as by JSC Klinkmann SPb, a distributor of AVEVA (InTouch V10), which has been trying to enter the Russian market since 2019.

According to experts, that is confirmed also in the works of researchers [17], the main drawback of standard design solutions is the replication of universal proposed tools without the proper orientation to a specific subject area. Besides, the functionality of the supplied equipment (software product) is due to the versatility, and therefore the excess of the means used, which leads to a decrease in reliability, the inability to take into account the specifics of the grain elevator, and leads to a lower level of automation.

TABLE VI. CHARACTERISTICS OF ALTERNATIVE SCADA SYSTEMS FOR RUSSIA

Name of the SCADA	The function of the process execution module	Cost of technical support, thousand USD	Availability of a free development environment	Price of the process execution module, thousand USD
InTouch V10	Monitoring, management, archiving	Free of charge	-	10.84
Trace Mode V6	Monitoring, management	Free of charge	+	1.62
Master SCADA V3.1	Monitoring, management, archiving	0.25 per year	+	2.03
iFix V4	Monitoring, management, archiving	2.2 per year	+	8,64
GENESIS32 V9	Monitoring, management, archiving	4.8 per year	+	11.92

The second class of tasks is handled by small IT companies. Their products, as noted by one of the experts (Nikolai K., 12 years of experience), "are subject-oriented, often unique and belong to non-standard equipment". This allows them to create competitive, subject-oriented, non-redundant, unique, and in some cases significantly more reliable products that have no analogs in terms of price/quality ratio [18]. However, non-standard equipment requires additional costs for verification and metrological certification, which significantly narrows the scope of its application and, in the face of the risk of uncertainty of the final result, in the assessment of the customer, leads to insufficient funding and is usually limited to a small-scale or single-item production [19].

According to one of the experts (Alexander, 12 years of experience) "systems that are implemented using serial standard and unique non-standard tools today function locally and do not interact with each other in any way. Integrated systems that have proven themselves and are implemented using both standard and non-standard tools into a single integrated ACS will make it possible to minimize the disadvantages of each approach and maximize the benefits of each of them".

Speaking about the tasks solved by the integrated ACS of the grain elevator, experts put in the first place the possibility of drying grain in automatic mode (Table IV), since drying grain, according to one of the respondents, is "the most important stage of storage and processing technological processes, whose results depend on both consumer and technological characteristics of grain quality". As an argument, the fact is given that a deviation from the target value of the grain moisture towards increase can lead to fire-fanging of grain mass during storage, while a deviation towards decrease –to a deterioration in consumer characteristics, weight, etc. and thus, to the lost profit.

At that, the operator judges the technological process progress and the quality of grain subjectively, based on own experience. The reason for this is the inability to measure grain quality indicators directly during the technological process. This conclusion can be explained by the results of the study [20]. The operator monitors the technological process based on the current values of temperature and, in the best case, humidity, and can control the process only by setting the drying cycle time and the burner operating mode. Automatic control of the burner is impossible without an adequate control model.

Therefore, it is extremely difficult to build an adequate model for controlling the technological process of grain drying, which would allow judging the expected consumer characteristics of grain quality by the observed technological parameters, without the knowledge and experience of a qualified operator. According to experts, the drying process management using deterministic control models in practice is currently unknown. As a result, the grain drying process is controlled manually and depends entirely on the operator's qualifications.

Building a control model that would allow performing grain drying in an automated or automatic mode is an urgent task, whose solution would allow excluding unskilled actions of the operator, and therefore reducing the likelihood of deterioration of consumer characteristics of grain quality [21]. The solution of this problem is associated with the determination of the relationship between the observed parameters of the technological process and grain quality indicators, and the significance of these relationships [22]. The technological process parameters are controlled by the CPCS of the grain drying process, while the grain quality indicators are controlled by the laboratory assistant at his workstation in the quality laboratory.

According to one of the experts (Mikhail, 16 years of experience), a real alternative to deterministic models, is "building a knowledge model using the fuzzy logic instrument, which provides a link between the controlled technological parameters and the grain quality characteristics, determined in laboratory conditions. Therefore, the timely inclusion in the grain drying model of the quality characteristics of grain at the dryer inlet simplifies building a proper model and allows solving the main problem of grain drying: obtaining (or improving) the quality characteristics of grain according to their specified values".

At present, in the ACS, operating at grain elevators, there are no connections between local subsystems. Creating a knowledge model of a qualified operator, which would take into account the quality indicators and technological parameters, is an urgent task, whose solution will significantly improve the quality of grain drying [23].

Experts point out that executing grain receiving and shipping operations (Table IV) requires controlling the route of grain movement at given productivity. The grain shipment regulations require maximum possible specified performance, which can lead to congestion in problematic areas of transportation. To eliminate congestion, it is necessary to install conveyor (sectional) weighers on sections of the actuator control loop (ACL), which are functioning as intelligent shipment performance sensors. Depending on the measurement result, it is necessary to increase or decrease the shipment intensity by adjusting the rotation of the actuating mechanism (speed of the conveyor belt on the route). The solution of this problem within the framework of the ACS does not always lead to the necessary result [24]. The efficiency of solving the above-mentioned problem is significantly increased when applying a control model using data from grain movement control (MICS) and a subsystem for continuous grain level measurement in storage silos (CPCS), which is difficult or impossible to solve in the framework of SCADA systems [25].

Besides, the integration of the grain movement control subsystem and the route management subsystem allows performing technological operations providing the optimal route in terms of minimizing energy consumption, taking into account the state of technological equipment, the possibility of bypassing equipment units that have failed, by creating an alternative route, and suchlike.

According to experts, an effective solution to the problem of losses caused by theft (Table IV) is impossible without creating integrated systems based on a single information base CPCS and MICS, logical models for checking the grain movement starting from its reception operation through the shipment operation, taking into account the identified bottlenecks and taking appropriate comprehensive measures to ensure mutual control of employees responsible for production process accounting and the technology of reception, cleaning, drying, movement, storage, and shipment (production).

In the course of grain storage, pockets of self-heating may appear (losses due to the storage peculiarities, Table IV), which can be revealed by the thermometry system indicators and eliminated by moving grain from one grain storage container to another with simultaneous cooling.

The integration of some subsystems (thermometry, grain movement, grain movement control, ventilation, and electricity metering subsystems taking into account the daily tariff variations) will allow identifying automatically the hotbeds of self-heating, determining the availability of free containers; finding the optimal route of grain movement and the time of its execution, and performing grain storage control processes in automatic mode [26]. All these measures will allow minimizing the impact of the human factor, leading to the exclusion of unjustified losses, improving grain quality, reducing energy consumption required for its movement, as well as significantly reducing the costs of controlling the systems of the ventilation system, aspiration, etc.

VII. CONCLUSION

The research results confirmed the hypothesis that the implementation of automation in the grain storage process in elevators leads to an improvement of grain quality, increase in productivity, reduction or elimination of losses caused by theft and the grain storage peculiarities, saving energy resources, minimizing the impact of the human factor, as well as the risks of emergency situations.

The results of the study show that the main tasks solved by the integrated ACS are drying grain in automatic mode, performing operations of receiving and unloading grain with a given capacity, and reducing or eliminating losses caused by theft and features of grain storage.

The most effective practical implementation of these tasks is possible through the cooperation of organizations that specialize in the development of systems using standard tools, as well as organizations that develop non-standard automation tools.

A promising area for further research is the analysis of technologies based on reducing the volume of grain drying, ensuring high quality and reliable storage of grain products.

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