Information-Analytical System of Plants Harvesting Project Management

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Abstract. The information technologies and IT projects applying aspects for management decision support during the project's realization of material and technical development in agricultural enterprises are analyzed. The components that should be taken into account in the information-analytical systems of management decision support during the project's development of crop harvesting technological systems are distinguished. The general scheme of the information-analytical system of management decisions support in crop-harvesting projects is presented. The using expediency of statistical simulation modeling methods for the cumulative impact of unmanaged and stochastic components of project environment on the work timeliness and effectiveness of these projects are considered. Methods of statistical simulation with multiple iterations of virtual crop harvesting projects were used. This helps to take into account the project environment's stochastic nature, to perform computer experiments and to process their results using mathematical statistics methods. The relationship between the components of the crop harvesting projects that affect their effectiveness is shown. On the basis of the developed information-analytical system the management decisions are grounded to coordinate the start-up time of crop harvesting projects and production area projects with the technical equipment parameters. It is shown, that the usage of IT in the project management of enterprises materially-technical re-equipment allows to accompany management decisions and to ensure the effectiveness of these projects.

Keywords: Project, IT, Enterprise development, Project environment, Information-analytical system, Modeling, Value, Support of management decisions.

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1 Introduction

The agricultural project's development is important to create long-term industry efficiency [7;16;19]. An important sign of this efficiency is projects aimed at increasing the income from agricultural production. Priority role in solving such problems should be given to projects of materially-technical development of agricultural enterprise (AE). However, for their implementation, you need to have specific knowledge of the project environment impact, project configuration and their objects, projects structure and programs that are appropriate to implement in the industry. You also need to have specific methods and models of project management in both the manufacturing and IT sectors. This will allow the creation and use of information-analytical systems (IAS) support of management decisions (SMD).

The projects management of AE development, including those related to the crop cultivation and harvesting, requires the use of IAS, which take into account the nature of the unmanaged components and affect the effectiveness of managing the respective projects. In particular, ensuring the timely operational management of crop production processes depends on agrometeorological conditions. Stochastic and unmanageability of these conditions leads to delayed crop harvesting. This increases the probability of crop technological loss. In practice, agro-meteorological conditions should be forecasted, soil and crop conditions should be monitored, perform the analysis and forecast tendencies of their change (yield increase, etc.), as well as make decisions about the project start-up time and the duration of the respective operational processes. The effectiveness of these decisions depends on the IAS SDS adequacy and relies on the information reliability about the project environment. The peculiarity of this environment is that it is stochastic.

2 Analysis of Recent Research and Publications

The task of the start-up time determining [12] and project management [17;18], programs [19] and portfolios of their development are devoted so many scientific works [1;3;6;15;20]. Particularly in agriculture, this problem is considered from the point of the project work efficiency (implementation of mechanized technological processes (TP)) [7;12;13]. For this purpose, the optimal time of their implementation there was substantiated. Scientific and methodological bases of parameters rationalization of project configuration (technological machines complexes) for timely execution of works are developed [12;17;19]. In these works, the rational parameters of the technical equipment are determined by the cost criterion – the minimum specific total cost of funds (operating costs and losses of the harvested crop). The solution of these management problems is based on the task of start-up time determining of the relevant work in projects (start-up time of projects, programs and portfolios). In particular, this problem has already been solved in the practical plane [12] and a method for determining the optimal startup time for sugar beet harvesting (SBH) projects was made in a given natural area. The analysis of the developed methods convinces them that they do not consider the influence of the managerial component – the possibility of using the different technical equipment of projects, different time of their start-up and extent of work (area of culture). However, this scientific work has revealed the methodological features of its solution based on statistical simulation modeling [4;8;11;14], which is important from the point of the IAS SMD development. Determining the optimal start-up time for SBH projects is based on the technological criteria. Therefore, these provisions are initial and require development from the point of relevant technological systems (TS) project management.

The aim of the research is to demonstrate the IAS SMD structure and to establish the effectiveness regularities of the SBH projects for different parameters of technical equipment, the start-up time of these projects and the production area of plants.

3 Results of Research

It is a well-known fact that the first step in developing models for evaluating management decisions to support projects and their implementation is to identify goals, external and internal environments, as well as the features of their interaction and the overall impact on the performance of these projects.

According to the project management knowledge system, specific project management methods and models throughout their life cycle need to be applied in order to achieve these goals. Therefore, in order to develop the IAS SMD for estimating the value of projects under incertitude, it is necessary to draw on the experience and knowledge of previous projects [2;5]. However, the use of this approach has its disadvantages. In particular, there are limitations in the projects implementation with the number of qualified managers in the team, projects have their own characteristics and it is not always possible to use the experience of previous ones, etc. Therefore, IT should be used for effective project management, enabling them to take into account their particularities on the basis of the development of specialized methods and models for IAS SMD.

The objectives of IAS SMD also included the tasks of projects development of material and technical re-equipment of AE well as formation of production resources. This makes it possible to accomplish the objectives of agricultural production projects while ensuring the limited use of scarce resources. In fact, the development of TS of AE projects are geared towards material-level linkage at the crop area, a set of specialized machines attached to them, and contractors. These parameters of the TS, in case they are mutually agreed, make it possible to provide an extreme of performance indicators for both individual TS projects and their systemic efficiency.

Based on the theory of project management, it should be emphasized [1;9;13], that other projects of production subsystems are being implemented for the effective functioning of such production systems. This set (project program) includes a number of interrelated projects. The management of the projects which are the part of agricultural production programs (in particular, the cultivation and crops harvesting), are carried out jointly and simultaneously to ensure their coordination and obtain a systemic (synergistic) effect and increase controllability. This cannot be achieved without the use of IAS SMD.

It is known from the subject area that the time of launching crop harvesting projects depends on such components of the project environment as the condition of the fields and the rate of yield [12;14]. This time for individual cultures and projects also depends on the available technical capacity [19]. Determining the timing of arable projects starts is an important management task, the resolution of which largely determines their value, in particular, the volume of the harvest. Methods for determining the time of project start-up should take into account the stochasticity of the project environment, which is caused by the influence of agrometeorological conditions [12]. Thus, in agrarian production there is a scientifically applied problem of increasing the value of harvesting projects based on the development of IAS to evaluate the impact of their start-up time, volume of work and technical equipment parameters on the performance of these projects.

The use of IAS SMD to coordinate the startup time (τ_{sh}) of the SBH projects and the production area (S) of the crop with the technical equipment parameters of these projects plays an important role in ensuring the minimum specific aggregate cost of the funds. The establishment of these cost estimates is based on the functional indicators of the respective TP, which we obtained on the basis of computer experiments with the developed IAS (statistical simulation model of the TP SBH in MS Visual Studio C # [10]) (Fig. 1).

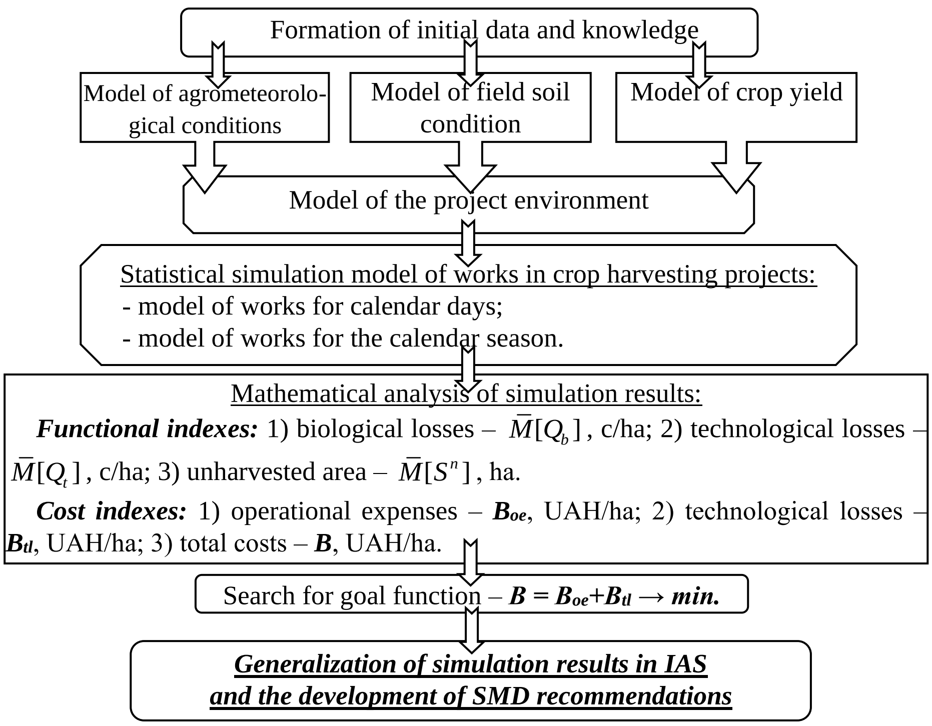

Fig. 1. Generalized scheme of information-analytical system of management decisions support during the crop harvesting projects.

The basis of this model is the system-event display of daily stages of work in projects, which allowed taking into account:

1) stochastic influence of the natural (agrometeorological and biological) component on the calendar terms of root crop harvesting and the naturally allowed time fund for the operation of technical equipment (beet harvester);

2) daily increase of root crops weight, as well as the impact of this indicator on daily harvesting rates;

3) the influence of the production area of the crop and the productivity of the combine on the duration of the respective TP, and therefore on the functional indicators of their efficiency.

Such a sequence of TP modeling in the developed IAS SMD is implemented in a pre-designed program of computer experiments. This will assess the impact of management decisions on the coordination of component projects – startup time (τ_{st}), production area (S) of culture and technical equipment parameters (P_{te}) on the performance indicators (E) of these projects. To account their cumulative effect on E for a given τ_{st}, S and P_{te}, the Np of iterations model was performed. Then τ_{st} was shifted on 1 day and the simulation was repeated. The increase in τ_{st} was performed for calendar limits from 260 (September 18) to 300 (October 28) days with increments of 1 day. Next, the S area was increased from 60 to 300 ha with an increase of 20 ha. Then, for each variant, the P_{te} repeatedly performed the specified steps of the simulation. The results obtained were recorded in the corresponding data sets.

The reason for the Np iterations (implementations) of the TP statistical simulation model in the developed IAS SMD is the need to take into account the probabilistic impact of the project environment. In particular, agro-meteorological and biological-subject components may affect the performance of TP and, in particular, their timeliness. Therefore, the simulation results are obtained as a set of data to perform the following mathematical processing. For this purpose, the IAS uses mathematical statistics methods, which allow constructing the regularity of changes in the estimates of mathematical expectations of projects performance. The regularities obtained are an important basis for assessing the impact of the respective constituent projects, and therefore the support of management decisions regarding the implementation of TS projects and projects of material and technical development of AE.

Establishing regularities of the mathematical expectation estimates of specific biological $\bar{M}[Q_b]$ and technological $\bar{M}[Q_t]$ losses volumes on the basis of the IAS SMD allow to estimate the specific cumulative cost, and thus to reconcile the τ_{st} of the SBH projects and the crop production area with the technical equipment parameters. Cost estimation of specific technological losses (B_{tl}) of funds is performed by the formula:

$$B_{tl} = \frac{U_{nd} \cdot S^n \cdot V_k}{S}, \qquad (1)$$

where U_{nd} – current yield of root crops, remaining in d-th day on the unharvested area S^m, c/ha; V_k – market value of sugar beet, UAH/ha; S – production area of the plant, ha.

For determine the specific operational expenses (B_{oe}) where use the well-known formula:

$$B_{oe} = C_1 + C_2 + C_3 + C_4, \qquad (2)$$

where C_1 – labor payment, UAH/ha; C_2 – the fuel and lubricants cost, UAH/ha; C_3 – depreciation for technical equipment, UAH/ha; C_4 – repair and maintenance costs, UAH/ha.

The developed statistical simulation model of TP SBH, which is a component of IAS SMD, allows reflecting the peculiarities of the use of technical equipment (beet harvesters) in the projects of SBH. Its application also allows taking into account the objective impact of agrometeorological and biological components on the timing and pace of relevant work, as well as forming a representative set of data for subsequent analysis of the effectiveness of management decisions. In addition, computer experiments with a simulation model of virtual projects make it possible to justify management decisions about the feasibility of using technical equipment with these or those parameters.

As already mentioned, it is advisable to justify such decisions on the basis of indicators of work timeliness in projects – change regularities of biological and technological losses. In particular, the use of these patterns and well-known cost estimation techniques in the projects made it possible to establish the specific total costs *B*, and thus to agree on the τ_{st}, *S* and P_{te} of the projects.

It should be mentioned that the peculiarities of the method of solving this management problem also takes into account the variability of the technological (harvesting) works execution in the projects of TP SBH. These rates are due to the productivity of technical equipment (beet harvesters) in the fields, as well as organizational and technological forms of project implementation. The performance of the technical equipment depends on the geometric (physical) parameters of the fields, as well as the characteristics of the harvest (which belongs to the objective component of the project environment), and therefore the rate of harvest will depend on these components. In addition, the pace of work in TP projects is still dependent on the spatial location of the fields with the harvest, harmonization with transport system projects, and the operation of the relevant reloading and transport vehicles [7;12].

An important requirement for the IAS is the need to take into account the temporal changes in the physical and biological state of the cultivated crop, including sugar beet. This state changes objectively. It depends on the τ_{st} of the SBH projects and varies over the duration of the seasonal work in these projects. The patterns of change in the state of the plant and plant component of the project environment are characteristic for each individual field that is included in the TP SBH projects. At the τ_{st}, this status is different and also changes during the work implementation. Knowledge about the regularities of change of the plant component before the τ_{st} of these projects, as well as its importance at the moment of execution of the corresponding works, allows predicting this state for any moment of the project realization. The possibility of predicting this condition is the basis for estimating potential losses due to premature or untimely execution of relevant works in projects. In case of premature performance, losses will be caused by a crop failure which is still growing and has not reached its maximum [12]. If the work on the projects lasts until the onset of autumn frosts, and part of the area with the harvest reached remains unaccounted, then the harvest is damaged by low temperatures. In the TP simulation model, this crop is identified as lost and is determined by the amount of not harvested area.

The possibility of probabilistic estimation of crop losses in the projects of TP SBH in case of premature and untimely execution of the corresponding works makes it possible to assess the risks. On this basis, management decisions on the correctness of the values of mutually agreed components – the τ_{sh}, S and P_{te} are substantiated. If necessary, the possibility of adjusting these components and minimizing the involved risks could be evaluated.

The implementation of the main stages of work modelling in the SBH projects and calculations for the technical equipment (beet harvesters and root crops tractor trailers-reloaders) of different capacity allowed to optimize the production area of S^{opt} culture (fig. 2), as well as to establish its dependence from the τ_{sh} of these projects and capacity N_{en} of the technical equipment (fig. 3).

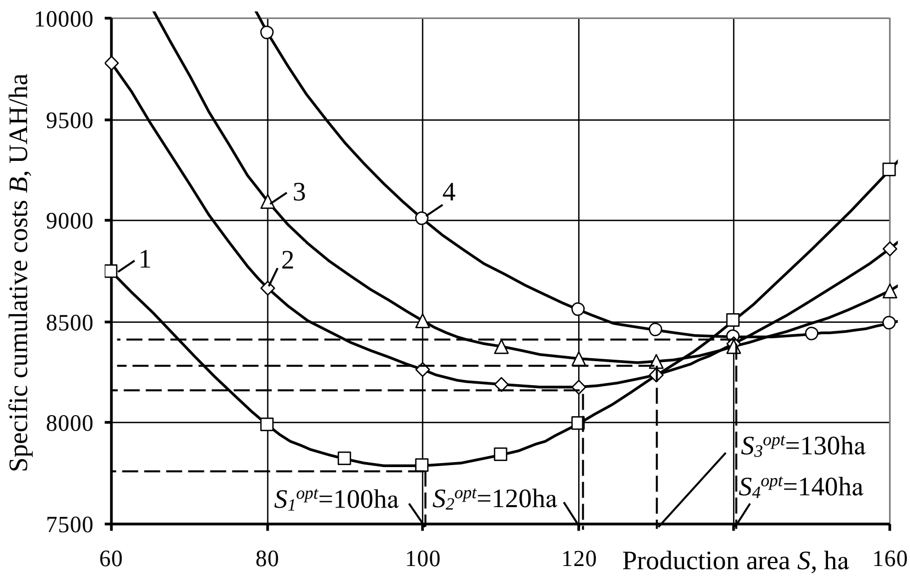

Fig. 2. The dependence of the specific total costs in the BSP projects on the production area of sugar beet (for τ_{sh}=275 day) with different technical equipment: 1 – Franz Kleine SF-10-2 (**275 kW**), HTZ-242K.20+Franz Kleine LS 16; 2 – SKS-624 «Polesie BS624-1» (**290 kW**), HTZ-243K.20+Hawe Ruw 2500T; 3 – Holmer Terra-Dos T2 (**308 kW**), HTZ-243K.20+Hawe Ruw 2500T; 4 – Ropa Euro-Tiger V8-3 (**444 kW**), Claas Axion 930+TPZ-49 Atlant + PZS-40.

The optimization calculations were performed on the basis of the numerical method, according to which for each value of the argument (production area of the crop) the specific operating costs for the execution of works in the SBH projects and the specific technological losses of root crops were determined. The optimal value of the S^{opt} production area for the given technical equipment of projects is determined graphically:

1) graphically depicted the dependencies of specific operating costs, specific technological losses and specific total costs of funds;

2) determined the areas at which the minimum values of the specific total cost of funds are reached;

3) fixed the optimum value of the production area for the corresponding harvesting projects start time.

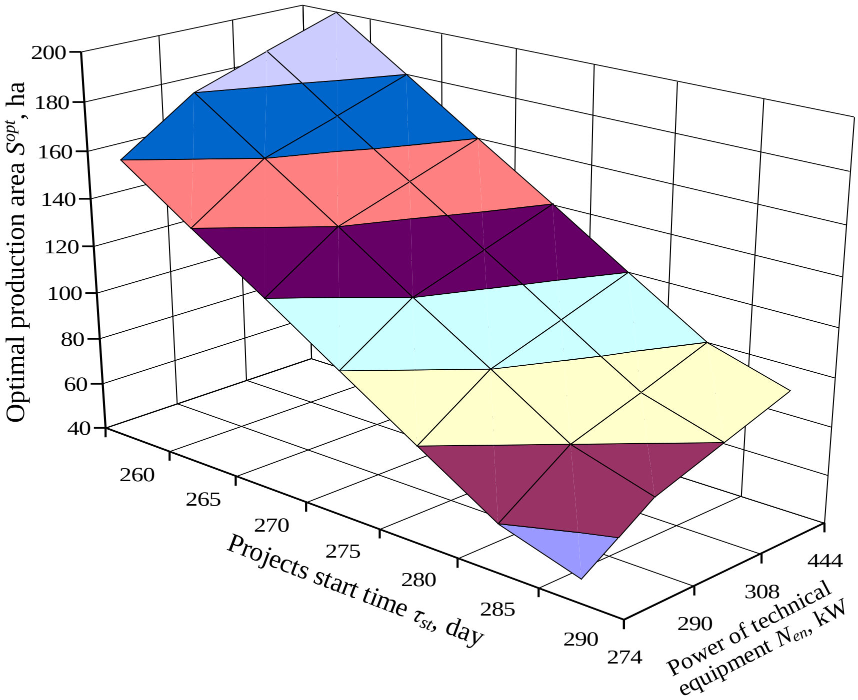

Fig. 3. Dependence of the optimum plant production area (S^{opt}) on the startup time (τ_{sh}) of the SBH projects and the capacity (N_{en}) of the technical equipment.

The results obtained confirm the hypothesis and state the practical possibility of harmonization of the project environment components of TP SBH (start time of projects, production area of culture and parameters of technical equipment) at which the extreme of the efficiency function is achieved – the minimum specific total costs of projects. According to it, the execution of computer experiments with a statistical simulation model of virtual projects of TP SBH and mathematical processing of their results in IAS SMD allows to establish statistical regularities of efficiency indicators change of these projects. On this basis, decisions are made to improve the efficiency of the TS project management, and therefore the material and technical development of the AE.

According to it, to provide the implementation of the SBH projects it is necessary to have: 1) IAS, which allow to quantify the indicators of project effectiveness and their risk; 2) qualified personnel who will monitor the state of the project environment and create a database for IAS SMD; 3) a management component with appropriate equipment that will use the IAS, monitoring data and evaluate the effectiveness of the works' content in the projects; 4) appropriate technical equipment; 5) required amount of labor, material, information resources, etc.

4 Conclusions and Prospects of Further Researches

The development of information-analytical system, including statistical simulation models of technological system projects of the field allows carrying out research of these projects, to evaluate the content and timeliness of works and to justify management decisions under probable conditions of the project environment.

Taking into account the information-analytical system support of management decisions on the influence of the agrometeorological component on the course of work in the respective projects allows obtaining objective results of computer experiments.

On this basis, they establish the regularities of changes in the efficiency indicators with the appropriate technical equipment of the projects, starting time of the works and the volume of the culture production area.

The choice of one or another reconciliation of the startup time of the sugar beet harvesting projects and the production area of the crop with the parameters of the technical equipment should be considered in the context of the technological system of the individual agricultural enterprise.

The use of technical equipment of different capacity (N_{en} = 275; 290; 308 and 444 kW) in the sugar beet harvesting projects causes the increase of the optimal production area of the crop (for τ_{sh} = 275 day (October 3) – S^{opt} = 100; 120; 130 and 140 ha respectively, fig. 2) as well as an increase in specific aggregate costs (B = 7786.6; 8176.2; 8305.5 and 8423.7 UAH/ha).

Offsetting the startup time of these projects from 260 (September 18) to 285 day (October 13) necessitates a reduction in the optimal production area of the crop by 68.8-55.0% for the technical equipment of the corresponding capacity (fig. 3).

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