The Information Technology Use for Studying the Impact of the Project Environment on the Timelines of the Crops Harvesting Projects

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Abstract

The influence of the project's environment on the start-up time and duration of works in sugar beets harvesting projects is characterized. The main attention is paid to the agrometeorological and subject-biological components of the project environment. The usage necessity of statistical simulation modelling methods for the features consideration of the project environment influence on works timelines in projects is substantiated. The main requirements for the statistical simulation model of harvesting projects are given. The main indicators that should be taken into account in the statistical simulation model of projects to establish the characteristics of the natural time of project start-up and duration of work are revealed, as well as assess their overall impact on the value of these projects. The main stages of the impact study of the project environment and substantiation of management decisions in crop harvesting projects are identified. The results of computer experiments with a statistical simulation model of crop harvesting projects according to the impact of the project environment on the work timing in these projects are processed and summarized. The distribution of naturally determined time of sugar beet harvesting projects start-ups with a different planned duration of their implementation has been established. The regularity of change of mathematical expectation estimations of naturally caused works duration in projects is given and this indicator is compared with their planned duration. The distribution of naturally determined works duration in harvesting projects with different planned value is substantiated. The differential functions of distribution and statistical characteristics estimation of naturally determined works duration are given. On the example of the task of the impact consideration of project environment on the timing of the works was proved a relevance the risk management task in crop harvesting projects. The development necessity of automated decision support systems is also confirmed.

Keywords 1

Project environment, Observations, IT, mathematical methods of statistics, Modelling, Support of management decisions, Start-up time, Project, Efficiency.

1. Introduction

A significant part of projects in agricultural production requires consideration of the impact of the project environment. The project environment is external influences that can change the outcome of the project compared to its planned value [17, 19]. Such components of the project environment of crop harvesting (CH) technological systems projects of agricultural crops include agrometeorological conditions and the reached yield [7, 14, 15]. The continuity and variability over time of these natural processes leads to the risk of the effectiveness of CH projects and the occurrence of losses.

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Accordingly, to determine the startup time and completion of CH projects, it is necessary to take into account the patterns of change of the projects environment, which will ensure their implementation with the highest indexes' of value [5, 15, 27]. Undoubtedly, such scientific and applied tasks are related to management and require the use of specific methods and models for their solution [2, 3, 25], and the use and processing of significant amounts of characteristics data of the project environment with information technology (IT) using. Thus, the implementation of CH projects requires solving a scientific and applied problem to improve the efficiency of relevant management processes by taking into account the impact of the project environment on the timing of their implementation and the value of projects in general. The solution of these problems requires the creation and use of specific methods and models of project management. Their construction requires a synergistic combination of different areas of knowledge – management, operational-subject, technological, mathematical statistics, simulation and IT.

2. Analysis of Recent Research and Publications

Time management tasks in projects have long been the subject of research in various fields of industrial production [12, 20, 23] and the national economy [3, 28-30]. In the field of agriculture, many scientific works are devoted to this task [1, 3, 14, 15, 27], based on a systems approach, use methods of mathematical statistics [6] and statistical simulation using IT [8, 9, 11, 16, 21]. Known works in which the tasks of project management for the development of technological systems involve the justification of rational parameters of specialized machines complexes in accordance with the planned scope of work and the natural timing of projects [1, 14]. In particular, the configuration and content of agricultural projects are substantiating by the cost criterion – the minimum unit cost. To do this, evaluate the rationality of decisions on project management – the consistency impact of project start-up time (start of work), configuration and content on the work timeliness and economic indicators of value (efficiency). The analysis of these works convinces of the need for a deeper study of management decisions on the coordination of project start-up time, content and duration of work, as well as the configuration of projects (technical equipment).

The aim of the research is to reveal scientific and methodical provisions and results of research of objective components influence of the projects environment on the time of start-up and works duration in agricultural crops harvesting projects.

2.1. Results of Research

Implementation of CH projects is based on the well-known project management processes, and also requires consideration of the impact of the project environment (rate of harvest, agrometeorological conditions), content (scope of work) and configuration (technical support, contractors) of projects. Therefore, the determination of the start time ($\tau_з$) (calendar day) of CH projects should be performed taking into account that the terms of their completion ($\tau_к$) coincide with the corresponding agro-technical terms [27]. In particular, such terms of completion of sugar beet CH projects are due to the correspondence between their content and configuration, as well as the impact of the project environment – harvest, continuous change of soil (its physical maturity) in autumn and the impact of agrometeorological conditions [27, 28]. Then the project will be considered in time, and the time of its launch will be rational. Note that the completion time ($\tau_ф$) of the soil's physical maturity reflects the production situation in which work in the sugar beet harvesting projects are stopped (due to the beginning of winter), the crop is lost, and the value of projects decreases.

The development of such methods and models of CH project management, which allow to take into account the peculiarities of the project environment (with probabilistic components) on the indicators of the value of their implementation requires the use of appropriate databases and knowledge, statistical simulation methods [9, 10, 13], information technology (IT) and generalization of the results of computer experiments (Figure 1).

On this basis, there is an opportunity to justify management decisions to improve the efficiency of project management processes, the development of concepts for the coordination of projects components for the development of agricultural production and their value in general.

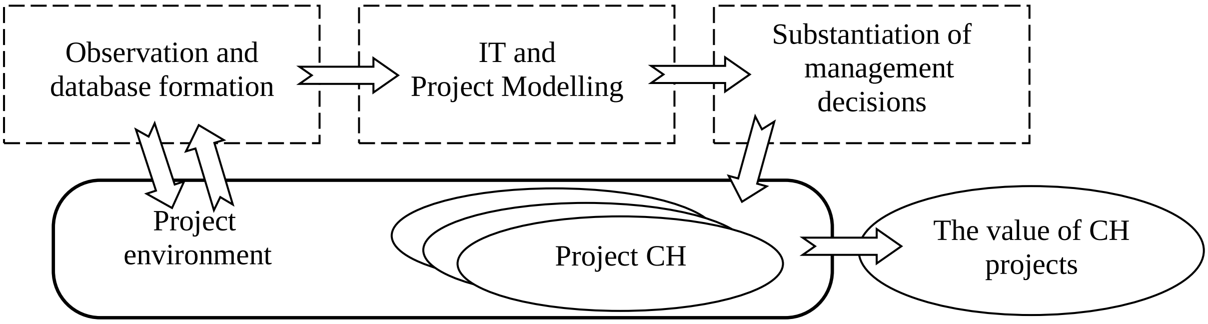

Figure 1: The main stages of the study of the project environment impact and substantiation of management decisions in the CH projects

To determine $\tau_з$ it is necessary to have a database on $\tau_ф$, as well as to know the duration of work (t_p) in CH projects:

$$t_p = \frac{\sum_{\gamma=1}^{\gamma=p} S_{n\gamma}}{W_д}, \tag{1}$$

where $S_{n\gamma}$ – the area of the γ-th field, which forms the content of the CH projects with p-th their total number, ha; $W_д$ - daily rate of works in CH projects, ha/day.

Thus, the start time $\tau_з$ of the CH projects must be determined so that all work is completed before the event $\tau_ф$, then the equality – $\tau_к = \tau_ф$ will be ensured. Abstracting from the influence of the agrometeorological component of the project environment $\tau_з$ can be defined ideally as the time difference between the calendar day $\tau_ф$ and the duration of work t_p. However, in production conditions, the time of completion of $\tau_к$ projects of CH is characterized by the probability due to the influence of agrometeorological component:

$$\tau_к = f(\tau_з, W_д, S_n, \Sigma t_н). \tag{2}$$

where $\Sigma t_н$ – the total duration of non-rainy intervals during the implementation of projects, days.

Information on $\Sigma t_н$ can be obtained from official data of agrometeorological stations [1].

The probable character of the CH projects completion time $\tau_к$ complicates its accurate forecasting. Therefore, for any planned (defined) time of launch $\tau_з$ of projects there is only a certain probability that specialized works will be completed at the moment $\tau_ф$ and the condition – $\tau_к=\tau_ф$ will be fulfilled. This feature of CH projects is due to the probabilistic influence of the project environment – agrometeorological allowed fund time for the implementation of works in projects.

The objective reason for such stochasticity is also the influence of non-rainy intervals ($t_н$), which leads to an increase in the duration t_p of the corresponding works in the projects and the risk of their timeliness. Occurrence of non-rainy intervals $t_н$ presupposes the need to shift the start time $\tau_з$ of CH projects at an earlier date by the total duration of non-rainy intervals – $\Sigma t_н$. Accordingly, the actual duration t_p of work in CH projects will increase in direct proportion, which reflects the objective need to develop methods and models for content and time management in these projects.

It should be mentioned that the daily rate of works $W_д$ in CH projects is also characterized by variability. These rates are determined by the productivity of beet harvesters [18, 22, 26], as well as organizational and technological forms of relevant work [1, 14, 15, 27]. Seeing that the productivity of the beet harvester depends on the fields and the state of the crop grown characteristics, the pace of work in the projects of CH will be variable.

As for the state of the grown crop, in particular sugar beets, this state changes objectively and not only before the launch of the CH projects but also during their implementation. The pattern of changes in this project environment component state is characteristic of each individual field $S_{n\gamma}$, which is included in the content of the CH projects. At the time of their launch, this state is different. Knowledge of the regularity of its change to the event $\tau_з$ as well as its significance at the time of $\tau_з$ allows you to predict this state (yield) for any time of work in these projects [7]. The ability to predict this condition is the basis for assessing potential losses from premature or untimely work. If they are performed prematurely, losses will occur due to a shortage of potential yield [7], which could grow to $\tau_ф$ [27]. In the case when works in CH projects are performed late (before the onset of frost, or $\tau_ф$) part of the area with the achieved harvest of sugar beets remains unharvested, and therefore the crop grown on them is lost completely. The possibility of estimating crop losses due to premature and untimely execution of works makes it possible to assess the risks of CH projects, and thus justify management actions to minimize them. This is achieved through knowledge of the patterns of change in the state of the biological component (sugar beet harvest) of the project environment during the relevant calendar period.

Having data on the timeliness of work in the CH projects there is a possibility of cost estimation of crop costs due to their early or undeveloped implementation. To assess (forecast) these costs, it is necessary to know the number of crop losses, their market value, material and technical costs, as well as the cost of time to work on these projects. Cost estimation is performed according to known methods [24].

Quantitative assessment of the timeliness of work in the CH projects with the appropriate technical support is carried out on the basis of modelling the impact of agrometeorological and subject-biological components of the project environment on the course of work in these projects. Given the probabilistic nature of many components, the model of CH projects should be statistical and simulation [9, 10, 13], which would reproduce the features of their interaction. It is the repeated (iterative) reproduction of works in projects that makes it possible to reflect and take into account the probabilistic components and determine the estimates of statistical characteristics [6] of the main indicators of the CH projects value.

Considering the key points of statistical simulation, which allow determining the number of works in the CH projects. Generating in the calendar time model ($\tau_ф$) the completion of the physical maturity of the soil (or the occurrence of frosts in the autumn-winter period) at which work in the projects of CH is completed allows you to set an "extreme point" to record the timeliness of work. For each iteration of the model, the value of $\tau_ф$ allows setting CH $\tau_з$. To do this, determine the duration of t_p in projects. Under favourable agrometeorological conditions ($t_н$ = 0 days) the duration of t_p is found by formula (1). For this purpose, the daily rate ($W_д$) of works in CH projects for the γ-th field is determined, which depends on many factors: 1) configuration (K_γ) and relief (ρ_γ) of the field; 2) yield of sugar beets (U_γ); 3) technical support of CH projects ($T_н$); 4) organizational and technological forms of their implementation ($T_Л$); 5) the daily duration of harvesting ($t_д$):

$$W_{д\gamma} = f(K_\gamma, \rho_\gamma, U_\gamma, T_н, T_Л, t_д). \quad (3)$$

Without resorting to the methodological principles of determining (forecasting) the daily rate of work $W_д$ for many fields with sugar beet harvest [18, 22, 26], note that the value of $W_д$ is taken as the average for all fields and is determined by statistical simulation modelling of project-technological works.

The availability of statistical models of $\tau_ф$, $t_н$ and clear intervals ($t_п$) for the autumn-winter period, as well as knowledge of the daily rate $W_д$ of works is the main database for statistical simulation of sugar beet projects and forecasting of terms $\tau_з$. In particular, the start time $\tau_з$ of projects for a known value of $\tau_ф$, in this case, will be determined by the formula:

$$\tau_{зi} = \tau_{фi} - (t_{p_i} + \sum_j t_{н_{ij}}). \quad (4)$$

where *i, j* – the indices of the multiplicity of the implementation of CH projects in the model and the values of the non-rainy period of the autumn-winter period.

Thus, the analysis of the preconditions for the formation of the start time $\tau_з$ of the CH projects shows that for a constant duration t_p is determined by three probabilistic components – the time of completion $\tau_ф$ physical maturity of the soil, as well as the duration of non-rainy ($t_п$) and rainy ($t_н$) intervals. Given this, the "scatter" of the values of the probabilistic value of $\tau_з$ will be larger compared to the values $\tau_ф$ [25]. This means that the risk of making an incorrect decision on the start time $\tau_з$ of CH projects increases compared to the accuracy of forecasting the time of completion $\tau_ф$ of physical maturity of the soil in the autumn-winter period.

Taking into account the impact of the agrometeorological component on the work in the CH projects makes it possible to objectively establish the statistical change patterns in their functional indicators of efficiency. In particular, to take into account the impact of this component of the project environment, the relevant observational data were collected, systematized and processed. Based on the processing of observation reports (TCX-1, KM-1) of the Volodymyr-Volyn meteorological station on the condition of the upper layers (0-2, 2-10 cm) of the soil (for the period of 45 years – 1971-2016), time and volume of precipitation rain (for 16 years – 2000-2016) formed empirical data (for the calendar period from September 1 to November 30): 1) the duration of the naturally allowed daily fund of time to perform work in the CH projects; 2) the duration of the naturally allowed time fund for these works during the autumn period; 3) the time of rain in the context of the day.

Empirical data are processed by known methods of mathematical statistics [6], as a result the theoretical distributions of probabilistic quantities are substantiated. The obtained statistical regularities are the basis for the reflection of the simulation model of the project environment impact on the timeliness of work in virtual projects of CH [13].

Thus, the method of performing production observations on the impact of agrometeorological and biological-subject components of the project environment is based on the results of specially organized observations of the meteorological station. On this basis, a retrospective set of indicators was obtained and their mathematical processing was performed, which made it possible to form an exhaustive list of statistical regularities to take into account time constraints on work in CH projects in their statistical simulation model.

The method of works modeling in projects is to reflect the impact of natural processes on the timing of their implementation, as well as to reflect the daily course of beet harvesting [18, 22, 26], which are performed adaptively to the continuous growth of sugar beetroots, their maturation, and physical maturity under the stochastic influence of agronomic conditions autumn period.

It is well known that due to such a biological feature of sugar beet root formation as an increase in their weight and sugar content in the autumn, it is quite economically motivated to harvest at the latest calendar dates [27]. However, due to the stochasticity of agrometeorological conditions, the timeliness of work in CH projects will be characterized by risk [15].

That is why the time fund for the implementation of these works must be coordinated with natural processes, to perform simulation modelling of the impact of the project environment on the value of CH projects, to use the appropriate database and IT. To reveal the relationship between the duration t_p of the work in the projects and the natural time of their beginning ($\tau_з^п$), as well as to assess the risk $\tau_з^п$, we performed a statistical simulation of the development of weather conditions in the autumn. In particular, $\tau_з^п$ it was determined for four variants of the planned duration of t_p – 5, 10, 15 and 20 days (Figure 2).

The analysis of distributions indicates of the $\tau_з^п$ a significant variation of this probabilistic value, which is 60 days. Accordingly, in practice it is quite difficult to accurately predict $\tau_з$ at which work in the CH projects will be performed with the provision of the condition – $\tau_к = \tau_ф$. This feature of the impact of the project environment determines the significant relevance of risk management tasks in CH projects and the development of automated decision support systems.

It should also be noted that due to the influence of non-rainy intervals, the duration of t_p will increase. This impact of the project environment also increases the probability of losses in CH projects. Our computer experiments made it possible to establish the influence of the agrometeorological component of the project environment on the "extension" of the duration of work t_p in projects compared to their planned value (Figure 3).

The obtained regularity of mathematical expectation estimates $\bar{M}[t_p^п]$ for different t_p in CH projects (Figure 3) confirms the hypothesis that for relatively large values of t_p duration the influence of agrometeorological component of the project environment on the timeliness of work will be more negative.

This phenomenon also causes a downtime of technical support at rainy intervals and affects the risk of timely work in projects. In particular, the value of the correlation coefficient – $r = 0.999$ states a close relationship between $\bar{M}[t_p^п]$ and t_p.

It is also established (Figure 4) that the increase in the planned duration tr leads to an increase in the scatter of the probabilistic quantity $t_р^п$.

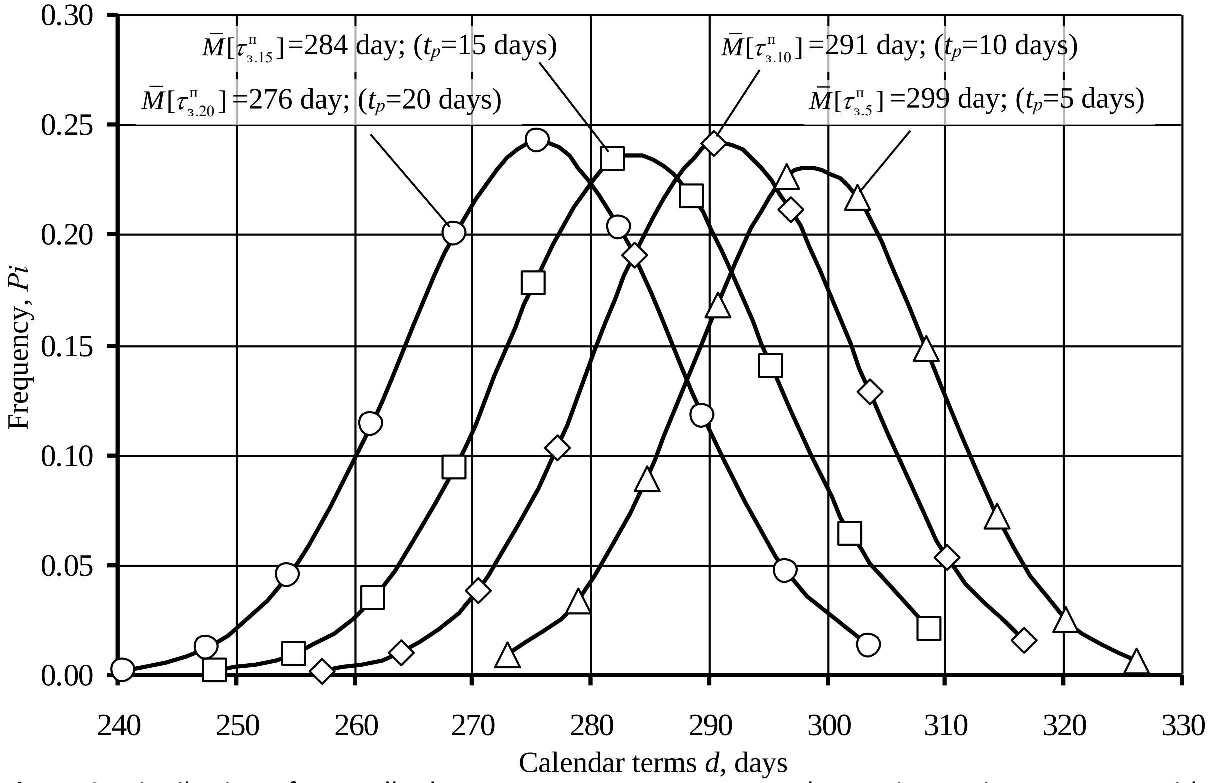

Figure 2: Distribution of naturally determined time of sugar beet harvesting projects start-up with different planned duration of their implementation: $\bar{M}[\tau^{п}_{з.5}], \bar{M}[\tau^{п}_{з.10}], \bar{M}[\tau^{п}_{з.15}]$, $\bar{M}[\tau^{п}_{з.20}]$ – the estimation of the naturally determined time mathematical expectation of the CH projects start-up for different (5,10,15 and 20 days) planned (t_p) their implementation

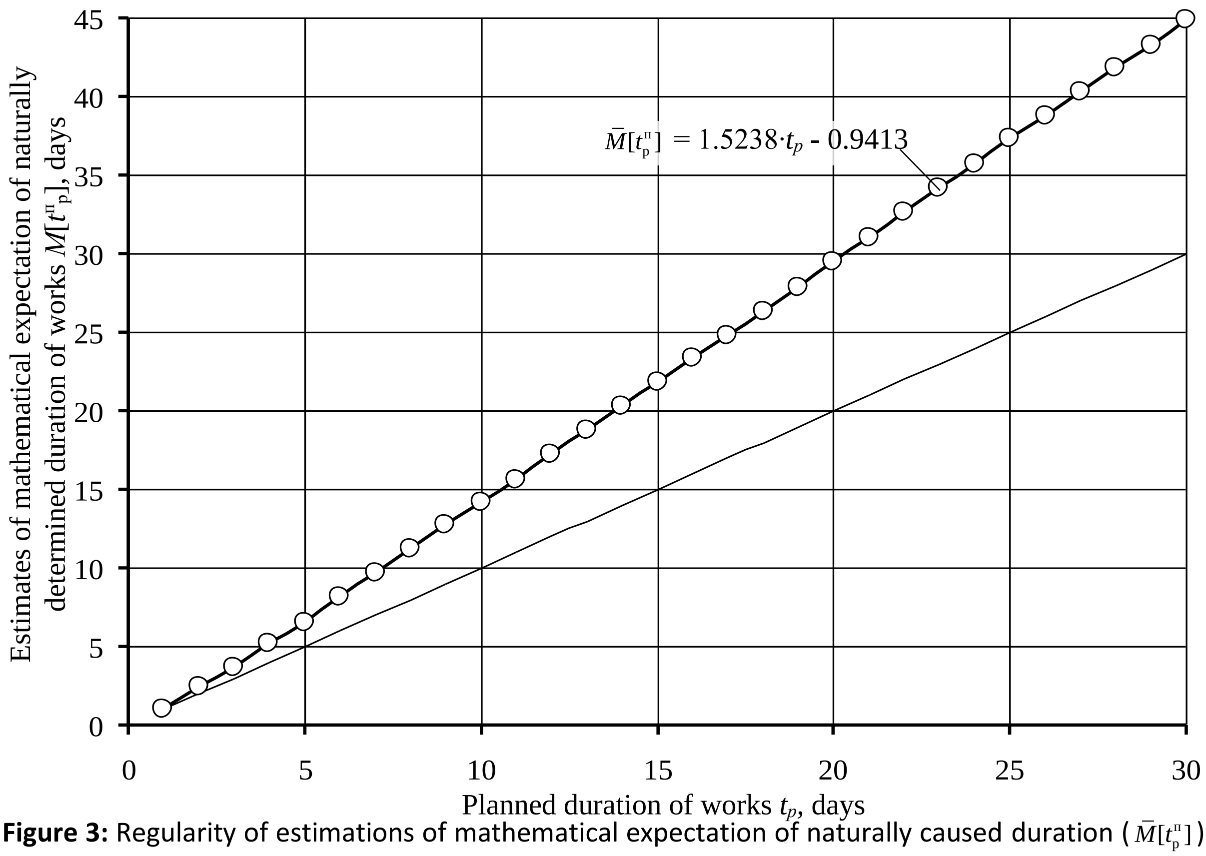

Figure 3: Regularity of estimations of mathematical expectation of naturally caused duration ($\bar{M}[t^{п}_{р}]$) of works in CH projects (in comparison with its planned value)

In particular, the study of the results of statistical simulation relatively $t_{р}^{п}$, allowed to establish that their empirical distributions are consistent with the theoretical law of Weibull distribution.

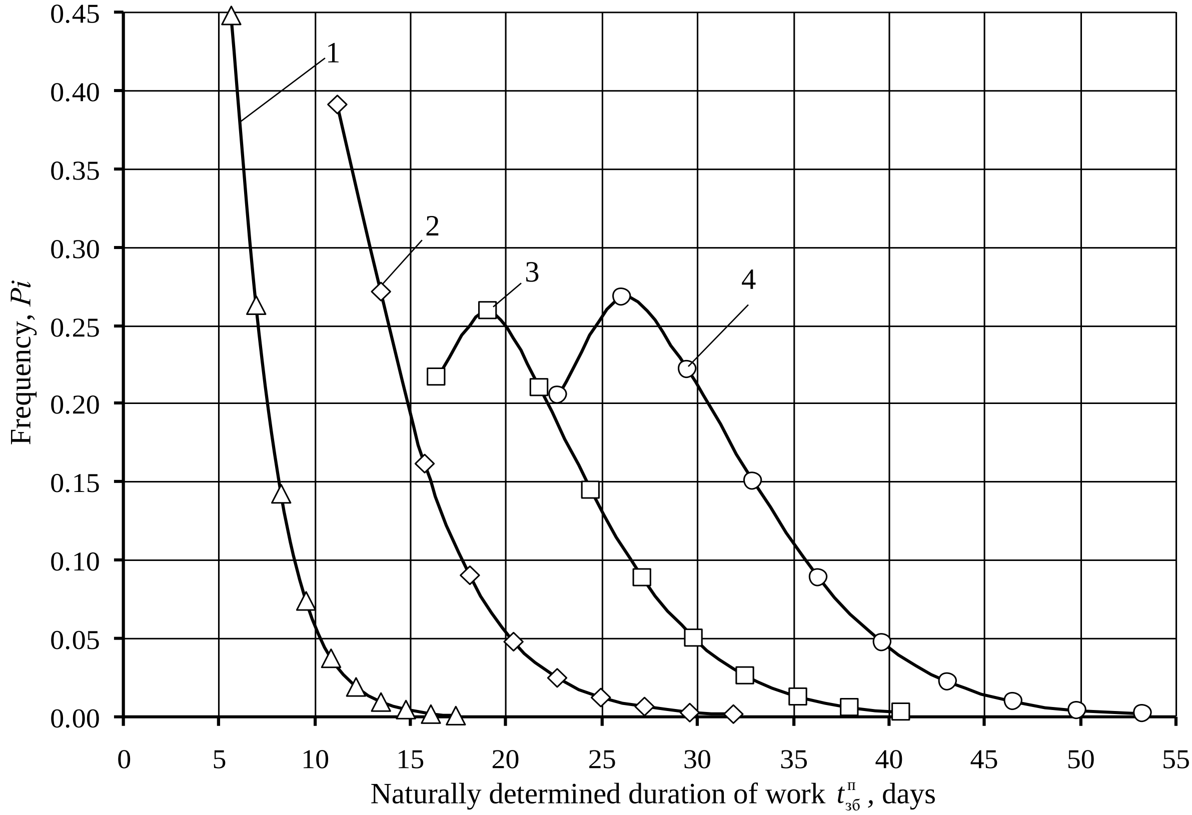

Figure 4: Distribution of naturally determined duration ($t_{р}^{п}$) of works in CH projects with different planned value (t_p): 1 – 5 days; 2 – 10 days; 3 – 15 days; 4 – 20 days

Table 1
Differential functions of distribution and estimation of statistical characteristics of naturally caused duration of works implementation in CH projects

Planned duration of works t_p, days	Differential distribution function (Weibull)	Estimates of statistical characteristics	
		$\bar{M}[t_{р}^{п}]$, day	$\upsilon[t_{р}^{п}]$
5	$f\left(t^{п}_{р.5}\right)=0,498\cdot\left(\frac{t^{п}_{р.5}-5}{2,169}\right)^{0,079}\exp\left[-\left(\frac{t^{п}_{р.5}-5}{2,169}\right)^{1,079}\right]$	7,12	0,939
10	$f\left(t^{п}_{р.10}\right)=0,258\cdot\left(\frac{t^{п}_{р.10}-10}{4,472}\right)^{0,154}\exp\left[-\left(\frac{t^{п}_{р.10}-10}{4,472}\right)^{1,154}\right]$	14,27	0,879
15	$f\left(t^{п}_{р.15}\right)=0,19\cdot\left(\frac{t^{п}_{р.15}-15}{7,624}\right)^{0,451}\exp\left[-\left(\frac{t^{п}_{р.15}-15}{7,624}\right)^{1,451}\right]$	21,91	0,698
20	$f\left(t^{п}_{р.20}\right)=0,161\cdot\left(\frac{t^{п}_{р.20}-21}{9,492}\right)^{0,528}\exp\left[-\left(\frac{t^{п}_{р.20}-21}{9,492}\right)^{1,528}\right]$	29,55	0,664

The obtained data sets were processed by the methods of mathematical statistics, which together with the application of Pearson's χ^2 criterion made it possible to substantiate the differential distribution functions $t_{\text{р}}^{\text{п}}$ (Table 1). Thus, taking into account the impact of the project environment (agrometeorological and subject-biological components) on the start-up and end dates of work in the CH projects plays an important role in assessing the risk of their timeliness. On this basis, the risk of losses in projects, the consistency of the start time, production area and parameters of technical support of projects is assessed, and then their value is determined. The generalization of tasks for the CH projects convinces that agricultural enterprises are interested in starting their implementation in the late calendar period at which the crop yield is maximum, as well as to perform of projects work in the shortest possible time. However, shifting project start times to late calendar periods increases the likelihood of delays in harvesting, frost damage to root crops, and reduced the project efficiency. Simultaneously, reducing the duration of work in these projects requires powerful technical support and leads to significant costs [24]. To solve this problem, it is necessary to reconcile the start up time of project and the culture production area with the technical support parameters of the respective projects. However, the choice of CH projects start up time with a known duration of work will allow to ensure their timeliness only with a certain level of probability. If the work is performed for a long time, there will objectively be a larger "scatter" of the distribution values of the naturally determined time of project start (Figure 4). This indicates that ensuring the timeliness of work in projects will be less likely, and thus increase the likelihood of losses and reduce the value of projects. Disclosure of the methodology of taking into account the impact of the project environment at the start up time of CH projects is aimed at identifying the criteria and function of the goal, as well as defining requirements for modelling techniques and establishing statistical patterns of functional indicators of relevant projects. The establishment of these patterns is the basis for testing the hypothesis that improving the efficiency of project management can be achieved by coordinating the interaction of its components, in particular, on the criterion of minimum specific total cost. The combined impact of agrometeorological and biological-subject components of the project environment of the CH is characterized by stochasticity and objectively forms the naturally determined terms of its implementation. Taking into account of this feature makes it possible to assess the timeliness of the relevant work in the projects for a given area of sugar beet and technical support. Substantiated distributions and statistical regularities of influence of agrometeorological and biological-subject components allow to reflect objectively a course of works in projects of CH in their statistical simulation model. The development of this model and the performance of computer experiments make it possible to obtain functional indicators of the efficiency of the relevant work, and thus to reconcile the time of their beginning and the production area of sugar beets with the parameters of technical support.

2.2. Conclusions and Prospects of Further Researches

The objectives specificity of the study necessitates a combination of production observations and computer experiments, which are aimed at system-event reflection of the impact of agrometeorological and biological-subject components of the project environment of CH on the timeliness of their implementation. Uncontrollability and stochasticity of basic events that affect the course of work, necessitate the consideration of functional indicators in probabilistic terms. The development of methods and models of CH project management that allow to take into account the probabilistic components of the project environment requires the use of appropriate databases and knowledge, methods of statistical simulation, IT, computer experiments and generalization of their results. This makes it possible to decisions substantiate for the efficiency increase of projects management, as well as to form programs for the development of technological systems for harvesting crops. The use of IT in the study of the project environment impact on the start-up time and duration of work in the projects of CH allows performing statistical simulation of these works and obtaining objective results of computer experiments. On this basis, establish patterns of change in the value of projects with the appropriate technical support (configuration), start-up time and crop harvesting area (content). The analysis of the established distributions of the naturally conditioned time of start-up of CH projects indicates a significant variation of this probabilistic value (60 days)

(Figure 2). Therefore, in practice it is quite difficult to predict the time of project launch at which the relevant work will be performed on time. This feature of the project environment impact, determines the significant relevance of risk management tasks in CH projects and the development of automated decision support systems. Due to the influence of the project environment, there is also a risk of the duration of work increasing in CH projects and increasing the likelihood of losses. Our computer experiments allowed us to establish the influence of the projects environment on the "extension" of the duration of work compared to its planned value (Figure 3). For a relatively longer planned duration of works, the impact of the project environment on the timeliness of work in the CH projects will be more negative. In particular, the study of the results of statistical simulation on the variability of the natural work duration in the projects of CH, allowed establishing (Figure 4) that their empirical distributions are consistent with the theoretical Weibull distribution law (Table 1). The choice of CH projects start up time with a known duration of work will allow to ensure their timeliness only with a certain level of probability. If the work is performed for a long time, there will objectively be a larger "scatter" of the distribution values of the naturally determined time of project start (Figure 4).

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4. References

[1] A. M. Polovyi, L. Yu. Bozhko, O. V. Volvach, Fundamentals of agrometeorology: Textbook. Odessa State Ecological University. Odessa: TES, 2012.

[2] A. Tryhuba, M. Rudynets, N. Pavlikha, I. Tryhuba, I. Kytsyuk, O. Korneliuk, V. Fedorchuk-Moroz, I. Androshchuk, I. Skorokhod, D. Seleznov. Establishing patterns of change in the indicators of using milk processing shops at a community territory. Eastern-European Journal of Enterprise Technologies: Control processes. 3/6(102), 2019, pp. 57-65.

[3] A. Tryhuba, V. Boyarchuk, I. Tryhuba, O. Ftoma. Forecasting of a Lifecycle of the Projects of Production of Biofuel Raw Materials With Consideration of Risks. IEEE International Conference on Advanced Trends in Information Theory (ATIT), 2019, pp. 420-425.

[4] A. Tryhuba, V. Boyarchuk, I. Tryhuba, O. Ftoma, R. Padyuka, M. Rudynets. Forecasting the risk of the resource demand for dairy farms basing on machine learning. Proceedings of the 2nd International Workshop on Modern Machine Learning Technologies and Data Science (MoMLeT+DS 2020), Vol. 1, 2020, pp. 327-340.

[5] D. Lukianov, M. Mazeika, V. Gogunskii, K. Kolesnikova. SWOT analysis as an effective way to obtain primary data for mathematical modeling in project risk management. CEUR Workshop Proceedings, 2711, 2020, pp. 79-92.

[6] E. A. Vukolov, Fundamentals of statistical analysis. Workshop on Statistical Methods and Operations Research using packages STATISTICA and EXCEL: study. allowance. 2nd ed., rev. and add. Moscow: FORUM, 2008.
[7] G. Heidari, Y. Sohrabi, B. Esmailpoor. Influence of harvesting time on yield and yield components of sugar beet. Agri. Soc. Sci., 4(2), 2008, pp. 69-73.
[8] H. Schildt, C#: The Complete Reference, Osborne: The McGraw-Hill Companies, 2003.
[9] J. P. Davies, K. M. Eisenhardt, C. B. Bingham. Developing theory through simulation methods. The Academy of Management Review. 32(2), 2007, pp. 480-499.
[10] K. Dooley, "Simulation research methods," Companion to Organizations, Joel Baum (ed.), London: Blackwell, 2002, pp. 829-848.
[11] L. Bertalanffy, W. Hofkirchner, D. Rousseau, General system theory. Foundations, development, applications, 1st. ed., George Braziller Inc, New York, NY, 2015.
[12] O. Mashkov, V. Chumakevych, V. Ptashnyk, I. Puleko. Qualitative evaluation of the process of functionally stable recovery control of the aircraft in emergencies with an algorithm based on solving inverse dynamic problems. CEUR Workshop Proceedings, 2631, 2020, pp. 384-394.
[13] P. Bratley, B. Fox, S. Linus, A Guide to Simulation, Springer, New York, NY, 1987.
[14] P. Lub, A. Sharybura, L. Sydorchuk, A. Tatomyr, V. Pukas, M. Cupial. Information-analytical system of plants harvesting project management. CEUR Workshop Proceedings 2565 (2020), 244-253.
[15] P. Lub, A. Sharybura, V. Pukas. Modelling of the technological systems projects of harvesting agricultural crops. 2019 IEEE 14th International Conference on Computer Sciences and Information Technologies (CSIT). Lviv, Ukraine, 2019, pp. 19-22.
[16] R. Y. Rubinstein, D. P. Kroese, Simulation and the Monte Carlo method, 2-nd ed., Wiley, 2007.
[17] S. Bushuev, D. Bushuev, R. Yaroshenko. Management of projects in the conditions of "behavioral economy". Management of complex systems development. Vol. 33, 2018, pp. 22-30.
[18] SSTU 7062:2009. Sugar beets. Harvesting. Quality indicators and methods of their determination. [Effective from 2011-01-01]. Kyiv: Derzhspozhyvstandart of Ukraine, 2011.
[19] The Standard for portfolio management. 3-d ed., Project management institute, 2013.
[20] T. M. Olekh, S. V. Rudenko, V. D. Gogunsky. Assessment of environmental projects. Eastern-European Journal of Enterprise Technologies, 1(10-61), 2013. pp. 79-82.
[21] T. Olekh, V. Gogunskii. Use of Discrete and Continuous Markov Chains for System Absorbing States. 2019 IEEE International Conference on Advanced Trends in Information Theory, ATIT 2019 – Proceedings, 2019. pp. 518-521.
[22] V. D. Grechkosiy, Complex mechanization of beet growing: textbook. Manual, National University of Life and Environmental Sciences of Ukraine, Vinnytsia, Nilan-LTD, 2013.
[23] V. Gogunskii, O. Kolesnikov, G. Oborska, A. Moskaliuk, K. Kolesnikova, S. Harelik, D. Lukianov. Representation of project systems using the Markov chain. Eastern-European Journal of Enterprise Technologies, 2(3-86), 2017, pp. 60-65.
[24] V. L. Pukas, Substantiation of the hardware parameters of sugar beet harvesting technological process (machines and means of mechanization of agricultural production), Ph.D. thesis, Lviv national agrarian university, Lviv, 2020.
[25] V. L. Pukas, The requirements substantiation of the determination method for brief-cases of projects beginning time of sugar beets harvesting, Mechanization and electrification of agriculture, Glevaha, 4(103), 2016, pp. 57-65.
[26] V. M. Bulgakov, Theory of beet harvesters: monograph, Kyiv: NAU Publishing House, 2005.
[27] V. V. Lykhochvor, V. F. Petrychenko, P. V. Ivashchuk, O. V. Korniychuk, Plant growing. Technology of growing crops, Lviv : NFV "Ukrainian technologies", 2010.
[28] Z. Pustova, N. Pustova, S. Komarnitskyi, O. Tkach, S. Zamoiskyi, A. Olenyuk. Influence of biopreparations on biomass yield and grain efficiency of energy corn. 6th International Conference – Renewable Energy Sources (ICoRES 2019) 154 (01008), 2020, pp. 1-10.
[29] E. Vasilevskis, I. Dubyak, T. Basyuk, V. Pasichnyk, A. Rzheuskyi, Mobile application for preliminary diagnosis of diseases. CEUR Workshop Proceedings, 2255 (2018) 275–286.
[30] M. Odrekhivskyy, V. Pasichnyk, A. Rzheuskyi, V. Andrunyk, M. Nazaruk, O. Kunanets, D. Tabachyshyn, Problems of the intelligent virtual learning environment development. CEUR Workshop Proceedings 2386 (2019) 359–369.