

Chapter 32

Consideration of NON-Factors in Complex Models of Agricultural Production



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Abstract Using a specific example of solving the problem of creating and using an integrated planning model for the functioning of a difficult-to-formalize agricultural process for harvesting grass feed, an analysis of the causes of the manifestation of a range of NON-factors that significantly affect the sustainability of the feed production process under consideration has been carried out. The combination of an operational-calendar logical-dynamic model represented by a system of differential equations with fuzzy-probability models describing volume-resource planning and synthesized on the basis of expert knowledge for predicting yield and quality of grasses, allows solving a large-scale multiparametric problem of the theory of schedules for individual stages of harvesting grasses for silage. The following NON-factors are recorded in the modeling: uncertainty, fuzziness, underdeterminacy, inaccuracy, etc. At the level of the general description of the complex model, the following properties were additionally highlighted and formally described: incorrectness, inaccuracy, inadequacy of the model and ambiguity of interpretation of modeling results. In the field of artificial intelligence, the modeling of NON-factors is of paramount importance. This is due to the fact that intelligent technologies are aimed at solving creative problems in conditions of significant uncertainty, incompleteness, inaccuracy, and fuzziness of the source data and the relationships between them when modeling complex objects in various subject areas. Such objects are fairly classified

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as difficult to formalize and poorly structured. It is shown and justified that the use of fuzzy-probabilistic and logical-dynamic approaches makes it possible to successfully identify, recognize the causes of manifestation and overcome the negative impact of most NON-factors, which significantly improves the quality of modeling difficult-to-formalize agricultural production in general and operational and calendar planning of grass harvesting processes for silage in particular.

32.1 Introduction

Humanity has always used, is using and will use a whole set of NON-factors in everyday life and science, but never before had there even been a thought about their special role in mathematics, computer science and other subject areas [1, 2].

Based on numerous interdisciplinary studies carried out, it has been established [3–8] that any formal system, including agricultural, is characterized by a certain set of uncertainties as an inherent property of any information. In engineering practice, such NON-factors as uncertainty, underdeterminacy, vagueness, inaccuracy, etc., are leading. The list of such negative factors consists of numerous nouns from production activities and not only with the prefix “not”.

In all countries, agriculture plays an important role in the economy, therefore, various possible efforts are being made to increase the productivity of agro-industrial complexes and farms by, for example, improving soil quality, reducing losses and using the latest technologies, including soil sensing, management of technical means, creating an integrated support network for smart management [9–12]. At the same time, it should be noted that modeling studies practically do not pay attention to the issues of identifying NON-factors, although their implicit overcoming is almost always carried out.

The most common concept of NON-factors is uncertainty. Uncertainty is, in the narrow sense, the absence or insufficiency and incompleteness of information about the state of an object or the conditions of a process, and in the broad sense, the generalization of all NON-factors and the fuzzy variables describing them. When synthesizing an integrated planning model for the state of a complex arbiological object (CABO), the concept of uncertainty is characterized by many different kinds of factors, both on the part of decision makers (decision makers) and uncontrolled natural influences. These include unreasonable (inaccurate and unclear) deadlines for the start or end of planned work stages for the entire multi-stage technology (sowing, plant care, fertilizing, mowing, harvesting grasses for silage and storing harvested feed), the degree of readiness of agricultural forage harvesting resources, unpredictable changes in weather conditions, and the lack of reliable estimates of the quality of crops material forecasting, yield forecasting, etc.

Inaccuracy and vagueness relate to the content of information (or the meaning of the essence) and, along with incompleteness and consistency, must necessarily be taken into account when presenting knowledge [2]. Examples of data inaccuracy occur not only when measuring physical quantities, but also depending on the degree

of mental state and health of the person making the measurements or the necessary records. It should be borne in mind that any measured value of a quantity is indistinguishable in a certain range of inaccuracy $M \pm t_p * s_m$ of a calculated or defined modal value M with an estimate of accuracy s_m and a confidence coefficient t_p (where the significance level $p = 1 - P$, P is the selected confidence probability) under a known distribution law.

In scientific research, NON-factor inaccuracy as a property of something being not entirely accurate or not meeting expectations can manifest itself in various forms. Thus, inaccurate information can be consistent or contradictory. At the same time, in practice, inaccuracy, as well as vagueness, can be manifested by the inability to accurately, clearly and intelligibly reproduce their thoughts and speeches when making decisions; a tendency to inconsistency, inconsistency in the performance of their duties; inability to show organization, accuracy and pedantry in their work.

Many NON-factors have led to the need to identify such main groups of factors as sources of uncertainty. Thus, four main groups of factors are described in [8] in relation to complex risk modeling in the development of management decisions in complex organizational and technical systems:

- I factors related to the object with which both the environment and the subject interact, or subjects with their own and “alienated” knowledge (for example, in the form of knowledge bases);
- II factors directly related to the environment (uncertainty of the impact of the environment on objects “immersed” in it);
- III factors generated by uncertainty, vagueness of human thinking and knowledge—subjective or personalistic uncertainty that manifests itself when a person interacts with his environment;
- IV factors caused by uncertainty, vagueness, inconsistency of accumulated knowledge, uncertainty of certain procedures.

In a more specific case, during the direct design process of a certain model [6], the following categories of NON-factors were identified at characteristic levels:

- display property \mapsto parameter: inaccuracy, fuzziness, uncertainty, ambiguity of measurements of properties;
- mapping parameters \mapsto model: non-multiplicative domains of parameters in the model, irreversibility of the model, non-orthogonality of parameters in the model;
- model—model relations: heterogeneity of formal apparatuses, incompleteness of the model-parametric space, inconsistency of models;
- Model—object relations (interpretation of models): incorrectness of the model, its inaccuracy, inadequacy of the modeled object, ambiguity of interpretation of modeling results.

Here, unlike the more general classification discussed above, NON-factors characterizing a whole range of specific uncertainties of our knowledge are not taken into account.

Thus, even on the basis of such a small study, it can be concluded that all NON-factors cannot be simultaneously taken into account in one planning model for the state of a complex arobiological object (CABO).

The choice of methods and algorithms for solving the problem of volume and calendar planning of the feed production process plays an important role in taking into account non-factors in complex models of agricultural production. Further, using the example of the process of harvesting grasses for silage as a typical representative of clogs, the current NON-factors and ways to account for them in each of the main components of the complex operating model of the enterprise will be demonstrated.

32.2 NON-Factors in the Complex CABO Model

The general formulation of the task of synthesizing enterprise operation plans in the implementation of modeling complex technologies and facilities is described in detail in works on this topic [3–5, 8]. The practical implementation of modeling the processes of planning the functioning of CABO is presented in the articles [13, 14].

In the formal description of this problem, a mathematical structure was chosen as the basic one for CABO, described by a model of a generalized dynamical system of the following type [8]:

$$\mathbf{x}(t) = \varphi(\mathbf{x}(t), \mathbf{u}_{\Pi p}(t), \mathbf{v}(\mathbf{x}(t), t), \xi(t), \boldsymbol{\beta}, t), \quad (32.1)$$

$$\mathbf{y}(t) = \Psi(\mathbf{x}(t), \mathbf{u}_{\Pi p}(t), \mathbf{v}(\mathbf{x}(t), t), \xi(t), \boldsymbol{\beta}, t), \quad (32.2)$$

$$\mathbf{u}(t) \in Q(\mathbf{x}(t), t), \quad (32.3)$$

$$\mathbf{v}(\mathbf{x}(t), t) \in V(\mathbf{x}(t), t), \quad (32.4)$$

$$\xi(t) \in \Xi(\mathbf{x}(t), t), \quad (32.5)$$

$$\mathbf{x}(t) \in \tilde{X}(t), \quad (32.6)$$

$$\boldsymbol{\beta} \in \mathbf{B}, \quad (32.7)$$

where $\mathbf{x}(t), \mathbf{y}(t)$ are, respectively, the generalized vector of the state and output characteristics of the dynamic system describing the processes of step-by-step harvesting of grasses for silage; $\mathbf{u}(t), \mathbf{v}(\mathbf{x}(t), t)$ are generalized vectors of clog functioning plans that implement the fulfillment of agrotechnical conditions at each stage of the applied technology harvesting of grasses under conditions of disturbing influences; $\xi(t)$ is a vector of disturbing effects of an endogenous or exogenous nature, for example,

changes in climatic conditions; β is a vector of structural parameters of the CABO that determine its current appearance at each stage of technology implementation at time $t \in (T_0, T_f]$; T_0, T_f are, respectively, the initial and final time points of the interval for completing a certain stage of technology; $Q(x(t), t), V(x(t), t), \Xi(x(t), t)$ —respectively defined areas of permissible agrotechnical and technical and technological impacts in real time at each of the stages of grass harvesting under conditions of permissible disturbing influences $\zeta(\tau)$; $\tilde{X}(t)$ the area of permissible current values of the vector of the state of the structural dynamics of CABO; \mathbf{B} is the range of acceptable values of structural parameters at each of the stages of the CABO; φ, ψ are defined transition and output functions that can be described both analytically using classical mathematical structures, logical–algebraic, logical–linguistic, fuzzy-probabilistic, and algorithmic (a combined version is possible).

An analysis of the general description of the task shows that a comprehensive model of agricultural production applied to CABO for the production of grass feed has shown [13, 14] that a specific model of volume and calendar planning should include: a fuzzy-probability model (FPM) and a logical-dynamic model (LDM) detailing a generalized formal description of the functioning of CABO (32.1–32.7). At the same time, as shown above, in practice, the level of reasonableness of management decisions made (for example, when planning the operation of CABO) in conditions of significant uncertainty and inconsistency of information inevitably decreases due to the influence of many NON-factors [2, 6, 7].

Consideration of the issues of identification, formal description and analysis of active NON-factors in the synthesis of FPM and LDM is the purpose of this study, the results of which are presented in the article.

32.3 Active NON-Factors and Their Consideration in the Synthesis of FPM

According to [8], the influence of NON-factors is manifested not only in groups of factors I (see above) related to the object or group II related to the environment, but also at the junction of mappings [6]. Thus, during the synthesis of NVM, mappings are allocated that describe the relationship between properties-parameters and parameters—models.

When displaying the property-parameters, expert knowledge is used, which has: uncertainty in choosing a limited (no more than seven) factor space from a set of fuzzy linguistic variables to solve the problem—incompleteness and vagueness of the expert’s verbal assessments. The first of them, incompleteness, is taken into account by the expert by including in the factor space the most significant linguistic variables that systematically represent the description of the object under study (that’s why he is an expert). How well the manifestation of this NON-factor is taken into account by the expert is usually checked at the end of the study by checking the degree of adequacy of calculations based on the model to the actual condition of the CABO.

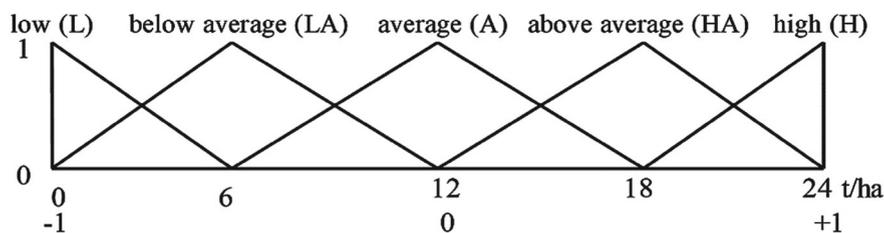


Fig. 32.1 Output of green mass per 1 ha of harvested area Y as a linguistic variable

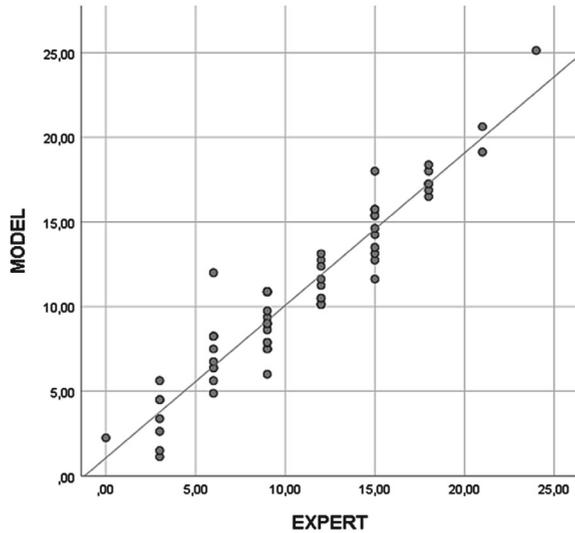
Modeling of the NON-factor is the fuzziness of verbal estimates (in fact, expert knowledge) based on a characteristic property of a parameter and the transition from a fuzzy verbal assessment of a parameter based on the model of a linguistic variable to its numerical value (an example of such a transition in Fig. 32.1). At the same time, using a linguistic variable, the NON-fuzziness factor additionally describes the process of its arithmetization and is necessary for the transition from ordinal (ordinal) scales to numerical ones. Thus, inherently vague verbal expert knowledge undergoes a number of transformations at the stages of its extraction and presentation before performing the formalization stage, using a specially developed FPA [15]. Such models of accounting for NON-factors belong to groups III and IV of factors caused by uncertainty, vagueness, inconsistency of accumulated knowledge, uncertainty of certain procedures.

When displaying the parameters of the model, the same NON-factors appear in different, quite understandable categories. Thus, data fuzziness, inference fuzziness, problem statement fuzziness, and modeling fuzziness belong to different categories as characteristics of the relationship between an object and a model.

It should be particularly noted [15] that all subject information in the expert's mind is stored in a fuzzy form (at least not in numbers) and based on it, he develops a fuzzy assessment in a fuzzy (verbal) form for fuzzy linguistic variables with modes low, below average, average, above average, high, as shown in Fig. 32.1. The further translation of fuzzy estimates from verbal and numerical tables into quantitative indicators, on the one hand, eliminates the influence of the uncertainty factor of the initial information, and on the other hand, it makes the transition from the ordinal scale to the numerical scale (the process of arithmetization), which makes it possible to apply traditional methods of mathematical statistics for computer processing to obtain generally accepted statistical characteristics, such as arithmetic mean, variance, etc. In addition, the heterogeneity of quantitative and qualitative variables is eliminated by converting them to a standardized format, so that all data values are presented in the range $[-1, +1]$. Such techniques, combined with polar scales, are used to overcome (model) identified NON-factors [6, 7, 15].

One of the features of the fuzzy probability approach, which is based on the synthesis of elements of fuzzy set theory and methods of experimental planning theory, is taking into account the NON-factor of non-orthogonality (independence) of parameters, since the first-order planning survey matrices are orthogonal, and all

Fig. 32.2 Correlation between expert estimates and calculated values according to the model (2)



variables are represented on a standardized scale [15]. The location of the expert's knowledge survey at the vertices of the hypercube of the orthogonal multifactorial space determines the independence of variables, which is a fundamental feature of the theory of experimental planning. In addition, NON-factors of inconsistency, fuzziness of data, fuzziness of conclusions, fuzziness of problem formulation and fuzziness of modeling are taken into account by checking the degree of adequacy of calculations according to FPM [15], first the expert's opinion, and then the actual data [13, 14]. Thus, Fig. 32.2 shows a strong correlation (Pearson correlation coefficient $R = 0.949$) between expert estimates and calculations performed using the model. This confirms the fact that the entire set of NON-factors identified above has been sufficiently fully taken into account and overcome during the construction of the FPM.

It is also worth noting that the accuracy of calculations based on FPM, as a rule, does not exceed the initial fuzziness of expert information due to the preliminary use of additional arithmetic operations with fuzzy numbers in FPM as the main components of fuzzy linguistic variables. The introduction of additional arithmetic operations made it possible to preserve the initial fuzziness of expert assessments as one of the main advantages of FPA [15].

32.4 Active NON-Factors and Their Consideration in the Synthesis of LDM

Under the conditions of LDM synthesis, modeling is carried out in the field of deterministic mathematics; however, it should be borne in mind that any formal system of using and representing knowledge in a computing environment inevitably contains NON-factors [5–8]. However, improving the quality of decisions made during the synthesis of technologies and operational calendar planning of clogs at the stage of grass harvesting requires the use of the concept of integrated planning based on a system-cybernetic approach. At the same time, it is necessary to develop such models and approaches that will allow, based on the generalized vector of states (1), to form vectors of control actions (3), (4) for the synthesis of output characteristics of a dynamic system (2) describing the processes of step-by-step harvesting of grasses for silage in the presence of disturbing effects of an endogenous or exogenous nature (5), for example changes in climatic conditions, given the structural and temporal parameters of the CABO, which determine its current appearance at each stage of the implementation of a specific technology of forage production when harvesting grasses for silage.

At the same time, the given transition and output functions (1) and (2) can be represented both analytically using classical mathematical structures, logical-algebraic, logical–linguistic, fuzzy-probabilistic, and algorithmic (a combined version is possible) [8].

In the case of CABO modeling, when carrying out calendar planning of resource allocation using LDM, disturbing effects can be directly set both in expressions for transitional functions (1)–(2), and when setting constraints of the form (3)–(4). In [13, 14], the LDM of grass harvesting planning (HP) was presented, in which scenarios of disturbing effects were set in an interval form:

$$\sum_{r=1}^n u_{ikr} \leq \xi_k P_k, \forall i, \forall k; \sum_{k=1}^l u_{ikr} \leq \xi_r P_r, \forall i, \forall r; u_{ikr}(t) \in \{0, 1\};$$

$$\xi_k \in \left[\frac{1}{P_k}; 1 \right]; \xi_r \in \left[\frac{1}{P_r}; 1 \right]; \quad (32.8)$$

where u_{ikr} is a control action that takes the value 1 if K_k^i operations are performed using one of the agricultural forage harvesting resources (TFR) included in the set R, and 0 in the opposite case; P_k, P_r are specified constants characterizing the technical and technological limitations associated with the possibility of using the material and energy resources of the TFR when performing various operations related to harvesting herbs (HH); ξ_k, ξ_r are matrix time functions that allow you to set in an interval form disturbing effects on the components of the HH process from the external environment, for example, possible effects of weather conditions (in the same way, effects that cause failures and breakdowns in the TFR, the readiness of

technical agricultural units for operation can be set). In this case, using approximated reachability ranges for disturbing factors, it is possible to assess the stability and robustness of synthesized schedules for the allocation of agricultural machinery resources for the most general case of describing uncertain factors associated with the effects of a disturbing environment, since they are set in an interval form in the absence of any measure [8, 13].

The conducted research on solving the problem of volumetric calendar planning of the feed production process is combined with the results of calendar planning and leads to the synthesis of a comprehensive model of the state of clogs in agricultural production. The result of complex modeling of operational and calendar planning of grass harvesting processes for silage is expressed in the construction of a work planning diagram for the TFR, a sample of which is shown in Fig. 32.3 when performing technological operations with threefold sawing of the mowed soil in cool weather conditions.

The following designations of operations along the ordinate axis are used in the figure: M—mowing, S1—first turning (stirring), S2—second turning (stirring), S3—third turning (stirring), R—raking, C2—picking up (collecting grass); the legend indicates the technical units performing the technological operations:

■ MTZ-1221 connected with GMS3600, ■ MTZ-1221 connected with VOLTO64, ■ MTZ-82 connected with GVR-6.0, ■ RSM1401; on the abscissa axis—time in hours.

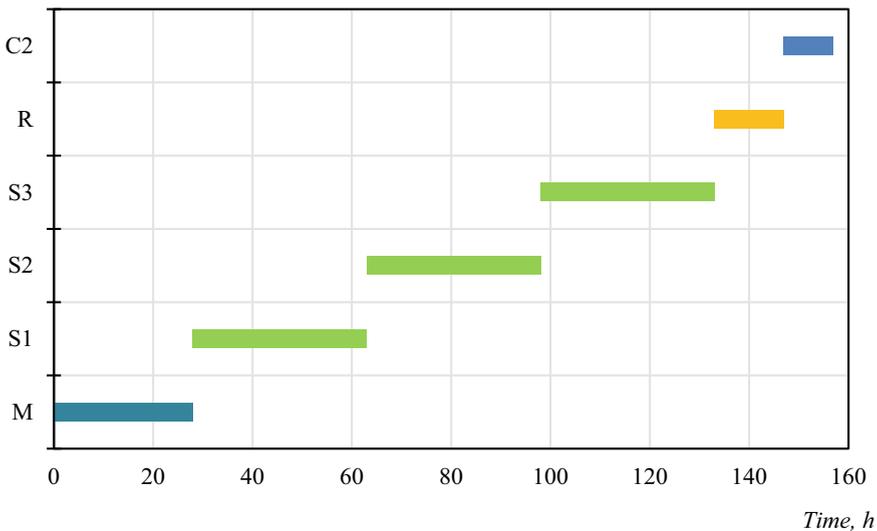


Fig. 32.3 Diagram of work scheduling for technical forage harvesting units along the technological chain of operations map

32.5 Conclusion

The advantage of this approach is that at its various stages of solving the problem, the manifestation of many NON-factors was shown: vagueness, incorrectness, inaccuracy, inadequacy of the model, etc. Of particular importance, as many authors emphasize, are the skills of preliminary analysis of the manifestation of possible NON-factors in the process of modeling the functioning of the phenomenon or object under study. The identification of NON-factors in modeling the state of CLOGS has shown the possibility of overcoming them in various ways, including interval analysis, the introduction of polar scales, and traditional assessments of the adequacy of synthesized models. In this study, another approach (FPA) is proposed to overcome many NON-factors simultaneously, as shown above in a concrete example of the synthesis of an integrated model of operational and calendar planning of grass harvesting processes for silage.

An important conclusion of the work is the need to use the principle of preliminary consideration of a multitude of NON-factors and their interactions as the most important mechanism for improving the quality of synthesized multimodel systems. In other words, effective modeling is impossible without taking into account NON-factors.

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