Component selection model of the indoor automated system on the basis of system analysis

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Abstract. The paper aims at solving the task of the greenhouse automation in the conditions of resource minimization. It gives the analysis of the agro-industries involved in growing greenhouse vegetables as well as describes the main development tendencies of this market. The model of component parts choice for indoor ground automation system is carried out. The task of multi-criteria choice and alternative ranging is solved. The proposed management system model combines both criteria system developed by the experts in greenhouse production and the algorithm of component part choice based on three principles: construction, sensors and greenhouse coating.

1. Introduction

Modern technologies of growing vegetables, seedlings, flowers require constant maintenance of a certain microclimate in the indoor ground systems, i.e. automated greenhouses. Any automated greenhouse is the object of managing temperature and humidity regime the main difficulty of which is parameter instability [5].

In Russia as well as abroad close attention is paid to the search of new technologies of the indoor ground micro-climate control [1]. Nowadays the problem of material choice and construction types as well as of the equipment for closed soil is very urgent. The person taking decision can have various types of information and cannot be an expert in all choice directions.

This problem shall be solved by the use of information systems defined as decision support systems (DSS). DSS allowing a user without special knowledge and skills to find necessary equipment are underrepresented in agribusiness in general and in greenhouse production in particular.

2. Problem statement and research methods

The general task of selecting components for an automated greenhouse can be divided into three sub-tasks:

1. The problem of choosing constructive solutions.
2. The task of selecting a sensor system for an automated greenhouse.
3. The task of selecting the element base for an automated greenhouse.

The object of the study is an automated system of indoor ground.
The purpose of the study is to increase the efficiency of decision support when selecting components for an automated closed-ground system based on the developed model of component selection.

Methods of research. To solve the tasks, methods of system analysis, mathematical modelling, decision-making methods for multi-criteria problems were used.

3. Model of the system component choice

The model of the component choice can be represented in the following way:

\[ M_{cch} = \{CS, II, CA\}, \]

where: CS - the criteria system used to make choice; II - input information; CA - choice algorithm.

Criteria system consists of four subsets and can be represented as follows:

\[ CS = \{XP, XC, XS, XE\}, \]

where: XP - criteria system of the plant type choice (life time, temperature, humidity, lighting, carbon dioxide concentration, humidity level); XC - criteria system of construction and material choice for the greenhouse (construction, coating, frame materials); XS - criteria system for sensor choice (humidity, soil moisture, air temperature, carbon dioxide concentration, light level); XE - criteria system of the element base choice for microclimate changes (watering, lighting, heating, ventilation).

Input information includes the knowledge of the person taking decision of all four elements of the indoor ground automated system [3].

To work with the system of criteria, it is also necessary to introduce an exception system, which is the relationship between the chosen alternatives and the exclusions of those pairs of alternatives that can not interact with each other.

To solve the selection problem of structures, coating materials, sensors and element base, it is necessary to develop a model of decision support that can be represented as a set of the following objects:

\[ Mdsp = \{MO, PS, CS, CF, OI\}, \]

where MO - modelling object; PS - the input set of parameters; CS - the criteria system represented by the set:

\[ CS = \{XP, XC, XS, XE\}, \]

where CF - choice function; OI - output information.

Modelling object is presented in this work as an automated system.

Input set of parameters are represented as the values of structural parameters, coating materials, types of sensors, types of elements (which are added to the database of the information system); values of importance factors that are determined by the user (through natural language).

The system of criteria for selection of components for the greenhouse is determined according to the classifications of all the elements included in the automated greenhouse system.

The selection function represents algorithms, techniques and functions of transferring input parameters into the output ones (method and algorithmic support for the selection of the greenhouse components).

The output information includes the options for selecting components for the greenhouse, ranking them for risk assessment - variants of a system with high risk and low risk, each of which satisfies the preferences of the decision maker.

The scheme for selecting the components for the greenhouse is shown in figure 1.
Figure 1. Component choice scheme.

The input data necessary for solving the multi-criteria task of selecting components for the greenhouse can be defined as follows:

\[ OI = \{DT, ST, ET, PT, CS, \alpha, \beta, \varphi, \lambda\} \]

where \( DT = \{d_1, d_2, \ldots, d_r\} \) — many types of design solutions used in greenhouse production; \( ST = \{s_1, s_2, \ldots, s_s\} \) — many types of sensors presented on the market; \( ET = \{e_1, e_2, \ldots, e_t\} \) — a variety of options for elements used in an automated greenhouse; \( PT = \{p_1, p_2, \ldots, p_p\} \) — many types of plants that can be grown in a greenhouse; \( CS = \{u_1, u_2, \ldots, u_u\} \) — a set of criteria for selecting the components of the greenhouse; \( \alpha_i, i = 1, M \) — a set of values of importance coefficients for a set of DT criteria; \( \beta_j, j = 1, Q \) — set of values of importance coefficients for the set of ST criteria; \( \varphi, z = 1, X \) — a set of values of the importance coefficients for the set of ET criteria; \( \lambda_h, h = 1, B \) — a set of values of the importance coefficients for the set of PT solutions.

4. Multi-criteria choice task decision

To solve the multi-criteria choice problem, it is necessary to rank the alternatives of each criterion of the first level in terms of the importance established by either the decision maker or the system and present the decision maker with two alternatives for each criterion - an alternative with maximum risks that satisfies the selection conditions and an alternative with minimal risks that satisfies the selection conditions.

The collection of data for the formation of the criteria system is carried out by interviewing an expert. For the purpose of assigning weights, it is permissible to use the Harrington’s verbal-numerical scale [2] presented in table 1.

Table 1. Verbal-numerical scale.
| Description of gradations | The numerical value |
|---------------------------|---------------------|
| Very high                 | 1-0.8               |
| Moderate                  | 0.79-0.6            |
| Low                       | 0.59-0.4            |
| Very low                  | 0.39-0.2            |
| Does not reach the required level | 0.19-0 |

All vertexes $e_{i,j}$ are ranked by the expert in terms of their significance with respect to the conformity of the components in indoor ground automation. In this case, each $j$-th vertex $e_{i,j}$ of the $i$-th level is associated with its weight coefficient $W(e_{i,j}) \in [0,1]$, and $\sum_{j=1}^{C} W(e_{i,j}) = 1$.

To form a system of vertex weight coefficients in order to form a rating of vertexes, the expert performs the vertex ranking in terms of their significance:

$$e_{i,1} > ... > e_{i,j} > ... > e_{i,C},$$

where $X \neq Y \neq Z$ – vertex indexes. The weight coefficients of the edge are assigned by experts in advance, and under incomplete information these coefficients are ranked according to their preferences by Fisher's formula [7]:

$$W(e_{i,j}) = \frac{2^j(C_n-j+1)}{C_n(C_n+1)} ,$$

where $C_n = \text{vertex amount}$. The described method makes it possible to order the elements in terms of their significance, taking into account the opinion of the expert.

5. Conclusion
The manufacturing of greenhouse products in the modern market requires continuous improvement of the technological process. Automation of useful crop plant cultivation is the main trend of the agro-industrial complex. The choice of appropriate equipment for different needs (small and medium-sized agricultural enterprises, private farmers, large industrial greenhouses) requires automation. Development of information and advisory systems that help the decision-maker to prepare a ready-made technological solution is an important task for industry development.

The proposed model of the management system combines both a system of criteria developed by experts in the field of greenhouse production, and an algorithm for selecting components in three positions: constructions, sensors and the covering of greenhouses. The information system allowing to perform the selection of equipment takes into account the lack of knowledge of the user in some issues of product selection and supports decision making when selecting components of an automated indoor-ground system.

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