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# DEVELOPMENT OF DECISION-MAKING TECHNOLOGY FOR THE PROVISION OF SERVICES IN PROJECT IMPLEMENTATION

*The object of research is decision-making processes regarding the provision of services within the framework of cross-border projects.*

*To achieve the aim of the research, an analysis of the service provision market was first conducted, its features have been revealed and problems arising in the processes of its functioning have been identified. The main problem is to find the optimal distribution of services between performers in the service management system. A mathematical model of the problem of single- and multi-criteria optimization has been developed, where the problem is decomposed into independent sub-problems. The problem is presented in the form of a linear programming problem. Various efficiency criteria of the found distributions are proposed. Depending on the number of criteria, the problem will be a single-criteria Boolean programming problem or a multi-criteria optimization problem. An iterative method for finding the optimal distribution of services has been created, and individual methods are laid out in the form of production rules, which is understandable and allows to gain new knowledge.*

*Based on the obtained data, a decision-making technology has been developed regarding the distribution of service consumers between performers. At the same time, decision-making methods were used, which allow optimizing the processes of service provision. A systematic approach was used when designing information technology. This made it possible to create an effective and problem-relevant technology that helps in making informed decisions about the distribution of services between participants of cross-border projects. A structural and functional diagram of the decision support system has been developed. Its structural elements are detailed.*

*The obtained results reflect a thorough analysis of the current state of the services market and the development of effective decision-making technology, which contributes to the optimization of work in the field of cross-border projects. This approach can be useful for various subjects involved in the implementation and coordination of international projects.*

**Keywords:** *decision-making, linear programming problem, screening, service provision, cross-border project, service consumers, service providers.*

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## 1. Introduction

The implementation of cross-border projects contributes to the improvement of cooperation and interaction between different countries and regions. This allows the exchange of knowledge, experience and resources to jointly achieve common goals. Such projects can contribute to the development and modernization of infrastructure in border areas, which increases the efficiency of trade and economic development.

Inadequacy of mathematical and software in the process of their implementation can complicate effective management, which can lead to delays, interruptions and failures. For example, this may be due to the complexity of analyzing different aspects of the project, such as demand forecasting, determining optimal routes and resources, and environmental impact assessment. Mathematical models allow to take into account and manage various risks associated with the project, such as financial risks, technical problems and political factors. The lack of a mathematical basis can make it difficult to plan resources for a project, including financial, human and material resources.

Thus, the development of mathematical models and information technologies is a necessary prerequisite for increasing the efficiency, competitiveness and innovative development of individual enterprises and regions as a whole in the modern world.

The development and implementation of formalized models and methods in the field of project management allows to increase the effectiveness of relevant management decisions [1–3]. The tasks involved are usually multi-criteria [4, 5], and the models characterizing them are multi-factorial.

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They can often be described by systems of linear equations and inequalities and are reduced to one- or multi-criteria problems of linear programming [6, 7]. A characteristic feature of the stage of building models for such tasks is the need to take into account all the multifaceted processes and regulatory restrictions that take place in the researched field.

One of the problems that are solved during the implementation of a whole class of cross-border projects is the problem of choosing the end users who will be provided with services [8]. In the event that the project goals clearly spell out the requirements for the end user of the provided services, and the number of requests for services is large enough, it is advisable to use specially developed tools to effectively find a solution to the problem. Also interesting is the case when, in the process of project implementation, not only the selection of consumers is carried out, but also their distribution among performers or relevant employees. Such a problem can be reduced to an assignment problem, but its large dimension and possible subjectivity within the given limitations make it unsuitable for solving by conventional methods.

*The aim of research* is to design information technology for the choice of consumers and service providers in compliance with the standards and wishes of customers on the basis of flexibility and adaptability.

The main hypothesis of the research is models, methods and decision-making approaches regarding the selection of service consumers, which, as a result of the iterative procedure of screening out inefficient alternatives, clarifying limitations and taking into account all the selected performance criteria, allow the development of management decisions.

The practical value of research is that the developed information technology will make it possible to make effective management decisions regarding the provision of services to a wide range of consumers in the process of implementing cross-border projects.

## 2. Materials and Methods

*The object of research* is decision-making processes regarding the provision of services in the implementation of cross-border projects.

In order to effectively conduct the research, the service provision market, its features and problems that arise in the processes of its functioning were analyzed. The basis of the technology was decision-making methods regarding the distribution of service consumers between performers.

When designing information technology, a systematic approach was used, which made it possible to make it effective and relevant to the problems under investigation.

## 3. Results and Discussion

**3.1. Formalization of tasks and decision-making processes regarding the provision of services to consumers.** The decision-making process regarding the selection of consumers for further provision of services to them will be presented in the form of a sequence of the following stages:

1. Stage of formation of the base of service providers (employees). At this stage, information about potential performers, types and volumes of services that they can provide to consumers is formed.

2. Stage of selection of service consumers is characterized by the collection of information about potential consumers. Their selection can be carried out, for example, in accordance with socio-demographic portraits, medical anamnesis and taking into account the standards adopted by the customers, as well as established by the relevant legal acts, goals and objectives of the project.

3. Stage of distribution of services between contractors involves the selection of such an optimal ratio between contractors and customers that would ensure the optimal use of available resources, meet the wishes of the customer, project goals and satisfy the needs of consumers.

The mathematical formulation of the task of selecting consumers and distributing services among performers is as follows:

Let $S=\{s_1,s_2,...,s_M\}$ be the set of services that can be provided on the market; $SC=\{\overline{sc}_1,\overline{sc}_2,...,\overline{sc}_K\}$ – a set of vectors with the characteristics of consumer requests for services, where $\overline{sc}_k=(sc_{1k},sc_{2k},...,sc_{Mk})$, $sc_{jk}$ – the ordered volume of service $s_j$ from the consumer with the number $k$; $W=\{\overline{w}_1,\overline{w}_2,...,\overline{w}_N\}$ – a set of vectors with the characteristics of the performers of work, where $\overline{w}_i=(w_{i1},w_{i2},...,w_{iM})$, $w_{ij}$ – the maximum service volume $s_j$ available for execution by the performer with the number $i$; $X=(x_{ijk})$, $i=\overline{1,N}$, $j=\overline{1,M}$, $k=\overline{1,K}$ – Boolean matrix with information on the distribution of work between performers, where $x_{ijk}=1$, if the performer under the number $i$ will provide the service $s_j$ to the customer under the number $k$ and $x_{ijk}=0$ in the opposite case.

The task of finding the distribution of services between performers is to find such a distribution $X$ that satisfies the following conditions and restrictions:

– the condition for the possibility of providing the service:

$$\text{if } w_{ij}=0 \text{ then } x_{ijk}:=0,\ \forall k=\overline{1,K}; \tag{1}$$

– the condition of the absence of fictitious works in the distribution:

$$\text{if } sc_{jk}=0 \text{ then } x_{ijk}:=0, \forall i=\overline{1,N}; \tag{2}$$

– the condition of not exceeding the maximum available services from the performers:

$$\sum_{k=1}^{K} x_{ijk}sc_{jk}\le w_{ij},\ \forall i=\overline{1,N}; \tag{3}$$

– the condition of service indivisibility, which ensures that each service is provided to the consumer by only one performer:

$$\sum_{i=1}^{N} x_{ijk}\le 1,\ \forall k=\overline{1,K}; \tag{4}$$

– the condition for excluding the trivial (zero) distribution:

$$\sum_{i=1}^{N}\sum_{j=1}^{M}\sum_{k=1}^{K} x_{ijk}>0. \tag{5}$$

In addition to the specified conditions and restrictions, the customer may impose additional ones, which include, for example:

– compliance with quotas for the number of provided services of a certain type:

$$\Delta\underline{c}_j\le\sum_{i=1}^{N}\sum_{k=1}^{M} x_{ijk}\le\Delta\overline{c}_j,\ j\in\{1,2,...,M\}; \tag{6}$$

– compliance with quotas for the volumes of services provided:

$$\Delta \underline{v}_j \le \sum_{i=1}^{N}\sum_{k=1}^{M} x_{ijk} sc_{jk} \le \Delta \overline{v}_j, \ j \in \{1,2,...,M\}, \quad (7)$$

where $\Delta \underline{c}_j, \Delta \underline{v}_j, \Delta \overline{c}_j, \Delta \overline{v}_j$ – non-negative real numbers determined by standards or by the customer of services.

Restrictions (1)–(5) are usually mandatory, (6), (7) are permissible if necessary. In the event that the set of admissible solutions of the problem is non-empty and contains more than one solution, the selection of the optimal distribution can be performed taking into account one or more optimality criteria:

1. Criterion for maximizing the number of provided services:

$$\sum_{i=1}^{N}\sum_{j=1}^{M}\sum_{k=1}^{K} x_{ijk} \to \max. \quad (8)$$

2. Criterion for maximizing the volume of services provided:

$$\sum_{i=1}^{N}\left(\sum_{j=1}^{M}\sum_{k=1}^{K} x_{ijk} sc_{jk}\right) \to \max. \quad (9)$$

3. Maximum use of available resources:

$$\sum_{i=1}^{N}\sum_{j=1}^{M}\left(w_{ij} - \sum_{k=1}^{K} x_{ijk} sc_{jk}\right) \to \min. \quad (10)$$

4. Maximization of the number of consumers to whom services are provided in full. To formalize this criterion, it is possible to introduce a function $\chi(\overline{sc_k})$ which values are calculated according to the rule:

$$\text{if } \forall j = \overline{1,M} : sc_{jk} \ne 0 \ \exists i \in \{1,2,...,N\} : x_{ijk} = 1,$$
$$\text{then } \chi(\overline{sc_k}) := 1 \text{ else } \chi(\overline{sc_k}) := 0. \quad (11)$$

The optimality criterion has the form:

$$\sum_{k=1}^{K} \chi(\overline{sc_k}) \to \max. \quad (12)$$

5. Uniformity of service provision. For each consumer, let's consider a vector $\overline{\rho}_k = (\rho_{1k}, \rho_{2k}, ..., \rho_{Mk})$ which components are calculated according to the rule:

$$\rho_{jk} = \begin{cases} 1, \text{ if } sc_{jk} > 0; \\ 0, \text{ if } sc_{jk} = 0. \end{cases} \quad (13)$$

Then the optimality criterion has the form:

$$\max_{k=\overline{1,K}} \frac{\sum_{j=1}^{M}\left(\rho_{jk} - \sum_{i=1}^{N} x_{ijk}\right)}{\sum_{j=1}^{M} \rho_{jk}} \to \min. \quad (14)$$

The customer of services can also add other criteria for the optimality of allocations.

Depending on the number of criteria, the problem will be a single-criteria Boolean programming problem [9] or a multi-criteria optimization problem [10].

It is proposed to use the iterative method of finding the optimal distribution of services, described in [8], to develop appropriate management decisions.

**3.2. Designing a decision support system.** An integral part of the designed information technology is the decision support system (DSS), which reflects the built models and selected decision-making methods.

The structural and functional diagram of the system is shown in Fig. 1.

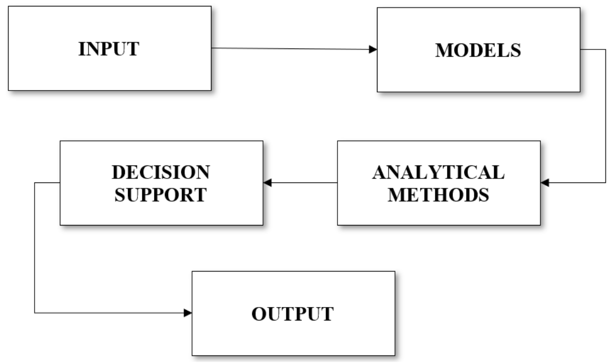


**Fig. 1.** Structural and functional DSS scheme

As can be seen from Fig. 1, the DSS scheme is linear. The INPUT block provides a translation of input information into a form convenient for processing. Mechanisms for working with data of various types and relational databases are implemented in the input block.

The MODELS block implements the main decision-making models (1)–(14). With the help of these models, it is possible to adjust the system to the requirements of each specific project.

The ANALYTICAL METHODS block contains the software implementation of decision-making methods developed in [8] regarding the selection of service consumers and their distribution among performers.

The DECISION SUPPORT part provides interpretation of the obtained results and the possibility of their clarification after additional user settings of the decision support system.

OUTPUT outputs the result in a user-friendly form.

**3.3. Discussion of the research results.** The elements of information technology for decision-making regarding the provision of services during project implementation have been developed.

The mathematical model of the problem of choosing consumers to provide them with services is performed in the form of an optimization problem of linear programming with Boolean variables. It is possible to choose the criterion of optimality (8)–(14) in accordance with the goals of project implementation, the specifics of the subject field of research, and the relationship between available resources and consumer requests for providing them with services. It is also possible to select several criteria and reduce the problem to a multi-criteria selection problem.

A feature of the formulated problem is its large dimension. The number of variables depends on the number of consumers and the set of services that can be provided within the project implementation. Despite the fact that the variables are Boolean, a large dimension in the general case can lead to large time costs when solving the problem using classical linear programming methods.

Another feature of the problem, as shown by studies [8], is often the initial set of admissible solutions of the problem is empty. This requires the use of appropriate dialogue procedures to clarify constraints (1)–(7).

Taking into account such features of the task, the iterative method developed in [8] was chosen as the basis of the developed DSS for finding options for distributing consumers between performers. Thus, when applying DSS, the decision-maker will be able to clarify the main parameters of the task in a dialog mode for working out options for management decisions. This makes the developed DSS flexible and adaptive.

The developed components of information technology, in particular, DSS, can be effectively used in the process of implementing projects related to the provision of services to consumers.

The emergence of the idea of the research topic and the growth of its relevance are connected with the state of war that currently exists in Ukraine. With the growth of the number of internally displaced persons, the need to provide them with social, advisory and other services has increased. In response to such a challenge, various organizations began to implement international and cross-border projects designed to meet the needs of internally displaced persons and ensure their rights. It is expected that the automation of such processes will reduce the burden on process participants and make service provision procedures transparent and understandable.

The developed models and tools can be used in the process of implementing projects and in the functioning of institutions that provide services to the population. At the same time, it is possible to take into account the maximum possible volume of services that can be provided by performers. The model allows to find the optimal distribution of services between performers in accordance with the existing requests and capabilities of performers.

The next stage of the research may be the development of fuzzy models and methods for solving the given task to allow for the subjective nature of the decision-maker's judgments to be taken into account.

## 4. Conclusions

The study is dedicated to solving the problem of finding the optimal distribution of social services between consumers, which takes place in the service management system in the processes of implementing relevant projects. In the course of the research, the subject field was analyzed, and on the basis of the performed analysis, a mathematical model of the corresponding problem was built in the form of a linear programming problem. The application of this model allows finding the optimal distribution of services between performers, taking into account the available resources and requests from consumers. A system of criteria for solving the problem is presented. The criteria make it possible to maximize the volume of services provided, ensure the uniformity of service provision between consumers and maximize the use of available resources. The choice of criteria depends on the purpose of project operation and rests with the person making the decision.

A structural and functional scheme of the decision support system has been developed, which is based on an iterative method of finding the distribution of services based on the proposed mathematical model. The system is flexible and adaptive, which makes it interesting for the end user and allows to produce management solutions in the case when the initial set of admissible solutions is empty. Also, the system allows to take into account several efficiency criteria at the same time by solving the corresponding multicriteria problem.

## Conflict of interest

The authors declare that they have no conflict of interest concerning this research, whether financial, personal, authorship or otherwise, that could affect the study and its results presented in this paper.

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The study was performed without financial support.

## Data availability

The paper has no associated data.

## Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating this work.

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# DESIGNING AN INTERNET OF THINGS SOLUTION FOR MONITORING VITAL SIGNS

*The object of study is the process of monitoring vital signs using an automated system based on an Internet of Things (IoT) solution. The study investigates and analyses the best existing solutions for continuous monitoring of human health. The research is important in the context of a possible pandemic and general health monitoring.*

*An IoT model of a solution for monitoring and analyzing vital signs in patients is proposed. The project involves the creation of hardware and software for tracking vital signs. The interaction of the two parts will ensure that the main task is to obtain the result and analyze the indicators of vital functions of the human body. The hardware is implemented using devices for scanning data on heart rate, temperature, saturation, and the ability to track electrocardiograms. It is possible to transmit data on the state of the body. The position of the sensors attached to the body is taken into account in case they come off. The device itself should be placed on the human body in the area of the front chest wall, wrists, and ankles. The device is also programmed to respond to sudden changes in these values. The software implementation is based on a web-based interface. The design of the final solutions for the interaction between the local and intermediate server was implemented using Django and Python. The ability to administer the intermediate server of the client's time zone was written using HTML, CSS, and JavaScript. The use of the IoT solution allows monitoring the indicators of vital functions of the body and their analysis. A scheme of information exchange in the system for monitoring health indicators has been built.*

**Keywords:** *vital signs monitoring, client-server architecture, information system, Internet of Things, IoT.*

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## 1. Introduction

Everyone faces health problems in their lives. It can be a common cold or a chronic illness. It is an important and integral part of our lives. This paper deals with the research side of continuous monitoring of vital signs. It is proposed to simplify the conduct of such studies and better record information using the created database and sensors.

An analysis of existing solutions shows that there are some automated systems, such as an ECG system from Norav Medical [1] or a monitoring system from Cardiomo [2]. In today's world, many companies use microcomputers [3]