Building an Intelligent System for Managing Emigration Labor Resources in Conditions of Uncertainty of Military Actions Based on Markov Chains

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Abstract

The possibility of using elements of the theory of discrete Markov chains for modelling the kinetics and emigration of the able-bodied population caused by military operations has been studied. A database and a conceptual model of the emigration resources management system have been developed, suitable for determining the structure of relationships between the main motivating factors for evacuation. In contrast to the traditional use of Markov chains, time is not an argument for managing emigration labour resources but a discrete sequence of states. The step number and discretization hierarchy are determined by the moments of occurrenceof external disturbances and reactions to them. Simulation models for implementing control systems have developed, the flexibility of which is ensured by adaptability to impact the external environment with the ability to adjust to each information situation.

Keywords

Intelligent systems, Markov chains, control, uncertainty and construction features.

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1. Introduction

The topic's relevance is aimed at solving one of the modern problems of information support for resource management in conditions of uncertainty caused by the unpredictability of the development of possible scenarios of military operations. At the end of 2022, 16.3 million refugees left Ukraine, 8 million became internally displaced persons. Due to restrictions on the exit from Ukraine of males of military age from 18 to 60 years, 90% of Ukrainian refugees are women and children. Due to the duration of hostilities, some experience has emerged in assessing the problems faced by those who left their homes regarding employment, accommodation, food, and other everyday issues.

The main difficulties faced by displaced persons are:

- Misuse of their labour resources (mainly auxiliary workers in the field of construction, work in the service sector, cleaning the territory, security, etc.);
- Uneven evacuation and the associated variable quantitative composition of the resident population caused by the emergence and duration of hostilities;
- The difference in the time component: continuous time associated with organizational movements abroad, discrete-time caused by the offensive, the seizure of territories, the destruction of objects of vital use;
- Different age composition of the able-bodied population, because mainly women with children and pensioners were let through the border.

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The task of managing the potential of labour resources based on big data of a stochastic nature can be formulated as a decision-making problem under conditions of uncertainty with the probability of possible outcomes and scenarios. The choice of the dominance of alternatives for evacuation places, the country, living conditions, financial and material support, and the assessment of readiness for relocation has become the prerogative of intuition. Management of emigration labour resources in the states of constant variability of the external situation is a complex process that uses structured, unstructured and semi-structured data. One of the critical problems in making decisions about evacuation due to unpredictable military operations is the lack of a unified methodology for constructing probabilistic models and intelligent control systems for complex processes. For rigorous mathematical support of the management of emigration resources under the uncertainty of military operations, this paper uses the mathematical apparatus of Markov processes, which allows a more reliable and reasonable approach to making managerial decisions at various stages of the evacuation process. Using the Markov goals, it is possible to predict the system's state and compare the results of predictive data with real ones.

The technology of managing complex organizational and technical systems in conditions of uncertainty and fuzzy ideas about the influence of the external environment requires a gradation of the main determining factors and motives for evacuation. The main directions of the refugee movement are Poland, Germany, Romania, Slovakia, Czech Republic, Moldova, Norway, and Ireland. According to the Financial Times, the warm reception of refugees after 10 months of emigration began to change into fatigue associated with the pressure of rising inflation and the burden on the state budget. Countries' infrastructure is often insufficient for such a large influx of emigrants, and humanitarian and social measures to support refugees are often limited. Many refugees faced some difficulties related to the lack of jobs and the inability to enrol their children in schools and kindergartens. The coordination of emigration flows requires constructing intelligent systems under the uncertainty of military operations based on Markov chains.

Markov chains make it possible to improve the mechanism for making decisions and diagnosing the situation at various levels of processes [1, 2]. The use of information technologies for assessing the suitability of enterprises for innovative transformations using Markov chains is presented in [3]. Information support for managing complex organizational and technical objects based on Markov chains is presented in [4]. Models of Markov processes of logical transitions, taking into account probabilistic estimates of the states of methods, are presented in [5, 6]. In [7], the main methodological provisions for constructing a homogeneous Markov network with a fixed number of states and a discontinuous period are presented in detail. Markov chains with discrete time are used [8, 9]. An intelligent forecasting model for a hydrological water system is described in [10]. The connection between control and the human factor in mathematical models of complex systems based on the Markov chain is presented in [11]. In [12], the possibility of checking the asymptotic distribution of transition probabilities of the Markov sequence of a parametric family was studied. In [13], stochastic interception using filtering and smoothing is described, in [14] stochastic estimation of the efficiency of transport materials. The scenario-based stochastic optimization model is described in [15]. The information-entropy model of the basis for making managerial decisions under conditions of uncertainty is presented in [16], the analysis of delay in constructing the hierarchy of Bayesian networks in [17]. The use of information technology to identify uncertainty parameters in statistical estimates is presented in [18, 19]. Mathematical support for excluding the human factor's influence on navigation equipment systems under uncertainty and risk is presented in [20-22]. A quantitative assessment the uncertainty forecasts is presented in [23], in [24] a review of the fate of the characteristics of mechanical tests is given. The origin and destination matrix based on Markov chains is presented in [25]. Intelligent charging of connecting electric vehicles under driving behaviour uncertainty is shown in [26]. Evolutionary trends in building a business management system are presented in [27, 28]. The application of the Monte Carlo method in the construction of Markov chains is described in [29-31]. This review shows that the practical applications of Markov chains are wide and varied. Separate fragments of the presented experience were used to develop the research methodology.

2. Materials and methods

When solving information support and building an intelligent system for managing emigration resources in the face of uncertainty of military operations, observations and statistical information can be used as materials, and Markov chains can be used as a method. Markov chains are a synthetic property that accumulates heterogeneous factors of an exogenous nature, such as changes in the situation due to hostilities, spontaneous evacuation, destruction of civilian facilities, and endogenous ones, such as the availability of own funds for moving, language barriers, etc.

As a result of some influences at times t_1 and t_2, the system passes from state S_1 to state S_2. Transitioning from one state to another can be represented as a broken line. Assuming the dependence of the subsequent transition of the system on the previous state S_1, which is determined with a certain probability P_1, the pair of states S_i and S_j can be assigned a conditional probability.

When Markov chain modelling is chosen, the goal is to determine the evolution of the state distribution over time. Knowing the initial allocation, we can calculate the distribution at the time $t_{1,}$ then t_2 and so on. The initial issuance and the matrix of transition probabilities determine the finite-dimensional distribution of a homogeneous Markov chain.

The dynamics of the process is determined by two aspects - the initial probability distribution and the matrix of transition probabilities.

The equation describes the initial probability distribution

$$P(X_o) = q_o\ (S) \quad \forall_{S \in E}\ , \tag{1}$$

where S - discrete state, Q_o - probability distribution at time t=0, ∀ - universal quantifier.

Meaning *E* is the number of possible states E-{e_1, e_2... e_n}.

The matrix of transition probabilities is a contact of transition probability vectors.

$$P(X_{n+1} = S_{n+1} | X_n = S_0) = P\big(S_n, S_{n+1}\big)\ \forall\big(S_n, S_{n+1}\big) \in E \times E \tag{2}$$

The construction of the matrix, its analysis and its features have the following properties: The sum of the matrix elements for each row is equal to one. The time intervals during which the system makes transitions are represented as discrete values of the integer series 0,1,2…m…n. Thus, a Markov chain is a sequence of random events with a finite number of transitions, implemented in practice with discrete time and discrete state space.

The probability of transition from one state to another is defined as a transition matrix

$$P_{ij}(\mathrm{n}) = \mathrm{P}(x_{n+1} = \mathrm{j}\ \big|x_n = \mathrm{i}) \tag{3}$$

Range of random variables $\{X_n\}$ is the state space of the circuit, and *n* is the step number.

$$\begin{array}{cc} & \begin{array}{cccc} s_1 & s_2 & \cdots & s_n \end{array} \\ P = \begin{array}{c} s_1 \\ s_2 \\ \cdot \\ s_n \end{array} & \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1n} \\ p_{21} & p_{22} & \cdots & p_{2n} \\ \cdot & \cdot & \cdots & \cdot \\ p_{n1} & p_{n2} & \cdots & p_{nn} \end{bmatrix} \end{array}, \tag{4}$$

where $0 \leq \mathrm{p} \leq 1$, $\sum P_{ij\,,}\quad i = \overline{1, m}\,, j = \overline{1, n}.$

If the transition probability P_{ij} out of state S_i and S_j depends only on the states, then the trajectory representing the Markov chain will be homogeneous with a fixed time.

3. Methodology

The use of Markov chains to build an intelligent system for managing emigration resources in the face of uncertainty of military operations is to build and analyze a system of states characterized by initial parameters S_i and S_j…S_n, occurring under the influence of unpredictable external disturbances at discrete times. Such transitions will be steps.

The Markov chain is mathematically written as follows

$$P(X_{n+1} = S_{n+1} | X_n = S_n), X_{n-1} = S_{n-1}, X_{n-2} = S_{n-2} \dots P(X_{n+1} = \ S_{n+1} | X_n = S_n) \tag{5}$$

If the initial probability distribution and the transition probability matrix are known, then the determination of the overall dynamics of the process can be calculated cyclically.

A Markov chain simulates random events as a discrete sequence of phases, each located in a discrete state space. Vectors over the rows of the matrix of transition probabilities can characterize the Markov chain at any moment. Suppose we multiply the row vector describing the distribution of probabilities at a particular stage of the evacuation of the population by the matrix of transition probabilities. In that case, we will obtain the probability distribution at the analysis process's next stage.

In preparing for the evacuation, events may occur B_1 and $B_2 \ldots B_n$, the probabilities of which are known from the available experience in implementing similar situations. The onset of events B1 transfers the system of preparation and readiness for emigration into one of the discrete states S_i and $S_j \ldots S_n$. Getting into another state, for example, the liberation of an already occupied territory, is considered a random event.

In case, all possible states of the parameter are enumerated, characterizing the degree of readiness for evacuation with their probabilities. These iterations of random processes with discrete states and time serve as the foundation for constructing stochastic control models under the uncertainty of military operations. It should be noted that these processes do not have a constant time reference but determine the approximation of the achievement of specific results in providing motivational decisions for evacuation.

The formalization of the primary measures for the management of emigration resources is shown in fig.1.

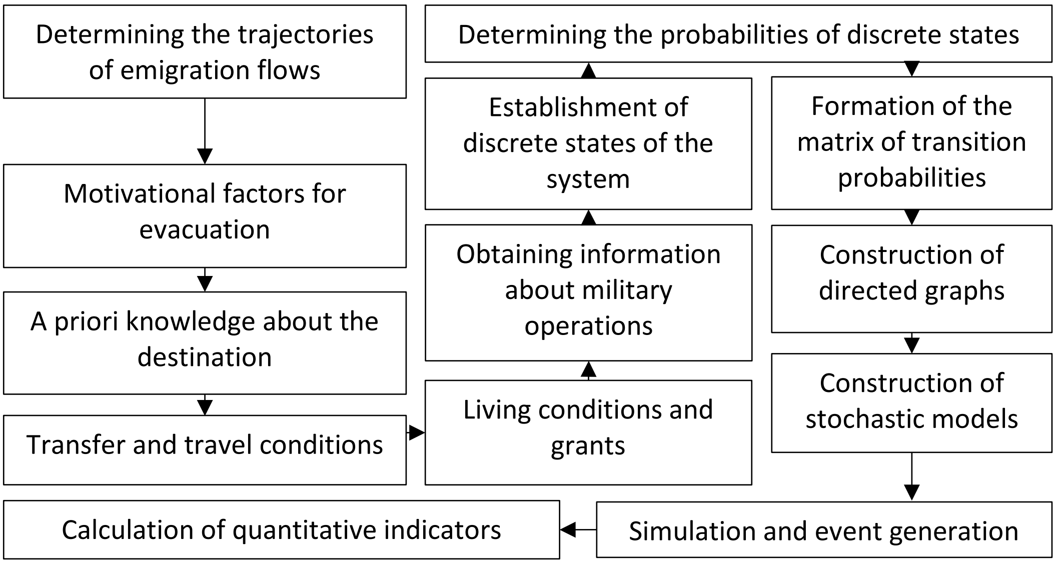

Figure 1: Conceptual model of an intelligent system for managing emigration resources

When making evacuation decisions, it is necessary to take into account various unrelated situations:

1. The situation with the search for sources of funding for the move;
2. The situation, with a lack of means of communication and lack of knowledge of the language;
3. The situation related to other climatic conditions and inevitable acclimatization;
4. The situation associated with the need and possible financial support from the host in the form of subsidies and subsidies;
5. The problem related to living in a foreign territory manifested in the availability of accessible housing for the duration of the stay in the evacuation;
6. Employment situation;
7. The situation associated with the lack of work in the specialization, according to the existing qualifications.

For a Markov process with discrete time, the transition of the following state occurs when the corresponding volume of economic, informational and other types of resources is accumulated. Each combination of parameters characterizing the current situation is assigned a certain probability, written as a line of the state matrix. Only assessing the system's current state will be infallible when making evacuation decisions.

4. Experiment

The state statistics of Ukraine estimate the number of labour emigrants at 1.3 million people, and experts estimate 2 million. People up to 4 million people Disagreements arise because of differentdata collection methods. Probabilistic estimates of the dynamic influence of the main factors are presented in Table. 1 was obtained by processing the available information from the UNICEF, UNESCO, the Institute of Demography of the National Academy of Sciences of Ukraine, Officeof the UN Military Commissariat. When determining the probabilities of acclimatization, the working capacity of the female part of the labour force was taken into account. Pensioners and disabled people with disabilities represented the male part. In countries such as Romania, Slovakia, Germany, the Czech Republic, Poland, acclimatization is not a significant indicator, however, in countries such as Canada, Finland, Norway, Ireland, accounting for this indicator is necessary. Having chosen the lack of funds for moving as the main parameter of the decision to evacuate, the subsequent states can be represented in the form of a 7x7 matrix. The information state of preparation for deciding on evacuation is described by the parameters v_i,presented in Table. 1.

Table 1
Probability distribution of the current state of the information system of emigration resources

№	Parameters	Weights of arcs	Vertices of graphs
1	Lack of funds to move	0,25	v_1
2	Unknowing of the language	0,12	v_2
3	Climate	0,10	v_3
4	Subsidies and grants	0,16	v_4
5	Free housing	0,10	v_5
6	Not proof of qualification	0,13	v_6
7	Jobs	0,10	v_7

The appearance of a hierarchical structure in the information systems of emigration resources is due to the presence of a large amount of information about the evacuation processes and the impossibility of processing it by one control centre.

The random stochastic process of determining the degree of decision-making about evacuation is a set of random variables indexed by the set T, denoting different stages of this process. The first step in creating a Markov chain is forming a matrix of transition probabilities, where the current state is the initial state, and the rest are subsequent. The values of conditional probabilities of the decision-making process for evacuation are presented in Table. 2.

The initial state vector in accordance with Table. 1 can be written in the form:

$$P(0)=(0.25, 0.12, 0.12, 0.16, 0.14, 0.13, 0.1) \tag{6}$$

The transition probability matrix has the following form:

$$T=\begin{vmatrix} 0{,}25 & 0{,}12 & 0{,}1 & 0{,}16 & 0{,}14 & 0{,}13 & 0{,}10 \\ 0{,}20 & 0{,}12 & 0{,}1 & 0{,}2 & 0{,}12 & 0{,}12 & 0{,}12 \\ 0{,}15 & 0{,}19 & 0{,}12 & 0{,}16 & 0{,}12 & 0{,}14 & 0{,}12 \\ 0{,}15 & 0{,}1 & 0{,}1 & 0{,}1 & 0{,}12 & 0{,}16 & 0{,}14 \\ 0{,}10 & 0{,}16 & 0{,}16 & 0{,}12 & 0{,}14 & 0{,}16 & 0{,}1 \\ 0{,}20 & 0{,}16 & 0{,}16 & 0{,}18 & 0{,}16 & 0{,}16 & 0{,}1 \\ 0{,}16 & 0{,}12 & 0{,}14 & 0{,}2 & 0{,}16 & 0{,}1 & 0{,}12 \end{vmatrix} \tag{7}$$

State S_o characterized by the absence of external disturbances.

Table 2
Conditional probabilities of the evacuation decision process

Subsequent state / Current state	Lack of funds to move	Unknowing of the language	Climate	Subsidies and grants	Free housing	Not proof of qualification	Jobs
Lack of funds to move	0,25	0,12	0,10	0,16	0,14	0,13	0,1
Unknowing of the language	0,2	0,12	0,1	0,2	0,12	0,14	0,12
Climate	0,16	0,18	0,12	0,16	0,12	0,14	0,12
Subsidies and grants	0,18	0,1	0,1	0,2	0,12	0,16	0,14
Free housing	0,1	0,16	0,16	0,12	0,2	0,16	0,1
Not proof of qualification	0,2	0,1	0,1	0.18	0,16	0,16	0,1
Jobs	0,16	0,12	0,14	0,2	0,16	0,1	0,12

According to Table. 1 and 2, the information state system of preparation for deciding on evacuation can be in one of seven states. If the question of having one's own means of transportation is not the only factor, then the probability of this, according to Table. 2 is equal to 0.25. For accommodation in a foreign territory, compulsory knowledge of the language is required, the probability of which, according to Table. 2 is equal to 0.12. The possibility of adaptation of the organism to local climatic conditions is 0.1. The likelihood that the host country will provide emigrants with the necessary financial assistance is 0.16. The probability of living in the form of free housing is 0.14. A serious obstacle to emigration is the non-recognition of having qualifications. This is especially important for categories such as doctors and teaching staff. The probability of nostrification of qualification documents is 0.13. The probability of vacancies is 0.1. This information is placed in the first row of the matrix T.

The first step by building a system of management of emigration resources is to establish the availability of your own means for moving in your territory, characterized by the parameter v_1.

Let us denote the probability of the influence of the parameter v_1, characterizing the first stage of decision-making on the evacuation S_1 preparation process for moving through P(1). Multiplying the initial state vector P(0) by the matrix of transition probabilities T, we obtain the probability distribution at the first stage of making decisions about evacuation P(1). By the methodology for calculating Markov chains, this probability will be equal to:

$$P(1)=(0.25,0.12,0.12,0.16,0.14,0.13,0.1)\ \text{x} \begin{vmatrix} 0,25 & 0,12 & 0,1 & 0,16 & 0,14 & 0,13 & 0,10 \\ 0,20 & 0,12 & 0,1 & 0,2 & 0,12 & 0,12 & 0,12 \\ 0,15 & 0,19 & 0,12 & 0,16 & 0,12 & 0,14 & 0,12 \\ 0,15 & 0,1 & 0,1 & 0,1 & 0,12 & 0,16 & 0,14 \\ 0,10 & 0,16 & 0,16 & 0,12 & 0,14 & 0,16 & 0,1 \\ 0,20 & 0,16 & 0,16 & 0,18 & 0,16 & 0,16 & 0,1 \\ 0,16 & 0,12 & 0,14 & 0,2 & 0,16 & 0,1 & 0,12 \end{vmatrix} =$$

$$= (0.18, 0.14, 0.12, 0.16, 0.14, 0.14, 0.11)$$

Abrupt environmental changes caused by hostilities make their own adjustments to the distribution of conditional probabilities. The probability of having own funds for organizing the movement will be on the second line of Table 2 and is 0.20. The possibility of learning a foreign language remains at the level of 0.12. Acclimatization manifests itself after a certain time of stay in a foreign territory and in the short term remains the same 0.1. In turn, financial support acquires a more significant value, the probability of which becomes 0.20. The probability of getting free housing will drop to 0.12. This is because the accommodation is not always comfortable and consists of multi-bed hostels, former gyms, etc. The probability of confirmation of qualification remains at the same level of 0.14. The probability of having vacancies for employment is 0.12.

The second step in building a system for managing emigration resources is considering the language's ignorance, characterized by the parameter v_2. Multiplying the state vector P(1) by the matrix of transition probabilities T, we obtain the probability distribution at the next stage of decision-making

P(2). Probability P(2) that being in the state S_1 evacuation decision information system will go from state S_o, characterized by parameters v_2 characterized by parameters:

$$P(2)=(0.18,0.14,0.12,0.16,0.14,0.14,0.11)\text{x}\begin{vmatrix} 0,25 & 0,12 & 0,1 & 0,16 & 0,14 & 0,13 & 0,10 \\ 0,20 & 0,12 & 0,1 & 0,2 & 0,12 & 0,12 & 0,12 \\ 0,15 & 0,19 & 0,12 & 0,16 & 0,12 & 0,14 & 0,12 \\ 0,15 & 0,1 & 0,1 & 0,1 & 0,12 & 0,16 & 0,14 \\ 0,10 & 0,16 & 0,16 & 0,12 & 0,14 & 0,16 & 0,1 \\ 0,20 & 0,16 & 0,16 & 0,18 & 0,16 & 0,16 & 0,1 \\ 0,16 & 0,12 & 0,14 & 0,2 & 0,16 & 0,1 & 0,12 \end{vmatrix} =$$

$$= (0.17, 0.13, 0.12, 0.15, 0.13, 0.14, 0.11)$$

The third step in building a system for managing emigration resources is to consider climatic conditions characterized by the parameter v3. The corresponding information about the conditional probabilities of the parameters is presented in the third row of the matrix T. The probability of climate change in neighbouring countries is manifested through insignificant temperature fluctuations for the organism. However, acclimatization is one of the dominant parameters when emigrating to more remote countries such as Norway, Finland, Japan, China, and Thailand. Redistribution of conditional probabilities of the parameters of Table. 2 in this step occurs in the direction of their reduction. Multiplying the state vector P(2), characterized by the parameter v_2, by the matrix of transition probabilities T, we obtain the probability distribution at the next decision-making stage P(3).

$$P(3)=(0.17,0.13,0.12,0.15,0.13,0.14,0.11)\text{x}\begin{vmatrix} 0,25 & 0,12 & 0,1 & 0,16 & 0,14 & 0,13 & 0,10 \\ 0,20 & 0,12 & 0,1 & 0,2 & 0,12 & 0,12 & 0,12 \\ 0,15 & 0,19 & 0,12 & 0,16 & 0,12 & 0,14 & 0,12 \\ 0,15 & 0,1 & 0,1 & 0,1 & 0,12 & 0,16 & 0,14 \\ 0,10 & 0,16 & 0,16 & 0,12 & 0,14 & 0,16 & 0,1 \\ 0,20 & 0,16 & 0,16 & 0,18 & 0,16 & 0,16 & 0,1 \\ 0,16 & 0,12 & 0,14 & 0,2 & 0,16 & 0,1 & 0,12 \end{vmatrix} =$$

$$= (0.17, 0.13, 0.12, 0.15, 0.13, 0.13, 0.11)$$

The fourth step in building a system for managing emigration resources is accounting for monetary assistance in the form of subsidies and subsidies, characterized by the parameter v_4. The amount of this assistance varies from country to country. The duration is also different. The probability of the system transition from the state S_3 into a state S_4 due to the change and intensification of hostilities on both sides and the uncertainty of this influence is determined by multiplying P(3) by the matrix of transition probabilities.

$$P(4)=(0.17,0.13,0.12,0.15,0.13,0.13,0.11)\text{x}\begin{vmatrix} 0,25 & 0,12 & 0,1 & 0,16 & 0,14 & 0,13 & 0,10 \\ 0,20 & 0,12 & 0,1 & 0,2 & 0,12 & 0,12 & 0,12 \\ 0,15 & 0,19 & 0,12 & 0,16 & 0,12 & 0,14 & 0,12 \\ 0,15 & 0,1 & 0,1 & 0,1 & 0,12 & 0,16 & 0,14 \\ 0,10 & 0,16 & 0,16 & 0,12 & 0,14 & 0,16 & 0,1 \\ 0,20 & 0,16 & 0,16 & 0,18 & 0,16 & 0,16 & 0,1 \\ 0,16 & 0,12 & 0,14 & 0,2 & 0,16 & 0,1 & 0,12 \end{vmatrix} =$$

$$= (0.16, 0.13, 0.11, 0.15, 0.13, 0.13, 0.1)$$

A comparison of the parameters v3 and v4 presented in P(3) and P(4) showed either a decrease in identical parameters, their constancy, or a decrease at higher orders of smallness.

The fifth step in building a system for managing emigration resources in the face of uncertainty is solving the main issue of life support related to obtaining free housing. The payment for accommodation is a significant part of the emigrant's budget, and getting free housing, which is paid by the state, is one of the most important phases of emigration. Of course, the quality of housing does not always correspond to desires. Therefore this option v_5, is determined with some probability. State Transition S_4 in S_5, implemented by parameter v_5, is determined by transformation transformations of the probability P(4) using matrix T (formula 7):

$$P(5)=(0.16,0.13,0.11,0.15,0.13,0.13,0.1)\ x \begin{vmatrix} 0,25 & 0,12 & 0,1 & 0,16 & 0,14 & 0,13 & 0,10 \\ 0,20 & 0,12 & 0,1 & 0,2 & 0,12 & 0,12 & 0,12 \\ 0,15 & 0,19 & 0,12 & 0,16 & 0,12 & 0,14 & 0,12 \\ 0,15 & 0,1 & 0,1 & 0,1 & 0,12 & 0,16 & 0,14 \\ 0,10 & 0,16 & 0,16 & 0,12 & 0,14 & 0,16 & 0,1 \\ 0,20 & 0,16 & 0,16 & 0,18 & 0,16 & 0,16 & 0,1 \\ 0,16 & 0,12 & 0,14 & 0,2 & 0,16 & 0,1 & 0,12 \end{vmatrix} =$$

$$= (0.16,\ 0.12,\ 0.11,\ 0.14,\ 0.12,\ 0.13,\ 0.1)$$

The sixth step in building a system for managing emigration resources under conditions of uncertainty is the transition from the state S_5 in S_6, implemented by parameter v_6, reflecting the possibility of confirming the existing qualifications of emigrants. Often the probability of nostrification of qualification documents is delayed and is not always necessary, since there are practically no vacancies and vacancies without knowledge of the language.

$$P(6)=(0.16,0.12,0.11,0.14,0.12,0.13,0.1)\ x \begin{vmatrix} 0,25 & 0,12 & 0,1 & 0,16 & 0,14 & 0,13 & 0,10 \\ 0,20 & 0,12 & 0,1 & 0,2 & 0,12 & 0,12 & 0,12 \\ 0,15 & 0,19 & 0,12 & 0,16 & 0,12 & 0,14 & 0,12 \\ 0,15 & 0,1 & 0,1 & 0,1 & 0,12 & 0,16 & 0,14 \\ 0,10 & 0,16 & 0,16 & 0,12 & 0,14 & 0,16 & 0,1 \\ 0,20 & 0,16 & 0,16 & 0,18 & 0,16 & 0,16 & 0,1 \\ 0,16 & 0,12 & 0,14 & 0,2 & 0,16 & 0,1 & 0,12 \end{vmatrix} =$$

$$= (0.15,\ 0.12,\ 0.11,\ 0.14,\ 0.12,\ 0.12,\ 0.1)$$

The state P(0) characterizes the system's initial state without control, while the first control step starts from P(1). Observation of the previous calculations shows that the probability at each control step decreases P(6) < P(7). The likelihood of control transition from the state S_6 in S_7, characterized by the parameter v_7 is equal to:

$$P(7)=(0.15,0.12,0.11,0.14,0.12,0.12,0.1)\ x \begin{vmatrix} 0,25 & 0,12 & 0,1 & 0,16 & 0,14 & 0,13 & 0,10 \\ 0,20 & 0,12 & 0,1 & 0,2 & 0,12 & 0,12 & 0,12 \\ 0,15 & 0,19 & 0,12 & 0,16 & 0,12 & 0,14 & 0,12 \\ 0,15 & 0,1 & 0,1 & 0,1 & 0,12 & 0,16 & 0,14 \\ 0,10 & 0,16 & 0,16 & 0,12 & 0,14 & 0,16 & 0,1 \\ 0,20 & 0,16 & 0,16 & 0,18 & 0,16 & 0,16 & 0,1 \\ 0,16 & 0,12 & 0,14 & 0,2 & 0,16 & 0,1 & 0,12 \end{vmatrix} =$$

$$= (0.15,\ 0.12,\ 0.1,\ 0.13,\ 0.12,\ 0.12,\ 0.1)$$

For any given point in time, the conditional distribution of the future states of the process, given the present and past states, depends only on the current state.

Comparison of identical parameters that make up the formalized record of the probabilities P(i) shows a decrease in all parameters. This emphasizes the reliability and quality of intelligent systems for managing emigration labour resources in the context of the uncertainty of military operations based on Markov chains. The overall probability of determining the stage of evacuation, represented as steps of Markov chains, can be described as a system of inequalities P(1) > P(2) > P(3) > P(4) > P(5) > P(6) > P(7). The presented system covers the degree of influence of military operations and the associated uncertainty of estimates on the main variables for making decisions about evacuation shown in Table. 1.

The presented system covers the degree of influence of military operations and the associated uncertainty of estimates on the main variables for making decisions about evacuation presented in Table. 1. Problem situations caused by the uncertainty of the impact of hostilities can methodologically be reduced to separate associatively homogeneous management decisions. At the initial moment of time, based on the initial conditions, the control is selected on the time interval [0, t]. After some time, the system's state changes, and additional information appears that facilitates the transition to the next level of the hierarchy. These iterations are carried out for different states S_i with their parameters and probabilities.

5. Results and discussion

Since the system's transition from one state to another occurs at indefinite intervals, the occurrence of which is due to the emerging military situation and the accumulation of an appropriate amount of innovative and other resources, it has a consistent Markov process in discrete time.

An oriented graph of Markov chains for building intelligent systems for managing emigration labour resources in the face of uncertainty in military operations is shown in Fig. 2.

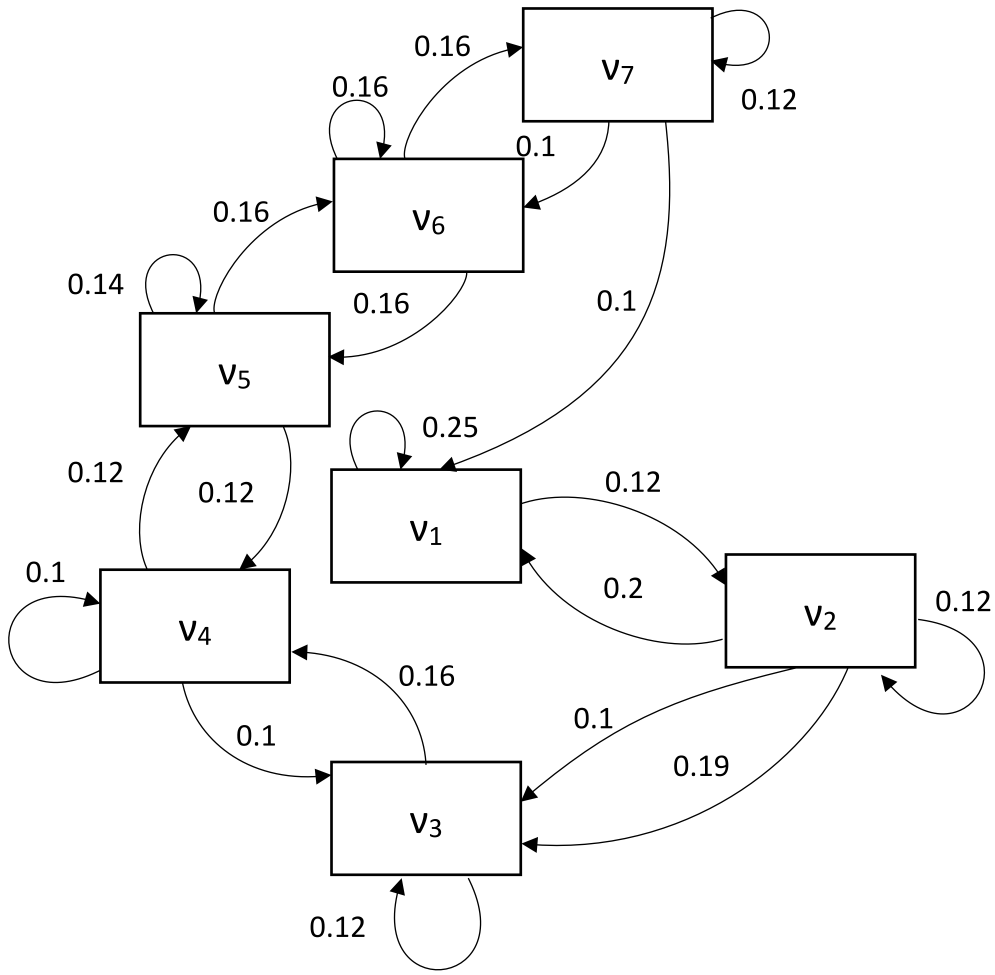

Figure 2 Oriented graph of Markov chains for building intelligent systems for managing emigration labor resources

The presented directed graph can serve as a simulation model for implementing an intelligent system for managing emigration labour resources under the uncertainty of military operations. Management of the evacuation process is achieved by the accumulation of appropriate resources and the transition to the next step of subsystems $v_1(t)$, $v_2(t)\ldots$ $v_i(t)$.

The determining parameter in the presented scheme (Fig. 2) was the parameter v_1, however, when implementing control processes, the first step can be performed from any other parameter. Such simulation models will be adaptive to the changing information situation caused by military operations since the presented scheme represents a ring interaction of conditional probabilities of evacuation parameters.

An attempt to create a system for managing emigration resources in the unpredictable effects of military operations with a quantitative gradation of the probabilities of influence of the main dominant factors in making decisions about evacuation in a real situation should be considered relevant, timely and necessary. The flow of refugees at the beginning of hostilities was massive, and they received sufficient financial and material support for their improvement. Further, with development and growth of emigration due to burden on host countries, the amount of this assistance decreased and acquired the character of necessary funds. At the same time, the main property of Markov chains is traced when each subsequent event indirectly depends on the previous one. The conditional distribution of future states by given current and past states depends only on the current state, not on past states. Based on the formalization of the accumulated knowledge and experience in considering the parameters of evacuation, an intelligent system for managing emigration labour resources was created, taking into account the influence of uncertain destabilizing environmental factors using Markov chains. The novelty of the technology for managing emigration resources using Markov chains is replacing equal-step time intervals with a discrete sequence of states caused by military operations. Markov chains are powerful tools that provide real substantiation of the decision based on processing a large number of experimental data, some of which form a database obtained with one or another probability.

Markov chains allow you to set priorities, the main content and the level of changes caused by external disturbances. Based on the calculations made, a step-by-step plan is drawn up, restrictions are established, and strategies are developed for obtaining additional resources to achieve a common goal. The use of Markov chains reveals the essence and relationship of the main organizational parameters of evacuation in the conditions of hostilities with the probability of their manifestation in various manifestations of the external environment.

6. Conclusions

An intelligent system for managing emigration resources under the uncertainty of military operations based on Markov chains has been developed. A list of the main diagnostic parameters, limitations and the size of the necessary resources in the conditions of the uncertainty of the external environment caused by military operations has been compiled. Markov chains reveal the essence of the relationship between the probability distribution of the main control parameters in a visual form and at various levels.

About the task of optimizing labour resources, the use of Markov chains lies in the possibility of: predicting the results of further actions to ensure the validity of decision-making on evacuation from the war zone; develop software for predicting random events of the impact of military operations on the development of situations; generate and predict problems without the use of mathematical algorithms.

The advantage of the developed intelligent system for managing emigration resources is the ability to model and regulate the process of making appropriate decisions in real time and adjust the system to any information situation.

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