

INFORMATION INTELLIGENCE SYSTEMS AND MACHINE-LEARNING ALGORITHMS FOR ADAPTIVE DECISION-MAKING IN THE EASTERN SECURITY LANDSCAPE

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The study investigates the role of intelligence-type information systems integrated with machine-learning algorithms in supporting adaptive decision-making within Eastern security, in the context of regional crisis scenarios. The research aims to develop a predictive model capable of anticipating the potential distribution of Moldovan refugees across European states, using a set of variables relevant to the dynamics of forced migration: distance from the Republic of Moldova, cultural similarities, religious similarities, living standards, and the historical number of refugees. The methodology is based on the use of the RandomTree algorithm from the WEKA platform, selected for its ability to generate interpretable models and its suitability for multicriteria classification problems in the field of security.

The resulting decision tree highlights distance as the primary factor shaping initial mobility, followed by cultural and religious determinants for neighbouring states, and economic and diasporic indicators for more distant destinations. The hierarchical structure of the tree confirms the hypothesis that relocation decisions are the result of a complex interaction between geographical proximity, socio-identity affinities, and socioeconomic attractiveness.

Integrating this analysis into intelligence information systems enhances the capacity of security institutions to anticipate mobility flows in crisis situations, providing a robust and transparent predictive tool useful for resource planning, early warning, and developing adaptive strategies in the Eastern neighbourhood.

Keywords: information system; intelligence; machine learning; adaptive decision-making; WEKA platform;

INTRODUCTION

The transformations within the geopolitical landscape of Eastern Europe, amplified by military aggression, internal instability, and hybrid pressures, require a new operational framework for risk management and decision-making in the field of security. In this regard, intelligence-type information systems become essential for the real-time assessment of crisis dynamics, particularly with respect to forced migration and population mobility (Dragomir, 2023-a, 2025).

For example, in the case of the Republic of Moldova – strategically positioned between Eastern and Western spheres of influence – a regional crisis may generate significant refugee flows. Anticipating such phenomena requires integrating predictive models into the state’s informational architecture (Dragomir, Enache, 2023). The use of machine-learning (ML) algorithms, such as RandomTree, facilitates not only the analysis and classification of possible scenarios but also the clear interpretation of the main determinants of mobility: geographical distance, cultural affinities, economic factors, and the presence of a historical diaspora (Azizyan, Gheisari, 2025; Dragomir, 2021-b).

This approach aligns with the paradigm of algorithmically assisted adaptive decision-making, which brings to the forefront the idea of a proactive institutional response supported by multi-level information systems (Dragomir, 2023-b). Thus, the multi-layered analysis of data – ranging from digital monitoring of radicalization trends to ideological modelling of terrorism – becomes an integrated component of security policy (Dragomir, 2025-c; Dragomir, Alexandrescu, Postolache, 2018).

At the same time, the ethical dimension of using such systems cannot be neglected. The “*confidentiality – loyalty – responsibility*” triad provides an indispensable normative framework within modern decision-making architectures (Dragomir, 2021-e). Moreover, algorithmic transparency becomes a legal necessity in the context of protecting fundamental rights, being closely linked to the legality of automated decisions (Dragomir, 2022-d).

Therefore, in regional crisis scenarios such as the one analysed in this study, the combined use of information systems and ML-assisted predictive models ensures a superior institutional response capacity. This capacity is essential for strategic planning, resource allocation, and maintaining stability in the Eastern neighbourhood (Pietras, 2025; Thomas, 2024).

INTELLIGENCE INFORMATION SYSTEMS SUPPORTING ADAPTIVE DECISION-MAKING

The ability of a military organization or state to anticipate, interpret, and rapidly respond to changes in the operational environment depends decisively on the quality of its informational infrastructure and on the level of integration between data, analysis, and algorithms. Adaptive decision-making relies on a continuous flow of relevant information, processed in real time and contextualized through advanced analytical methods. In this regard, intelligence information systems become integrated platforms that connect various types of data – structured, semi-structured, or unstructured – with predictive models capable of supporting strategic and operational actions in a volatile environment.

❖ Data Collection (Data Acquisition Layer)

The first layer integrates all relevant information sources needed to build a comprehensive situational picture. This stage includes ISR systems (electro-optical, radar, satellites), OSINT sources – originating from social networks, media streams, or public databases – HUMINT components such as field reports and direct observations, to which SIGINT and CYBINT flows may be added in specialized contexts.

The diversity of these data types, ranging from images and raw signals to structured or unstructured text content, requires advanced protocols for integration, filtering, and validation, designed to reduce uncertainty and enhance the reliability of subsequent decisions. Additionally, the system must incorporate automatic anomaly-detection mechanisms that identify deviations from typical patterns and filter out irrelevant or compromised information.

❖ Data Processing and Storage (Data Processing & Storage Layer)

During the processing stage, collected data undergo automated cleaning, transformation, and semantic labelling to ensure compatibility with analytical models in the upper layers. This type of processing is followed by storage in a secure infrastructure, which may include relational databases, data lakes, or hybrid platforms optimized for scalability and distributed access. Managing massive volumes of mission-critical data requires implementing advanced cybersecurity standards and strict access-control policies to safeguard the integrity and confidentiality of the information.

❖ Algorithm-Assisted Analysis (Analytics & ML Layer)

This analytical level represents the space where the strategic value of the information system is fully realized, as traditional cognitive processes of analysts are augmented by advanced algorithmic tools. They include classification and regression

techniques, pattern-detection methods, clustering and similarity analysis, predictive models such as decision trees, neural networks, or Bayesian structures, as well as adaptive learning systems capable of updating parameters in real time.

Integrating machine learning into this layer not only optimizes information processing but also enables forecasting of potential developments, generating alternative scenarios, early detection of emerging threats, and significant reduction of cognitive biases inherent in exclusively human analysis.

❖ **Dissemination and Decision Support (Decision Support Layer)**

The final layer of the architecture focuses on delivering analytical results to decision-makers in a clear, accessible, and operational format. It is achieved through intuitive graphical interfaces, interactive dashboards, automated alerting systems, and advanced data-visualization tools.

The core purpose of this layer is to reduce the time between the occurrence of an event and the strategic response, thereby enabling adaptive, robust, and context-aware decisions. Essentially, this level transforms processed information into actionable knowledge capable of supporting planning, risk assessment, and real-time operational coordination.

Recent research highlights a significant shift in the development paradigm of intelligence information systems, which are moving from static architectures toward dynamic, adaptive designs capable of functioning under conditions of disrupted and volatile operational environments. These systems are designed not only to collect and analyse data but also to learn and react in real time to emerging threats or informational disruptions, particularly in complex military theatres (Wang et al., 2025; Smaliukienė, Giedraitytė, 2025).

A reference example in this direction is represented by new-generation anti-jamming systems used in active conflict zones, where maintaining uninterrupted communication becomes critical for ensuring operational advantage. The architecture proposed by Wang et al. (2025) introduces an advanced multidimensional transfer-learning model that enables automatic recognition of modifications in the electromagnetic spectrum – typically caused by enemy electronic interference – and adjustment of transmission protocols to ensure continuity and security of transmitted data.

This approach provides two essential tactical advantages:

❖ **Real-time adaptivity** – The system relies on advanced reinforcement-learning and online-learning techniques, continuously adjusting its parameters according to changes in the electromagnetic environment. Practically, the system becomes

“intelligent” in the sense that it evolves alongside the operational context without constant human intervention (Wang et al., 2025).

❖ **Resilience to infrastructure degradation** – In environments characterized by instability, physical destruction, or severe radio interference, the architecture maintains critical communication functionality through self-optimization and distributed redundancy, as demonstrated by tactical simulations and stress tests (Ib.).

Furthermore, this research direction aligns with the broader trend of developing cognitive information systems – systems that not only “respond” to stimuli but “understand” the operational context by integrating multisource data and generating highly reliable predictions even under conditions of systemic uncertainty (Byranvand, 2025; Smaliukienė, Giedraitytė, 2025). This aspect fundamentally transforms real-time decision-making, offering a significant strategic advantage in hybrid conflict and electronic warfare environments.

The adaptive decision-making approach in the context of modern security and information management presupposes the use of machine-learning (ML) algorithms as analytical and operational support tools. These technologies are especially applied in two main directions, essential for the efficiency of real-time decision-making and for reducing uncertainty.

Algorithms such as *RandomTree* or reinforcement learning are already implemented in areas such as refugee-distribution analysis, environmental monitoring, or autonomous network surveillance. In these cases, the generated models are explainable, rule-based, and allow decision-makers to quickly understand the logical structure behind predictions (Kumar, Shekhar, Tewary, 2025). For example, Dwivedi (2025) proposes an analytical framework for intelligent energy systems, based on partially observable decision-process modelling (POMDP), which enables continuous updating of predictions based on real-time data. This approach offers critical flexibility in dynamic contexts such as those generated by humanitarian crises or unpredictable military actions.

Another major benefit of using ML is its ability to reduce uncertainty within large datasets, often ambiguous or incomplete. ML technologies contribute to clarifying the Common Operational Picture (COP) by eliminating informational noise and extracting the most relevant variables (Kothinti, 2025). ML systems implemented in adaptive architectures – such as those in the automotive or military domains – significantly improve decision coherence and strategic agility by rapidly identifying anomalies, updating risk scenarios, and suggesting actions based on learning from historical and contextual data (Park, 2025; Thomas, 2024).

METHODOLOGY

❖ Conceptual Foundation of the Model

The methodology used in this study is based on the application of the RandomTree algorithm, available in the WEKA platform, for analysing and modelling the potential distribution of Moldovan refugees under regional crisis scenarios. The choice of RandomTree was grounded in the need for a method capable of generating an explicitly interpretable model that highlights the relationships among the key variables underlying forced mobility. RandomTree is a non-ensemble algorithm that constructs a single decision tree. Unlike Random Forest, it does not aggregate the results of multiple trees; instead, it generates a unique structure whose branches are influenced by the random selection of attribute subsets. This characteristic makes it a valuable exploratory instrument, enabling the identification of variables with high predictive power in the spatial distribution of refugees.

❖ Fundamental Parameters of the Model

The RandomTree model was built using four variables considered essential for explaining a refugee’s decision under conditions of uncertainty. The parameters were selected based on specialized literature on forced migration and on the availability of comparable data.

❖ Geographical Distance from the Republic of Moldova

The physical distance between the analysed states and the Republic of Moldova constitutes a fundamental logistical indicator with a decisive role in shaping the initial flows of human mobility. Within the context of decision modelling, this variable emerges as the root of the classification tree, confirming its strategic importance in anticipating the behaviour of populations under critical pressure.

Territorial proximity influences not only the speed at which a population may access the territory of a neighbouring state, but also that state’s institutional capacity to manage an immediate influx – reducing transit costs, travel risks, and logistical barriers. Thus, geographical distance becomes the first filter structuring migration scenarios, functioning as a structural determinant of accessibility and reaction time for both individuals and state response mechanisms.

Indicatori	ȚĂRI										
	A	B	C	D	E	F	G	H	I	J	K
Distanta (Km)	820	1541	1519	2291	968	435	1344	946	3584	2594	487

Table 1: Geographical distance (in kilometres) between the Republic of Moldova and the analysed states (author’s design)

❖ Cultural Similarities

This aggregated indicator reflects the degree of identity proximity between the population of the Republic of Moldova and communities in the potential destination states, integrating elements related to language, traditions, shared historical references, and normative compatibility. In the analytical model, cultural similarities significantly influence relocation preferences, especially within immediate geographical spaces where the cultural barrier is minimal and the probability of rapid integration is considerably higher.

From this perspective, the variable functions as a facilitator of mobility, reducing perceived uncertainty, lowering the costs of social adaptation, and strengthening the sense of familiarity between origin and destination communities. The algorithm used this parameter to model the spontaneous choices of refugees, suggesting that, in the absence of other major constraints, cultural proximity can become a determining factor in the initial direction of migration.

❖ Religious Similarities

The variable referring to confessional compatibility captures the value-oriented dimension of the migration process, having direct implications for the potential of social integration within host communities. In states where the religious structure is similar to that of the Moldovan population, the climate of acceptance and community cohesion can consolidate more rapidly, reducing sociocultural tensions and facilitating individuals' participation in social and civic life.

In modelling relocation behaviour, religious similarities function as an indicator of normative and symbolic compatibility, influencing refugees' willingness to choose states in which spiritual values and religious practices do not constitute a barrier but rather an element of identity continuity.

❖ Standard of Living in the Analysed States

This socioeconomic parameter – articulated through indicators such as GDP per capita, cost of living, and purchasing power – represents one of the most important factors shaping destinations located at medium and long distances.

Unlike variables associated with geographical or cultural proximity, the standard of living acts as an attractor in the later phases of mobility, when individuals begin to prioritize economic opportunities, financial stability, and long-term prospects.

The algorithm integrated this indicator as a decisive node in the tree structure, signalling that states with a high level of prosperity tend to be perceived as preferred final destinations, even if the distance implies a higher migration cost. Therefore, the standard of living becomes a relocation-optimization factor, guiding populations toward spaces offering the best prospects for sustainable economic integration.

Indicatori	ȚĂRI										
	A	B	C	D	E	F	G	H	I	J	K
Nivel de trai pe cap de locuitor	29177	37549	63834	51061	42465	38096	31967	23534	46551	63877	14150
Procent comparativ cu cel din R. Moldova (16482)	1.77	2.28	3.87	3.10	2.58	2.31	1.94	1.43	2.82	3.88	0.86

Table 2: Standard of living in the Republic of Moldova and the analysed states (author’s design)

❖ Dataset Construction

The dataset used in this study was constructed by operationalizing the four selected parameters into discrete values corresponding to ordered classes, allowing the model to capture significant differences between states without depending on numerical variations that are difficult to compare. The dataset development process included a systematic stage of normalizing and standardizing distance intervals to ensure the geographical relevance of each state in relation to the Republic of Moldova. In parallel, socioeconomic values such as GDP per capita, cost of living, and other indicators of living standards were classified into comparative ranks, enabling their transformation into a format usable by the RandomTree algorithm without losing conceptual significance. Regarding the socio-identity dimension, cultural and religious variables were aggregated into ordered categories based on their degree of similarity to the Republic of Moldova – an approach that contributed to shaping interpretable causal relationships within the decision tree. Additionally, data on the Moldovan diaspora were incorporated through the inclusion of values related to the relative number and distribution of pre-existing Moldovan refugees in the analysed states, an indicator integrated to capture network effects that significantly influence migratory behaviour. This stratified and coherent structuring of data allowed the RandomTree algorithm to generate clear, consistent, and easily interpretable branches, maximizing the analytical utility of the model.

RESULTS

The RandomTree algorithm was configured using the default settings of the WEKA platform, as they provide an optimal balance between exploring data structure and preventing overfitting. The configuration included the random selection of attribute subsets during the construction of each node – a mechanism that introduces controlled variability and allows the identification of combinations of factors with high predictive power. To maintain an adequate degree of generalization and avoid excessive model complexity, tree-depth limitation was applied, preventing the

generation of overly detailed branches that would not significantly contribute to interpretability or accuracy. Model robustness was evaluated using a cross-validation procedure, which enabled performance testing across multiple dataset partitions and reduced the influence of potential statistical peculiarities of the sample. Unlike ensemble models, RandomTree generated a single decision tree, allowing for direct interpretation of the resulting causal chain. The final model presents an extended tree whose nodes are logically organized according to information gain and controlled random selection process, offering a coherent picture of how each parameter contributes to the probable distribution of refugees in the analysed scenario.

Applying the RandomTree algorithm to the dataset constructed from the four selected parameters generated an extensive decision tree in which *geographical distance from the Republic of Moldova* emerged as the root variable, confirming its role as the primary determinant of refugee mobility during crises. The model shows that when distance is minimal, relocation behaviour is predominantly influenced by cultural similarities, indicating that states such as Bulgaria, Ukraine, and Romania are preferred depending on the degree of identity proximity, which underscores the importance of socio-historical continuities in the early phases of forced migratory flows. As distance increases, the decision tree shifts from identity-based criteria to confessional compatibility: at moderate distances, religious similarities become the major discriminating factor, directing flows toward states such as Poland, Serbia, or again Bulgaria, depending on doctrinal concordances and familiar community structures. For greater distances, economic factors become decisive: the standard of living in the analysed states gains significant relevance, and the algorithm identifies a distribution oriented toward destinations such as Croatia, Russia, or Germany – states perceived as possessing superior socioeconomic absorption capacity and medium-term stabilization potential. Finally, for the most distant destinations, the tree structure reveals a heightened role of the historical presence of Moldovan refugees, suggesting that diaspora-driven network effects function as a dominant attractor.

This dynamic is visible in the model's orientation toward states such as Sweden, Spain, or Italy, where established Moldovan communities reduce the psychosocial costs of transition and facilitate informal support and integration mechanisms. Overall, the results provided by the RandomTree model reveal a stratified decision structure in which geographical proximity acts as the primary selection factor, followed by cultural and religious identity at short and medium distances, and, at greater distances, by economic factors and diaspora distribution.

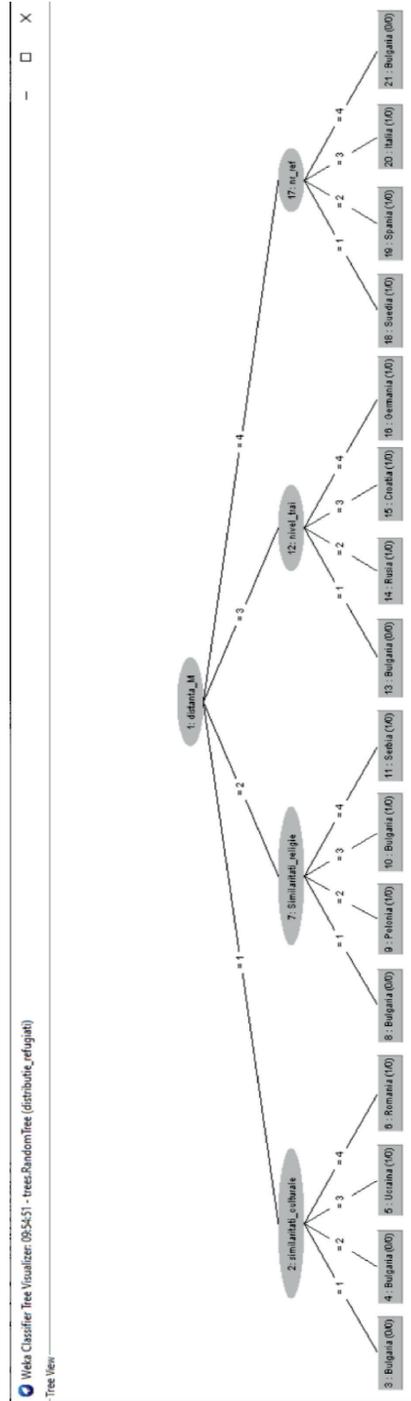


Figure 1: Random Tree Decision Tree (author's design)

This pattern indicates the existence of a complex, multilevel logic governing migratory behaviour during regional crisis scenarios.

DISCUSSION

The analysis of the results obtained through the RandomTree algorithm highlights a deeply stratified decision architecture in which each parameter contributes differently to modelling the relocation behaviour of Moldovan refugees under conditions of regional crisis. The dominance of distance as the primary factor confirms, first and foremost, the fundamental thesis in the literature on forced mobility, which states that geographical proximity represents the immediate criterion of any initial displacement. Individual decision-making is strongly anchored in the need for speed, safety, and reduced exposure to risk, which explains the immediate orientation toward states in direct territorial proximity. The role of cultural and religious similarities, evident in the branches corresponding to short and medium distances, underlines the decisive influence of collective identity on migratory behaviour. Choosing states perceived as culturally or confessionally close suggests the existence of a logic of familiarity-seeking, in which refugees prefer environments that reproduce – at least partially – the sociocultural patterns of their place of origin. This orientation aligns with theories of social capital and recent studies on integration within host communities, which show that identity similarities simplify transition, reduce psychological stress, and provide an immediate sense of continuity.

As distance increases, the model indicates a transition from identity-related factors to structural factors, particularly economic ones. The emergence of the standard of living as a decisive variable for long-distance destinations suggests that, in the absence of cultural familiarity, refugees become far more sensitive to the availability of material opportunities. This logic indicates a strategic behaviour oriented toward financial stability, access to services, and institutional protection – elements capable of compensating for the disadvantages of greater distance and sociocultural differences.

For the most distant destinations, RandomTree reveals the strong importance of the historical number of Moldovan refugees, indicating the robustness of network effects. The presence of an established diaspora in states such as Italy, Spain, and Sweden not only signals the availability of potential community support but also acts as a mechanism for reducing uncertainty through access to information, logistical assistance, and already validated adaptation strategies. This finding aligns consistently with migration network theories and highlights an important empirical

reality: migration flows tend to become self-reinforcing over time, consolidating through transnational connections. Taken together, the discussions derived from the RandomTree model confirm that relocation decisions in crisis situations cannot be reduced to a single factor, but instead represent the expression of an adaptive interaction between proximity, identity, and economic structure. This multidimensional perspective is essential for designing security and migration-management policies that are sensitive to the real dynamics of human behaviour and can provide precise instruments for strategic anticipation in the Eastern security context.

CONCLUSIONS

The analysis conducted using the RandomTree algorithm highlights a complex and stratified decision architecture, deeply dependent on the interaction between geographical proximity, identity compatibilities, and socioeconomic attractiveness – elements that decisively shape the behaviour of Moldovan refugees in regional crisis scenarios. The results allow the formulation of major conclusions regarding the dynamics of forced mobility and the usefulness of machine-learning-based modelling in the context of Eastern security. The emergence of geographical distance as the root variable confirms that human mobility under conditions of instability is governed, in its initial phases, by pragmatic criteria related to the urgency of crossing safer spaces with minimal exposure to operational risks. This finding validates the specialized literature and supports the integration of distance as a strategic indicator in information systems used for anticipating migratory flows.

The relevance of cultural and religious similarities in relocation choices associated with short and medium distances reflects the fact that identity proximity remains an essential determinant of relocation, significantly influencing perceptions of social continuity and psychological safety. Remarkably, the model shows that refugees do not orient themselves exclusively toward the closest states, but rather toward those that offer a familiar cultural or confessional environment. It suggests the necessity of a multidisciplinary approach to understanding forced migration.

The emergence of the standard of living as a dominant variable for distant destinations confirms that refugees' decisions evolve from immediate reactions to medium-term adaptive strategies, in which economic, institutional, and welfare-related criteria become priorities. This transition highlights that mobility during crises is not a one-dimensional phenomenon, but one characterized by a progressive evolution of motivations. The strong role of the network effect, reflected through

the historical number of Moldovan refugees, demonstrates that the diaspora functions as a central vector in shaping flows toward distant states, constituting an informal resource that reduces uncertainty, facilitates integration, and influences long-term patterns of mobility. This conclusion is especially relevant for public policy, indicating the need to monitor the evolution of diasporic communities as an instrument for anticipating migratory pressures.

Overall, the study demonstrates that the use of ML algorithms such as RandomTree within intelligence-type information systems can significantly strengthen early-warning capabilities, strategic planning, and adaptive management of population flows in the context of Eastern security. At the same time, the research highlights both the potential and the current limitations of data-assisted modelling, suggesting future directions for development that include expanding datasets, integrating dynamic geopolitical indicators, and developing hybrid machine-learning architectures capable of capturing the evolving complexity of the operational environment. The results obtained through modelling the migratory behaviour of Moldovan refugees have significant strategic implications for regional security architecture, as they describe with a high degree of granularity the mechanisms through which potential population flows may be redirected during crises, revealing critical elements that can support proactive public policies.

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