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APPLICATION OF MATRICES IN THE TOURISM MANAGEMENT
SYSTEM OF THE REPUBLIC OF ARMENIA

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This article aims to justify the need for the application of matrix-based models in the tourism management system, using the Republic of Armenia as a case study, and to demonstrate their effectiveness, as data-driven decision making, tools for the tourism sector.

This study investigates the tourism management system, with a particular focus on the spatial interrelationships of tourism infrastructure, including food service establishments and banking services (ATMs), and evaluates their accessibility through the application of matrix-based methods. The research employs geoinformatics and cartographic tools to perform the spatial analysis and visualization of tourism-related data. This methodological approach enables the identification of spatial interdependencies and enhances the accuracy of analytical outcomes.

As a result, an analysis of the spatial distribution of banking ATMs was conducted using the ArcGIS Pro software through the OD Cost Matrix tool, based on the case of Yerevan City. This tool makes it possible to identify and measure the least-cost paths along a network from multiple origins to multiple destinations.

The results indicate that matrix-based methods constitute effective instruments for managing tourism flows and destination attractiveness and can be applied not only within the Tourism Committee of the RA but also by Destination Management Organizations (DMOs) and non-governmental organizations (NGOs).

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Introduction. Tourism is one of the sectors of strategic importance to the economy of the Republic of Armenia. This is evidenced by the fact that approximately 2 mln tourists visit the Republic of Armenia annually, according to the Statistical Committee of the Republic of Armenia. In 2023, a record number of 2.3 mln tourists was registered in the Republic of Armenia, while in 2024 the number amounted to 2 208179 tourists, and in 2025 it increased by 2.5%, reaching 2 263642 tourists [1]. In addition, according to the “Strategic Program for Tourism Development of the Republic of Armenia for 2026–2030”, the average expenditure per tourist in the RA

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amounted to USD 776 in 2023, a pattern that has been maintained over time [2]. The effective development of the sector is contingent upon the existence of a data-driven management system. At present, data collection in the tourism sector of the Republic of Armenia is carried out mainly through surveys, interviews, and statistical records, which often fail to reflect the actual structure of tourism flows, the purposes of visits, and the degree of infrastructure load.

The incompleteness of data, as well as the insufficient consideration of their seasonality and spatial distribution, hinders effective decision-making by both public and private institutions. For this purpose, pursuant to Decision No 884-N of the Government of the RA dated June 22, 2006, the Law “On Establishing the Border Electronic Management Information System of the Republic of Armenia, Defining the Procedure for Its Operation, and Determining the List of System Users” was adopted, aimed at improving the mechanism for collecting accurate statistical data in the tourism sector [3]. As a result, the Border Electronic Management Information System (BEMIS) was established, enabling the collection of more accurate and comprehensive information on inbound and outbound tourist flows by citizenship, gender and age groups, border crossing points by means of transport, duration of visits, and the number of repeat tourist visits. The system was further improved in 2020 through the application of relevant software, allowing for the acquisition of more precise data on tourists visiting Armenia [4]. However, during the period 2023–2025, the responsible authorities have been discussing the revision, improvement, and clarification of the BEMIS system [5, 6]. In this context, there emerges a need for the application of systematic approaches and data-driven methods, which can be implemented through the use of matrix-based models. The latter is considered a methodological tool that enables the structuring of available data, the identification of interrelationships, and the optimization of management processes.

According to the research of Professor Edward Groenland of Nyenrode Business University (the Netherlands), matrices are used as a powerful tool for the analysis of qualitative data [7]. Dana Rosenberg Coker and Janice Nahra Friedel in the results of their research, note that matrices enable the rapid development of insights into how a particular functional area is evaluated by different groups. Matrices facilitate the integration of data collected through various research instruments, which may relate to any service or functional area [8]. As a result, tourism, as a spatial phenomenon, can be effectively assessed through the use of matrices. Studies of the international market have shown that the tourism sector primarily employs such matrix-based tools as the SWOT Matrix, Ansoff Matrix, Innovative Matrix and Destination Competitiveness Matrix. In the Republic of Armenia, attempts have also been made to apply matrix-based approaches, as evidenced by the article “Assessment of the Tourist Satisfaction Index: Evidence from Armenia” by G. Tovmasyan, in which the author evaluates tourist satisfaction in the Republic of Armenia using the IPA matrix [9].

Materials and Methods. This study investigates the tourism management system, with a particular focus on the spatial interrelationships of tourism infrastructure, including food service establishments and banking services (ATMs), and evaluates their accessibility through the application of matrix-based methods. The research employs geoinformatics and cartographic tools to perform the spatial

analysis and visualization of tourism-related data. This methodological approach enables the identification of spatial interdependencies and enhances the accuracy of analytical outcomes. As a result, an analysis of the spatial distribution of banking ATMs was conducted using the ArcGIS Pro software through the OD Cost Matrix tool, based on the case of Yerevan city. This tool makes it possible to identify and measure the least-cost paths along a network from multiple origins to multiple destinations [10].

Data collection in the tourism sector of the Republic of Armenia is based on a variety of methods, including both quantitative and qualitative research, aimed at analyzing tourism flows, consumer behavior, sectoral revenues, and other indicators. Market analysis shows that these methods are primarily implemented through online and offline surveys, interviews, and focus group discussions [11].

However, the existing methods are largely subjective in nature, which reduces the objectivity of the data. Moreover, a significant portion of the available data is not utilized within the tourism management system as a basis for practical decision-making. This circumstance necessitates the application of alternative research methods, and, as proposed in this study, the use of matrices as an alternative and complementary approach to data collection and analysis.

The paper presents the current state of tourism data collection and analysis in the Republic of Armenia, as well as the proposed matrix-based methods. A key component of the tourism system is *the tourist*. In the Republic of Armenia, data collection related to tourists continues to be problematic, as evidenced by discrepancies between official statistics and actual tourist behavior. In particular, data on religious tourism do not reflect the true nature of visits, since the majority of tourists, regardless of their primary travel purpose, visit at least one religious site [12]. This issue is attributable to imprecise data classification methodologies. Under such conditions, the application of the Boston Consulting Group (BCG) Matrix [13] or a correlation matrix [14] would make it possible to cross-analyze tourists' country of origin, travel purpose, and selected destination, thereby revealing interrelationships among these variables. This, in turn, would allow for the development of a more comprehensive and professionally structured database for the management of tourism flows.

To enhance the effectiveness of tourism data analysis and the level of visual representation, it is advisable to apply the ArcGIS Pro software, which enables the use of various matrix-based tools. In particular, the OD Cost Matrix is widely used in the software for spatial data analysis, while the Confusion Matrix is applied to assess the accuracy of data classification. Each of these tools is discussed separately below, with the aim of identifying their functional capabilities and specific features in the context of tourism data analysis.

Results and Discussion.

OD Cost Matrix in ArcGIS Pro. This matrix serves not only as a data collection tool but also as a data analysis instrument in tourism, applied through the Network Analyst tool in ArcGIS Pro to enable the spatial analysis of least-cost paths and network-based calculations (Fig. 1).

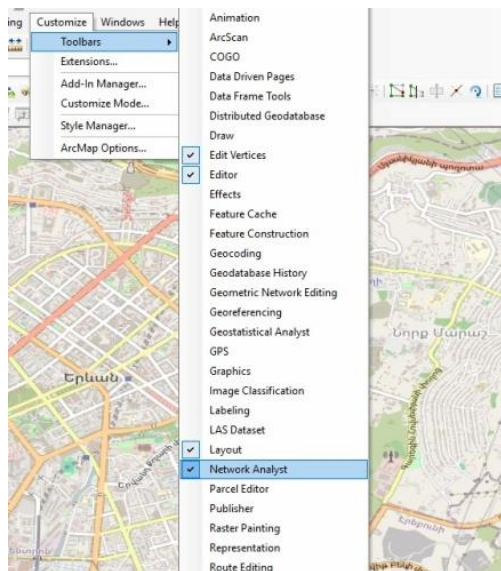


Fig. 1. Network Analyst tool in ArcGIS Desktop 10.x.

The matrix formation process is outlined as follows. In the initial stage, an appropriate Network Dataset must be created, which entails importing the relevant data into the designated fields (Fig. 2).

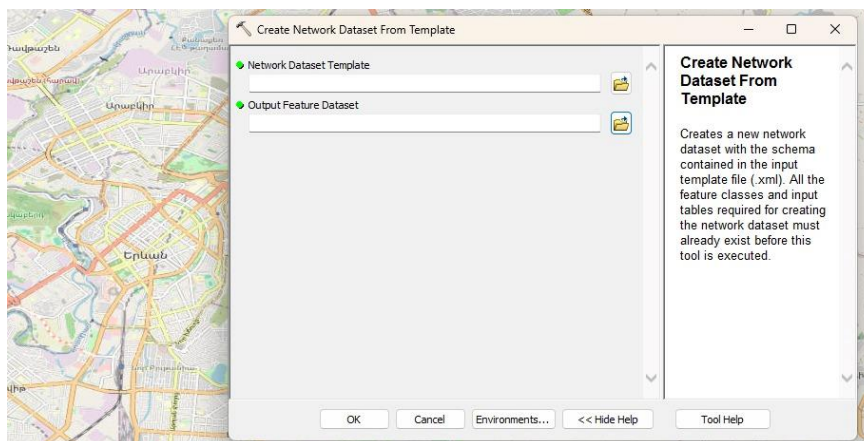


Fig. 2. Network Dataset used for matrix formation in ArcGIS Desktop 10.x.

Following the creation of the Network Dataset, the next step involves selecting the New OD Cost Matrix function (Fig. 3), specifying the relevant origins and destinations along with the required information.

The OD Cost Matrix identifies the nearest facilities based on travel time when the measurement unit parameter is set to time. Similarly, if the measurement units are based on distance, the tool calculates travel distance. At least one origin and one destination must be specified for the tool to operate successfully. The OD Cost Matrix allows the inclusion of up to 1 000 origins and 1 000 destinations, up to 250 point barriers, and a limited number of line or polygon barriers; however, line

barriers cannot intersect more than 500 street features, and polygon barriers cannot intersect more than 2 000 features [10].

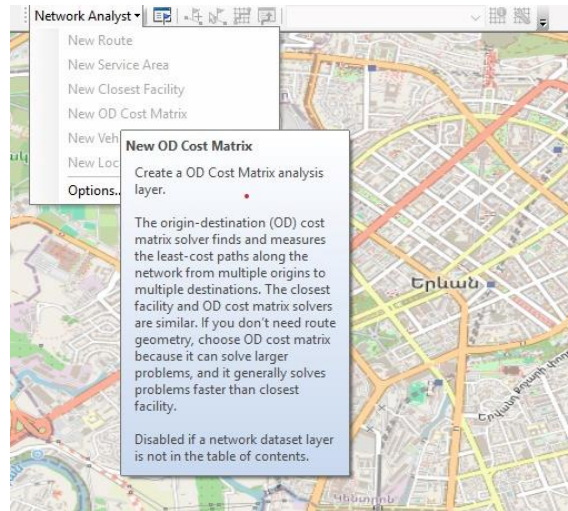


Fig. 3. OD Cost Matrix tool in ArcGIS Desktop 10.x.

In this study, a similar analysis was conducted. Several public food areas, including pubs, and banking services, such as ATMs, located in the city of Yerevan were selected, as these are currently in high demand in the tourism market. It was assumed that identifying public food areas or pubs located near ATMs would be advantageous, since tourists are likely to spend more money in these areas. To address this problem, the OD Cost Matrix method was applied, with the necessary input data presented in Table, which illustrates the origin–destination relationships.

Table 1

Attribute table of the OD Cost Matrix for ATM's in Yerevan

ObjectID	Shape	Name	OriginID	DestinationID	DestinationRank	Total_Minutes
31	Polyline	Քուբ:Սևադրյան վանք - ATM	74	3	1	0.729377
25	Polyline	Քուբ:Սևադրյան վանք զին վանք - ATM:HSBC	73	1	1	0.771568
19	Polyline	Քուբ:Թավ քաղա - ATM:HSBC	72	1	1	0.863298
13	Polyline	Քուբ:Նալբանդյան - ATM:HSBC	71	1	1	0.919745
7	Polyline	Քուբ:Յե. Բիբրյան - ATM:HSBC	70	1	1	0.951777
1	Polyline	Քուբ:Տարառու քա - ATM:HSBC	69	1	1	1.132689
26	Polyline	Քուբ:Սևադրյան վանք զին վանք - ATM	73	3	2	1.390844
32	Polyline	Քուբ:Սևադրյան վանք - ATM:HSBC	74	1	2	1.399678
20	Polyline	Քուբ:Թավ քաղա - ATM	72	3	2	1.462584
14	Polyline	Քուբ:Նալբանդյան - ATM	71	3	2	1.539032
8	Polyline	Քուբ:Յե. Բիբրյան - ATM	70	3	2	1.571063
2	Polyline	Քուբ:Տարառու քա - ATM	69	3	2	1.751976
27	Polyline	Քուբ:Սևադրյան վանք զին վանք - ATM	73	2	3	4.589968
21	Polyline	Քուբ:Թավ քաղա - ATM	72	2	3	4.681708
15	Polyline	Քուբ:Նալբանդյան - ATM	71	2	3	4.738155
9	Polyline	Քուբ:Յե. Բիբրյան - ATM	70	2	3	4.770167
3	Polyline	Քուբ:Տարառու քա - ATM	69	2	3	4.951099
33	Polyline	Քուբ:Սևադրյան վանք - ATM	74	2	3	5.218088
34	Polyline	Քուբ:Սևադրյան վանք - ATM	74	4	4	6.538662
35	Polyline	Քուբ:Սևադրյան վանք - ATM	74	5	5	6.538662
28	Polyline	Քուբ:Սևադրյան վանք - ATM	74	6	6	6.538662

As a result, the following matrix-based map was generated (Fig. 4).

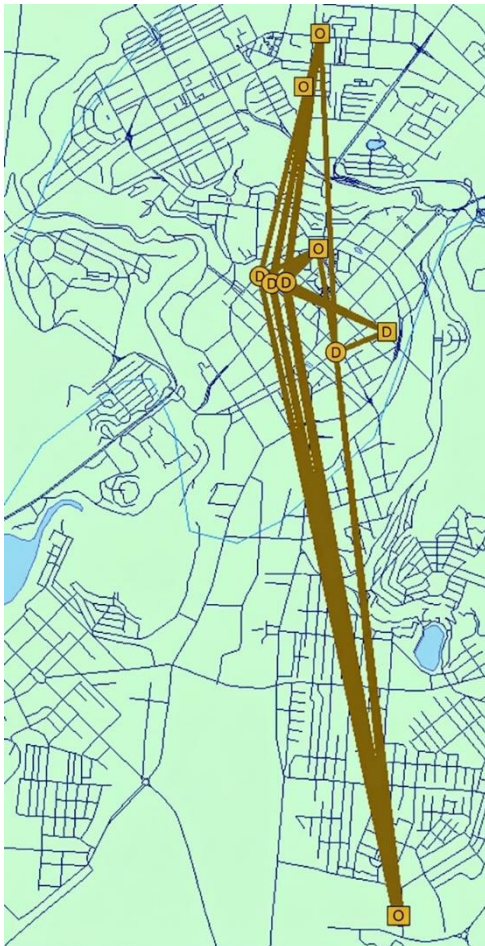


Fig. 4. Spatial Distribution of Banking ATMs in Yerevan: OD Cost Matrix Analysis.

In the matrix, vertical connections represent the interrelationships among the selected objects, while the values of the OD Cost Matrix indicate the calculated travel times between them. This approach enables the examination of the spatial organization of the tourism market and the assessment of service accessibility within the context of tourism planning and management, using both visual and quantitative analyses. The application of this matrix-based method allows for a more efficient, systematic, and highly accurate analysis of the tourism market.

Confusion Matrix. The Confusion Matrix is an analytical tool commonly used in data classification to evaluate model performance when both actual and predicted classes are available. It provides a method for comparing the output of a network or system and assessing the accuracy of classification systems (Fig. 5) [15].

In ArcGIS Pro, the Confusion Matrix is primarily used for image classification analysis, for example, to assess the accuracy of satellite image classifications. It can also be applied during the analysis of other spatial data when it is necessary to compare classification results with actual data.

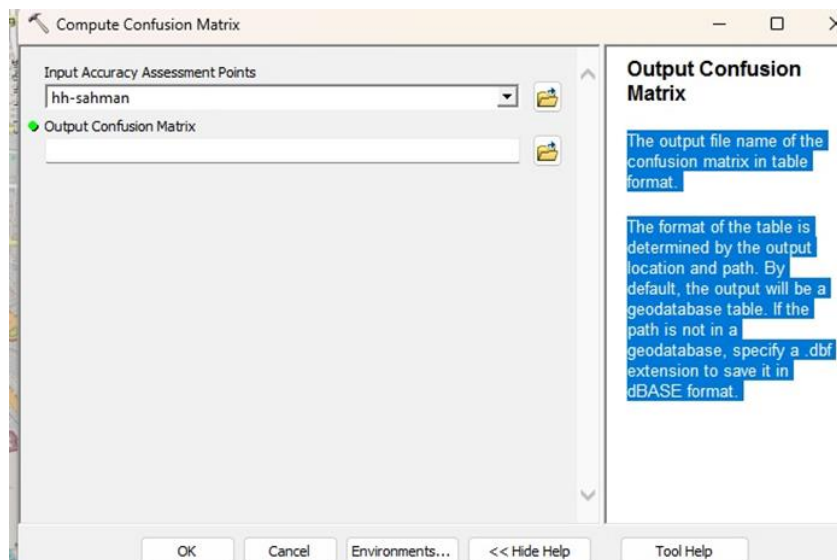


Fig. 5. Confusion Matrix tool in ArcGIS Desktop 10.x.

In the context of spatial analysis, the Confusion Matrix can be useful, for instance, when testing a data model that predicts the categorization of different areas (e.g., levels of environmental risk, types of land use, or urban and rural boundaries). It can show which areas are misclassified, thereby enabling improvements in model accuracy.

If specific domain applications are considered, the Confusion Matrix can assist, for example, in tourism data analysis by evaluating how accurately certain areas are classified as high- or low-visit zones based on actual data. The Confusion Matrix can be applied to tourism data analysis when it is necessary to assess the accuracy of data classification. The method can be used as a tool for managing flows and tourist attractions by evaluating classification accuracy and detecting misclassifications.

Thus, enhancing the efficiency of tourism management in the Republic of Armenia requires the use of matrix-based models, which enable the analysis and management of tourism flows. These approaches facilitate the development of evidence-based strategies and ensure the optimal administration of tourist services.

Conclusion. Tourism is one of the primary sectors of the economy in the Republic of Armenia, and its effective development is largely dependent on the presence of a data-driven management system. Although interviews, statistical surveys, and the BEMIS system are commonly employed in the sector, they do not fully reflect the actual structure of tourism flows and the purposes of visits, which limits the effectiveness of management decisions.

A review of the literature specific to the tourism sector has shown that most authors emphasize the existing challenges in the collection and analysis of tourism data; however, comprehensive and systematic solutions to address these challenges have not yet been sufficiently developed. In this context, the main objective of this study was to propose a methodological approach that would enhance analytical

precision in the sector and enable data-driven decision-making. To achieve this goal, a matrix-based method was selected, which provides structural organization of the data, allows for the identification of spatial and seasonal patterns, and serves as a basis for informed decision-making in the tourism sector.

According to established perspectives, interdisciplinary research increases the value of sector-specific scientific analysis. By combining this approach with cartographic methods, it was possible to develop the OD Cost Matrix for the city of Yerevan. The integration of matrix-based analysis and cartography allows for the visualization of the tourism market and the conduction of spatial data analysis. In summary, matrix-based methods can serve as effective tools for managing tourism flows and attractiveness, being applicable not only within the Tourism Committee of the Republic of Armenia but also in Destination Management Organizations (DMOs) and non-governmental organizations (NGOs).

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Մ. Ս. ՏԱՇՅԱՆ, Ա. Ս. ՓԻԼՈՅԱՆ

ՄԱՏՐԻՑՆԵՐԻ ԿԻՐԱՌՈՒՄԸ ՀԱՅԱՍՏԱՆԻ ՀԱՆՐԱՊԵՏՈՒԹՅԱՆ
ՉՔՈՍԱՇՐՋՈՒԹՅԱՆ ԿԱՌԱՎԱՐՄԱՆ ՀԱՄԱԿԱՐԳՈՒՄ

Ա մ փ ո փ ու մ

Մույն հոդվածի նպատակն է հիմնավորել մատրիցային մոդելների կիրառման անհրաժեշտությունը զբոսաշրջության կառավարման համակարգում՝ Հայաստանի Հանրապետության օրինակով, և ցուցադրել դրանց արդյունավետությունը որպես տվյալահեն որոշումներ կայացնելու գործիք զբոսաշրջության ոլորտում:

Աշխատանքում ուսումնասիրվել է զբոսաշրջության կառավարման համակարգը, մասնավորապես՝ զբոսաշրջային ենթակառուցվածքների, այդ թվում՝ սննդի հաստատությունների և բանկային ծառայությունների (ATM-ների) տարածական փոխհարաբերությունները, և գնահատվել է դրանց մատչելիությունը մատրիցային մեթոդների միջոցով: Հետազոտության ընթացքում օգտագործվել են գեոինֆորմատիկայի և քարտեզագրության գործիքներ՝ զբոսաշրջային տվյալների տարածական վերլուծության և վիզուալիզացիայի նպատակով: Նշված մեթոդաբանական մոտեցումը հնարավորություն է տալիս բացահայտել տարածական փոխկապակցվածությունները և բարձրացնել վերլուծության արդյունքների ճշգրտությունը:

Արդյունքում, ArcGIS Pro ծրագրային ապահովման կիրառմամբ իրականացվել է բանկային ATM-ների տարածքային վերլուծություն՝ OD Cost Matrix գործիքի միջոցով, Երևան քաղաքի օրինակով: Տվյալ գործիքը թույլ է տալիս բացահայտել և չափել ցանցի երկայնքով ամենացածր ծախս ունեցող ուղիները բազմաթիվ ելակետերից դեպի բազմաթիվ նպատակակետեր:

Արդյունքները ցույց են տալիս, որ մատրիցային մեթոդներն արդյունավետ գործիքներ են զբոսաշրջային հոսքերի և զբոսաշրջային ուղղությունների գրավչության կառավարման համար և կարող են կիրառվել ոչ միայն Հայաստանի Հանրապետության զբոսաշրջության կոմիտեում, այլ նաև դեստինացիոն կառավարման կազմակերպությունների (DMO-ներ) և հասարակական կազմակերպությունների (NGO-ներ) կողմից:

М. С. ТАШЯН, А. С. ПИЛОЯН

ИСПОЛЬЗОВАНИЕ МАТРИЦ В УПРАВЛЕНИИ ТУРИСТИЧЕСКОЙ
СИСТЕМОЙ РЕСПУБЛИКИ АРМЕНИЯ

Резюме

Цель данной статьи – обосновать необходимость применения матричных моделей в системе управления туризмом на примере Республики Армения и продемонстрировать их эффективность в качестве инструментов принятия решений на основе данных для туристического сектора.

В работе изучалась система управления туризмом, в частности пространственные взаимосвязи туристической инфраструктуры, включая предприятия общественного питания и банковские услуги (банкоматы), и проводилась оценка их доступности с использованием матричных методов. В ходе исследования применялись инструменты геоинформатики и картографии для пространственного анализа и визуализации данных, связанных с туризмом. Данный методологический подход позволяет выявлять пространственные взаимозависимости и повышать точность аналитических результатов.

В результате с использованием программного обеспечения ArcGIS Pro была проведена пространственная аналитика размещения банковских банкоматов с применением инструмента OD Cost Matrix на примере города Ереван. Этот инструмент позволяет выявлять и измерять маршруты с минимальными затратами по сети от нескольких точек отправления к нескольким пунктам назначения.

Результаты показывают, что матричные методы являются эффективными инструментами управления туристическими потоками и привлекательностью туристических направлений, и могут применяться не только в Комитете по туризму Республики Армения, но и организациями управления дестинацией (DMO), а также общественными организациями (NGO).