Neutrosophic Multinominal Logistic Regression Technique for Optimizing Adaptive Reuse of Historical Castles

Rama Hussen Omar [*1], Mohamed Najeb Kayali [1], Mohamed Bisher Zeina[2]

[1] Faculty of Architectural Engineering, University of Aleppo, Aleppo, Syria
[2] Department of Mathematical Statistics, University of Aleppo, Aleppo, Syria

Emails: rama.hseen.omar@gmail.com; mohamed.najebkayali@gmail.com; bisher.zeina@gmail.com

Abstract

Defining and utilizing Neutrosophic Multinomial Logistic Regression (NMLR) is significant in architecture because it introduces a novel approach to prioritizing the optimal alternative for adaptively reusing a historic building. This is particularly crucial in post-conflict recovery. NMLR presents an intelligent classification system and decision-making tool that optimizes the evaluation process for adaptive reuse projects, even under conditions of uncertainty. The integration of Neutrosophic sets and digital technologies provides decision-makers with a more accurate and reliable tool to make rational decisions regarding functional spaces reuse. The effectiveness of this approach is demonstrated through a case study of the Castle of Aleppo. The study determined that the most suitable alternative for the castle is a multi-purpose facility that caters to tourism. This approach can be adapted to various restoration projects, and the assessment of proposed alternatives can be customized according to the weight of the criteria by creating desktop application which contributes to the sustainability and improvement of post-disaster reconstruction efforts.

Keywords: Multi Criteria Decision Making; Neutrosophic; Multi-Nominal Logistic Regression; Adaptive Reuse; Historic Building; Machine learning; Castles; Building Information Modelling

1. Introduction

The aim of the current research is to propose a comprehensive model for the redevelopment of abandoned historic castles by combining 3D-HBIM and mathematical techniques. Various concepts for redeveloping buildings are being analysed. It is proposed to apply a complex system of criteria, consisting of technological, economic, and environmental sub-systems. The proposal is to define and use the NMLR model to select the best alternative concept. Digital construction techniques are suggested to support the selection process, including 3D simulation of alternatives, and to further implement a full lifetime management strategy for a building.

The goal of sustainable development is not to construct new urban areas but to revitalize abandoned territories and restore life to historic contexts instead of preserving them as museum sites[1]. Complex decisions regarding conservation can be supported by the Building Information Modelling specialized for heritage cases (3DH-BIM) methodology and various digital construction techniques[2]. The modelling technique can be considered a new method for ensuring project quality[3]. It can be utilized in any phase of the project life cycle, providing numerous benefits such as detailed documentation of the building process and recording every alteration made to previous stages as a "digital passport"[4]. During the rehabilitation and maintenance phases, any changes made to the building must be evaluated with respect to both the building's heritage and sustainability. Alternative solutions for redeveloping buildings can be effectively evaluated using Multiple Criteria Decision Making (MCDM) methods[5].

It is well-known that fuzzy logic is a mathematical approach that deals with uncertainty and imprecision in data[7]. It allows for the representation of partial truths, which is especially useful in situations where exact values are not available or difficult to obtain. Fuzzy logic has been applied in various fields, including artificial intelligence [8],

DOI: https://doi.org/10.54216/IJNS.210305
Received: April 23, 2023 Revised: May 22, 2023 Accepted: June 18, 2023

control systems, and decision making[9]. While, Neutrosophic logic is a relatively new concept that has gained popularity in various fields of study [10], including probability [10]–[14], engineering [15], [16],[17] medicine [18], [19], education [20], [21], decision making [22], [23] and artificial intelligence [24]–[26]. enabling a more comprehensive representation of uncertainty, ambiguity, and contradiction. One of the primary benefits of utilizing neutrosophic theory is that it offers a more precise depiction of reality. Neutrosophic logic allows for the representation of uncertainty in human decision making, which can lead to more accurate predictions [10].

2. Preliminaries:

2.1 Interval-Valued Neutrosophic Numbers:[27]

Interval-valued neutrosophic numbers are defined by a determinant part, an indeterminacy part as N = D + I, where D represents the determinant part of the number and I represents indeterminacy. For Example: $N = 5 + I$ where $I \in [0,0.1]$

2.2 Operations on interval-valued neutrosophic numbers:

Let $N_1 \in [a, b]$ and $N_2 \in [d, c]$ be two interval-valued neutrosophic numbers. Operations on N1,N2 are defined as follows:

$$N_1 + N_2 = [a + d, b + c]$$
$$N_1 - N_2 = [a - c, b - d]$$
$$N_1 * N_2 = [a * c, b * d]$$
$$\frac{N_1}{N_2} = \left[\frac{a}{c}, \frac{b}{d}\right]$$
$$\sqrt{N_1} = [\sqrt{a}, \sqrt{b}]; a \geq 0, b \geq 0$$

2.3 Classical Multinominal Logistic Regression:

Multinomial regression is a classification model that estimates the relationship between a dependent variable (a categorical variable) and one or more explanatory (or independent) variables [28]. This model is used to measure and analyze complex phenomena. The technique enables quantitative analysis of the interrelationships among multiple variables, thereby facilitating a more dependable decision-making process [29]. The basic setup is similar to logistic regression, with the only difference being that the dependent variables are categorical instead of binary. This means that there are K possible outcomes, rather than just two.

3. Methodology:

3.1 The Model Framework of Prediction System Using NMLR:

This paper proposes a complex adaptive reuse decision-making model for historic buildings. When assessing the potential for adaptive reuse potential (ARP) for distracted or abandoned castles [30], it is important to consider various factors such as their current condition, location, and the resources available for their restoration and maintenance [5], [31]. The first step is to create a database containing information on 60 castles, including their original function, valuable architectural properties, structural characteristics, artistic decoration, interior geometry, technical state, and different zones of functions after adaptive reuse selection and criteria weighting. The next step involves using the Neutrosophic Multi-Nominal Logistic Regression Technique (NMLR) to predict the potential for adaptive reuse of Syrian castles using the created desktop application.

The mathematical foundation of the neutrosophic multi-nominal regression technique is primarily rooted in probability theory with many variations. It is a combination of two theoretical frameworks: the theory of random variables and the theory of fuzzy sets[29]. Random variables are particularly useful in describing the probabilities of events, while fuzzy sets are effective in describing the uncertainty associated with predicting events. The combination of these two approaches enables accurate and reliable prediction of the interactions between variables and their outcomes.

NMLR was created to enable the simultaneous consideration of multiple criteria and uncertainties in the decision-making process. It achieves this by combining 3DH-BIM data as input for NMNR, which predicts the potential for adaptive reuse of castles based on various factors, including architectural significance, cultural value, and economic feasibility. The equation for the neutrosophic regression model is:

DOI: https://doi.org/10.54216/IJNS.210305
Received: April 23, 2023 Revised: May 22, 2023 Accepted: June 18, 2023

$$y_N = a_N + b_{N_1}X_{N_1} + b_{N_2}X_{N_2} + \ldots + b_{N_n}X_{N_n}$$

where y_N is the dependent variable, a is the intercept, X_{N_1}, X_{N_2}, ..., X_{N_n} are the independent variables, and b_1, b_2, ..., b_n are the coefficients that are estimated in the regression.

It involves constructing a linear predictor function by using a set of weights that are combined linearly with explanatory variables. The score obtained from this function can be converted into a probability value, which indicates the probability of an observation selecting a specific outcome. This approach helps to avoid the propagation of errors in real-world predictive models that consist of multiple components.

Taking the following transformation yields to a neutrosophic probability value as follows:

$$\log(\text{ odds }) = \operatorname{logit}(P_N) = \ln\left(\frac{P_N}{1-P_N}\right) = a_N + \mathrm{b}_{N_1}\mathrm{x}_{N_1} + \mathrm{b}_{N_2}\mathrm{x}_{N_2} + \mathrm{b}_{N_3}\mathrm{x}_{N_3} + \cdots$$

$$P_N = \frac{\exp\left(a_N + \mathrm{b}_{N_1}\mathrm{x}_{N_1} + \mathrm{b}_{N_2}\mathrm{x}_{N_2} + \mathrm{b}_{N_3}\mathrm{x}_{N_3} + \cdots\right)}{1 + \exp\left(a_N + \mathrm{b}_{N_1}\mathrm{x}_{N_1} + \mathrm{b}_{N_2}\mathrm{x}_{N_2} + \mathrm{b}_{N_3}\mathrm{x}_{N_3} + \cdots\right)} \qquad (*)$$

Where:

P_N is the interval-valued neutrosophic probability that a case is in a particular category,

a_N is the interval-valued neutrosophic constant of the equation,

b_{N1}, b_{N2},… = are the interval-valued neutrosophic coefficients of the predictors or independent variables.

We can estimate values of a_N, b_1, b_2,… using the iterative equation:

$$b_{i_N}^{(k+1)} = b_{i_N}^{(k)} + X_N\left(Y_N - \widehat{Y_N}^{(k)}\right)\left(X_N^T P_N (1-P_N)^{(k)} X_N\right)^{-1}$$

$$a_N^{(k+1)} = a_N^{(k)} + X_N\left(Y_N - \widehat{Y_N}^{(k)}\right)\left(X_N^T P_N (1-P_N)^{(k)} X_N\right)^{-1}$$

Where:

X_N is an interval-valued neutrosophic matrix of inputs $X_{N1}, X_{N2}, \ldots$.

Y_N is an interval-valued neutrosophic vector of outputs.

The prediction system was created using the R programming language, which served as the foundation for the desktop program. This program enables the creation of a visually appealing and intuitive interface. Various alternatives can be generated using a parametric database collection, which can be accessed through a comprehensive BIM model using Grasshopper in Rhino.

3.2. Criteria Selection for Castles Adaptive Reuse:

Each heritage building possesses unique historical and architectural features that make it challenging to establish a consistent methodology that applies to all cases. Therefore, to determine whether the process of adaptive reuse for a historic building will meet the requirements of the new function without compromising its authenticity and identity, key criteria must be defined comprehensively. These criteria should include the quality of the original construction, the potential for the building to be repurposed. However, in practice, the decision to adaptively reuse a building is often made in a piecemeal manner, and the promised benefits do not always align with the actual outcomes. This suggests that, in reality, decisions are often made based on reasons that differ from those commonly mentioned in the rhetoric. Therefore, the decision to adaptively reuse a castle must be made on a case-by-case basis, taking into account the specific context and situation of the building in question[31].

All the criteria listed in Table 1 have been selected based on previous studies and models such as ARP and AdaptSTAR[32], [33]. These criteria will be weighted according to the context of users, producers, regulators, and investors to evaluate the performance of each functional alternative in terms of the criteria system[34].

DOI: https://doi.org/10.54216/IJNS.210305
Received: April 23, 2023 Revised: May 22, 2023 Accepted: June 18, 2023

Table 1: Criteria system

	Input	Criteria	Model 1		Model 2		Model 3	
			$coef_L$	$coef_U$	$coef_L$	$coef_U$	$coef_L$	$coef_U$
	Intercept		20.212	22.261	-31.252	-28.191	-46.679	-43.186
Area		Area [4]	0	0	0	0	0	0
Landscape	Mountain	Landscape [1]	0	0	0	0	0	0
	Mountain and moat	Landscape [2]	3.284	4.268	32.328	33.725	37.614	38.137
	coastal	Landscape [3]	-16.456	-15.751	-17.892	-17.567	2.168	2.335
	Surface land	Landscape [4]	27.11	27.296	31.552	32.091	58.449	60.882
	Hill	Landscape [5]	-29.616	-29.485	66.673	66.72	-1.038	-0.981
Associati-on	city	Association [1]	0	0	0	0	0	0
	Small town	Association [2]	-30.932	-29.663	-7.94	1.605	34.498	35.302
	Isolated or Rural	Association [3]	9.698	12.217	-39.252	-38.405	1.039	2.566
Architectural Type	Concentric Castle	Spatial Type [1]	0	0	0	0	0	0
	Stone Keep	Spatial Type [2]	-5.185	-4.921	3.084	3.507	-5.34	-5.134
	Motte and Bailey	Spatial Type [3]	-17.705	-15.776	16.866	17.356	-18.072	-17.446
	square tower	Spatial Type [4]	-95.468	-92.641	-21.333	-19.565	-4.311	-4.136
	cylindrical tower	Spatial Type [5]	0	0	0	0	0	0
Structural System	Enclosed	Structural System[1]	0	0	0	0	0	0
	Enclosed city	Structural System[2]	-2.464	-1.611	-12.157	-10.817	-21.02	-20.72
	Wall Tower	Structural System[3]	-51.64	-48.892	-34.446	-34.012	-28.058	-26.287
	Wall, Recess and Tower	Structural System[4]	9.951	12.161	-31.2	-30.213	-44.782	-43.933
	Roundel	Structural System[5]	-51.283	-51.038	-6.131	-5.65	1.734	1.863
weighted criteria	X_1	Physical	-63.397	-61.321	-10.989	-10.489	-26.724	-25.616
	X_2	Economical	-21.38	-19.259	-66.327	-60.444	40.576	43.813
	X_3	Functional	-16.104	-13.594	-34.419	-23.689	-29.035	-24.845
	X_4	Technological	14.959	16.149	18.452	18.464	3.79	10.167
	X_5	Social	-30.812	-30.208	26.923	39.927	14.047	15.876
	X_6	Political	-21.667	-20.228	2.265	8.404	-1.993	0.065
	X_7	Legal	12.85	13.647	1.247	2.446	-3.217	-2.808
	X_8	Historical	-69.289	-68.458	-42.792	-42.765	-30.095	-22.247
	X_9	Aesthetic	-7.371	-6.966	-3.422	-3.317	-0.527	-0.517
	X_10	Cultural	113.225	119.781	18.49	19.328	-8.139	0.158
	X_11	Urban	-30.485	-30.441	-27.423	-26.861	-5.862	-5.179
	X_12	Environmental	13.742	13.977	-24.623	-24.361	2.019	7.332
	X_13	Educational	-37.89	-35.447	105.078	111.53	-23.921	23.838
	X_14	Entertainment	3.829	4.397	0.004	0.013	-0.241	-0.226
	X_15	Museography	149.181	158.488	-18.234	-16.633	1.949	2.451

Table (1) displays the neutrosophic coefficients of the (*) model, which is designed to predict the optimal alternative for adaptive reuse among tourism, cultural functions, commercial services, and educational centers. The neutrosophic model makes predictions using the following approach:

First, we input the criteria weights, which were determined by experts, and other physical aspects of the selected building into each model independently. Model 1 selects between cultural function and tourism based on the neutrosophic probability calculation, with a vote for cultural function if the calculated neutrosophic probability is greater than 0.5. The same process occurs with model 2, which selects between commercial services and tourism,

DOI: https://doi.org/10.54216/IJNS.210305
Received: April 23, 2023 Revised: May 22, 2023 Accepted: June 18, 2023

and model 3, which chooses between educational centers and tourism. Finally, the adaptive model takes into account the four voting probabilities and selects the corresponding alternative.

3.3. The Alternative Selection Model using R and C#

The proposed Neutrosophic Multi-Nominal Regression Model for evaluating the adaptive reuse potential of historical castles involves collecting data on various factors that could impact adaptive reuse. This includes the condition of the castle, with two databases to account for uncertainty in different criteria. The cases are then divided into testing and training sets, with the seed set at (959). This approach resulted in an accuracy range of 95% for the training data and 97% for the testing data as designing an interface that can be used by non-professional users as a decision-making tool.

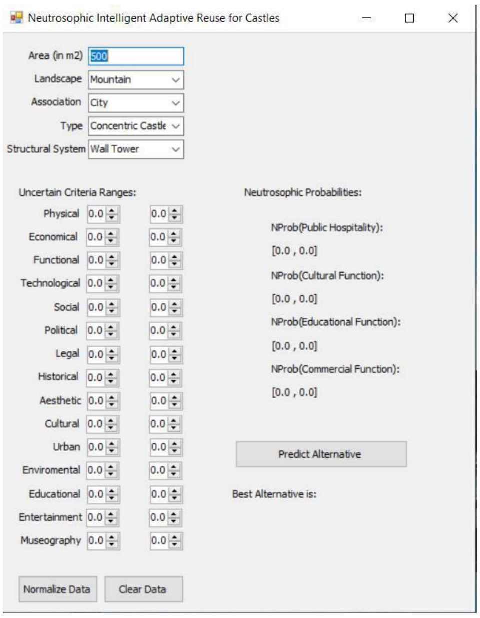

Figure 1: Desktop Application

3.4 Case Study: Castle of Aleppo:

The historic castle was built in the 3rd century BC. It is the oldest building in the ancient city of Aleppo, Syria[35].with the assist of the BIM model information [36], The optimal alternative is selected and evaluated [37]based on a set of criteria listed in Table1. The most preferable option, as determined by applying the NMLR technique, involves combining touristic and cultural functions to allow the castles to offer a range of facilities, such as hotels, commercial spaces, and libraries.

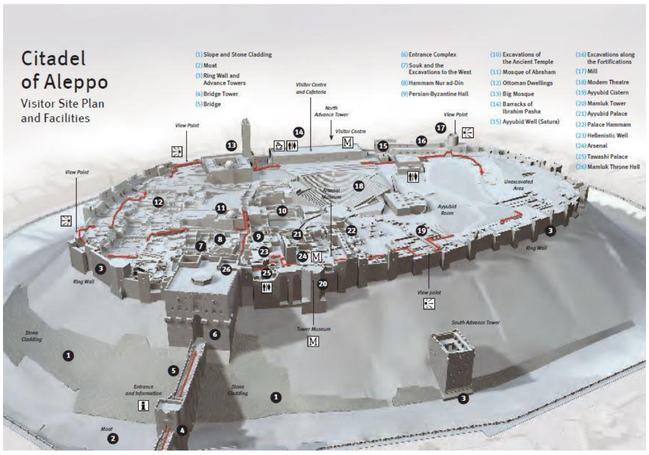

Figure 2: Castle of Aleppo

DOI: https://doi.org/10.54216/IJNS.210305
Received: April 23, 2023 Revised: May 22, 2023 Accepted: June 18, 2023

4. Future Research Directions:

Developing a more comprehensive dataset that includes a wider range of historical buildings from various regions and time periods will facilitate the investigation of using other machine learning techniques, such as decision trees or neural networks, to evaluate the adaptive reuse potential of other types of historic structures, such as religious, industrial, or commercial buildings. These buildings can be transformed as a plug-in within the 3D BIM engineering concept.

Furthermore, the Neutrosophic Multi-Nominal Regression Technique (NMLR) has been applied in diverse fields, including medical diagnosis, finance, and social sciences. Comparing the NMLR model with other models, such as decision trees, can lead to a more precise assessment of the potential for adaptive reuse. The integration of NMLR with grasshopper in Rhino data enables the simultaneous consideration of multiple criteria and uncertainties in decision-making, making it a more comprehensive and efficient approach. Therefore, the proposed approach can be adapted to various restoration projects and contributes to the sustainability and enhancement of post-disaster reconstruction efforts.

5. Conclusion

It has been concluded that a comprehensive approach to predicting the optimal potential for the adaptive reuse of Syrian castles involves combining the use of 3D Building Information Modelling (BIM) and the Neutrosophic Multi-Nominal Regression Technique (NMLR). The use of 3D BIM as a tool for collecting and analyzing data on historic buildings, along with MLR as a tool for predicting outcomes under uncertainty can provide an accurate and reliable prediction system. This approach can be applied not only to historic buildings in Syria but also to those worldwide. The presented case study, along with an analysis of scientific literature and the implemented project, leads to the conclusion that restoring historic castles is highly attractive. When considering sustainable development, it becomes clear that the redevelopment of industrial buildings is a complex issue. Therefore, a prediction model has been developed to support the selection of the most effective decisions. This model has proven to be highly suitable for addressing the multifaceted challenges of industrial building redevelopment. The BIM technique is recommended for supporting the selection process based on multiple criteria, as well as for implementing a project and developing a comprehensive lifetime management strategy for a real object. This involves simulating virtual prototypes with assigned static and dynamic information.

Funding: “This research received no external funding”

Conflicts of Interest: “The authors declare no conflict of interest.”

References

[1] A. Oppio, M. Bottero, V. Ferretti, U. Fratesi, D. Ponzini, and V. Pracchi, “Giving space to multicriteria analysis for complex cultural heritage systems: The case of the castles in Valle D’Aosta Region, Italy,” *J Cult Herit*, vol. 16, no. 6, pp. 779–789, Nov. 2015, doi: 10.1016/j.culher.2015.03.003.

[2] A. Kamari, C. Laustsen, S. Peterson, and P. H. Kirkegaard, “A BIM-based decision support system for the evaluation of holistic renovation scenarios” 2018. Available: http://www.itcon.org/2018/18

[3] Khyati Chaudhary,Gopal Chaudhary, A Decision Support System for Credit Risk Assessment using Business Intelligence and Machine Learning Techniques, Journal of American Journal of Business and Operations Research, Vol. 10 , No. 2 , (2023) : 32-38 (Doi : https://doi.org/10.54216/AJBOR.100204)

[4] Nesrine M. Roumieh,Sonia Ahmed, Adopting Risk Management Professional Methodologies as an Effective Strategy to Protect Heritage Sites in Syria, Journal of International Journal of BIM and Engineering Science, Vol. 5 , No. 1 , (2022) : 61-72 (Doi : https://doi.org/10.54216/IJBES.050104)

[5] R. R. Nadkarni and B. Puthuvayi, “A comprehensive literature review of Multi-Criteria Decision Making methods in heritage buildings,” *Journal of Building Engineering*, vol. 32. Elsevier Ltd, Nov. 01, 2020. doi: 10.1016/j.jobe.2020.101814.

[6] Hrudaya Kumar Tripathy,Sunday Adeola Ajagbe,El-Sayed M. El-Kenawy, Sustainable Management for the Architectural Heritage in Intelligent Cities using MCDM methods, Journal of Journal of Intelligent

DOI: https://doi.org/10.54216/IJNS.210305
Received: April 23, 2023 Revised: May 22, 2023 Accepted: June 18, 2023

Systems and Internet of Things, Vol. 6 , No. 1 , (2022) : 41-58 (Doi : https://doi.org/10.54216/JISIoT.060104)

[7] W. Slany, P. Klement, ? ? Christian, and E. P. Klement, "Fuzzy Logic in Artificial Intelligence Fuzzy Logic in Artiicial Intelligence Christian Doppler Laboratory for Expert Systems Technische Universitt at Wien Institut ff ur Informationssysteme Abteilung ff ur Datenbanken und Expertensysteme Fuzzy Logic in Artiicial Intelligence," 1997.

[8] Lootsma, Freerk A. Fuzzy logic for planning and decision making. Vol. 8. Springer Science & Business Media, 2013.

[9] F. Smarandache, D. Stanujkic, D. Karabasevic, and G. Popovic, "A novel approach for assessing the reliability of data contained in A novel approach for assessing the reliability of data contained in a single valued neutrosophic number and its application in a single valued neutrosophic number and its application in multiple criteria decision making multiple criteria decision making A Novel Approach for Assessing the Reliability of Data Contained in a Single Valued Neutrosophic Number and", doi: 10.5281/zenodo.4030337.

[10] M. B. Zeina and Y. Karmouta, "Introduction to Neutrosophic Stochastic Processes," *Neutrosophic Sets and Systems*, vol. 54, 2023.

[11] F. Smarandache, "Introduction to Neutrosophic Measure, Neutrosophic Integral, and Neutrosophic Probability," *ArXiv*, 2013.

[12] F. Smarandache, "Introduction to Neutrosophic Statistics," *Branch Mathematics and Statistics Faculty and Staff Publications*, Jan. 2014, Accessed: Feb. 21, 2023. Available: https://digitalrepository.unm.edu/math_fsp/33

[13] M. B. Zeina, "Neutrosophic Event-Based Queueing Model," *International Journal of Neutrosophic Science*, vol. 6, no. 1, 2020, doi: 10.5281/zenodo.3840771.

[14] M. B. Zeina, "Erlang Service Queueing Model with Neutrosophic Parameters," *International Journal of Neutrosophic Science*, vol. 6, no. 2, pp. 106–112, 2020, doi: 10.54216/IJNS.060202.

[15] "Solving Thermal System Problem Via Fuzzy Mohand Transform under Neutrosophic Initial Conditions", doi: 10.54216/IJNS.2.

[16] M. Alqarni, A. H. Samak, S. S. I. Ismail, R. M. Abd El-Aziz, and A. I. Taloba, "Utilizing a Neutrosophic Fuzzy Logic System with ANN for Short-Term Estimation of Solar Energy," *International Journal of Neutrosophic Science*, vol. 20, no. 4, pp. 240–259, 2023, doi: 10.54216/IJNS.200422.

[17] Z. Khan, M. Gulistan, N. Kausar, and C. Park, "Neutrosophic Rayleigh Model with Some Basic Characteristics and Engineering Applications," *IEEE Access*, vol. 9, pp. 71277–71283, 2021, doi: 10.1109/ACCESS.2021.3078150.

[18] M. Kanan, N. Omer, S. S. I. Ismail, R. M. Abd El-Aziz, and A. I. Taloba, "Neutrosophic Fuzzy Neural Network Modelling and Current-Voltage Analysis for Forecasting Post-Surgery Risks," *International Journal of Neutrosophic Science*, vol. 20, no. 4, pp. 232–239, 2023, doi: 10.54216/IJNS.200421.

[19] M. B. Zeina and M. Abobala, "A novel approach of neutrosophic continuous probability distributions using AH-isometry with applications in medicine," *Cognitive Intelligence with Neutrosophic Statistics in Bioinformatics*, pp. 267–286, Jan. 2023, doi: 10.1016/B978-0-323-99456-9.00014-3.

[20] N. Moussa, B. Yousef, S. A. Naby, and S. Al Qudah, "Neutrosophic Environment and E-Learning: An Investigation into Student Satisfaction and Attitudes in the College of Engineering," *International Journal of Neutrosophic Science*, vol. 20, no. 4, pp. 164–180, 2023, doi: 10.54216/IJNS.200413.

[21] N. M. Alnaqbi and W. Fouda, "Exploring the Role of ChatGPT and social media in Enhancing Student Evaluation of Teaching Styles in Higher Education Using Neutrosophic Sets," *International Journal of Neutrosophic Science*, vol. 20, no. 4, pp. 181–190, 2023, doi: 10.54216/IJNS.200414.

DOI: https://doi.org/10.54216/IJNS.210305
Received: April 23, 2023 Revised: May 22, 2023 Accepted: June 18, 2023

[22] N. Gayathri, M. Helen, and P. Mounika, "Utilization of Jaccard Index Measures on Multiple Attribute Group Decision Making under Neutrosophic Environment," *International Journal of Neutrosophic Science (IJNS)*, vol. 3, no. 2, pp. 67–77, 2020, doi: 10.5281/zenodo.3742151.

[23] I. Deli and Y. Şubaş, "A ranking method of single valued neutrosophic numbers and its applications to multi-attribute decision making problems," *International Journal of Machine Learning and Cybernetics*, vol. 8, no. 4, pp. 1309–1322, Aug. 2017, doi: 10.1007/s13042-016-0505-3.

[24] A. H. Alamoodi *et al.*, "Based on neutrosophic fuzzy environment: a new development of FWZIC and FDOSM for benchmarking smart e-tourism applications," *Complex and Intelligent Systems*, vol. 8, no. 4, 2022, doi: 10.1007/s40747-022-00689-7.

[25] D. Zhang, Y. Ma, H. Zhao, and X. Yang, "Neutrosophic Clustering Algorithm Based on Sparse Regular Term Constraint," *Complexity*, vol. 2021, 2021, doi: 10.1155/2021/6657849.

[26] M. Abdel-Basset, M. El-hoseny, A. Gamal, and F. Smarandache, "A novel model for evaluation Hospital medical care systems based on plithogenic sets," *Artif Intell Med*, vol. 100, Sep. 2019, doi: 10.1016/J.ARTMED.2019.101710.

[27] M. Miari, M. T. Anan, and M. B. Zeina, "Neutrosophic Two Way ANOVA," *International Journal of Neutrosophic Science*, vol. 18, no. 3, pp. 72–83, 2022, doi: 10.54216/IJNS.180306.

[28] S. Hossain, S. E. Ahmed, and H. A. Howlader, "Model selection and parameter estimation of a multinomial logistic regression model," *J Stat Comput Simul*, vol. 84, no. 7, pp. 1412–1426, 2014, doi: 10.1080/00949655.2012.746347.

[29] H. A. E.-S. A. A. H. R. Abdalla, "Fuzzy multinomial logistic regression analysis: A multi-objective programming approach," *AIP Conf Proc*, pp. 10–6, 2023.

[30] Y. Hong and F. Chen, "Evaluating the adaptive reuse potential of buildings in conservation areas," *Facilities*, vol. 35, no. 3–4, pp. 202–219, 2017, doi: 10.1108/F-10-2015-0077.

[31] D. Misirlisoy and K. Günçe, "Assessment of the adaptive reuse of castles as museums: Case of Cyprus," *International Journal of Sustainable Development and Planning*, vol. 11, no. 2, pp. 147–159, 2016, doi: 10.2495/SDP-V11-N2-147-159.

[32] S. Conejos, C. Langston, and J. Smith, "Designing for better building adaptability: A comparison of adaptSTAR and ARP models," *Habitat Int*, vol. 41, pp. 85–91, 2014, doi: 10.1016/j.habitatint.2013.07.002.

[33] A. Sharifi, "Most appropriate time for the adaptive reuse of historic buildings using ARP model," *Property Management*, vol. 38, no. 1, pp. 109–123, Jan. 2020, doi: 10.1108/PM-07-2019-0039.

[34] M. Dell'ovo, F. Dell'anna, R. Simonelli, and L. Sdino, "Enhancing the cultural heritage through adaptive reuse. A multicriteria approach to evaluate the Castello Visconteo in Cusago (Italy)," *Sustainability (Switzerland)*, vol. 13, no. 8, Apr. 2021, doi: 10.3390/su13084440.

[35] A. Yaghi, "Restoration Protocol In Conflict Zones 'Practical Insights From The Old City Of Aleppo,'" 2017. Available: https://archnet.org/collections/54/sites/6414

[36] T. Aga Khan, *Aleppo Citadel The of Aleppo Citadel Opposite: A detail of a relief above the Gate*. 2008. Available: www.akdn.org

[37] S. Ibrahim, "Decision-making methodology between revitalisation and rehabilitation of world heritage city centers. Case study: The ancient City of Aleppo (Syria)," in *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, International Society for Photogrammetry and Remote Sensing, Jul. 2020, pp. 255–262. doi: 10.5194/isprs-archives-XLIV-M-1-2020-255-2020.

DOI: https://doi.org/10.54216/IJNS.210305
Received: April 23, 2023 Revised: May 22, 2023 Accepted: June 18, 2023