The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLVIII-M-2-2023
29th CIPA Symposium “Documenting, Understanding, Preserving Cultural Heritage:
Humanities and Digital Technologies for Shaping the Future”, 25–30 June 2023, Florence, Italy

EVALUATION OF MODERN HERITAGE ASSETS IN POZNAN USING MONOTONIC DECISION RULES

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KEY WORDS: Heritage Protection, Multiple Criteria Decision Analysis, Monotonic Decision Rules, Modern Heritage Assets, Machine Learning.

ABSTRACT:

The protection of cultural heritage is an important task of communities on various levels of social organization. The institutionalization of the processes of protection of modern heritage assets provides the necessary instruments (legislative, juridical, financial) enabling the actual realization of the assumed tasks. The criterion of age, which is still a dominating premise for monument protection, proved not to be sufficient, especially concerning protection of monuments of Modernism. A step that led to the determination of the value of individual architectural objects of the 20th century was the establishment of 10 evaluation criteria proposed by historians of architecture in Warsaw, and afterwards in Poznan.
In this work, we focus on the architectural value of post-war buildings, which are most difficult to evaluate. Furthermore, we wanted to apply AI to objectify the process of decision making. The adequacy of the Dominance-based Rough Set Approach (DRSA) method has been established. This method takes into account preference orders on criteria and models patterns observed in data in terms of monotonic “if ..., then …” decision rules.

1. INTRODUCTION AND CONTEXT OF THE RESEARCH

1.1 Justification

The role and meaning of modernist heritage have undergone a significant re-evaluation in the last decades - from the initially reluctant approach of historians and public opinion to a gradual increase in interest and appreciation of their importance and high-quality architectural solutions. Contemporary research indicates the need to create lists and registers of modern monuments created after World War II in order to protect the most valuable works from uncontrolled transformations or demolition (Figure 1).

The starting point for the protection of historic buildings is their assessment. Scientific considerations on evaluation criteria and methods have been conducted for many years (Ghirardo, 1980) (Gifford et al., 2000), but existing methods seem to be insufficient. Also in Poland, the protection of modernist heritage has been discussed by researchers in recent years. An important step that led to the determination of the value of individual 20th-century architectural objects was the establishment of evaluation criteria proposed by Warsaw and Poznan architecture historians (Grzeszczuk-Brendel et al., 2009). The assessment and protection of modernist architecture was also developed in the following years by other scientific circles (Szmygin, 2016) (Lewicki, 2017). Each such process related to the assessment of historic buildings was based on expert evaluation, which was necessarily subjective (Rumieź, Świt-Jankowska, 2022). The aim of the method presented in the text is to achieve greater objectivity in the assessment of modernist buildings and complexes erected after World War II.

To reach this goal, artificial intelligence algorithms based on multicriteria decision-making methods were introduced. The key was to choose a method that provides good prediction but also a well-grounded insight into the decision process itself. All those aspects were considered to provide for deeper understanding of what is regarded valuable for a generalized expert, especially aspects that are initially implicit.

Figure 1. One of the examples of valuable modernist buildings in Poznan. “The Okrąglak”. Built according to Marek Leykam's design in the years 1948–1954. Source: authoring.

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1.2 Historical background

For several years, there has been discussion in Poland about the need to assess the value of modernistic buildings and to provide them with appropriate protection. This is quite a difficult problem, especially because the heritage of Modernism is often associated in Poland with the era of communism and enslavement. Public opinion is often reluctant to look at buildings built after 1945, and there is social acceptance for their demolition. In this way, many valuable buildings were irretrievably destroyed.

The first author who drew attention to the need to protect monuments of modern architecture was Zdzisław Bieniecki (Lewicki, 2017). He proposed breaking with the restriction (introduced after 1945) of recognizing as historic buildings only the buildings erected before 1850. In 1969 he presented several criteria which could be helpful in assessing contemporary monuments and divided them into basic and auxiliary (subjective) ones. Additionally, he introduced a division of the basic criteria into practical and theoretical ones.
Theoretical criteria were:

- age,
- uniqueness,
- typicality,
- progress,
- local specificity,
- authorship and historic value.

Practical criteria according to Bieniecki were:

- preservation,
- technical condition,
- utility value,
- relation to the spatial development plan.

What was important, Bieniecki emphasized in his studies that all criteria should be treated equally.
The assessment method proposed by Bieniecki became the basis for further research in this area. This coincided with similar actions undertaken in the international arena. In 1972, the General Conference of UNESCO was held at which the Convention Concerning the Protection of the World Cultural and Natural Heritage was adopted – with the primary goals of nature conservation and the preservation of cultural properties. There were defined criteria to select objects worth keeping, but still the most important criterion was the time of creation. In 1988, DOCOMOMO was created – an association whose main task is the documentation and conservation of buildings, sites and neighborhoods of the Modern Movement.

Among the studies on the value assessment of buildings erected in the second half of the 20th century, two groups of publications can be distinguished in Poland: source studies and empirical assessments. In the group of source studies, one can find studies discussing newly erected buildings. The second group consists of numerous empirical studies by recognized and outstanding scientists. One of the first attempts at a synthetic elaboration was the work of Jan Zachwatowicz, in which the most important buildings erected before 1965 were listed.

A breakthrough in the development of the list of outstanding works of architecture of the second half of the 20th century was the development of criteria for the protection of architecture by individual departments of SARP (the Association of Architects of the Republic of Poland), which were created in connection with the regulations introducing the concept of contemporary cultural heritage, contained in the then passed act on spatial planning (Resolution of the Government of the Republic of Poland on spatial planning and development, stating that local governments may designate objects for protection as cultural goods in spatial development plans, not included in the register of monuments, 27.03.2003). The first criteria for the protection of 20th-century architecture were created in 2000-2003 on the initiative of the members of the Warsaw Branch of SARP. Thanks to them, it was possible to prepare the List of Contemporary Culture Heritage. Unfortunately, most of the buildings included on it were later destroyed or transformed.

1.3 Database – criteria of assessment

The example of Warsaw was used by other polish local centers to create their own lists of criteria, as exemplified by the activity of the Poznan branch of SARP (in 2006-2008). The first criteria, developed in Warsaw, were to help classify the architecture created in the years 1945-1960.
These criteria included 8 points, which were:
[1] the criterion of innovation in the context of architectonic, spatial and technical solutions;
[2] the criterion of context, coexistence - both at the creation stage and during the following spatial development of the location;
[3] the criterion of the tradition of place, including negation as attempts at creating new values or creative accumulation of generations' heritage;
[4] the criterion of symbol in general perspective, e.g., for visitors;
[5] the criterion of appreciation by contemporaries – awards, distinctions, opinion polls;
[6] the criterion of the test of time, preserving spatial and aesthetic values despite degradation resulting from technical wear or/and administrator's neglect, or spontaneous building development of the adjoining terrain;
[7] the artistic criterion;
[8] the criterion of uniqueness (e.g., the only object preserved in an unchanged form).

In Poznan, in 2006-2008, two more criteria were added to these criteria (Grzeszczuk-Brendel, 2009):
[9] representativeness criterion – concerning objects that are typical examples of historical, formal and ideological tendencies, etc. (visible in a larger group or number of objects of similar character or spatial structure);
[10] the criterion of conservation authenticity of matter – concerning objects rebuilt after World War II, which are often only a conservation creation, such as Old Town in Poznan, buildings that are currently valorized, rebuilt from a state of far-reaching devastation.
These ten criteria became the basis of this research and started an attempt to find an algorithm that would support the decision-making process. On their basis, 113 buildings from the period 1945-1989 were assessed in Poznan. Their value was evaluated on individual criteria by 0-3 points in the following way (Figure 2):

- local value - 1 point,
- national value - 2 points
- international value - 3 points.

which made up the learning set, in which we were looking for rules guiding the final classification of the buildings.

https://doi.org/10.5194/isprs-archives-XLVIII-M-2-2023-1373-2023

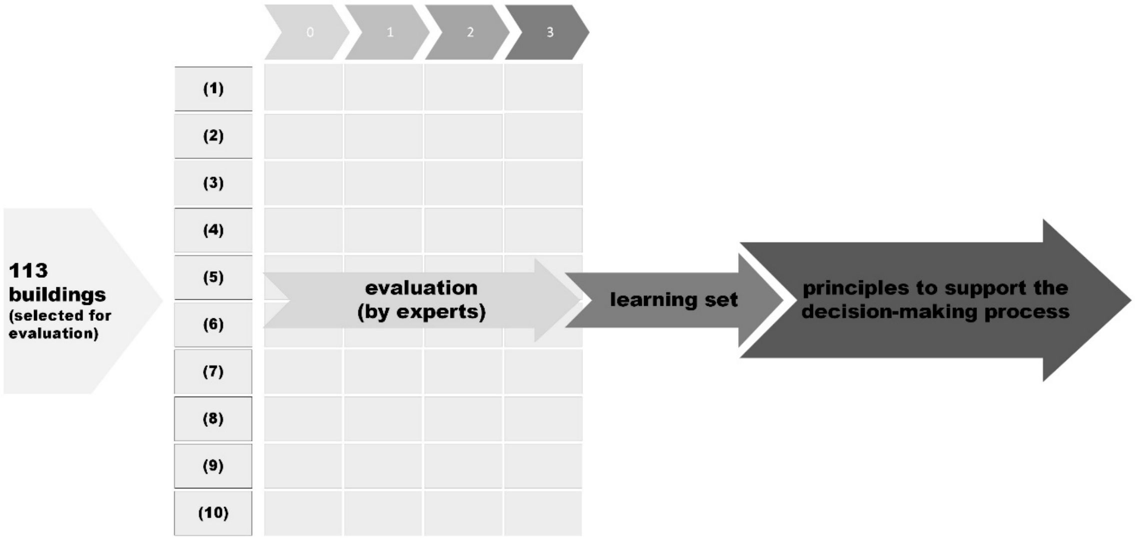

Figure 2. Diagram showing the scheme of research process; source: authoring.

2. METHODOLOGY AND ASSUMPTIONS

2.1 Process of finding the right algorithm

To reach the research goals, it was crucial to choose a method that provides both good prediction and insight into the decision process. To determine which strategy would be the most suitable, an AI algorithm has been used to ensure the highest standards of objectivity. The engine applied was the MCDA-Method Selection Software (Cinelli et al., 2022), which is a decision support system helping in determining adequate Multiple Criteria Decision Analysis (MCDA) methods for a given problem.

On the process of choosing the most appropriate method, the questions that has been addressed were grouped in four sections:
1. problem typology,
2. preference model,
3. elicitation of preferences,
4. exploitation of the preference relation induced by the preference model.

Each decision narrowed the spectrum of choices. For example, after determining problem statement as "sorting problem" and scale leading the recommendation as "ordinal", 33 methods were proposed. It was important that a possible answer "I don't know" was also included, which operatively helped to tune up with the reached algorithms even if not all aspects of the design and data were initially eminent to us. With further interview, the Dominance-based Rough Set Approach (DRSA) was suggested as the most appropriate method.

2.2 Methodology – DRSA

DRSA (Greco, Matarazzo, and Słowiński, 2001) is a method of data analysis that takes into account the domain knowledge concerning preference orders of attributes (gain- and cost-type criteria). It can also handle inconsistency of data with respect to Pareto dominance relation. It is useful in finding patterns hidden in data and modeling them in terms of monotonic "if …, then …" decision rules (Błaszczyński, Słowiński, and Szeląg, 2011). Such rules are useful in explaining decisions observed in data, and in classifying new objects (Szeląg, M., Słowiński, R., 2022). In this paper, we applied DRSA with the methodological extensions implemented in the ruleLearn Java library (ruleLearn Development Team, 2023), used along with WEKA (Frank, Hall, and Witten, 2016) in the ruleLearn-experiments (Szeląg, 2023) project developed to perform the experiments described below. Extended DRSA is also available in RuLeStudio web application (RuLeStudio Development Team, 2022).

3. MAIN RESEARCH STRUCTURE

3.1 Main experiments' scheme

In this section, we describe the design of a computational experiment (case study) concerning evaluation of modern heritage assets in Poznan. On the first stage of the design development, analysis of the given database needed to be procured. Records have been adapted to the format used by ruleLearn and WEKA.

The data comprises of 10 main condition attributes (criteria: K1-K10) and additional ones: years of construction (Year1, Year2), authorship (one or more names), function of a building, and location. All records were grouped in two classes: (1) Monument = yes – buildings that are designated for protection, (2) Monuments = no – buildings that are not listed for protection. Provided data is balanced: number of records in each class is nearly the same (57 monuments and 56 non-monuments). That allowed us to focus on learning capacity of compared decision models, although it is worth noting that there also exists an implementation of DRSA that can operate in the environment of highly imbalanced data.

Our team conducted 7 different experiments: 6 of them were connected to each other and one was independent. In all experiments, the results of DRSA from ruleLearn were confronted with the results of other ML algorithms from WEKA (version 3.8.6), such as: C4.5 (J48 in WEKA), Naïve Bayes (NaiveBayes), Support Vector Machine, SVM (SMO), Random Forest (RandomForest), and Multilayer Perceptron (MultilayerPerceptron).
The flow of the experiments is presented on the scheme (Figure 3).

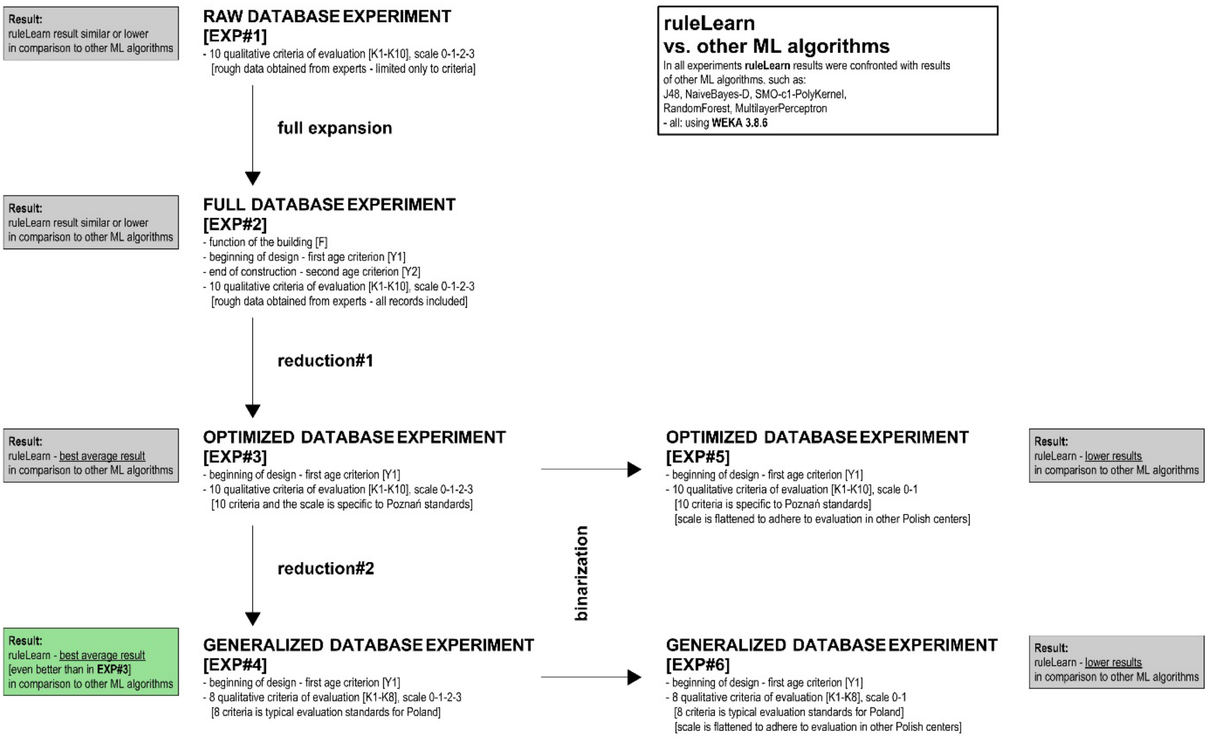

Figure 3. Diagram showing different scenarios in building an adequate model for machine learning algorithms; source: authoring.

We started with raw data – as it was acquired from the group of experts ([EXP#1]). We included only the main condition attributes, namely 10 criteria of evaluation, as it was the initial prerequisite for the design of the experiment. As a result, we achieved satisfactory accuracy, although we've decided to analyze further the problem to improve the predictive and explanatory capacity of the algorithm used. Hence, we aimed at full expansion of the condition attributes and included three additional dimensions: both indicators of the years of construction (Year1 and Year2) and function of the building (F). We decided to exclude other data such as authorship (hard to take into account in DRSA as some buildings have more than one author) and location (because each building has a unique address). Such a structure was proposed for the second experiment ([EXP#2]). There was no significant difference, namely the DRSA results were similar or lower, compared to other ML algorithms. That prompted us to analyze the importance of particular attributes. With the help of RuLeStudio, that generates a minimal set of rules, we were able to discriminate some attributes from the general design (reduction#1). Consequently, we proposed 11 attributes only: K1-K10 and Year1 ([EXP#3]. This step resulted in DRSA obtaining the best average result in prediction accuracy, better than the five other considered ML algorithms.

At this stage, our preliminary goals were reached: predictive means were very high, but what was even more profound – the generated rules were interpretable and in line with the domain knowledge. Further experiments were justified by the prospective expansion of the scope of the research and the database.

As mentioned above, in Warsaw only the first 8 criteria were used. Therefore, we conducted experiment [EXP#4] with further reduction on attributes (reduction#2), to adhere to the Warsaw framework. It was additionally justified by the analysis of the set of rules induced in [EXP#3] - criteria K9 and K10 did not appear in any rule. In [EXP#4], we obtained results that were even more promising than in [EXP#3]. Also, the minimal set of rules remained the same.

Next step addressed the criteria evaluation scale. In our database, all criteria are determined using the scale 0-1-2-3, whereas in Warsaw, they are evaluating criteria bivalently only, namely the scale is 0-1. Therefore, we considered binarization in both frameworks: with and without K9 and K10 (respectively [EXP#5] and [EXP#6]). In both cases, the predictive capacity of DRSA dropped substantially.

In parallel to those 6 steps, we've conducted another inquiry [Minimal Set of Rules Experiment - EXP#7], which was to determine if it is possible to manually generate a better (more concise) set of rules than the 17 rules induced by DRSA. This step was important to understand how a human-driven rule generation heuristic performs with respect to the one provided by DRSA. Hence, we analyzed an exhaustive set of minimal rules generated by the JAMM decision support system (4Mka II Development Team, 2003). Then, we attempted to find a smaller set of rules that covers all instances in the initial database being consistent with the dominance principle (namely 111 buildings). As a result, we determined a set comprised of the same number of rules for 'YES' decision (supporting claim that the building is a monument), and one less rule for the opposite decision.

3.2 Results

Here we present the most informative results for the Generalized Database Experiment [EXP#4], comparing DRSA and considered ML algorithms. Table 1 presents the comparison of reclassification accuracy and average accuracy from 10 independent runs of a 10-fold cross-validation.

Method (Algorithm)	Reclassification accuracy	Cross-validation* average accuracy
GENERALIZED DATABASE EXPERIMENT [EXP#4]		
DRSA	**99.12%**	**89.03%**
C4.5	92.04%	85.22%
Naïve Bayes	89.38%	86.28%
SVM	90.27%	86.11%
Random Forest	99.12%	86.19%
Multilayer Perceptron	97.35%	81.77%

* 10 independent runs of a 10-fold cross-validation

Table 1. Comparison of accuracy in reclassification and 10x10-fold cross-validation; source: authoring.

The brief analysis of this table reveals that DRSA performs best with respect to reclassification accuracy and average cross-validation accuracy. One can also notice that the differences throughout chosen methods are not that profound, e.g., Random Forest displays the same reclassification accuracy and high performance in cross-validation. Nevertheless, the added value of the DRSA is its transparency ("glass box" approach), i.e., one can examine the intelligence that governs the predictions, for there is an explicit set of rules that is generated. What is more, the rules are interpretable and in line with the expert's background knowledge.

As an example, we wish to present interpretation of the 3 first rules concerning monuments from the minimal set of rules generated by DRSA. The list of rules supporting "YES" decision is as follows:
[01] (K7 >= 2) => (Monument = yes) [support: 31]
[02] (Year1 <= 1954) => (Monument = yes) [support: 13]
[03] (K8 >= 2) => (Monument = yes) [support: 7]
[04] (Year1 <= 1958) & (K7 >= 1) => (Monument = yes) [support: 12]
[05] (Year1 <= 1963) & (K1 >= 1) & (K6 >= 1) => (Monument = yes) [support: 9]
[06] (K5 >= 1) & (K2 >= 1) => (Monument = yes) [support: 5]
[07] (K2 >= 1) & (K3 >= 1) & (Year1 <= 1974) => (Monument = yes) [support: 8]
[08] (K2 >= 1) & (K7 >= 1) & (K6 >= 1) => (Monument = yes) [support: 11]
[09] (K2 >= 1) & (K1 >= 1) & (K6 >= 1) => (Monument = yes) [support: 10]
[10] (K7 >= 1) & (K3 >= 1) => (Monument = yes) [support: 9]

Considering the first rule, one can read: if a building is evaluated on the artistic criterion (K7) as national or international (2 or 3 on the scale), then it will be listed as a monument. Such a decision has support of 31 buildings in the whole learning data set. Then, the second rule can be understood as follows: if a building is relatively old (criterion Year1), i.e., built before 1955, then it will also be listed as monument [support: 13 buildings]. Also, for the third one: if uniqueness is national or international (2 or 3 on the scale) – then the decision is the same as previously. The following rules are more complex, but remain also informative for a specialist, for example: [04] building can be younger (Year1) than in previous cases (namely, built before 1959), but then it needs to exhibit at least local artistic value (1, 2 or 3 on the scale of K7). Logical and intuitively consistent interpretations can be given for all the rules generated by DRSA.

Taking into account the above, DRSA proved to be the method that provides useful feedback, explaining implicit premises in experts' decisions in the means of protection of modernistic buildings.

4. SUMMARY AND CONCLUSIONS

After conducting 7 experiments, and carefully examining their results, we claim that the DRSA method proved to be efficient for several reasons. First, it demonstrates very good prediction – better than competitive ML algorithms. Second, it generates interpretable rules that are in line with domain knowledge, which gives significant insight into the experts' decision-making process, enabling re-establishment of proper framework for evaluation of modern heritage assets in Poznan, and elsewhere. Third, DRSA approach does not demand independence of criteria, which would be critically difficult in such a qualitative inquiry, where limits of particular attributes are fuzzy by definition. Fourth, the database does not need to be perfectly consistent because the uncertainty that frequently appears in experts' questionnaires is reasonably managed by the DRSA.

In accordance with the flow of the experiments presented above, framework [EXP#4] with 9 attributes - 8 criteria (K1-K8) with the scale 0-1-2-3, and first indicator of the years of construction (Year1) - proved to be the most beneficial for the DRSA, allowing it to display the best prediction in comparison to other ML algorithms, along with being the most explainable method. Thus, we claim that reduction of criteria K9 and K10 is favorable. Also, binarization conducted in [EXP#5] and [EXP#6] resulted in lowering average accuracy by 3.36% and 3.54%, respectively. In conclusion, it is crucial to keep a deeper scale in further experiments.

5. PROSPECT AND DISCUSSION

There are several ways in which the research can be developed further. It would be beneficial to compare results based on Poznan instances of modernistic buildings with other evaluations. Data expansion, that we plan to procure, can be realized both on the national and international level. We are in the process of obtaining databases from Warsaw and Strasbourg, which will ensure general qualities of the proposed here framework.

One another vector of development of this research, that we consider beneficial, is to compare results with more ML algorithms, which could empower the claim that DRSA is well-suited for the given problem. Moreover, reaching for more rule-based methods, we will be able to compare interpretative qualities of generated models.

In the presented here study, we've omitted authorship and location of buildings in question, because of the construction of the initial database. Finding a proper way of organizing these dimensions would allow us to include such objective attributes within the framework of further experiments. Thus, we would be able to compare how these factors affect the overall performance of the algorithm and how they influence the decision-making process.

ACKNOWLEDGEMENTS

The 2nd author wishes to acknowledge the TAILOR project funded by EU Horizon 2020 programme, GA No 952215.

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