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Foroughi, Mahda; Andrade, Bruno; Roders, Ana Pereira

DOI
10.1016/j.culher.2024.01.014

Publication date
2024

Document Version
Final published version

Published in
Journal of Cultural Heritage

Journal of Cultural Heritage 67 (2024) 1–8

Contents lists available at ScienceDirect

Journal of Cultural Heritage

journal homepage: www.elsevier.com/locate/culher

Original article

Capturing experts' knowledge in heritage planning enhanced by AI: A case study of windcatchers in Yazd, Iran

Mahda Foroughi*, Bruno Andrade, Ana Pereira Roders

Department of Architectural engineering and technology, Faculty of Architecture and Built Environment, Technical University of Delft, the Netherlands

ARTICLE INFO

Article history:
Received 11 October 2022
Accepted 30 January 2024

Keywords:
Expert
Cultural significance
Value
Attribute
Text classification
Natural language processing

ABSTRACT

Experts have always played an important role in heritage planning, practice, and theory. There is a wealth of literature published every year regarding heritage and its cultural significance. Experts also contribute to heritage planning and developing policy documents. Still, literature is rarely used as a source of primary research to systematically reveal and compare experts' opinions on the cultural significance of built heritage. Analyzing them as a whole is costly and time-consuming, especially on built heritage, when much has been written about. While the automation of methods has proven to mitigate such restrictions in other fields, as digital humanities, their application in heritage planning, practice, and theory is still scarce. Hence, this paper aims to investigate the potentials of AI models (e.g., multi label text classification) in analyzing scientific documents, revealing the cultural significance of built heritage, values and attributes. This was done to better understand the similarities and differences between the experts' opinions. Yazd, Iran, is taken a case study, with a particular focus on windcatchers, a key attribute conveying cultural significance, of outstanding universal value, due to its inscription on the UNESCO World Heritage List. This paper has three subsequent phases: 1) state of the art on the application of AI in heritage planning; 2) methodology of data collection and data analysis related to coding values and attributes of windcatchers, addressed in relevant documents; 3) preliminary findings on the experts' opinions over values and attributes of windcatchers. Results contribute to the scientific discussion, revealing the cultural significance of windcatchers of Yazd from experts' point of view. Besides, the potential of AI for heritage planning is revealed in terms of (de)coding and measuring the cultural significance of built heritage from the available documents, showing the opinions of experts with various backgrounds. This model can be applied to other key attributes in Yazd and other case studies and scales to support heritage planning, practice, and theory.

Introduction

Experts have always been important stakeholders in heritage planning. Most studies considered experts' opinions by means of interviews (e.g., [1–5]). Only few studies explored experts' opinions in a more active and peer review way such as collective mapping, participatory walk, expert meetings (e.g., [6]), and Delphi [1].

Often, selected experts are involved in heritage planning leading to the restriction of conflictual opinions and ignoring marginalized groups' opinions [7]. This is while the necessity of inclusivity and the importance of digital libraries have been recognized more than ever in the field of heritage studies (Mirzakhani et al., 2021; Li et al., 2020; Fabio et al., 2023). The growing number of publications considering wider groups of experts' opinions on heritage planning has been an indication of this shift. Nevertheless, literature is barely used directly in heritage planning as a data source on experts' opinions.

On the other hand, there is an increasing interest in using digital tools, such as Artificial Intelligence (AI) and digital libraries, that could contribute to reviewing the literature automatically. One of the popular applications of AI in heritage studies is to analyse the data through clustering (Fiorucci et al. 2020). Many scholars used various AI models and methods to cluster textual data (e.g., Fabio et al., (2023), images (e.g., [8,9]; Condorelli et al. 2020), and movies (e.g., Condorelli et al. 2020). These studies explore a wide range of subjects including constructing a codebook of visual words to chronologically classify ancient paintings by unsupervised style adaptation [8]; grouping paintings by artistic style using un-

* Corresponding author at: Julianalaan 134, 2628 BL Delft.
E-mail address: m.foroughi@tudelft.nl (M. Foroughi).

https://doi.org/10.1016/j.culher.2024.01.014

supervised feature learning [9]; grouping 3D morphometric data of pounding stones to infer the intensity of humane use [10]; studying osseous projectiles using geometric morphometrics [11]; and Mapping social perceptions of cultural significance through graph-based semi-supervised classification.

Natural Language Processing (NLP) is an emerging field of AI for textual data analysis that is particularly relevant to qualitative research. Although there have been studies exploring the application of NLP in heritage studies (e.g., Bordoni et al. 2016; Condorelli et al. 2020; Fiorucci et al. 2020; Matrone et al. 2020; [12]), more research is needed to fully appreciate and integrate the opportunities offered by NLP techniques (Fiorucci et al. 2020; [12]). For example, there is a lack of literature on digital tools targeting the identification of the cultural significance of built heritage, in particular, distinguishing and relating heritage attributes and values (Bai et al., 2021). Our research applies AI in line with the previous literature, using NLP, to model categories of values based on experts' perceptions of one case study, as described in the literature published as papers and books.

Research aim

While artificial intelligence has proven to mitigate such restrictions in other fields, such as digital humanities, their application in heritage planning, practice, and theory is still scarce. This paper aims to contribute to this knowledge gap by investigating the potential of AI methods to reveal the opinions of wide groups of experts about the heritage cultural significance using the literature (as a data source). The Historic City of Yazd in Iran, a UNESCO World Heritage Site, serves as our case study, with a particular emphasis on windcatchers. These iconic building elements play a pivotal role in representing the city's Outstanding Universal Values, as recognized in the UNESCO World Heritage inscription in 2017 (v). Criterion (v) acknowledges the harmonious interaction between human civilization and the desert environment, demonstrating the astute management of limited resources in this arid setting. Windcatchers, along with other attributes including courtyards and thick earthen walls, contribute to the creation of a pleasant microclimate through a natural ventilation system.

Method

The process followed in this research entailed four steps. Accordingly, data acquisition, data pre-processing, data analysis and results (see Fig. 1).

Data acquisition

Three peer-reviewed academic databases - Scopus, Sciencedirect, and Sid - were taken as data sources. All the literature that refered to windcatchers and Yazd in their title, abstract, or keywords were considered. Papers use different Persian and English terms to refer to windcatchers (e.g., "badgir", "windcatcher", "بادگیر "). All these terms were included in the search terms. To find more papers, the snowball method was used, using the references of the identified papers (e.g., [13,14]). Overall, two book chapters and 92 papers (2 Persian sources and 92 Engligh sources, mostly are written by Iranian) were found, including 11 inaccessible papers. All the sentences in these papers addressing windcatchers were extracted to be analysed. Finally, the sentences that refers to windcatchers of Yazd (use variants of windcatchers and Yazd) were structured and analysed.

Data cleaning and pre-processing

All variations of "windcatcher" and "Yazd" were normalized to "windcatcher" and "Yazd" (both in Persian and English e.g. "Yazd", "yazd", "یزد "). Moreover, the text cleaning included the removal of unnecessary data (e.g. stop words, references, punctuation marks, and website links) to facilitate data analysis. After the exclusion, 231 sentences addressing windcatchers of Yazd were analyzed.

Data analysis

After data cleaning and pre-processing, the dataset was ready for automatic classification analysis. Each sentence was analysed and assessed through automatic quantitative content analysis and qualitative categorical analysis. The quantitative analysis revealed the most and least frequent attributes and values in the sum of posts, and, identifying patterns of the relation between attributes and values.

Content analysis: cultural significance

To reveal the cultural significance, a theoretical framework was used to decode the attributes and values conveyed in the literature (see Fig. 2). Conducting a multi-class text classification analysis, using a) the theoretical framework on cultural significance, broken down in values, as developed by Pereira Roders (2007) and b) by attributes as developed by Veldpaus (2015). The general analysis of attributes and values was undertaken using Python libraries, including Numpy (for calculation analysis), Pandas (for research on the data frame), and Bert model (for word embedding).

In the multi-label text classification problem, the choice between deep learning (e.g., convolutional neural networks and recurrent neural networks) and embedding models often depends on the size of the dataset and the available computational resources to capture. In this study, there was no existing train dataset and the train dataset was manually prepared. Due to the limited train dataset and lack of access to powerful computer resources, an embedding model was used (see Appendix A for more details).

The "bert_24_1024_16" version of BERT word embedding for a multi-label text classification task is used due to BERT's state-of-the-art performance in NLP, its contextual word embedding capabilities that capture nuanced word meanings, and the availability of various pre-trained BERT models that allow a balance between computational resources and performance (Devlin et al., 2019). The selection of a BERT model trained on "book_corpus_wiki_en_cased" aligns with the domain and language style of the text data, providing a suitable foundation for text classification. Additionally, specifying the BERT version ensures the reproducibility of experiments

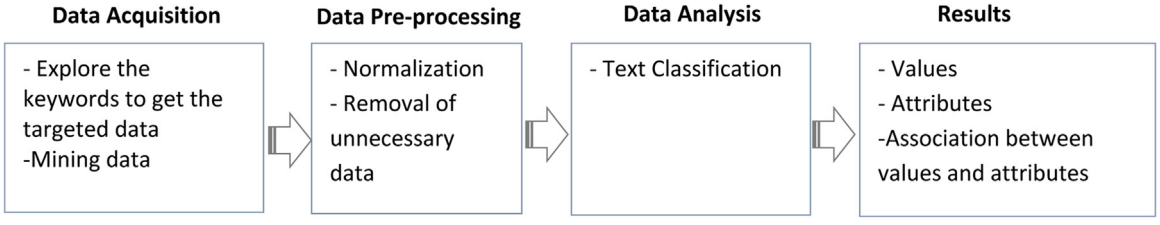

Fig. 1. Overview of the methodological framework.

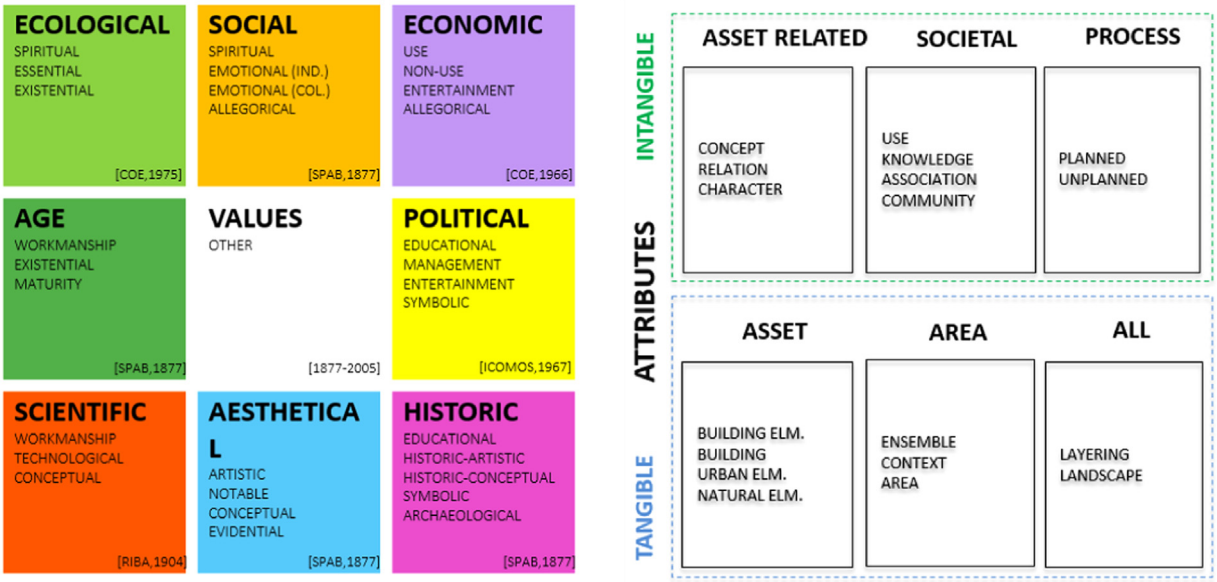

Fig. 2. Theoretical framework on cultural significance; values (Pereira Roders, 2007) and attributes (Veldpaus, 2015).

by clarifying the model used, an important factor in research and development. To replicate the model, the code is publicly available in the Github repository, an online platform [15].

As labels' distribution in the available train dataset distinct drastically and there were not enough trained datasets available,[1] this research used the cosine similarity method[2] for the multi-class text classification of the heritage values. Despite the algorithmic limitations, the reliability of the results was confirmed (accuracy[3]: 92%, precision_value[4]: 81%, and F-measure[5]: 68%). The cosine similarity method had low reliable results for attribute classification probably because of the numerous and diverse categories of the attributes framework. As a result, the most frequent attributes were classified manually.

Case study: windcatcher

Windcatcher is an architectural element to create natural ventilation in buildings using wind flow for many centuries. It is a vertical shaft with vents above the roof of a building to lead desired wind to the interior living spaces and provide thermal comfort. Windcatcher is usually used to cool a house by creating an air-conditioning system in one of the main rooms (see Fig. 3) where air is often passed over a pool of water (acting as a humidifier). The windows and doors contribute to the wind circulation [16].

Windcatchers were developed in different types (according to their shape and directions) probably in order to contribute to their cooling operation. There are various forms and plans such as circle, Octagon, polygon, square and oblong. Besides, they can be uni-

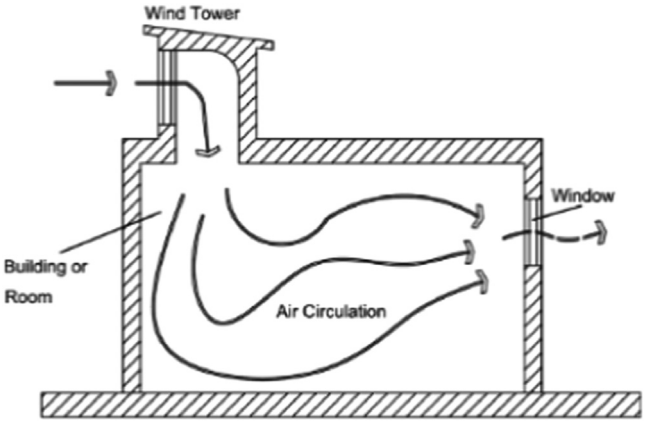

Fig. 3. Windcirculation in the main room with a windcatcher, source: Dehghanisanij et al. [17]: P.192.

directional, bidirectional, and multidirectional [16]. In each region, one of these types of windcatchers are common (see Fig. 4).

Results: cultural significance analysis

The activity of the scholars

The literature referencing the windcatchers of Yazd has a time frame for publication from 1978 until 2021. While in some years there were no publications, in some years, namely 2012, 2015, 2016 and 2017 (2017 - the year when the Historic City of Yazd was inscribed on the UNESCO World Heritage List), five or six papers were published (see Fig. 5). Generally compared to the large amount of literature on windcatchers in different contexts (e.g., [18–20]), the number of literature on windcatchers of Yazd remains quite limited.

Values of windcatchers in YAZD

Concerning the cultural significance of the windcatchers in Yazd, and in particular the values, around two-thirds of the posts (64%) conveyed at least one value. The most frequent values are

[1] While some of the eight value labels (e.g., age) repeated frequently, the others (e.g., political) rarely mentioned in the training dataset. Given that, the result of the model trained based on the training dataset was not reliable.

[2] **Cosine similarity** is one of the most widely used and powerful similarity measures in Data Science. This study uses this method because it does not consider the length of the vector. In other words, the frequency of the word is not taken into account.

[3] **Accuracy**: (TruePositives_1 + TruePositives_2)+(TrueNegative_1 + TrueNegative_2)/ ((TruePositives_1 + TruePositives_2) + (FalsePositives_1 + FalsePositives_2) + (TrueNegative_1 + TrueNegative_2)+(FalseNegative_1 + FalseNegative_2).

[4] **Precision_value**: (TruePositives_1 + TruePositives_2)/((TruePositives_1 + TruePositives_2) + (FalsePositives_1 + FalsePositives_2)).

[5] **F-measure**: (2 * Precision * Recall) / (Precision + Recall).

	 Iran's arid zone	 Persian gulf	 Iraq	 Egypt	 Pakistan	 Afghanistan
Climatic zone	Hot and dry	Hot and humid	Hot and dry	Hot and dry	Hot and humid	Dry and semi hot
Air direction	North-east	Breeze	North-west	North-west	South-west	North
Shape of cross-section	Square/rectangle hexagon, octagon	Square	Rectangle	Rectangle	Square	Square
Average dimensions (m)	0.5 × 0.8 0.7 × 1.1	1 × 1	0.5 × 0.15 1.20 × 0.60	-	1 × 1	1 × 1
Height (m)	3–5	3–5	1.80–2.10	One story above roof	5 And above	1.5 From roof
Direction according to the airblow	Diagonal	Diagonal	Ordinary	Ordinary	Diagonal	Ordinary
Ceiling of the Wind tower	45° Slope	30° Slope	45° Slope	30° Slope	45° Slope	30° Slope
Ventilated area	Dining room and basement	Dinning plus others	Only basement	Dinning plus one room	All rooms	All rooms
Airblow	Multi-side	Multi-side	One, two-side	One-side	One-side	One-side
Evaporative cooling	Sometimes	Never	Sometimes	Sometimes	Never	Never

Fig. 4. Various types of windcatchers in different climate zones, source: Dehghani-sanij et al. [17]: P.189.

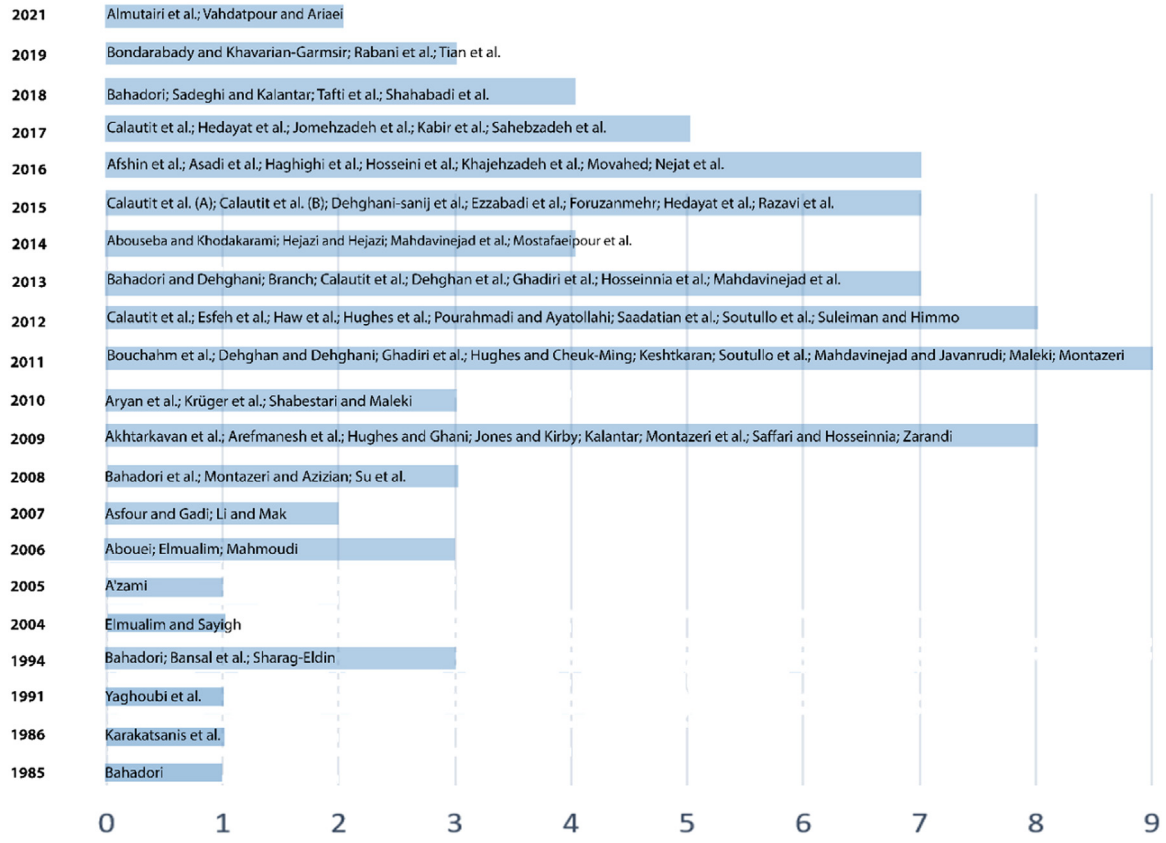

Fig. 5. Total number of literature related to windcatchers of Yazd published each year.

respectively economic (40%), ecological (19%), scientific (18%), age (7%), social (7%), historic (4%), aesthetical (3%), and political (2%) values (see Fig. 6). The frequency of all values changes steadily over time except for political and aesthetical values. Political values are only mentioned once in 2013. Aesthetical values are mentioned once in 2005 and seventh times in 2013.

Attributes of windcatchers in YAZD

Concerning the cultural significance of the windcatchers of Yazd, and related attributes such as city, building, architectural element, results reveal that the tangible attributes were referenced more frequently than the intangible ones (see Fig. 7). These tangible attributes mostly belong to the asset class, namely the building (e.g., house, building, mansion, etc.), the building element (e.g., room, window, wall, floor), and the natural element (garden, etc.).

Nonetheless, also intangible attributes were addressed, including architecture and design. The referenced intangible attributes mostly belong to the asset-related class, which includes the character (e.g., temperature, climate, summer, heat, thermal comfort), concept (architecture, design), and relation (e.g., direction). To be more precise, temperature, climate, summer, heat are natural elements and not attributes but they convey the intangible character of windcatchers. They are used in sentences addressing this wind-

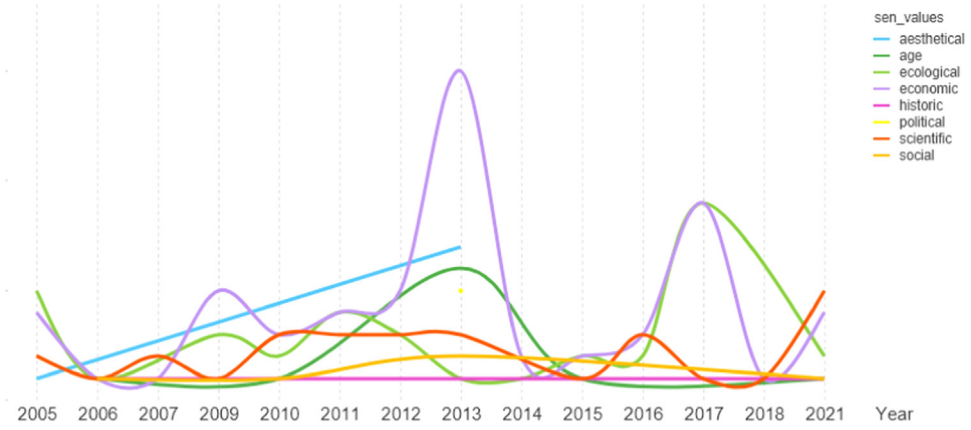

Fig. 6. The frequency of values in each year.

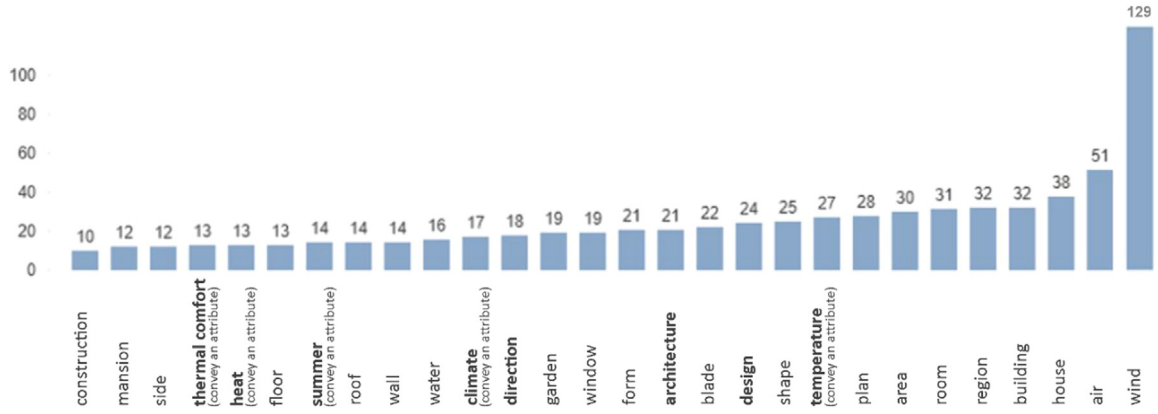

Fig. 7. Most frequent attributes addressed in 231 sentences from 83 publications (tangible: normal font style, intangible: bold font style).

Table 1
Several exemplary quotes conveying intangible attributes.

Attribute	Exemplary quote
Temperature (convey an attribute)	One of the main functions of Yazd windcatchers is to create **temperature difference** and cause airflow in the household.
Air	This research revealed that the ancient windcatchers under **hot and arid climate** conditions, as in the case of the Mortaz house in Yazd, perform by **changing the temperature of air** in and around the tower.
Climate (convey an attribute)	Intelligence in agreement with the **climate**, you can consider it the most specific examples of clean energy.
Heat (convey an attribute)	Because during the day, if there is wind, then cool air flows faster and at night, with wind, it may **absorb** the **heat of the walls**, because the night wind is cool enough.
Wind	Because the prominence of domed roofs means that they are constantly exposed to the flow of air caused by the **wind**, it is a useful way to **reduce** the **heat of the roof** due to severe sun radiation.
Heat (convey an attribute)	The kind of the windcatchers' **materials** is important because **heat transfer** and saved energy in the walls of tower depend on that.
Summer (convey an attribute)	Windcatchers can provide a **comfortable setting** throughout an entire **summer** without the use of electrical devices.
Summer (convey an attribute)	Viability of wind towers in achieving **summer comfort** in the hot arid regions.
Water	The most important result demonstrated that evaporative cooling is so efficient in a hot and dry region such as the city of Yazd that the temperature declines significantly, in case of equipping the windcatchers with the **water vaporization system.**
Water	This figure shows that, by using the logical amount of **water in the evaporating system** of windcatcher, the temperature decreases a lot and the relative humidity increases, both of which are suitable for hot and dry regions of a city like Yazd in Iran

catchers' intangible character that makes a comfortable microclimate in hot and arid climate in summer by decreasing the temperature (see Table 1).

Associations between values and attributes of windcatchers in YAZD

This sub-item explores addressed attributes in connection to windcatchers in terms of the values of those attributes, and the relations between those attributes and windcatchers. The frequency analysis between the values and attributes associated with windcatchers in Yazd revealed that the frequency portions of attribute classes is quite similar in different value classes (see Fig. 8). All of the most frequent attributes are associated with all the eight values except for the least addressed values, namely the political and aesthetical values (see Fig. 8).

Fig. 9 highlights the relation between values and most frequent attributes, concerning the windcatchers in Yazd. Accordingly, the relation between the cooling character of windcatchers (intangible attribute: asset-related: character) and natural attributes, characterizing the climate of Yazd i.e. wind, air, water. The case study re-

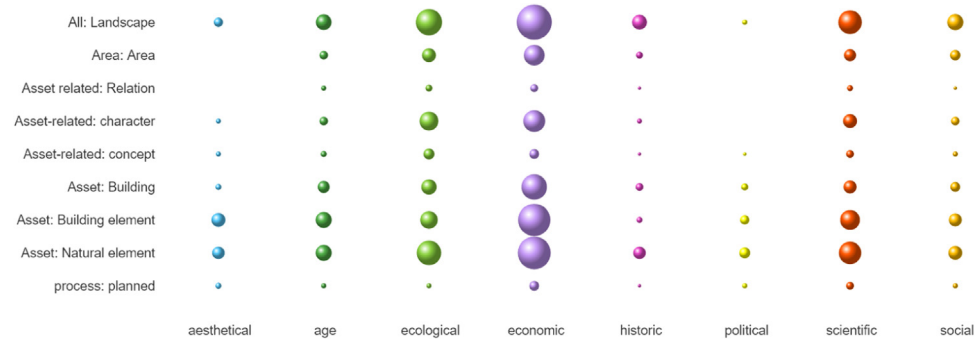

Fig. 8. The association between the categories of values and the most frequent attributes.

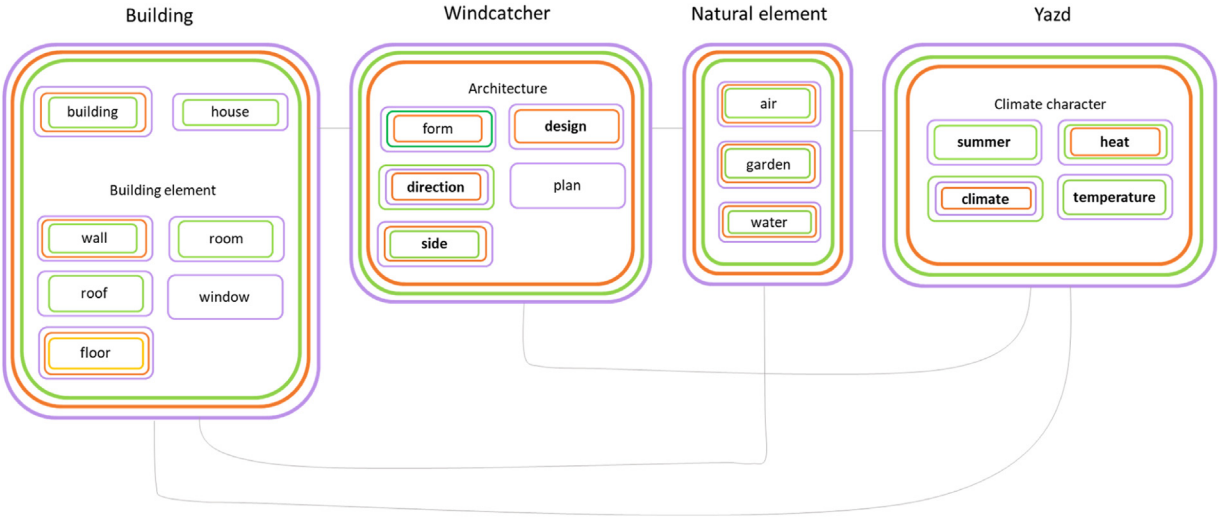

Fig. 9. The relation between values and most frequent attributes, concerning the windcatchers in Yazd.

veals that the cultural significance is revealed as a system of tangible and intangible attributes and values working together to insure the ventilation of a house and to create a micro-climate (economic value of windcatchers).

The economic value was revealed in literature as the most important values of windcatchers. However, preserving the economic value is not possible by only preserving the windcatchers without considering all the other related attributes, natural elements, and climate character that play a part in this system. The following examples from the literature shed lights on this issue:

*"… by using the logical amount of **water** in the evaporating system of windcatcher, the **temperature** decreases a lot and the relative humidity increases, both of which are suitable for **hot and dry regions** of a city like Yazd in Iran. … If the **walls** of the windcatcher are insulated, the **temperature** will decrease more at the exit of tower, and as a result, there will be a considerable decrease in the usage of **water**"* [21].

*"Since Iran's desert regions have predetermined season **winds** and daily breezes, windcatchers are built in the **direction** of the most pleasurable and strongest **winds**. … They divide the windcatchers column s interior into 4, 6, or 8 diagonal brick partitions in a way that from whichever **direction wind** blows down, in the opposite direction **wind** is sucked out"* [22]

Discussion and conclusion

This research confirmed the assumed benefit of analysing larger literature systematically with support of artificial intelligence models, to identify and interpret the cultural significance (values and attributes) of heritage. It confirmed the relations between diverse attributes and values associated with the windcatchers of Yazd. The research illustrated the importance of considering a system of relations of one attribute/value with other attributes/values, rather than researching them in isolation.

Machine learning and application of the artificial intelligence method were used to extract values and attributes related to windcatchers of Yazd. Literature mainly addresses the economic, ecological, and scientific values of windcatchers. Besides, the most frequent attributes were related to the cooling character of windcatchers, including natural attributes, that characterise the climate of Yazd, and tangible attributes, that characterise the building.

This research contributes to raising the voice of experts as a group by making a wider image of expert's complementary opinions. This approach avoids neglecting elements in the system of values and attributes that are highly related to each other by highlighting values and attributes mentioned by different experts. Still, there are values and attributes which are barely mentioned in the analysed literature, for instance the importance of windcatcher's height in urban scale as a main landmark in Yazd, which may be referenced by other stakeholders.

The results of the AI model discussed in this paper offer valuable insights for policy makers in heritage planning. This model efficiently and systematically analyzes experts' opinions on the cultural significance of built heritage, which can save time and resources compared to manual analysis. It provides a comprehensive understanding of cultural significance, values, and attributes from experts' perspectives, informing policy decisions related to heritage preservation and development. Furthermore, it highlights commonalities and differences in expert viewpoints, allowing for more inclusive and informed policy choices. Importantly, the model's ap-

plicability extends beyond the case of windcatchers in Yazd, offering a versatile tool for analyzing and measuring heritage significance in various contexts, thus supporting heritage planning and policy development in different regions.

Qualitative research introduces bias at multiple stages of the research process, and our data collection, utilizing a convenience sample through publication means, acknowledges its limitations and inherent biases. Notably, marginalized groups have not been explicitly explored, paving the way for a subsequent study to complement and contrast the findings presented in this paper. The training of the Natural Language Processing (NLP) model further introduces biases, and the perceived black box nature of NLP necessitates transparent documentation of model algorithm choices and parameter definitions. Despite this complexity, AI offers a chance to establish a reproducible, automated workflow, enhancing reliability across iterations. This approach, absent in traditional human assessment, allows for the consistent categorization of data from diverse survey methods, facilitating an ongoing review of people-centered values.

While this research investigates AI-empowered tools for the recognition of cultural heritage and gaining insights into experts' perspectives to facilitate more inclusive heritage planning, it is imperative to recognize and address the drawbacks and obstacles associated with this approach. These challenges encompass: 1. Data Bias: The performance of AI models heavily depends on the data they are trained on. If the training data incorporates biases or lacks diversity, AI systems may inadvertently perpetuate and amplify those biases, potentially neglecting or misrepresenting certain cultural facets. 2. Data Source Concerns: The utilization of available data repositories for collecting and analyzing user-generated data can lead to ignoring the less represented groups. In this study, academic experts were studied because information repositories representing the perceptions of other experts, including practitioners, could not be found. 3. Algorithmic Transparency and Accountability: Ensuring transparency and accountability in the AI models employed for heritage planning is of utmost importance. Explaining the decision-making processes of complex AI algorithms to stakeholders can be a daunting task, potentially giving rise to mistrust. 4. Lack of available train dataset: This issue can lead to reduced model accuracy, increased risk of overfitting, and difficulty in building a representative and effective model, limiting its practical utility. This is the main reason that other language models we used (e.g., aspect based sentiment analysis) resulted in accuracy of lower than 30 percent. But future research can explore this matter with the state-of-the-art advanced models like the Open AI.

In light of the limitations identified in this research, future studies can prioritize refining AI models to better comprehend heritage nuances, mitigating bias through diverse data curation, incorporating a broader range of expert perspectives, developing transparent tools to explain AI decision-making processes, and collaborating with data sources, and using data generation tools to expand and improve the training dataset. These efforts are crucial for harnessing AI's potential in cultural heritage recognition and heritage planning while ensuring reliability and inclusivity in the process.

Appendix A. Classification analysis

As mentioned in the method items, this study uses the cosine similarity method for the multi-class text classification. To replicate the model, the code is publicly available in the Github repository, an online platform [15]. The words for each label are selected based on the value framework definitions (Pereira Roders, 2007) and the training dataset (2000 posts).

Then three inclusion criteria were applied to these words:

1. The words for each label should only represent that label.
2. The cosine similarity of words embedding in each category should be more than 0.65
3. If the last criteria apply to all nominated words, nevertheless, there are two or more than two groups of terms with high cosine similarity in their embedding, then such words will become a sub-category. In virtue of this calibration process, the categories and sub-categories identified are as follows:
   - 'social': ['symbolic', 'emotion', 'moral'],
   - 'economic': ['economy', 'financial', 'commercial'],
   - 'political': ['political', 'government'],
   - 'age': ['old', 'ancient'],
   - 'scientific': ['intelligent', 'knowledge', 'technical'],
   - 'ecological'": ['ecological', 'environmental', 'natural'],
   - 'aesthetical': ['beautiful', 'beauty', 'art', 'artistic'],
   - 'historic': ['historic', 'history']

All words transform to their embedding by applying the Bert model. Then, the model reads word by word in each sentence of posts and calculates the distance between the word embedding and the embedding of the label (the average embedding of all the words in each label). For example, after transforming all the words to their embedding, the code specifies the label "antique" by calculating the cosine similarity of the embedding of antique with the embedding of each label. The label with the closest distance to the word will be considered as the nominated label, and if the distance between the word and the nominated label is more than 0.72, the label will be returned as the label of the word in the sentence or the hashtag. Then, the nominated label for "antique" is age as it has the highest cosine similarity, 0.74, and because this number is higher than 0.72, "age" is returned as the label of "antique." The distance between the two embeddings is calculated by Cosine similarity (the cosine of the angle between the two vectors). Cosine similarity is one of the most widely used and powerful similarity measures in Data Science. This study uses this method because it does not consider the length of the vector. In other words, the frequency of the word is not taken into account.

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