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Mapping and Clustering of Cultural Heritage Using Fuzzy Logic Approach in Heritage City of Parakan, Central Java, Indonesia

Saeful Bahri*[1], Ari Widyati Purwantiasning[2]

[1]*Departmennt of Electrical Engineering, Faculty of Engineering, Universitas Muhammadiyah Jakarta, Jakarta 10510, Indonesisa*
[2]*Department of Architecture, Faculty of Engineering, Universitas Muhammadiyah Jakarta, Jakarta 10510, Indonesisa*

*Corresponding Author: saeful.bahri@umj.ac.id

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ABSTRACT

This study is part of an ongoing multi-year project initiated in 2022, focused on exploring heritage trails in historical areas. The primary aim is to support the design and implementation of Heritage Trails by providing a detailed analysis of mapping and clustering cultural heritage sites. Specifically, this research applies the Heritage Trail's Guidelines to identify and categorize cultural heritage within the Heritage City of Parakan, located in Central Java, Indonesia. Utilizing a fuzzy logic approach, the study assesses and groups cultural heritage sites based on relevant attributes. The results of this research, combined with prior studies, contribute to establishing suitable clusters that can inform future heritage trail development. In doing so, the study helps fulfill fundamental principles of the Heritage Trail concept, which aims to support sustainable heritage tourism and cultural preservation in Parakan, Central Java, Indonesia.

Keywords: fuzzy, heritage, logic, Parakan, trail

1. Introduction

The Guidelines for Heritage Trails [1] outline a process for creating a Heritage Trail that involves four critical stages: (1) Identifying the focus or theme of the trail and defining the target audience; (2) Grouping objects with similar characteristics through mapping and clustering; (3) Designing a route that links objects with comparable historical significance; and (4) Evaluating and classifying the outcomes of the first three stages.

Among these, one of the most vital phases in developing a heritage trail is the grouping of cultural heritage objects with shared attributes through mapping and clustering, especially within historical districts [1][2]. These areas, often seen as the heart of the city, possess distinctive characteristics and typically represent the identity of the city [3]. Prior research suggests that enhancing the quality of a historical district by introducing engaging activities for both local and international tourists is a valuable approach. This study aims to promote the heritage city of Parakan in Central Java, Indonesia, by creating a heritage trail. The first step in constructing this trail involves mapping and clustering the cultural heritage objects in Parakan that share similar characteristics. To facilitate the mapping and clustering process, this study employs the fuzzy logic approach,

a tool for classification. The aim is that, by utilizing fuzzy logic, the proposed clustering and mapping of cultural heritage within Parakan will be achieved effectively.

Several studies have applied fuzzy logic as a decision-making tool. For instance, Santos et al. [4] utilized fuzzy logic to optimize maintenance and rehabilitation strategies for road pavements. Stetter [5] also demonstrated how fuzzy logic assists decision-making in automated guided vehicles, particularly in managing potential faults such as slippery surfaces. Additionally, Liu et al. [6] explored how fuzzy logic supports the decision-making process regarding pedestrian exit behavior in evacuation scenarios, highlighting its importance in safety planning. These examples underscore the versatility of fuzzy logic in diverse fields. Daradkeh and Tvoroshenko [7] further suggested that fuzzy logic methods could be employed for making reliable decisions across various applications. Moreover, fuzzy logic has been used to evaluate academic staff performance [8] and to determine optimal tram shelter locations in the historical area of Jakarta Old Town [9][10].

This research focuses on classifying, mapping, and clustering the cultural heritage objects within the heritage city of Parakan, Central Java, Indonesia, with the results forming the foundation for planning and designing a heritage trail. The fuzzy logic approach is applied to ensure reliable outcomes in the classification and clustering process. The study advocates for using clustering to support the promotion of heritage cities as tourist destinations. As highlighted in [11], heritage trails offer numerous advantages, particularly in the context of cultural heritage. These trails serve not only as educational tools that help communities appreciate and respect their local heritage but also foster a sense of ownership and pride in their history. Additionally, heritage trails promote the preservation of historic areas and enhance public engagement through recreational and educational activities. The inclusivity of heritage trails—catering to people of all ages and abilities—is essential. This inclusive approach also aligns with the concept of a "friendly city," which ensures mobility for elderly individuals and people with special needs, as mentioned by Rosenbloom [11][12] and Broome et al. [13]. Heritage trails contribute positively to the physical well-being of participants by encouraging outdoor activities and engagement with cultural heritage sites.

2. Method

To categorize cultural heritage within the Heritage City of Parakan, Central Java, Indonesia, this research utilized a fuzzy logic-based simulation for classification and clustering. The simulation was carried out using MATLAB software. Various cultural heritage (CH) objects were selected for this study, with each object's details outlined in Table 1. A classification system, incorporating different variables and fuzzy sets, was developed for this research (refer to Table 2). The system took data from Table 1 to identify objects with similar characteristics and group them accordingly. The grouping process was guided by selecting the most relevant recommendations for each cultural heritage cluster. In line with the definition outlined in the Indonesian Cultural Heritage Law (Undang-Undang RI No. 11 Tahun 2010) [15], "heritage" is defined as an individual object, a group of objects, or part of an object that is at least 50 years old or represents a unique style for at least 50 years, recognized for its historical, scientific, or cultural significance. Cultural heritage sites in Parakan, which are more than 50 years old and are of significant value, are shown in Table 1. The historical areas within the Heritage City of Parakan, as depicted in Figure 1, are categorized into two main zones: Kauman and Pecinan.

Furthermore, similar approaches have been used in research on urban mobility and aging populations. For instance, Zeitller et al. [14] explored how active aging is facilitated in suburban environments through mobility interventions, highlighting the importance of accessibility, which resonates with the goals of heritage trail design—making historical areas accessible and beneficial to all age groups.

Table 1. The list of cultural heritage within heritage city of Parakan

Name of Cultural Heritage	Location	Building Character
Pasar Legi	Parakan Kulon	Modern
Masjid Al Barokah	Parakan Kulon	Traditional-Modern
Langgar Wali	Parakan Kulon	Traditional
Makam KH Subuki	Parakan Kulon	Traditional
Rumah Candi KH Subuki	Parakan Kulon	Traditional
Makam Kyai Parak	Parakan Kulon	Traditional
BMT	Parakan Kulon	Modern
Kawedanan	Parakan Wetan	Colonial
Klenteng Hok Tek Tong	Parakan Wetan	Chinese
Rumah Marga Siek	Parakan Wetan	Hindis
Rumah Low Djing Tie	Parakan Wetan	Hindis
Rumah Marga Tjiong	Parakan Wetan	Hindis
Jalan KH Subuki	Parakan Wetan-Kulon	Hindis-Traditional
Stasiun KA Parakan	Parakan Wetan	Colonial
Perumahan PT KAI	Parakan Wetan	Colonial
Jembatan Rel KA Parakan	Parakan Wetan	Colonial
Rumah Bekas Controleur	Parakan Kulon	Colonial
Jembatan Kali Galeh	Parakan Wetan	Colonial

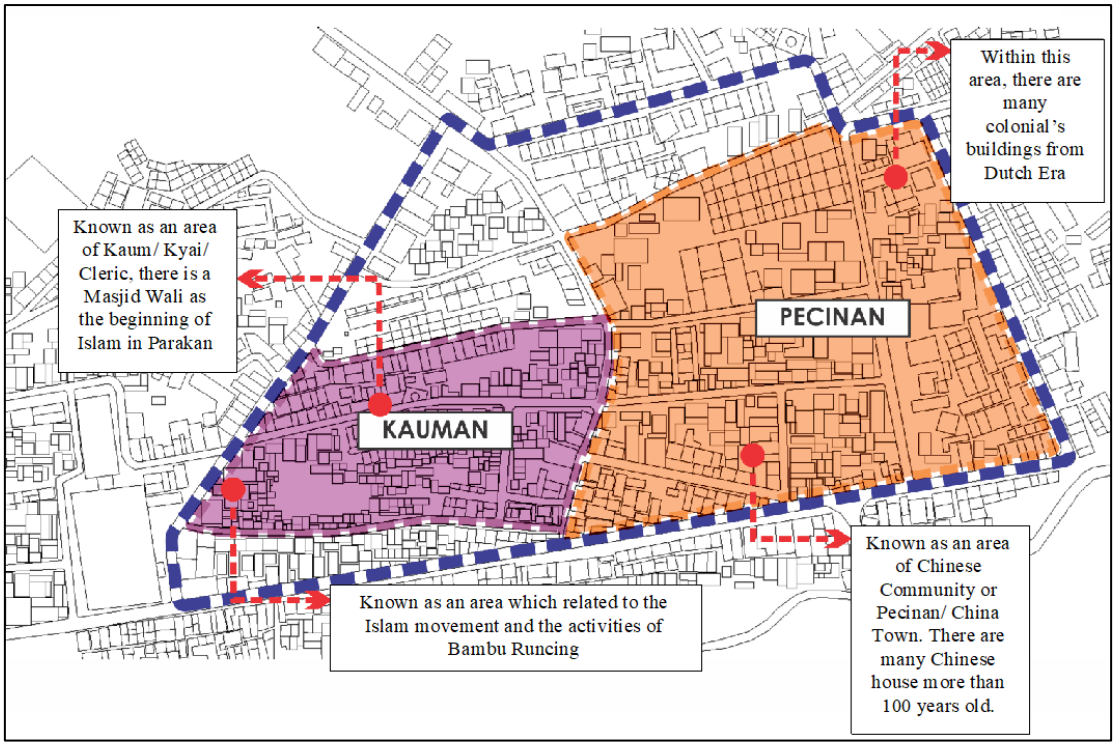

Figure 1. The zone of historical areas within heritage city of Parakan

Table 2. Variable of fuzzy and fuzzy sets

Items	Variables of Fuzzy		
	Inputs		Outputs
	Building Age	Building Character	Cluster Zone
Fuzzy Sets	Cultural Heritage	Traditional	1
		Hindis	2
	Non-Cultural Heritage	Colonial	3
		Modern	

3. Results and Discussion

A key principle in the design of Heritage Trails is the clustering and classification of cultural heritage objects that share common attributes. This classification process relates to the architectural style, building character, and the age of the buildings. Table 2 provides the data of each cultural heritage object used as input for the fuzzy logic system, which includes variables such as building character and age. For this research, building character is categorized as Traditional, Hindis, Colonial, and Modern, while building age follows the classification from the Indonesian Cultural Heritage Law, which distinguishes Cultural Heritage (buildings older than 50 years) from Non-Cultural Heritage (buildings younger than 50 years) [15].

The fuzzy logic system employed for clustering cultural heritage is illustrated in Figure 2. In this study, a Mamdani-type Fuzzy Inference System (FIS) was utilized, incorporating two input variables (Building Character and Building Age) and one output variable (Cluster Zone recommendation), as shown in Table 2. The Mamdani model was selected due to its established effectiveness in classification and clustering tasks within fuzzy logic systems [16].

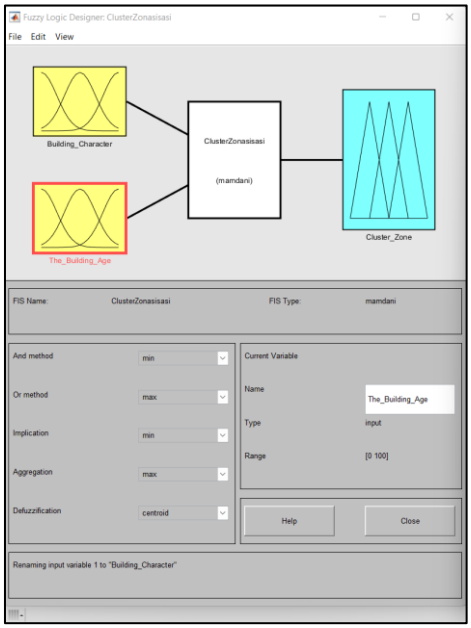

Figure 2. The fuzzy inference system (FIS) to determine the cluster of cultural heritage

Additionally, the fuzzy sets and their membership functions for the input variables—Building Character and Building Age—are displayed in Figure 3 and Figure 4, respectively. The fuzzy sets consist of four membership functions for building character and two for building age. Moreover, Figure 5 illustrates the fuzzy sets and membership functions for the output variable, "Cluster Zone." Based on these fuzzy sets, the system used a total of eight rules to determine the appropriate clusters, as shown in Figure 6. A simulation of the program, which provides a detailed view of these fuzzy rules, can be seen in Figure 7.

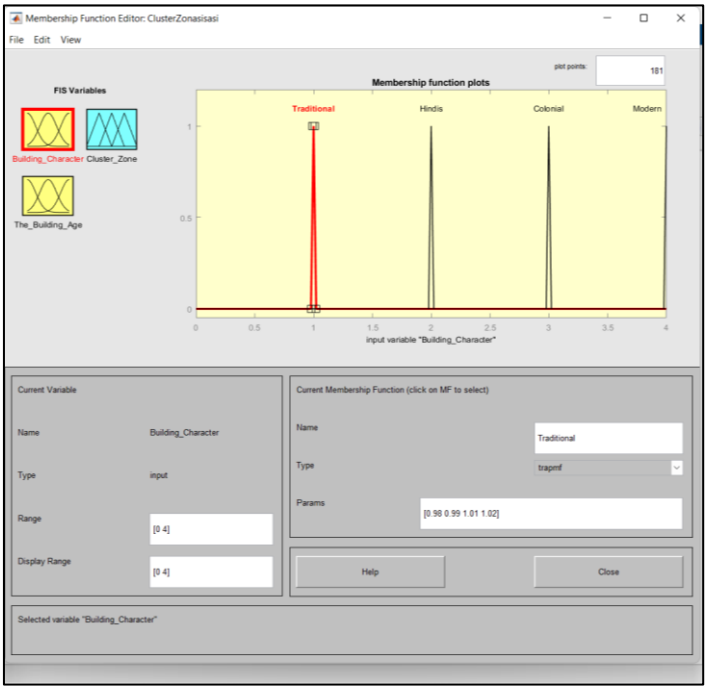

Figure 3. Fuzzy sets and membership functions for variable fuzzy input “Building Character”

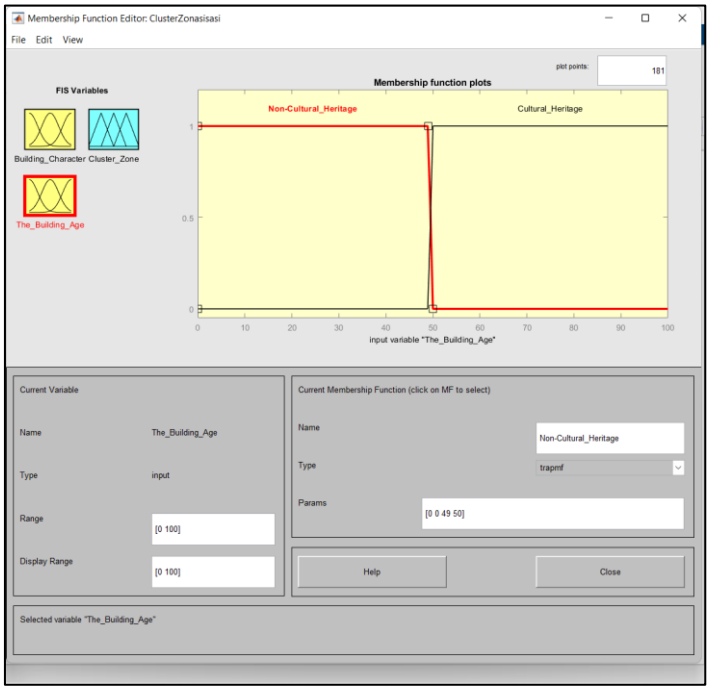

Figure 4. Fuzzy sets and membership functions for variable fuzzy input “The Building Age”

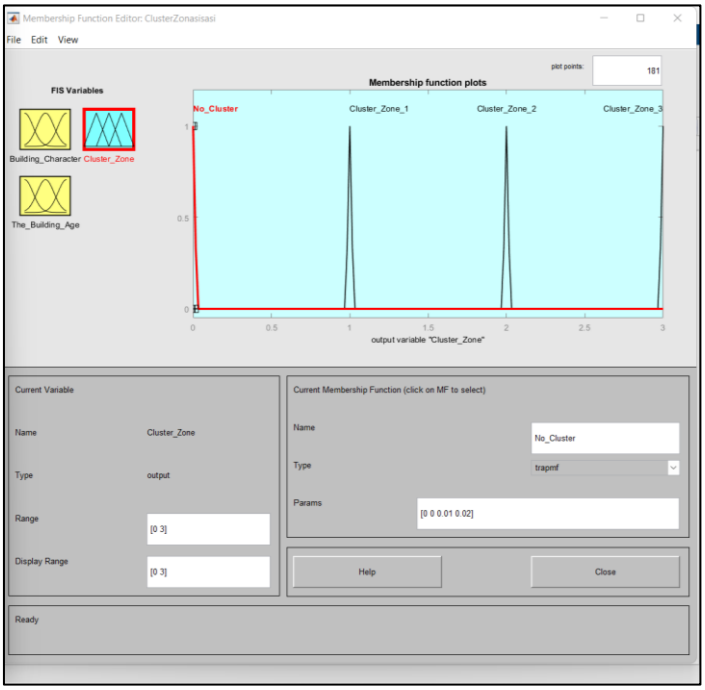

Figure 5. Fuzzy sets and membership functions for variable fuzzy output “Cluster Zone”

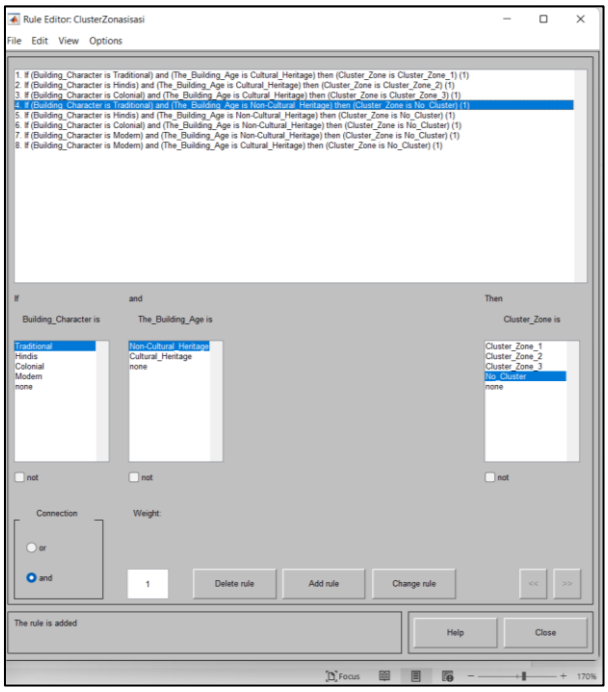

Figure 6. Fuzzy rules editor

Figure 7. Rules viewer

The fuzzy logic application yielded three distinct clusters, as summarized in Table 3. The 18 cultural heritage objects were grouped into three clusters: Cluster 1 (Kauman), Cluster 2 (Pecinan), and Cluster 3 (Colonial Buildings). These clusters are essential for further research and will serve as the foundation for designing a heritage trail in the Heritage City of Parakan.

Table 3. Fuzzy inference system results

Name of Cultural Heritage	Building Age	Building Character	Cluster Zone
Pasar Legi	100	Modern	1
Masjid Al Barokah	100	Traditional-Modern	1
Langgar Wali	150	Traditional	1
Makam KH Subuki	75	Traditional	1
Rumah Candi KH Subuki	100	Traditional	1
Makam Kyai Parak	200	Traditional	1
BMT	75	Modern	1
Kawedanan	150	Colonial	2
Klenteng Hok Tek Tong	250	Chinese	2
Rumah Marga Siek	150	Hindis	2

Name of Cultural Heritage	Building Age	Building Character	Cluster Zone
Rumah Low Djing Tie	150	Hindis	2
Rumah Marga Tjiong	150	Hindis	2
Jalan KH Subuki	200	Hindis-Traditional	1
Stasiun KA Parakan	100	Colonial	3
Perumahan PT KAI	75	Colonial	3
Jembatan Rel KA Parakan	100	Colonial	3
Rumah Bekas Controleur	100	Colonial	3
Jembatan Kali Galeh	100	Colonial	3

4. Conclusion

In conclusion, this study has successfully identified and categorized three distinct clusters of cultural heritage in the Heritage City of Parakan through the application of Fuzzy Logic. These clusters are: Cluster 1, Kauman; Cluster 2, Pecinan; and Cluster 3, Colonial Buildings. By utilizing fuzzy variables and fuzzy sets, the research established a reliable fuzzy logic system that analyzed and grouped cultural heritage objects in Parakan. The findings from this analysis provide key recommendations that could be instrumental in the effective implementation of the Heritage Trails concept within the region. It is hoped that these results will help guide future planning and development efforts to preserve and promote the rich cultural heritage of Parakan, Central Java, Indonesia.

5. Acknowledgments

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6. Conflict of Interest

The authors affirm that there are no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. All research processes, analyses, and interpretations have been independently undertaken, without any undue influence or involvement from external parties—whether financial, institutional, or personal in nature—that might compromise the integrity or objectivity of the findings.

References

[1] S. Bahri and A. W. Purwantiasning, Understanding the application of photovoltaic technology for public transportation, Test Eng. Management, Vol. 83, pp. 8497–507, (2020).
[2] S. Bahri and A. W. Purwantiasning, Understanding the application of photovoltaic technology for public transportation, Test Eng. Management, Vol. 83, pp. 8497–507, (2020).
[3] New South Wales Heritage Office, Guidelines for Heritage Trails (Sydney: New South Wales Heritage Office), (1995).

[4] S. Bahri and A. W. Purwantiasning, Modern Thought of Photovoltaic Technology in the Implementation of Transit Oriented Development's Concept and Revitalization for Jakarta Old Town, E3S Web Conf. 65, (2018).
[5] J. Santos, C. Torres-Machi, S. Morillas S and V. Cerezo, A fuzzy logic expert system for selecting optimal and sustainable life cycle maintenance and rehabilitation strategies for road pavements, Int. J. Pavement Eng. 0 1–13, (2020).
[6] R. Stetter, A fuzzy virtual actuator for automated guided vehicles, Sensors (Switzerland), Vol. 20, pp. 1–23, (2020).
[7] T. Liu, X. Yang, Q. Wang, M. Zhou and S. Xia, A Fuzzy-Theory-Based Cellular Automata Model for Pedestrian Evacuation from a Multiple-Exit Room, IEEE Access, Vol. 8, pp. 106334–45, (2020).
[8] YI. Daradkeh and I. Tvoroshenko I, Technologies for making reliable decisions on a variety of effective factors using fuzzy logic, Int. J. Adv. Comput. Sci. Appl., Vol. 11, pp. 43–50, (2020).
[9] P. Holeček, J. Talašová, and J. Stoklasa, Fuzzy classification systems and their applications, 29th International Conference, (Mathematical Methods in Economics 2011, September 6 – 9, 2011 Janská Dolina, Slovakia, (2011), pp 266-271.
[10] S. Bahri and AW. Purwantiasning, Designating the preference of tram shelter as a part of transit- oriented development's concept within Kota Tua Jakarta using fuzzy logic, The 1st International Conference on Sustainable Architecture and Engineering, IOP Conf. Series: Earth and Environmental Science 878, (2021).
[11] S. M. Santoso, Manfaat "Heritage Trail" dalam Pengembangan Wisata Daera,. Cendana NEWS, (Diakses pada tanggal 10 Juni 2022, 2021).
[12] S. Rosenbloom, Meeting Transportation Needs in an Ageing-Friendly Community, Journal of the American Society on Ageing, 33, 33-43, (2009).
[13] K. Broome, E. Nadler, and L. Worral, Age-Friendly Buses? A Comparison of Reported Barriers and Facilitators to Bus Use for Younger and Older Adults, Australian Journal of Ageing, 29, 33-38, (2010).
[14] E. Zeitller, L. Buys, R. Aird and E. Miller, Mobility and Active Ageing in Suburban Environments: Findings from In-Depth Interviews and Person-Based GPS Tracking, Current Gerontology and Geriatrics Research, (2012).
[15] Undang-Undang RI, UU RI No. 11 Tahun 2010 tentang Cagar Budaya, (2010).
[16] Y. Al Afis and AM. Abadi, Metode Mamdani untuk Klasifikasi Dalam Prediksi Indeks Pembangunan Manusia di Kota Banda Aceh, Seminar Matematika dan Pendidikan Matematika, Universitas Negeri Yogyakarta, T-42, (2017), pp 305-312.