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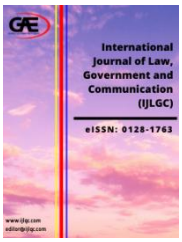

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UNLOCKING INSIGHTS: CLUSTER ANALYSIS OF THE ASNAF COMMUNITY IN PERLIS USING A HYBRID CLUSTERING MODEL

Rabiah Abdul Kadir[1*], Ummul Hanan Mohamad[2], Mohamad Syahmi Shahril[3]

[1] Institute of Visual Informatics, Universiti Kebangsaan Malaysia, Malaysia
Email: rabiahivi@ukm.edu.my
[2] Institute of Visual Informatics, Universiti Kebangsaan Malaysia, Malaysia
Email: ummulhanan@ukm.edu.my
[3] Institute of Visual Informatics, Universiti Kebangsaan Malaysia, Malaysia
Email: syahmishahril@ukm.edu.my
[*] Corresponding Author

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Abstract:

The main goal of the country is to eradicate poverty and make the lives of Muslims more prosperous. The Perlis Islamic Religious Council and Malay Customs Council (MAIPs) have always been committed to channeling assistance to the asnaf group since 2013 through the Kayuhan MAIPs Peduli program. The distribution of assistance to eligible groups has been carried out through 704 programs led by Tuanku Syed Faizuddin Putra Jamalullail. In determining the groups eligible to receive zakat, the zakat department will use the method of calculating and measuring the had kifayah. However, in determining the target among the selected asnaf, the support of digital technology that is growing rapidly today is still needed. With the support of digital technology that is capable of carrying out cluster analysis, the management of selecting and grouping these asnaf groups will be easy and effective for MAIPs in making decisions on assistance to target groups among the asnaf. This project conducts research and development of analytics dashboards that focus on grouping asnaf groups eligible to receive zakat, such as Fakir, Miskin, Amil, Muallaf, Al-Riqab, Al-Gharimin, Fisabilillah, and Ibnu Sabil. The analytics dashboards will be developed with artificial intelligence (AI) digital technology using a classification algorithm, namely Support Vector Machine (SVM), which is based on machine learning. This project involves five (5) phases of research and development, namely: (i) identifying features of asnaf groups for analysis purposes; (ii) designing a prototype based on machine learning; (iii) developing applications using the Support Vector Machine (SVM) algorithm; (iv) testing applications on a dataset of asnaf groups in Perlis; and (v) deploying applications to MAIPs to target assistance categories to selected asnaf groups. The results of this project are expected to

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increase the impact and services of the Kayuhan MAIPs Peduli program, which is one of the strengths of MAIPs in helping target groups among asnaf in Perlis. The developed analytics dashboard application also expands the reach and accessibility of services to other stakeholders in fostering innovation and collaboration in the same sector in Malaysia.

Keywords:

Artificial Intelligence, Data Analytics, Clustering, Asnaf

Introduction

Manual processes for determining the eligibility and distribution of zakat to asnaf groups remain a persistent challenge in many Islamic welfare institutions, including in Perlis. Currently, the identification of recipients and the allocation of aid are heavily reliant on subjective judgment and manual classification, often without systematic data analysis. This approach not only increases the risk of decision-making errors but also leads to inefficient zakat distribution and potential exclusion of deserving recipients (Mustapha et al., 2024). Additionally, there is a lack of effective mechanisms for monitoring clustering patterns among asnaf groups, which are critical for understanding socio-economic variations and targeting assistance appropriately (Abdullah & Salleh, 2018).

In light of these limitations, the current study hypothesizes that an analytical dashboard application, powered by machine learning, can provide deeper insights into the characteristics of various asnaf subgroups. By automating the classification process, the dashboard is expected to support more accurate and context-sensitive aid distribution. The hypothesis posits that the application can address misclassification and ensure that support is aligned with the actual needs of each asnaf subgroup. This hypothesis is grounded in the potential of Artificial Intelligence (AI) techniques—particularly Support Vector Machines (SVM)—to handle complex, multi-feature datasets with high accuracy and minimal human bias (Cortes & Vapnik, 1995, Cai et al., 2016).

Guided by this hypothesis, the research seeks to answer two core questions: (1) How can clustering be effectively implemented among asnaf groups, and which features are most influential in this process? (2) Is there a computable formula or model that can determine the appropriate amount of zakat aid for each asnaf group based on their unique characteristics? These questions aim to explore both the methodological and practical dimensions of zakat distribution, ensuring that both group classification and resource allocation are optimized through data-driven decision-making.

To achieve these goals, the project is structured around three specific objectives. First, it aims to identify and validate relevant socio-economic features of asnaf groups for cluster analysis using domain expert input and data pre-processing techniques. Second, it involves developing an analytical dashboard application that employs the SVM classification algorithm to categorize asnaf groups accurately. Lastly, the project will test and evaluate the application using real-world data from MAIPs to assess its classification accuracy, efficiency, and potential to enhance institutional service delivery (Al-Saadi & Jusoh, 2020; Powers, 2011). Through these steps, the study aspires to contribute a scalable, intelligent tool for more equitable and strategic zakat distribution.

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Literature Review

In today's era, poverty is one of the main problems that plague most developing countries in the world. In Malaysia, efforts to help bring the asnaf group out of poverty depend on assistance from zakat institutions. The main goal of the country is to eradicate poverty, make the lives of Muslims more prosperous and the country's economic prosperity can be enjoyed together (Ismail, M., Shariff, S. & Hussin, H., 2021). The asnaf group is a party that is eligible to receive Zakat assistance from Muslims. This matter is recorded in the Al-Quran through surah A-Taubah verse 60:

> *Indeed, the Zakat is only for the poor, the needy, the administrators of the Zakat, the converts whose hearts are persuaded, for (freeing) slaves, those in debt, for the cause of Allah and those on the way, as a decree made obligatory by Allah; and Allah is All-Knowing, All-Wise.*

The Perlis Islamic Religious and Malay Customs Council (MAIPs) has allocated RM22,897,200 to assist the asnaf group in the state of Perlis. The allocation was channeled to 36,310 recipients among the selected asnaf led by Tuanku Syed Faizuddin Putra Jamalullail (RTM News, 2022). MAIPS has an important role in the management and distribution of zakat to the eligible and needy groups in the state of Perlis (Alias et al., 2021; Ahmad et al., 2020). This task is carried out in accordance with the established sharia principles, ensuring that assistance is given to those who are truly in need. In the distribution of zakat, various criteria must be seen to ensure that a person belongs to the group that is eligible to receive zakat (Ismail, M.N., & Ali, N.A., 2022; Bhari, A. et al., 2022). Investigations must be carried out carefully to ensure that the distribution is to individuals who are truly eligible. To determine whether a person belongs to the group that is eligible to receive zakat, the zakat authority will use the had kifayah method, which is a calculation and measurement to determine whether a person is included in the asnaf group (Omer, M.S. & Mahmud, M.S., 2019; Zahid, E.S.M., 2010). The asnaf group consists of eight (8) groups that have certain features and require different forms of assistance (Irfaan, J., 2023):

- Fakir (al Fuqara)
  A group that does not have enough income to meet their own needs. They do not have a family to provide for their needs such as food, clothing and shelter.
- Poor (al-Masakin)
  A group that has the ability to work to obtain the necessities of life but is not fully sufficient.
- Amil
  A person appointed to collect and distribute zakat money.
- Muallaf
  A person who has just converted to Islam.
- Riqab
  A person who is shackled and has no personal freedom.
- Gharimin
  A Muslim debtor who does not have the resources to pay off debts that are required by Islamic law in matters that are fundamental to himself and the responsibilities that are obligatory upon him.
- Fisabilillah
  A person who struggles, strives and carries out activities to uphold and elevate the religion of Allah.

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- Ibnu Sabil
  A traveler who runs out of supplies on a journey or when starting a journey from his country that brings good returns to Islam and its people or a Muslim who has no supplies on the road.

The efficiency of zakat management and distribution to groups eligible to receive zakat assistance can be improved by using digital technology solutions that are capable of selecting targets accurately based on the features of each asnaf group and doing so more systematically. Prior research has emphasized that data-driven approaches enable zakat institutions to better identify socio-economic indicators crucial for classification and aid distribution (Abdullah & Salleh, 2018; Rahman & Dean, 2019). To ensure that MAIPs identify and assist target groups among asnaf, cluster analysis will be introduced in this research project to handle the process of selecting and classifying asnaf groups more easily and efficiently (Ismail & Ali, 2022). Artificial intelligence and machine learning techniques such as clustering have been shown to significantly enhance decision-making capabilities within Islamic financial institutions, including zakat bodies (Al-Saadi & Jusoh, 2020; Hassan & Aliyu, 2018). By determining various forms of assistance based on the results of accurately classifying asnaf groups, poverty can be eradicated, the well-being of Muslims improved, and the country's economic prosperity more equitably shared.

Methodology

This research adopts a five-phase Research and Development (R&D) framework as shown in Figure 1 which is designed to systematically develop and evaluate a machine learning-based system for clustering asnaf groups to enhance zakat distribution. Each phase aligns with specific research objectives and reflects a structured progression from data preparation to system deployment.

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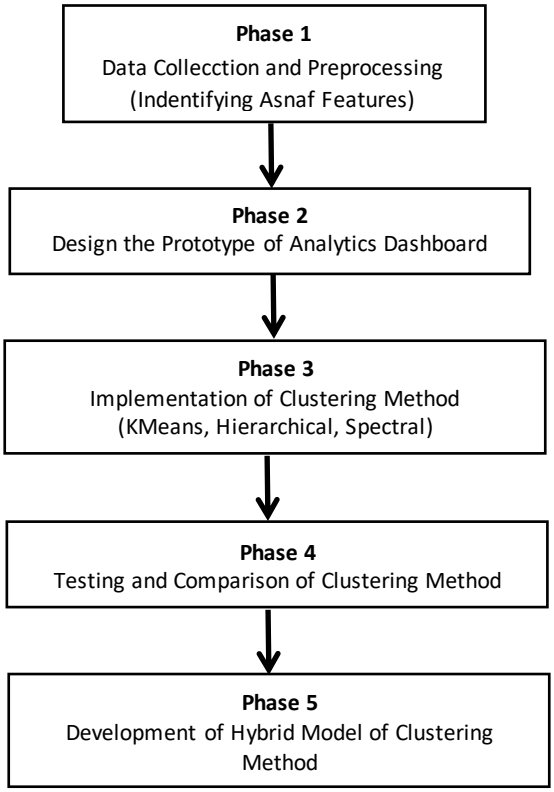

Figure 1: Flowchart of Research Methodology

Data Collection and Preprocessing for Asnaf Community

The data collection and preprocessing phase is a critical component in the implementation of this research, particularly in identifying the relevant features of the asnaf community for effective clustering. Data was sourced from the previous project with Faizuddin Centre Of Educational Excellence (FCOEE) on *Program Pembangunan Insan Terpilih Madani* (PPITM) supported by Perlis Islamic Religious and Malay Customs Council (MAIPs), encompassing socio-economic variables such as household income, number of dependents, occupation, type of residence, and zakat assistance history.

Subject Matter Experts (SMEs) from MAIPs were engaged to validate the relevance and accuracy of these attributes, ensuring that they align with the criteria outlined in Islamic jurisprudence and national zakat management guidelines. The raw data underwent rigorous preprocessing, including data cleaning, handling of missing values, normalization of numerical attributes, and encoding of categorical variables. This step was essential to enhance data quality and ensure consistency for machine learning input. Outlier detection techniques were applied to identify and remove anomalous data points that could bias the classification model. The outcome of this phase is a refined dataset with validated features that are representative of the asnaf community's socio-economic diversity, forming the foundation for reliable and interpretable machine learning analysis.

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Design the Prototype of Analytics Dashboard

The design of the analytics dashboard prototype was guided by both functional requirements and user-centric considerations to ensure it effectively supports zakat officers in analyzing and classifying asnaf groups. The dashboard integrates machine learning clustering algorithms, particularly K-Means and Spectral Clustering, to group recipients based on socio-economic features such as income, number of dependents, and housing status. The user interface was designed to be intuitive and interactive, allowing users to visualize clustering outputs through dynamic charts, heatmaps, and cluster-specific profiles. Key functionalities include filter options for specific features (e.g., income range or sibling count), real-time cluster updates, and automated suggestions for aid categories based on cluster characteristics. The dashboard architecture supports scalability and is built using web-based tools that allow integration with MAIPs' existing databases. Emphasis was placed on interpretability, enabling users with minimal technical background to understand cluster patterns and use the insights for informed zakat distribution. The prototype serves not only as a data analysis tool but also as a decision-support system for optimizing resource allocation among the asnaf community.

Implementation of Clustering Method

The implementation phase involved applying three clustering algorithms—K-Means, Hierarchical Clustering, and Spectral Clustering—to the preprocessed asnaf dataset to identify underlying patterns and subgroup classifications. K-Means was implemented as a baseline method due to its simplicity and efficiency in partitioning data into k distinct, non-overlapping clusters based on proximity to centroid points. Several values of k were tested using the Elbow Method and Silhouette Score to determine the optimal number of clusters. Hierarchical Clustering, both agglomerative and divisive, was employed to observe nested cluster relationships without predefining the number of groups. Dendrograms were used to analyze the structure and make informed decisions on cluster cut-off points. Both methods highlighted clear separations between high-income and low-income asnaf but showed limitations in handling overlapping or non-linear feature interactions.

To address these limitations, Spectral Clustering was introduced as an advanced technique capable of capturing complex, non-convex cluster structures within the dataset. By transforming the data into a graph-based similarity matrix and computing the eigenvalues of its Laplacian, Spectral Clustering enabled the identification of nuanced socio-economic groupings, such as the mid-income, mid-sibling Al-Riqab group, which were not well captured by the other methods. The clustering outputs were evaluated using metrics such as Adjusted Rand Index (ARI) and Silhouette Score, with Spectral Clustering consistently showing higher performance, especially in distinguishing overlapping classes like Fakir and Miskin. These implementations were integrated into the analytics dashboard to support interactive cluster analysis, enabling MAIPs officers to better understand the characteristics of each asnaf group for more precise zakat targeting.

Testing and Comparison of Clustering Method using Asnaf Dataset

The testing and comparison phase involved applying K-Means, Hierarchical, and Spectral Clustering algorithms to the validated asnaf dataset obtained from FCOEE to evaluate their performance in effectively grouping recipients based on socio-economic features. Each algorithm was tested on the same preprocessed dataset to ensure consistency in comparison. The number of clusters was determined using methods such as the Elbow Method for K-Means and dendrogram analysis for Hierarchical Clustering. For Spectral Clustering, the similarity

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matrix was derived using radial basis function (RBF) kernels to capture non-linear relationships. The clustering results were visualized through scatter plots, cluster centroids, and feature distribution charts to analyze the patterns of each method in classifying complex groups such as Fisabilillah, Fakir, and Miskin.

Performance evaluation was conducted using standard clustering validation metrics including Silhouette Score, Davies-Bouldin Index, and Adjusted Rand Index (ARI). K-Means performed efficiently but struggled with overlapping clusters, particularly between Fakir and Miskin, while Hierarchical Clustering showed better subgroup formation but tended to overgeneralize certain low-income categories like Miskin. Spectral Clustering outperformed the others by capturing non-linear separations and accurately isolating groups such as Al-Riqab (mid-income, mid-sibling). Additionally, user feedback was collected from MAIPs officers who reviewed cluster outputs via the dashboard, providing qualitative validation that Spectral Clustering offered clearer, more actionable groupings. This comprehensive testing and comparison confirmed that Spectral Clustering is the most suitable method for supporting effective, data-driven zakat distribution.

Development of Hybrid Model of Clustering Method

The development of a hybrid clustering model combining K-Means and Spectral Clustering was undertaken to leverage the strengths of both algorithms, K-Means' computational efficiency and Spectral Clustering's ability to capture non-linear structures. In this hybrid approach, the Spectral Clustering method was first applied to transform the original feature space into a lower-dimensional space using the eigenvectors of the Laplacian matrix derived from a similarity graph of the asnaf dataset. This transformation allowed for the representation of complex, non-convex relationships among data points. Subsequently, the K-Means algorithm was executed on the resulting spectral embedding to partition the data into distinct clusters. This two-stage process enhances the model's sensitivity to subtle feature interactions—such as variations in income and sibling count—while maintaining the scalability and simplicity of K-Means. The hybrid model was implemented using Python with Scikit-learn, where the number of clusters was optimized using Silhouette Score analysis. The integration of both methods in a pipeline architecture within the analytics dashboard enables efficient, interpretable clustering outcomes that support refined zakat targeting for MAIPs.

Experimental Result and Analysis of Clustering Method

The experimental results revealed significant differences in the performance of the three clustering methods applied to the asnaf dataset. K-Means provided clear segmentation based on income but struggled with overlapping classes, particularly among low-income groups such as Fakir and Miskin. Hierarchical Clustering captured broader groupings but tended to overgeneralize, often merging distinct subgroups. In contrast, Spectral Clustering demonstrated superior performance by effectively identifying complex, non-linear relationships which, successfully isolating unique clusters like Al-Riqab and Fisabilillah. Quantitative evaluation using Silhouette Score and Adjusted Rand Index confirmed that Spectral Clustering offered the most accurate and interpretable clustering outcomes, making it the most effective approach for supporting targeted zakat distribution.

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K-Means Clustering

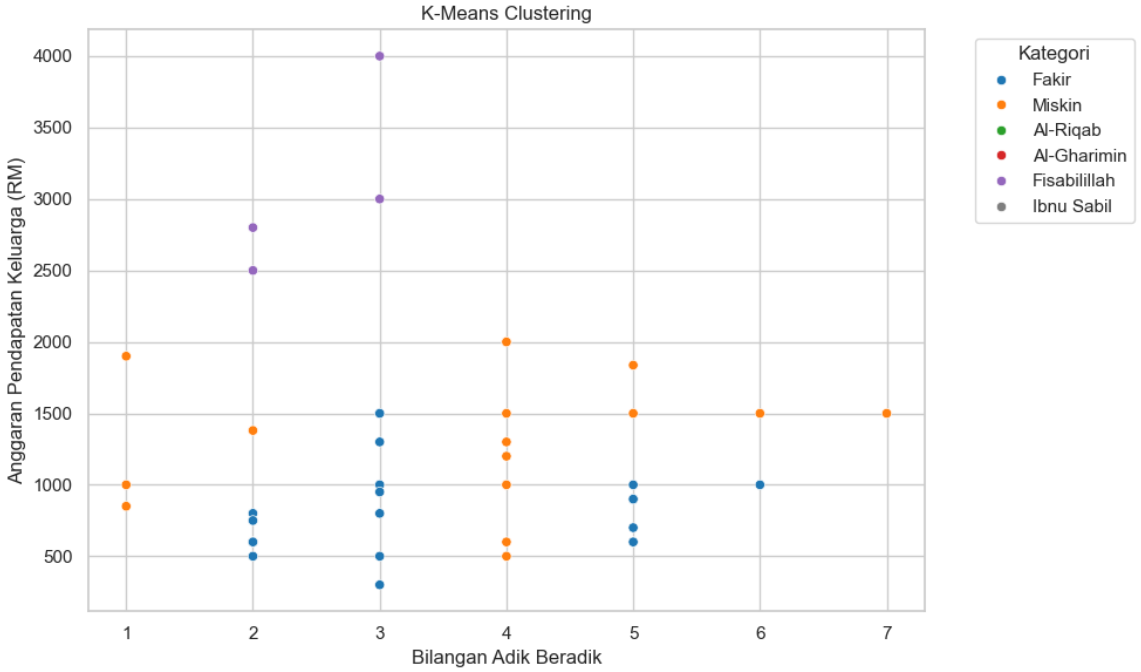

Figure 2: Analysis Result of K-Means Clustering

The clustering results in Figure 2 demonstrate a clear delineation between low-income households (Fakir and Miskin) and high-income households (Fisabilillah), with the latter consistently forming distinct clusters at the upper end of the income spectrum, independent of sibling count. In contrast, households with low sibling counts (1–3) are dispersed across a wide range of income levels, indicating weak separation based on this variable. Mid-range sibling groups (3–5) exhibit heterogeneous cluster assignments, reflecting income variability within these household structures. Notably, certain target categories such as Al-Riqab and Al-Gharimin are absent from the clustering output, suggesting limitations in the model's ability to capture the full spectrum of predefined classifications. Analyzing the relationship between variables, low-income clusters are distributed across the entire range of sibling counts (1–7), with no evident linear trend, whereas high-income clusters are predominantly associated with smaller family sizes. Overall, the KMeans algorithm appears to be primarily driven by income levels rather than sibling count, and it fails to capture a strong negative correlation between these two variables.

Hierarchical Clustering

The hierarchical clustering results as shown in Figure 3 reveals a strong bias toward assigning a large proportion of data points to the Miskin category, even across varying income levels, indicating potential overgeneralization in cluster formation. While high-income groups such as Ibnu Sabil and Fisabilillah are distinctly identified, their occurrences are limited, highlighting their rarity in the dataset. Families with four or more siblings are predominantly classified under low-income categories (Fakir or Miskin), supporting a mild trend that larger sibling counts may correlate with lower income. However, within low-income clusters, especially among smaller sibling groups, internal compactness is weak, suggesting variability that reduces the cohesion of these groups. Additionally, categories such as Al-Riqab and Al-Gharimin are absent, likely due to the merging effect inherent in hierarchical clustering, which consolidates smaller or less distinct groups into broader categories. From a relational perspective, low-

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income households remain widely dispersed across sibling counts, while high-income groups like Ibnu Sabil are confined to families with fewer children. Although there is a slight indication that higher sibling counts may correspond to lower income within some clusters, the overall correlation remains weak. Income continues to be the dominant variable influencing cluster separation, with sibling count exerting only a moderate secondary effect.

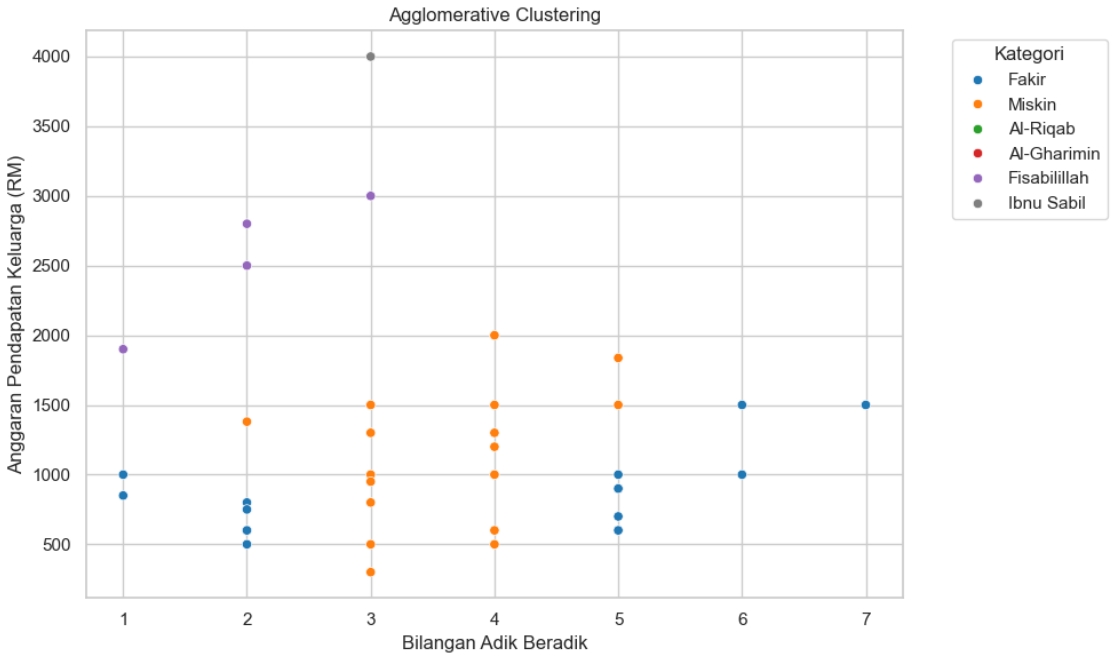

Figure 3: Analysis Result of Hierarchical Clustering

Spectral Clustering

The experimental results as shown in Figure 4 reveals several key clustering dynamics within the dataset. Notably, this is the first model to successfully capture the Al-Riqab cluster, particularly characterized by mid-sibling (4–5 siblings) and mid-income (RM 1,500–2,000) families where an area previously not well-defined. Fisabilillah, representing high-income individuals with low sibling counts, consistently forms a distinct and separate cluster, reinforcing its clear socio-economic profile. Meanwhile, the Fakir and Miskin groups, both occupying the lower-income range, exhibit significant overlap, especially at lower sibling counts, indicating difficulty in distinguishing them with simpler clustering methods. Al-Gharimin, however, remains either undetected or blends into larger clusters, suggesting a lack of distinctiveness or representation in the feature space. Importantly, spectral clustering shows a notable advantage in capturing these subtleties, outperforming KMeans by better adapting to non-linear separations in the data. Overall, the model highlights a weak inverse correlation between number of siblings and income, particularly within some clusters, and suggests that sibling-income relationships may follow more complex, non-linear patterns, especially evident in the spectral clustering's ability to reveal nuanced socio-economic groupings.

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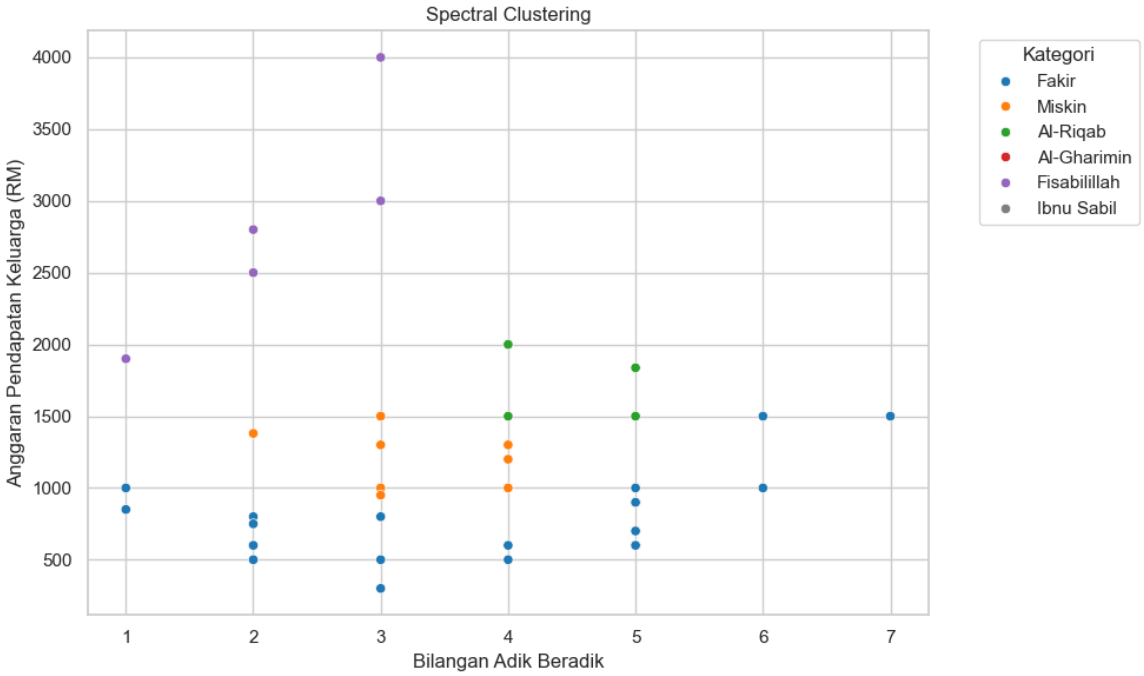

Figure 4: Analysis Result of Spectral Clustering

Table 1 depicts the comparison of clustering methods across key aspects shows that each algorithm has distinct strengths and limitations when applied to the asnaf dataset. K-Means Clustering performs well in clearly separating high-income groups like Fisabilillah from low-income categories such as Fakir and Miskin, but it struggles with sibling count influence and fails to detect nuanced groups like Al-Riqab and Al-Gharimin. Hierarchical Clustering moderately improves sibling count differentiation and captures rare categories like Ibnu Sabil, yet suffers from poor cluster compactness and often merges less distinct groups, making it less suitable for identifying subtle patterns. Spectral Clustering outperforms both by effectively separating complex, non-linear relationships—especially among mid-income and mid-sibling groups such as Al-Riqab—while also showing a weak but observable inverse correlation between income and sibling count. Although it still faces challenges in isolating Al-Gharimin, Spectral Clustering produces more refined and interpretable clusters, making it the most suitable method for capturing socio-economic diversity within the asnaf community.

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Table 1: Comparison of Clustering Result (KMeans, Hierarchical, Spectral)

Aspect	KMeans Clustering	Hierarchical Clustering	Spectral Clustering
Income Separation	Clear distinction between **high-income (Fisabilillah)** and **low-income (Fakir, Miskin)** households	Distinct high-income clusters (Fisabilillah, Ibnu Sabil), but less prevalent due to rarity	Strong separation of **Fisabilillah**; also captures **mid-income (Al-Riqab)** clusters
Sibling Count Influence	Weak separation by sibling count; low sibling counts found across all income levels	Moderate effect; families with 4+ siblings often classified as low-income	Complex, **non-linear sibling-income interactions** captured; mid-sibling (4–5) groups more distinctly separated
Cluster Compactness	Low-income clusters are broad and overlapping	Low-income clusters (especially Miskin) show **poor internal cohesion**, especially with small sibling counts	Better defined and **nuanced groupings** with **less overlap**, especially for Fakir vs. Miskin
Category Capture	**Al-Riqab** and **Al-Gharimin** not detected	**Al-Riqab** and **Al-Gharimin** merged or absent due to hierarchical consolidation	Successfully identifies **Al-Riqab** (mid-sibling, mid-income); **Al-Gharimin** still hard to isolate
Correlation Insight	Income is the dominant variable; sibling count shows **no strong negative correlation**	Slight trend: more siblings → lower income, but overall correlation remains **weak**	Weak inverse correlation observed; **better captures sibling-income complexity**
Strengths	Simple and clearly separates extreme income groups	Captures rare high-income types (Ibnu Sabil), good for coarse categorization	Best at capturing **complex socio-economic relationships**, and **non-linear patterns**
Limitations	Fails to detect nuanced categories (Al-Riqab, Al-Gharimin); limited by linear assumptions	Merges minor categories; compactness issues in low-income groups	Still struggles with **Al-Gharimin**; requires more data or features for even finer separation

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The hybrid clustering process begins by applying Spectral Clustering to the asnaf dataset to address complex, non-linear relationships that conventional clustering methods often miss. This is done by first constructing a similarity graph from the dataset, which reflects how similar or connected each asnaf record is to others based on features such as income level, sibling count, and household conditions. From this graph, the Laplacian matrix is derived and its eigenvectors are computed to perform dimensionality reduction, transforming the original data into a spectral embedding that reveals underlying structure in a lower-dimensional space.

Once this transformation is completed, K-Means clustering is applied to the spectral embedding. This second stage allows for fast and efficient partitioning of the data into distinct clusters based on the embedded coordinates. By combining these two stages, the hybrid model leverages Spectral Clustering's sensitivity to subtle patterns with K-Means' computational simplicity and scalability, as shown in Figure 5. The number of optimal clusters is determined using Silhouette Score analysis, ensuring a balanced model that reflects both socio-economic variability and technical efficiency.

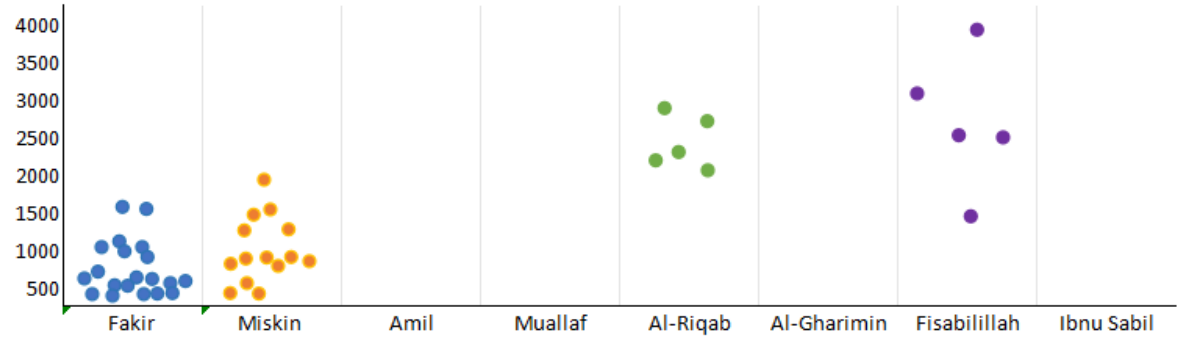

Figure 5: Asnaf Community Cluster using Hybrid Model Clustering

Conclusion

The proposed hybrid clustering model, which combines Spectral Clustering and K-Means, successfully enables more accurate and interpretable classification of the asnaf community. By capturing both linear and non-linear relationships in the data, such as income levels, number of dependents, housing conditions, and other socio-economic indicators. The model allows for more refined segmentation of asnaf groups. Previously indistinct categories such as Al-Riqab (mid-income, mid-sibling) were clearly identified, while overlapping low-income groups like Fakir and Miskin were better differentiated. This clustering capability provides a strong analytical foundation for institutions like MAIPs to make data-driven decisions in targeting zakat assistance.

With improved clustering accuracy, the proposed model enables zakat institutions to tailor aid distribution based on the specific needs of each identified asnaf cluster. For example, families with many dependents but moderate income levels may require different types of support compared to small households living in extreme poverty. By aligning assistance with real, data-based needs, the model not only increases the efficiency of zakat distribution but also ensures fairness and inclusivity. This personalized approach directly addresses the root causes of poverty within each subgroup, helping to lift individuals and families out of hardship through more appropriate and sustained support.

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Ultimately, the implementation of this model contributes significantly to the broader goal of poverty eradication and the promotion of socio-economic well-being in the Muslim community. By using artificial intelligence to optimize zakat management, the lives of the asnaf can be improved in a structured and impactful way. As more accurate data is collected and used to inform decisions, the system becomes increasingly effective over time. This contributes to a more prosperous Muslim society where economic benefits are shared more equitably, thereby supporting national development goals and fostering collective progress.

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