Investigating the Profile of Digital Readiness and Sustainability Development: An Explainable Clustering

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Abstract. The level of digital readiness within Islamic Higher Education Institutions (IHEIs) has emerged as a critical concern, drawing increasing scholarly and institutional attention over the past five years. This study aims to examine the empirical relationship between two key dimensions: digital readiness, as reflected by the National Readiness Index (NRI), and progress toward the Sustainable Development Goals (SDGs). Data were collected from more than 20 IHEIs between 2023 and 2024 to support a sequential analytical approach. Pearson's correlation coefficient was employed to identify associations between NRI-based digital readiness and SDG performance within the IHEI context. Subsequently, cluster analysis was conducted using the Duda–Hart Index, while the Pseudo T^2 statistic was applied to validate the robustness of the clustering outcomes. A cartographic visualization was also generated to illustrate variations across readiness and sustainability clusters. The results indicate a considerable disparity between digital readiness and sustainability among IHEIs. Only a limited number of institutions demonstrate consistent performance in both areas, suggesting that effective leadership and strategic investment in digital infrastructure are essential prerequisites for achieving sustainable institutional transformation.

Keyword: digital readiness of IHEI, network readiness index, sustainable development, clustering analysis, Islamic Higher Education Institution, digitalizations.

1. Introduction

1.1 *Background*

Since the last decade, digital transformation has hardly reshaped economic and social change. Several institutions across the nation were quickly encouraged to innovate the innovation of strategies[1]. The concept of digital transformation probably formulated the readiness. The emerging of a digital readiness context was largely significant impact and immediate toward both efficiency and effectiveness of organizations, and event though on the planning of individual stakeholders. In order to illuminate individual preparedness, the term of digital readiness was subsequently applied to the digital transformation when some people are utilizing the technology. In reality, the business sector, academia, industrial, and small and medium enterprise were often delineated as priority in the stage of digitalization; moreover, they are driving to economic growth and competitiveness, beside exploring innovation. Despite of high economic value, digitalization reinforced many institutions (e.g., private and public) where digital technology with readiness was potentially associated with the obvious achievement of the sustainable development goals (SDGs)[2]. Because the Islamic Higher Education Institutions (IHEI) are to be highlighted in the education context, sustainable development goals (SDGs) in this context tend to quality education (SDG 4)[3], industry, innovation, and infrastructure (SDG 9)[4], and sustainable cities and communities (SDG 11)[5] and climate action (SDG 13)[6].

Generally, in order to assess the readiness across the country, the Network Readiness Index (NRI), the Global Innovation Index (GII), and the AI Readiness Index (AIRI) were involved to measure the index of preparedness, as well as supporting government [7]. In other words, the countries' digital competitiveness and technology adoption capacity would be identified comparatively to receive valuable insight from the definitive tools. It is realized that NRI as the most critical tools related to the country, the planning assessment of readiness in HEI attempts to modify definited tools with selected cases (i.e., HEI). The NRI scheme was adopted comprehensively to closely define the readiness index in Indonesia within the IHEI scope due to the representation of the distributed area, besides as a key benchmark for assessing [8].

Initial recommendation of literature points out that social inclusion, environmental sustainability, and economic prosperity were concequently elevated through digital innovations. Furthermore, as one of the largest countries in the South East Asia, the progress toward the 2030 Agenda's SDGs would be achieved from the digitalization process, specifically in the higher education sector. The institutions of education within the Islamic scope that were indicated with better SDG performance when higher digital readiness was achieved, such as quality education (SDG 4), industry, innovation, and infrastructure (SDG 9), sustainable cities and communities (SDG 11), and climate action (SDG 13)[6].

The assessment processing of digital readiness in institutional education, particularly within IHEI, remains scarce, although many literatures on the recommended topic were frequently investigated to the method and model. Despite many educational institutions with a high level of digitalization, significant disparities in digital infrastructure, skills, and connected to technology has been recognized. Decisively, the economic growth from promoting contributed educational institutions had been obstructed unpredictably and higher educational institutions' ability to gradually reach the SDGs[9]. Thus, this study aims to critically investigate the extent to which digital readiness influences sustainable development performance in the IHEIs which utilized the clustering analysis[10]. Both similar levels of digital readiness analysis and potential sustainable development identified homogeneous groups of educational institutions, while correlation and clustering analysis provide the definitive method to be utilized as a grouping feature. As a results, the method of clusterization as the core of analysis generated probably the valuable insights to encourage the promotion of digital transformation, and a strategic plan has been incorporated into sustainable development. Therefore, in this study of relationship investigation following hypothesis is investigated: There is a significant relationship between a province represented by one of digitally readiness of IHEI and the characteristic in the SDG spectrum.

On the one hand, this planned study is limited to determine the sample of IHEI with correlating the readiness and SDGs, where clustering methods was implemented analytically. The collection of data was obtained through self-reporting using the survey method. Therefore, this research is evidently expected to generate different insights by deeply analyzing digital readiness, particularly with the Network Readiness Index (NRI), while the modification is enabled.

1.2 *Related Works*

The following research is intended to be brief, besides a non-exhaustive review of previous studies related to composite indicators that are roughly similar due to some literature on the readiness index for educational institutions being largely broad and diverse. Thus, with a particular focus on those that applied the Network Readiness Index (NRI), it has become an inspiration to deploy within the educational institutions' context globally confirming the case in Indonesia.

Banhidi (2024) has applied Data Development Analysis (DEA), Network Readiness Index (NRI), and Common Weight Analysis (CWA) to generate a scoring model and ranking for developing countries in Europe[11]. The construction of analysis had been defined by authors such as Technology, People, Governance, and Impact and was completed with weights of sub-pillars, but the statistical analysis for investigating empirically was not provided. For example, correlational analysis and cluster analysis were recommended from empirical analysis with statistical tools. The study of readiness with NRI was replicated by Košíková (2025), who has applied the clustering analysis with the same case study (i.e., European countries)[12]. The objectives derived from the case study reflect the authors' attempt to integrate digital readiness with sustainable development. After that, the result of the analysis acknowledged the limitation, which focuses on the European country as the basis sample, although the method has embodied a viable framework so that it can potentially be conducted in Asia narrowly within the context of educational institutions in the next research. Both Banhidi's and Košíková's works have also been previously explored with statistical analysis. Relating to a similar case, to assist the role of government, NRI was often selected to measure the performance in leveraging digitalization, for which many of the indicators had been examined to identify the most influence. Diego S. Silva (2022), in the final reporting, has stated that individual indicators have more influence than others, as implied in the extant literature[7].

An applied approach in education readiness of a universal metric has been achieved on the rating assessment and hierarchical criterion, which is named the Index of Information and Communication Technology and was proposed by Zhanbirov (2022)[13]. The researchers who have investigated rating assessment adopted the analogy of the Network Readiness Index (NRI) to expand the readiness evaluation. Proposing the existing method of assessment metric had been being critically evaluated, it remains neither limited to the deep analysis regarding the readiness nor the evidence of investigations, which was not specifically revealed, while the study focuses on the weighting with scoring applied on indicators. Abroon Qazi (2025) has improved and enhanced existing methods from previous literature, as the Bayesian Belief Network (BBN) was utilized to systematically analyze factors influencing NRI according to more than 100 countries in 2023. Because NRI was often leveraged independently through traditional technique, four pillars of NRI were applied with probabilistic assessment.

Madina Tokmergenova (2023) has collated the set of relationship analyses for NRI with 12 sub-pillars[14]. Multivariate statistics were involved, with an emphasis on Principal Component Analysis (PCA), which was formulated to perform a mapping of data that was intended for a lower-dimensional space. In order to investigate the relationship among 12 sub-pillars, the partial correlation coefficient was employed to generate findings, which indicators have influence through causal analysis. Furthermore, cluster analysis was assigned to assemble definitively targeted objects after particular 12 sub-pillar relationship evaluations were timely achieved.

2. Research Method

The data collection process in this study involved gathering self-reported information from Islamic Higher Education Institutions (IHEIs) located in selected representative provinces across Indonesia. Each participating IHEI was invited to submit institutional data through a centralized online submission system managed by the national data center. The collected datasets included evidence files and supporting documentation related to digital readiness and sustainability performance. All submitted data were standardized in accordance with the National Readiness Index (NRI) framework, which served as a reference point for data validation and metadata organization. The metadata were subsequently curated and administered by the central data management team to ensure consistency and traceability. To identify comparable patterns between digital readiness and sustainable development performance among various IHEI profiles, a hierarchical cluster analysis was employed. This method enabled the classification of IHEIs into homogeneous groups based on two dimensions: (i) scores across the four NRI pillars, Technology, People, Governance, and Impact; and (ii) performance on four SDG-related indicators, namely quality education (SDG 4), industry, innovation, and infrastructure (SDG 9), sustainable cities and communities (SDG 11), and climate action (SDG 13). Selected SDG indicators were integrated into the NRI sub-pillars to reinforce the analytical framework. In line with existing literature, the technological pillar primarily emphasized accessibility, functionality, and technological advancement, all of which are associated with economic impact, quality of life, and contributions to sustainable development.

Exploring the dataset from the selected case, the original source was received from the nationally representative respondents after the submission of self-reporting. Overall, the four main pillars and the SDG-related ones were inserted substantially from NRI and have scoring value. The recognizing in this step has monitored more than 20 IHEI, the members of public education institutions under the Ministry of Religion, besides the distributed provinces area. The criteria of selected figures for analysis required the performance self-reporting in 2024 as considering the most definitive year of initiation.

In order to prepare high-quality analysis from incoming sources, such as both consistency and completeness, the processing of dataset verification was performed administratively at the beginning. Data preparation, particularly potential transformation and modification after evident submission, which is related to user interaction, was restricted. Furthermore, NRI pillars and SDG indicators were being reflectively plotted to be two main subsets for determination of indicative variables. Providing the score of the corresponding was achieved respectively from the representative institution in the province. The solvable evaluation of the internal relationship between NRI and the selected variable in the clustering was simulated to be reinforced significantly by both descriptive analysis and Pearson correlation coefficients (r)[15].

According to the proposed methodology, hierarchical cluster analysis was supportively calibrated when the multidimensional nature of NRI had been delivered due to the considering ability to expose latent groupings, which adjusted from structural similarities. When conducting comparable strategy studies and examining local variations in digital integration, this new technique provided a solid foundation. To reduce the total within-cluster variance, a recommended method such as Ward's would have been utilized pointedly to combine two clusters. The result of reducing the cluster further calculated the distance between units while the Euclidean distance method was involved. Because this research received the sample, it does not have such a big dataset, and although the distribution of the dataset was recognized widely, executing a combination of methods is suitable with the equalized and standardized scores. The activity of quantifiable analysis would generate two main parallel educational institution classifications, including digital readiness (accepting the four NRI pillars) and another segment on sustainable development contributions (leveraging the selected SDG indicators).

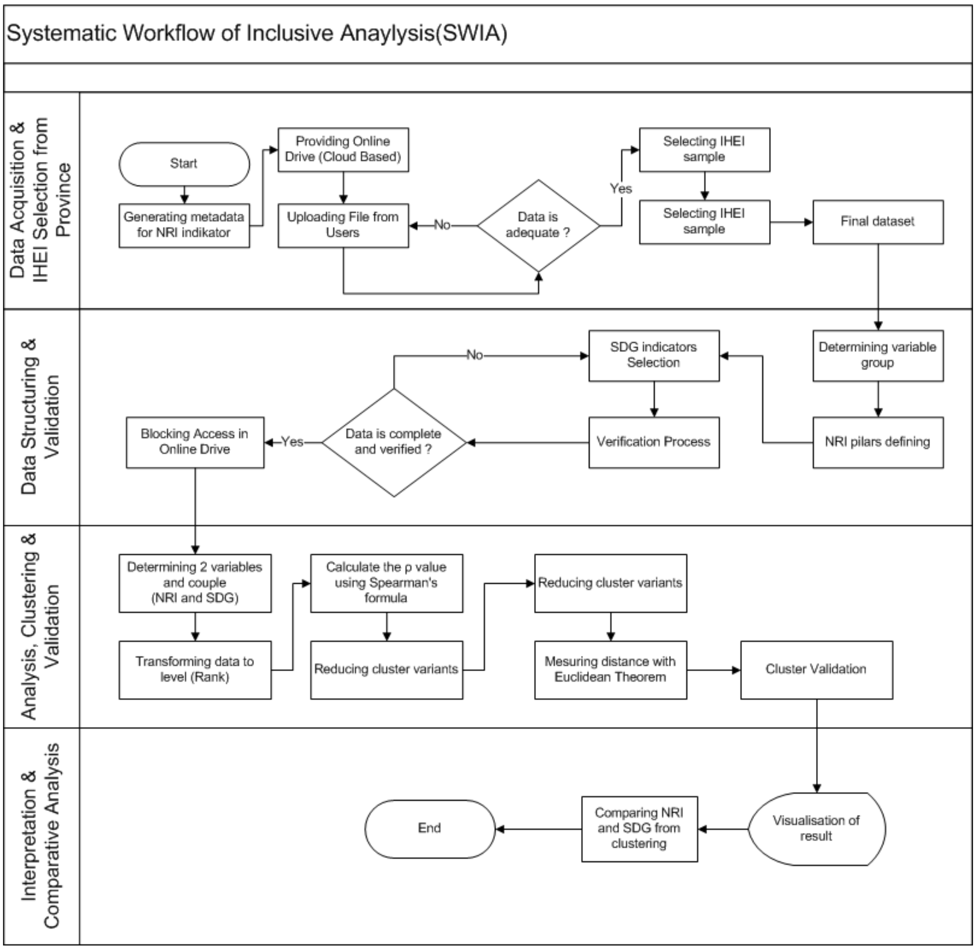

Figure 1. Methodological workflow of the study.

The clustering analysis was performed to optimize performance, and to find the best number of clusters, the related pseudo-T2 statistic was used[16]. These metrics help determine the optimal number of clusters by identifying the point at which two very different clusters merge. As a result of the sequential process of determining the ideal number of clusters, the NRI component form and the targets associated with the Sustainable are becoming optimal.

Moreover, presenting analysis results was illustrated through the utilization of a visual platform where not only was demographically distributed information presented but also empirical value. Juxtaposition and divergence between the country groupings had been appraised when a comparative analysis was applied to the two main concentrations, considering obvious digital readiness and SDG performance. In other words, attaching Spearman's rank correlation coefficient (rs) was involved to perform the assessment of classification, which is related to relationship; to that end, the quantifying value on monotonic had been recognized from respectively considering country rankings on the two sets of clusters.

An adequate analysis, specific understanding, and explorative conspicuousness were achieved with the implementation of correlation diagnostics and clustering toward the selected case study during the entire systematic workflow. Figure 1 illustrated the systematic workflow of the sequence analysis to present the performance of clustering with a completely visible framework. Therefore, the clustering analysis was supported as a suitable method to generate meaningful country typologies according to empirically evident relationships[17]. The objective of this study emphasized the pattern of convergence and divergence across IHEI representative provinces after the readiness and sustainable development outcomes had been explored through comparative observation on clustering.

3. Result and Discussion

Gradually, presenting the empirical findings from the work was outlined in this section, following the structure of the systematic workflow of inclusive analysis (SWIA). The ideal implementation of finding analysis is firstly evaluating the correlation context in statistically critical relationships when the four essential aspects of digital capability readiness (as outlined in the NRI) alongside the four targeted SDGs are regarded as primary indicators. Following the mentioned procedure, the internal coherence of the NRI had been appraised in this step to determine whether provinces with a higher level of readiness were represented by one of the IHEI, potentially illustrating more significant performance in specific sustainability domains. The characterization of provinces, which was represented by one of IHEI, was determined according to the defined two factors through hierarchical cluster analysis to employ these findings. There are two indications around classification, including digital readiness profiles from the province represented by IHEI and outcomes on the selected SDG indicators. Following the successful creation of clusters from the study results, patterns of the same or different across digital readiness and sustainability achievement were identified. Furthermore, the question is how tightly digital readiness is adjusted with SDG performance around the domestic level as the comparative analysis approach.

3.1. The Profile of Correlation Analysis

In the beginning, there are two main points to be delved into, such as the relationship in relation to the four fundamental pillars of the NRI (i.e., Technology, People, Governance, and Impact) and the selected definitive indicators (i.e., SDG 4, SDG 9, SDG 11, and SDG 13), until a correlation analysis is achieved before cluster analysis has been established effectively. It is obvious that the correlation analysis aims to assess the internal consistency and interconnection among the NRI pillars and to evaluate whether more prominent digital readiness is compatible with more significant sustainability performance. In order to provide precise intensity of differences across the province, which was represented by one of the IHEIs, the scoring process was applied toward every selected variable. Because the several variables in this case would be empirically examined related to the power of linear relationship, Pearson correlation coefficients were employed to furnish the statistical rudiments toward subsequent cluster analysis[18]. Moreover, according to the provided statement of the hypothesis in the previous section, a province, which is represented by IHEI, is significantly associated with the ability to contribute to the SDGs.

Table 1 is given to convey the generated result of Pearson correlation coefficients from the four NRI pillars and the elected SDG indicators[19]. The determination of correlation coefficients was sequentially categorized with three-level classification: if the values are below 0.40, then they are construed as either weak or insignificant correlations; values between 0.40 and 0.69 are moderate correlations; and values above 0.70 are strong positive correlations.

Table 1. Pearson Correlation Coefficient summary

Variables	A	B	C	D	SDG 4	SDG 9	SDG 11	SDG 13
A. Technology	1.000	0.7503	0.8097	0.8577	0.5612	0.7612	-0.0020	0.8652
B. People		1.000	0.7681	0.7902	0.3290	0.6953	-0.1634	0.8345
C. Governance			1.000	0.6178	0.5007	0.8622	-0.0801	-0.4012

D. Impact	1.000	0.7801	-0.0486	0.1047	0.5621
SDG 4		1.000	0.6617	0.1435	0.5631
SDG 9			1.000	-0.0376	0.4815
SDG 11				1.000	0.0361
SDG 13					1.000

The generated Pearson correlation on Table 1 presents the correlation matrix; the relationship among the NRI pillars was demonstrated initially with strong internal consistency. The technology and impact pillar (r = 0.8577) has achieved the highest correlation value, which implies a close link between technological advancement and the societal outcomes of digitalization. The next significant correlation in this result was followed by other pillars, between the pillar of technology and the pillar of governance (r = 0.8097) and between the people and impact pillars (r = 0.7902), for example. The presenting correlation matrix reveals that building a cohesive and interconnected system in the four main pillars has been embodied. It is clear that each pillar has unique value as a contribution, and the correlation approach does not achieve perfection at the multicollinearity (r = 1.0), notwithstanding the fact that the interrelationship was identified as strong. Notably, evaluated pillars indicated a distinct pattern of association, which attributed SDG-selected indicators, and the digital readiness–sustainability relationship was supported by the multidimensional nature.

After revealing the arguably described evidence from each NRI pillar, a distinct dimension of digital readiness is now identified. The infrastructure was reflected as technology, human capital and digital proficiency were denoted as people, regulatory quality and impact were pertained to as governance, and the societal and economic effect of digitalization was represented as impact. Internal consistency without suggesting statistical redundancy or collinearity was indicated by high values of inter-pillar. Each pillar presents a distinct yet interrelated perspective that collectively enhances the assessment of a province, which is represented by IHEI digital readiness.

Concerning the interplay between the digital pillars and the specified SDGs, the most prominent relational strength was noted between the Technology pillar and SDG 13 (r = 0.8652). Similarly, the Governance pillar also showed a strong correlation with SDG 9 (r = 0.8622), suggesting that the infrastructure and technology require the control of management and preparing for innovation investment in the strategic plan. Moderate-to-strong correlations between SDG 13 and the other pillars, such as Impact, reinforce the idea that the Impact pillar examined real results from the policy or adaptation program and changing mitigation; it is aligned that SDG 13 emphasized the policy implementation beside the strategic planning. Strong correlations were identified between the technology pillar and SDG 9 (r = 0.7612) as well as between people and SDG 13 (r = 0.8345). These findings suggest that the Technology pillar of the NRI is closely aligned with the goals of SDG 9, as it evaluates an IHEI from the representative province's digital infrastructure, technological readiness, and innovation capacity all of which are fundamental to building resilient infrastructure, fostering innovation, and promoting sustainable digitalization.

In opposition to this, the linkage between the People pillars and SDG 4 (r = 0.3290) is relatively low. The limited association observed could imply that the quality of individuals and education does not produce a direct or instant measurable impact on the education sector. The weak correlation between the People pillar of the NRI and SDG 4 suggests that while digital readiness at the individual level is important, it does not automatically translate into improvements in educational quality. This highlights the need for systemic integration of digital competencies into the educational ecosystem to achieve more meaningful progress toward quality education.

On the other hand, other SDGs, SDG 9, SDG 13, and the most critical, SDG 11, show no statistical measurable connection with any of the fundamental components of the NRI. As an illustration, the corresponding correlation coefficient for the Technology is practically nil (r = -0.0020), while the People have a somewhat negative value (r = -0.1634). Furthermore, neither the People (r = -0.1634) nor the Governance (r = -0.0801) have a statistically significant connection with SDG 11. These findings indicate that the level of digital governance of Islamic higher education in each province is not directly related to its performance in terms of social and urban impacts in the national context. Development through planned infrastructure and technology procurement and investment is driven by the establishment of reliable, inclusive digital governance, which is not aligned with development and sustainability strategies in the community and city sectors at the national level. Furthermore, improving human resources as part of the NRI (Network Readiness Index) needs to be carried out in line with the development of a programmed digitalization process governance. In reality, the human factor is central to all governance processes in welcoming the sustainability of communities and cities in a country, represented by each province in the digital readiness of Islamic educational institutions. The weak correlations thus highlight a potential thematic disconnect between the digital and sustainability agendas and emphasize efforts to better integrate both areas into national policy frameworks. A variety of digital tools, such as IoT, smart grids, smart cities, and even AI-based digital platforms, have the potential to accelerate progress on SDG 11, although this is not currently reflected in actual performance data.

3.2. Cluster Analysis

According to the presented correlation analysis result in the previous section, identification of a significant relationship was statistically achieved through the involvement of the pillar of digital readiness (NRI) and selected SDGs so that it continued gradually on hierarchical cluster analysis[20]. In other words, one of the objectives of a hierarchical cluster analysis was to classify the province represented by IHEI that was associated with two dimensions: (1) digital readiness profiles (Pillars of the NRI) and (2) performance in relation to selected SDGs (SDG 4, SDG 9, SDG 11, SDG 13).

The notably achieved clustering approach addressed enhancing insight from a deeper understanding of regional patterns; thus, both resemblance and discrepancy among IHEI from representative provinces had been illuminated in terms of digital readiness and sustainability performance. Consequently, the prepared correlation analysis not only supplied the effective framework through examination but also recognized various levels of readiness regarding two main concentrations in this study (digital readiness and sustainability). In the near future, the set of policies was designed to follow the priority that addresses the specific listed requirements for different province groups so that digital readiness in the digital transformation with the SDG has been assisted effectively.

3.3. Analysis of Clusters with Reference to NRI Pillars

In the clustering validation, whether the data was represented with one or two clusters so that it was intended to recommend the completely leveraging Duda–Hart index. Moreover, applying the Duda-Hart index was supported by the pseudo-T^2 value to determine the optimal point (according to the results of hierarchical clustering)[21]. Hence, first of all, the four main pillars of the NRI, such as technology, people, governance, and impact, were centralized to continue determining the optimal number of clusters in the hierarchical cluster analysis[22].

Given Table 2 demonstrated the Duda-Hart Index, the cluster distribution was identified by the NRI cluster analysis method with the intention of referring to the change in the Duda-Hart index (Je(2)/Je(1)), which significantly obtained a higher index value and a lower pseudo-T^2 value simultaneously, which was then considered as the optimal number of clusters. To exactly determine the most significant, refer to Figure 2. Breakpoints have been confirmed when dividing a number of provinces into five clusters, and this scheme was utilized for further interpretation and elucidation.

Table 2. Utilizing the Duda-Hart Index while considering the core pillars of the NRI

Number of Clusters	Je(2)/Je(1)	Pseudo-T2
1	0.328	57.23
2	0.356	23.10
3	0.461	10.34
4	0.512	5.56
5	0.701	3.19
6	0.000	0
7	0.412	5.34
8	0.392	3.45
9	0.472	4.53
10	0.000	0
11	0.178	0.32
12	0.219	3.41
13	0.231	3.56

The determination of the optimal number of clusters was conducted by evaluating two primary metrics, namely the Je(2)/Je(1) ratio and the Pseudo-T^2 value, calculated for cluster numbers ranging from 1 to 13. The results indicate that the Je(2)/Je(1) ratio consistently increased from 0.328 at one cluster to reach its highest peak of 0.701 at five clusters, suggesting a significant improvement in the quality of data partitioning at this point. Subsequently, the ratio sharply decreased to zero at six and ten clusters, which may indicate no improvement in cluster quality or possible errors in cluster formation at these points. The Pseudo-T^2 values also followed a significant downward trend, starting at 57.23 for one cluster and progressively decreasing to a low of 3.193 at five clusters. This decline indicates that clustering at five clusters yields the most significant and stable separation. Although Pseudo-T^2 values at certain points, such as six and ten clusters, were zero, overall trends in both metrics support the conclusion that the optimal number of clusters in this analysis is five. This conclusion is based on the highest peak in the Je(2)/Je(1) ratio and the lowest Pseudo-T^2 value, which indicate a significant breakpoint in the data segmentation.

3.4. Cluster Analysis Considering SDGs

The assessment of the selected SDGs specifically assigned in this second section includes four SDG aspects, namely SDG 4, SDG 9, SDG 11, and SDG 13. The assessment of the SDG context relates to the homogeneous character among the provinces represented by the IHEI, which indicated similar performance in various sustainability areas[23]. Thus, a homogeneous group regarding the collection of provinces based on the IHEI is identified. In substance, the applied method is also conducted with the identical objective of stipulating the optimal number of clusters; the Duda-Hart index is respectively involved and remains in the context of combination with pseudo-T2 statistics. This approach is presented with the intention that the clusters are divided appropriately, following the significant changes in the variance ratio and the corresponding pseudo-T2 values. With the same case shown in Table 3, it is clear that there are breakpoints that were observed when it was divided into five clusters, which also adjusted with the visual pattern identified. Thus, the number of clusters used as a basis has been refined with labeled boxes in order to increase the clarity of the grouping of provinces within each cluster.

To speculatively determine the most appropriate the total number of distinct clusters identified, the structural composition of clusters is assessed with the Je(2)/Je(1) ratio in conjunction with the Pseudo-T^2 test statistic for cluster numbers ranging from 1 to 13. The Je(2)/Je(1) ratio increased steadily from 0.407 for one cluster to a maximum value of 0.696 at five clusters, suggesting that the clustering quality improved most significantly at this stage. In parallel, the Pseudo-T^2 value dropped considerably, from 47.45 at one cluster to 5.21 at five clusters, indicating that inter-cluster separation became more distinct and stable.

Table 3. Analysis employing the Duda-Hart Index while incorporating aspects of the SDGs

Number of Clusters	Je(2)/Je(1)	Pseudo-T2
1	0.407	47.45
2	0.423	33.21
3	0.439	27.45
4	0.524	15.67
5	0.696	5.21
6	0.000	0
7	0.249	5.43
8	0.327	3.51
9	0.451	4.65
10	0.000	0
11	0.108	0.46
12	0.227	3.52
13	0.328	3.68

Notably, both metrics showed abrupt drops at six and ten clusters, with values of zero, implying either an over-partitioning of the data or a breakdown in the meaningfulness of further cluster separation. After the five-cluster solution, the patterns in both metrics fluctuated with no consistent trend, and no values surpassed those observed at the five-cluster mark. These findings strongly indicate that the five-cluster solution offers the most effective and interpretable partitioning of the dataset, as it is associated with both the peak in the Je(2)/Je(1) ratio and a substantial decline in the Pseudo-T^2 statistic.

3.5. Comparison of Province Classification References from NRI and SDGs

On the one hand, when two separate cluster analyses have been achieved one according to the main four pillars of digital readiness about the NRI definitive aspects (Technology, People, Governance, Impact), the selected SDG indicators (4, 9, 11, 13) were determined in another step. There are two main points: both digital readiness and sustainability performance are dependent analyses from the clusters that have several provinces (represented by IHEI). The normal assignment of provinces to the concerned NRI and the provided SDG of listed clusters appeared in Table 4.

Specifically, in order to ensure the availability of a linear relation in the between provinces' rankings in the digitalization forwardness and SDG accomplishment clusters, further analysis attempts to adopt the method of Spearman's rank correlation in evaluation and adequately pertains to the examination of the degree of alignment. Although this relationship was not strictly confirmed to be linear, the observation upon the notable deviation remained. Overall, the provinces exhibiting elevated degrees of digital readiness commonly achieve superior results relative to the mean in the selected SDG metrics, which was proven by the generating correlation coefficient (rs = 0.615) with a moderately intense positive correlation.

The greatest consistency across rankings is discovered toward the identified provinces such as Lampung, West Java, Yogyakarta, and South Sulawesi. Some of these provinces are considered essentially at the lead in digital readiness (clusters 1, 3, and 4). Conversely, several provinces including West Kalimantan, North Sulawesi, West Sulawesi, and Maluku are categorized within the lower digital readiness clusters (Clusters 4 and 5), yet demonstrate relatively higher rankings in the SDG clusters (Cluster 2). The identified pattern appears to indicate a potentially synergistic relationship between constrained digital preparedness and persistent sustainability deficits. This dynamic is particularly exemplified by provinces such as Jambi, Bengkulu, and Papua, each of which is situated within the lowest tier of digital readiness (Cluster 5), thereby reinforcing the manifestation of this phenomenon. Evidence of this alignment is prominently reflected in both Table 4 and the contingency heatmap

(Figure 4), which collectively highlight the spatial and categorical convergence between underdeveloped digital infrastructures and suboptimal sustainability outcomes. The recurrent co-location of provinces within both low-performing NRI and SDG clusters suggests a notable intersection of the digital divide and sustainability challenges.

Table 4. Comparative Levels of NRI and SDG Performance Across Indonesian Provinces

Province	NRI	SDGs	Province	NRI	SDGs
Aceh	2	3	West Kalimantan	4	2
North Sumatera	1	3	Central Kalimantan	3	4
West Sumatera	2	3	South Kalimantan	1	4
Jambi	5	5	East Kalimantan	1	5
Riau	3	1	North Sulawesi	4	2
Bengkulu	5	3	Gorontalo	3	1
South Sumatera	2	5	Central Sulawesi	2	2
Lampung	1	1	South Sulawesi	1	1
Banten	3	5	South-East Sulawesi	3	5
DKI Jakarta	2	5	West Sulawesi	4	1
West Java	1	1	Maluku	4	5
Central Java	2	2	West Nusa Tenggara	2	3
Yogyakarta	1	1	Papua	5	2
East Java	2	3			

Although this association does not manifest uniformly across all regional contexts, the persistent pattern observed in several cases implies the existence of a systemic interplay one in which digital underdevelopment may act as a structural barrier to accelerated progress toward the Sustainable Development Goals.

Simultaneously, the analysis revealed significant inconsistencies in the alignment between digital readiness and sustainability outcomes. A salient example is provided by East Kalimantan Province, which, despite its inclusion in the most advanced NRI grouping (Cluster 1), is concurrently classified within the lowest-performing SDG cluster (Cluster 5). In contrast, West Sulawesi demonstrates an inverse pattern, as it occupies a lower-tier position within the NRI framework (Cluster 4) while attaining the highest level of achievement in terms of SDG performance. These pronounced disparities may reflect a partial decoupling between digital infrastructure development and its practical application in fostering sustainable outcomes. Specifically, such misalignments might indicate that elevated digital capabilities have not yet been effectively operationalized, or that institutional frameworks necessary for supporting digital transformation remain underdeveloped in comparison to those facilitating progress in sustainability objectives. This observed disjunction emphasizes the pivotal role played by human capital not only in driving technological adoption, but also in cultivating environmental consciousness and promoting long-term sustainability.

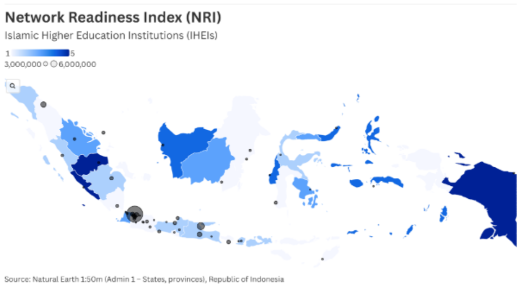

Figure 2. Cartogram considering pilar of NRI.

Figure 3. Cartogram considering SDGs.

Figure 2 illustrated the visualization of the geographic distribution of the digital readiness cluster of the NRI pillar, and Figure 3 demonstrated the distribution of SDGs clusters[24]. These figures are explained visually from the comparison of clustering from Table 4. Both figures (Figures 2 and 3) display clusters in provinces across Indonesia, specifically represented by Islamic educational institutions. Indicators are represented by color depth, with the lightest colors indicating the highest ranking. The results of these two figures clearly demonstrate a distinction between digital readiness (NRI) and sustainability.

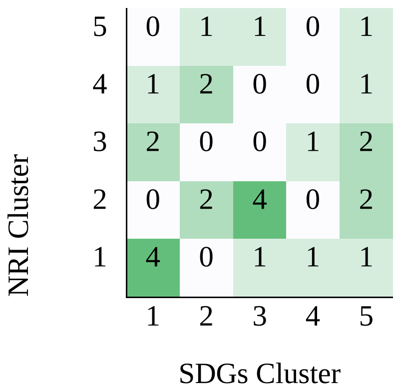

Figure 4. Possibility heatmap analysis from different color classification.

The validity of these observations is further reinforced by the contingency heatmap (Figure 4), which visually articulates the spatial distribution of provincial entities across the intersecting categories of the Networked Readiness Index (NRI) and Sustainable Development Goals (SDG) clusters. A particularly notable concentration encompassing four distinct provinces emerges at the intersection of NRI Cluster 1 and SDG Cluster 1. This prominent convergence serves as a compelling indication of a strong alignment between digital readiness and sustainability performance within this subset. An equivalent magnitude of clustering is also discernible at the intersection of NRI Cluster 2 and SDG Cluster 3, thereby suggesting a comparably high level of internal consistency in the alignment between digital infrastructure development and sustainability indicators. Furthermore, other intersection specifically those involving NRI Cluster 2 with SDG Cluster 5, as well as NRI Cluster 3 with SDG Cluster 5 underscore additional patterns of notable cluster overlap, thereby reinforcing the presence of systematic relationships between varying levels of digital preparedness and sustainable development outcomes.

The connection between digital readiness and SDG 13 lies in the enabling role of digitalization in promoting environmentally sustainable practices within IHEIs. A higher level of digital readiness allows institutions to implement energy-efficient technologies, adopt paperless and remote systems, and monitor resource utilization through digital tools, all of which contribute to reducing carbon emissions. Moreover, digitally advanced institutions are better positioned to conduct climate-related research and integrate sustainability into their curricula and campus management. Therefore, digital readiness indirectly supports climate action by strengthening institutional capacity and innovation toward sustainability goals.

On the one hand, the study specifically focuses on Islamic Higher Education Institutions (IHEIs) as a distinctive segment within Indonesia's higher education system, characterized by unique governance structures, funding mechanisms, and socio-religious missions. In contrast to public or private secular universities, IHEIs encounter additional challenges in digital transformation arising from resource disparities, regulatory dependencies, and cultural considerations in technology adoption. Focusing on IHEIs enables a context-sensitive understanding of digital readiness and sustainability alignment within faith-based education systems. The scope was therefore deliberately limited to IHEIs to ensure analytical depth and contextual relevance rather than broad generalization across all higher education institutions.

4. Conclusion

This study presents a correlation analysis between digital readiness in the network readiness index and sustainable development in the context of Islamic Higher Education Institutions. Observations have clarified that the clustering analysis results present quite significant differences between digital readiness in IHEIs and sustainable development. Twenty-seven Islamic educational institutions have been assessed in terms of digital readiness and sustainable development. Three institutions indicated consistency between digital readiness and sustainable development, while the other institutions also had quite high readiness index values with inconsistent SDG values. Initially, the correlation process was supported by the Pearson coefficient to determine the relationship; furthermore, clustering methods such as Duda-Hart showed performance capable of distinguishing two clusters between digital readiness and sustainable development. Future research should combine classification and clustering among IHEIs related to digital readiness and sustainable development.

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