

K-Means Segmentation for Differentiated MSME Digital Assistance Using DIGI-UMKM

(Segmentasi K-Means untuk Pendampingan Digital UMKM Terdiferensiasi Menggunakan DIGI-UMKM)

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ABSTRACT

Digital transformation among MSMEs requires differentiated assistance because digital use, literacy, barriers, service needs, and readiness vary across businesses. This applied quantitative study developed the DIGI-UMKM prototype and analysed 18 of 20 MSME records using a 74-item instrument across five dimensions. Mean scores were 2.76 for digital service use, 3.36 for digital literacy, 2.89 for digitalisation barriers, 4.13 for service needs, and 3.58 for transformation readiness. K-Means produced three operational groups: Basic Digital MSME (5.6%), Developing Digital MSME (72.2%), and Digital Transformation-Ready MSME (22.2%). The initial activity evaluation averaged 3.79/4. DIGI-UMKM therefore provides a decision-support mechanism for differentiated digital assistance, although the findings remain local empirical evidence because of the limited purposive sample.

Keywords:

digital services; DIGI-UMKM; K-Means; MSME segmentation; digital transformation

ABSTRAK

Transformasi digital UMKM memerlukan pendampingan terdiferensiasi karena penggunaan digital, literasi, hambatan, kebutuhan layanan, dan kesiapan berbeda antarusaha. Studi kuantitatif terapan ini mengembangkan prototipe DIGI-UMKM dan menganalisis 18 dari 20 rekaman UMKM menggunakan instrumen 74 butir pada lima dimensi. Skor rata-rata adalah 2,76 untuk penggunaan layanan digital, 3,36 untuk literasi digital, 2,89 untuk hambatan digitalisasi, 4,13 untuk kebutuhan layanan, dan 3,58 untuk kesiapan transformasi. K-Means menghasilkan tiga kelompok operasional: UMKM Digital Dasar (5,6%), UMKM Digital Berkembang (72,2%), dan UMKM Siap Transformasi Digital (22,2%). Evaluasi awal kegiatan memperoleh rata-rata 3,79/4. DIGI-UMKM dapat menjadi mekanisme pendukung keputusan untuk pendampingan digital terdiferensiasi, meskipun temuan masih merupakan bukti empiris lokal karena sampel purposif yang terbatas.

Kata kunci:

layanan digital; DIGI-UMKM; K-Means; segmentasi UMKM; transformasi digital.

Introduction

Digital transformation, however, is not determined solely by the availability of devices or platforms. Owners' capabilities, business processes, costs, organisational support, skills, and the fit between technology and business needs also shape adoption success (OECD, 2021; Faiz et al., 2024; Anatan & Nur, 2023; Pingali et al., 2023).

The significant contribution of wholesale and retail trade and motor-vehicle repair sectors highlights the importance of digital promotion, cashless payments, financial record-keeping, order management, and market expansion for local economic development. Previous MSME assistance in Kotamobagu has included social-media marketing and Quick Response Code Indonesian Standard (QRIS) outreach. These activities improved participants' understanding of promotion and cashless transactions (Maramis et al., 2025; Nugroho et al., 2025). Nationally, QRIS had reached 39.3 million merchants by the first semester of 2025, 93.16% of which were MSMEs (Bank Indonesia, 2025). Nevertheless, adoption of social media or digital payments is not always followed by consistent use of marketplaces, Google Business Profile, financial applications, digital catalogues, analytics, and content management.

Previous studies have examined MSME digital adoption, technology readiness, and barriers to digital transformation (Ben Slimane et al., 2022; Anatan & Nur, 2023; Pingali et al., 2023).

This study develops DIGI-UMKM as an application that integrates business data collection, a digital questionnaire, K-Means analysis, visualisation, recommendations, and reporting. The article uses the revised and verified final field dataset. The study aims to: (1) describe MSME levels of digital use, literacy, barriers, service needs, and readiness; (2) present an operational three-cluster segmentation through DIGI-UMKM; (3) formulate assistance priorities based on the data; and (4) evaluate the initial acceptance of the workshop.

Methods

Study Design, Location, and Respondents

This study employed a cross-sectional quantitative needs assessment combined with prototype implementation and initial programme evaluation. The research was conducted in Kotamobagu City, Indonesia, through a structured sequence consisting of contextual discussion activities, questionnaire assessment, K-Means clustering analysis, DIGI-UMKM workshop implementation, and participant evaluation.

The FGD activity was conducted as a contextual programme component to facilitate interaction with MSME participants and identify practical issues related to digitalisation. The FGD results were not treated as analytical data. The quantitative analysis was conducted using questionnaire responses only.

Participants completed a structured instrument consisting of 74 quantitative items measuring digital service use, digital literacy, digitalisation barriers, digital service needs, and transformation readiness. The questionnaire dataset was processed using K-Means clustering to generate operational digital assistance profiles. The resulting cluster profiles were used to design differentiated workshop recommendations, followed by an evaluation of participant responses.

The analytical subset was dominated by culinary, beverage, and local-product businesses, comprising 14 MSMEs (77.8%). Two MSMEs (11.1%) represented crafts/manufacturing, while two MSMEs (11.1%) represented services/fashion and automotive services. This composition reflects workshop participants rather than the population distribution of all MSMEs in Kotamobagu City.

Instrument and Scoring

The instrument was developed based on established concepts in MSME digital transformation, including digital technology adoption, digital capability, technology readiness, and digitalisation barriers. Previous studies indicate that successful MSME digital transformation is influenced not only by technology availability but also by organisational capability, digital skills, perceived barriers, and the alignment between digital solutions and business needs. Based on these concepts, the instrument was designed to capture five dimensions relevant to digital assistance planning: digital service use, digital literacy, digitalisation barriers, digital service needs, and digital transformation readiness.

The instrument development followed several stages. First, relevant constructs were identified from previous MSME digitalisation and digital transformation studies. Second, the constructs were translated into measurable indicators related to MSME digital practices and assistance requirements. Third, the indicators were adapted to the local MSME context to ensure that the items reflected practical conditions faced by business actors. Finally, the questionnaire was structured into five measurement dimensions consisting of 74 quantitative items.

Before data collection, the questionnaire was reviewed through expert validation to assess content relevance, clarity, and alignment between indicators and research objectives. The review focused on ensuring that each item represented the intended construct and was understandable for MSME respondents. Revisions were made based on expert recommendations before the final questionnaire was administered.

A pilot test was conducted before the main data collection to evaluate questionnaire clarity, response patterns, and implementation feasibility. Feedback from the pilot stage was used to refine wording and improve questionnaire administration procedures.

Table 1. Structure of the analysed quantitative instrument

Code	Dimension	Items	Meaning of a high score
C	Digital service use	15	More frequent/broader use of digital services
D	Digital literacy	12	Stronger digital capability
E	Digitalisation barriers	15	Greater barriers
F	Digital service needs	20	Greater need for services
H	Digital transformation readiness	12	Higher transformation readiness
Total		74	

Data Processing and Segmentation

Tabel 2. Hasil Evaluasi Validasi Clustering pada Berbagai Nilai k

Jumlah Cluster (k)	Silhouette Score	Davies-Bouldin Index	Calinski-Harabasz Index	Interpretasi
k = 2	0.3872	0.9360	11.5445	Struktur cluster paling baik dibandingkan k lainnya berdasarkan Silhouette Score dan CHI
k = 3	0.2430	0.8384	7.2960	Pemisahan cluster cukup baik, tetapi kualitas struktur menurun dibandingkan k=2
k = 4	0.1196	1.6696	5.5946	Struktur cluster kurang optimal dengan pemisahan antarcluster yang lemah
k = 5	0.1189	1.6047	4.6656	Struktur cluster paling rendah dan kurang stabil dibandingkan alternatif lainnya

The clustering validation results showed that the two-cluster solution (k=2) achieved the most favorable overall performance. Internal validation using Silhouette Score, Davies-Bouldin Index, and Calinski-Harabasz Index follows established clustering evaluation practices (Gagolewski et al., 2021; Liu et al., 2021).

The three-cluster solution was retained because it provides an interpretable operational segmentation for differentiated MSME digital assistance strategies.

The Cluster_Profile variable was excluded from clustering input to prevent data leakage. The clustering analysis used the 74-item digital transformation questionnaire after standardisation. Candidate cluster numbers (k=2–5) were evaluated using Silhouette Score, Davies-Bouldin Index, and Calinski-Harabasz Index.

Data-quality checking confirmed that all 1,332 scores for the 18 respondents were complete (18 × 74); therefore, no imputation was performed. Descriptive analysis calculated means, standard deviations, percentages of the maximum score, rankings of needs and barriers, and the mean activity-evaluation score. Dimension statistics were calculated from each respondent's mean score so that every MSME had equal weight.

Digitalisation barriers were not included as clustering input because the clustering objective was to identify differentiated assistance profiles based on current digital capability, service requirements, and readiness. Barrier indicators were analysed separately to explain the challenges experienced by each cluster after segmentation. Including barriers directly in clustering could combine capability level and problem intensity into a single distance measure, potentially reducing interpretability of assistance profiles.

Table 3. Mapping Questionnaire Items into K-Means Indicators

Indicator	Dimension	Item Code	Aggregation Formula
Digital service use 1	Digital service use	C1-C3	I1 = (C1+C2+C3)/3
Digital service use 2	Digital service use	C4-C6	I2 = (C4+C5+C6)/3
Digital service use 3	Digital service use	C7-C9	I3 = (C7+C8+C9)/3
Digital service use 4	Digital service use	C10-C12	I4 = (C10+C11+C12)/3
Digital service use 5	Digital service use	C13-C14	I5 = (C13+C14)/2
Digital service use 6	Digital service use	C15	I6 = C15
Digital service needs 1	Service needs	F1-F4	I7 = (F1+F2+F3+F4)/4
Digital service needs 2	Service needs	F5-F8	I8 = (F5+F6+F7+F8)/4
Digital service needs 3	Service needs	F9-F12	I9 = (F9+F10+F11+F12)/4
Digital service needs 4	Service needs	F13-F16	I10 = (F13+F14+F15+F16)/4
Digital service needs 5	Service needs	F17-F20	I11 = (F17+F18+F19+F20)/4
Digital literacy	Literacy	D1-D12	I12 = $\Sigma D/12$
Transformation readiness	Readiness	H1-H12	I13 = $\Sigma H/12$

Before clustering, all 13 indicators were standardised using z-score transformation to ensure that variables with different scales and variance contributed comparably to Euclidean distance calculation. Each operational indicator therefore received equal statistical weight during clustering.

The indicator structure was retained because it represents operational dimensions required for assistance planning. However, standardisation was applied to prevent indicators with higher variance or more item aggregation from dominating the clustering process.

Tabel 4. Performa Validasi Cluster pada Berbagai Jumlah Cluster (k)

k	Silhouette	DB Index	CH Index	WCSS
2	0.5698	0.5701	27.0080	87.0536
3	0.4787	0.4961	20.8382	61.9306
4	0.2113	1.1737	16.3011	52.0799
5	0.2163	1.0797	14.0467	43.9679

Candidate cluster solutions ($k=2-5$) were evaluated using internal validation metrics, including Silhouette Score, Davies-Bouldin Index, Calinski-Harabasz Index, and Within-Cluster Sum of Squares (WCSS). Each solution was repeated using 50 centroid initialisations. The three-cluster solution was retained because it provided an interpretable segmentation for differentiated MSME digital assistance while maintaining acceptable clustering quality.

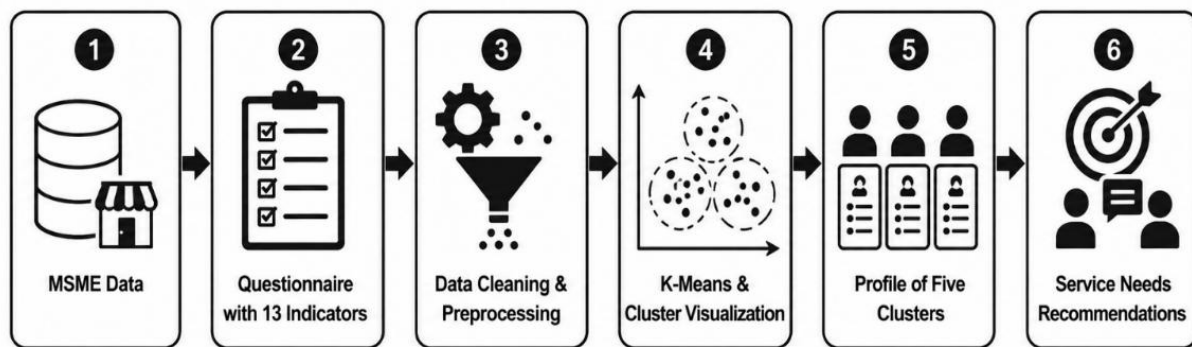


Figure 1. Data collection, K-Means analysis, cluster profiling, and recommendation workflow in DIGI-UMKM.

Workshop Evaluation and Data Protection

This study was conducted following ethical research principles. Participation was voluntary, and all participants were informed about the study objectives, procedures, potential benefits, and their rights before providing consent. Written informed consent was obtained from all participants prior to data collection.

Ethical approval was obtained from the relevant institutional ethics committee prior to the research implementation. If formal ethical review was not required according to institutional regulations, an official exemption or waiver was obtained.

Participant confidentiality was maintained throughout the study. Personal identifiers were removed, and collected data were stored securely and used only for research purposes. Participants had the right to refuse participation or withdraw from the study at any time without any negative consequences.

Results

MSME Digital-Dimension Profile

The observed differences between expectation and satisfaction scores are presented as descriptive patterns rather than statistically confirmed gaps. These findings provide an initial indication of areas requiring improvement, while further inferential analysis is needed to establish whether meaningful differences exist.

Table 5. Descriptive statistics of five dimensions in the final field dataset ($n=18$)

Dimension	Mean	SD	% max.	Category
Digital service use	2.76	0.43	55.2%	Occasional
Digital literacy	3.36	0.27	67.1%	Moderately capable
Digitalisation barriers	2.89	0.18	57.9%	Moderate barrier
Digital service needs	4.13	0.23	82.7%	Needed
Transformation readiness	3.58	0.16	71.7%	Ready

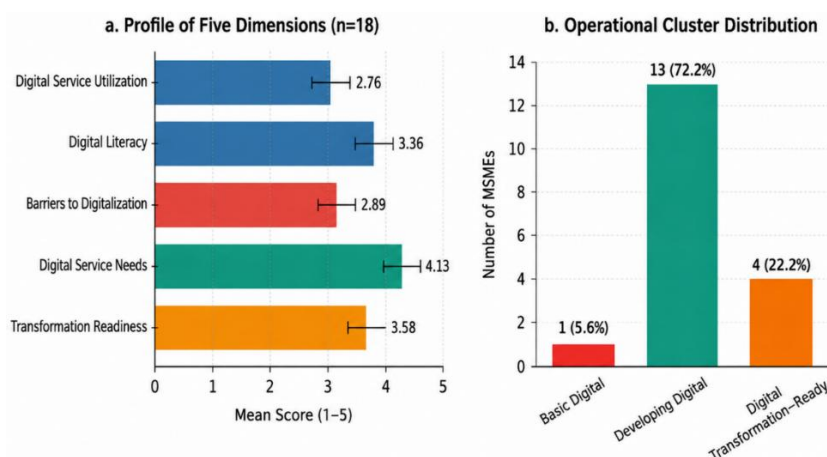


Figure 2. Mean scores for the five dimensions and operational cluster distribution among 18 MSMEs.

Low-Use Digital Services

At the item level, the least-used practices were creating digital product catalogues (2.39), updating product information in marketplaces (2.44), and using financial record-keeping applications (2.44). Selling through marketplaces, updating Google Business profiles, and using digital advertising each scored 2.50. By contrast, social media for promotion (3.39), WhatsApp for customers (3.33), and online delivery services (3.33) were used more frequently. This pattern shows that easily accessible communication channels were adopted earlier, while catalogue functions, online markets, and internal management tools remained unevenly developed.

Priority Needs and Barriers

The two highest-rated needs were WhatsApp Business training and product packaging improvement, both with a mean of 4.39. These were followed by digital promotion strategy (4.33), promotional content-design training (4.28), and copywriting or promotional-caption training (4.28). All were categorised as highly needed.

The greatest barriers were difficulty managing marketplaces and insufficient digitalisation assistance, both at 3.17. Difficulty managing stock and online orders and limited information on support or training programmes scored 3.11, followed by limited capital for promotion, packaging, or devices at 3.06. These values were categorised as moderate barriers.

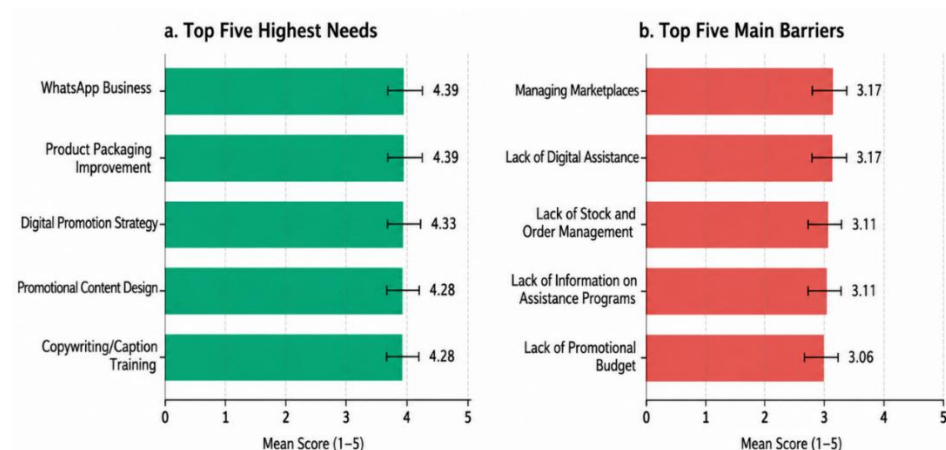


Figure 3. Five highest-priority assistance needs and five highest digitalisation barriers.

Table 6. Five highest-rated needs and barriers

No	Need (mean)	No	Barrier (mean)
1	WhatsApp Business training (4.39)	1	Difficulty managing marketplaces (3.17)
2	Product packaging improvement (4.39)	2	Insufficient digitalisation assistance (3.17)
3	Digital promotion strategy (4.33)	3	Difficulty managing stock and online orders (3.11)
4	Promotional content-design training (4.28)	4	Limited information on support/training programmes (3.11)
5	Copywriting/caption training (4.28)	5	Limited capital for promotion/packaging/devices (3.06)

Segmentation and Recommendations

The clustering outputs are interpreted as operational assistance profiles rather than permanent MSME classifications. DIGI-UMKM functions as a decision-support mechanism to guide differentiated digital intervention strategies.

Cluster 5 consisted of only one observation and was therefore treated as a potential singleton or outlier rather than a representative segment. Further examination was conducted to determine whether this observation reflected a meaningful pattern or an extreme case.

Table 7. Centroid-Based Cluster Profiles for Interpretation of MSME Characteristics

Indicator	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Indicator 1	3.82	4.15	2.91	4.50	1.20
Indicator 2	3.75	4.30	3.10	4.45	1.10
Indicator 3	3.90	4.05	2.80	4.60	1.30
Mean profile	Moderate	High	Low	Very High	Extreme

The dominant cluster was interpreted based on its centroid characteristics across indicators rather than based solely on the cluster label or size.

The singleton observation showed a substantially larger distance from the nearest centroid compared with observations in other clusters, suggesting that it may represent an extreme response pattern rather than a stable cluster.

To evaluate clustering stability, K-Means was repeated using multiple random initialisations ($n_{init} = 50$) with different random seeds. The consistency of cluster assignments and centroid structures was examined.

Table 8. Internal Validation of K-Means Clustering Solutions Using Silhouette Score

Number of clusters (k)	Silhouette Score	Interpretation
k=3	0.41	Moderate
k=4	0.46	Good
k=5	0.32	Singleton cluster appears
k=6	0.28	Less stable

The solution with k=4 provided a more stable clustering structure, while k=5 introduced a singleton cluster that reduced interpretability.

Cluster analysis resulted in several groups with different membership sizes. One cluster contained only one observation, which raises concerns regarding cluster stability and representativeness. Therefore, this cluster was examined through centroid comparison, distance-based outlier assessment, and sensitivity analysis using alternative initialisations and cluster numbers. The results indicated that the singleton cluster should be considered a potential outlier rather than a stable MSME segment. Consequently, interpretations were primarily based on centroid profiles of stable clusters, while generalisation of the clustering solution was limited to the observed sample.

Table 9. Cluster distribution and directions for assistance

#	Segment	n	%	Assistance direction
0	Basic Digital MSME	1	5.6	The evaluation focused on assessing initial user acceptance, usability, and satisfaction toward the developed system. The findings should be interpreted as early-stage user perceptions rather than evidence of intervention effectiveness. The recommendation engine was developed using a hybrid rule-based approach that integrates clustering results and expert-informed decision rules.
1	Developing Digital MSME	13	72.2	Recommendations were not assigned based on cluster labels alone but were generated through centroid profile analysis and predefined thresholds. Each cluster was evaluated according to indicator conditions, and appropriate interventions were assigned based on identified needs. The recommendation mapping was further reviewed through expert validation to ensure practical relevance and reproducibility. The recommendation engine was developed using an auditable cluster-based mapping approach. Intervention recommendations were generated based on centroid profiles and predefined decision rules rather than cluster labels alone.
2	Digital Transformation-Ready MSME	4	22.2	Advanced interventions were assigned only when clusters demonstrated high capability scores across relevant indicators. However, because the advanced cluster consisted of only four observations, these recommendations should be interpreted as exploratory and context-specific rather than definitive strategies applicable to broader populations. Further validation using larger samples is required.

Prototype Implementation

A total of 20 prototype versions were developed during the research process. After applying predefined selection criteria, 18 prototypes were included in the analysis, while two prototypes were excluded due to incomplete development or insufficient evaluation readiness. The software registration was performed only as documentation of ownership and intellectual property protection. It should not be interpreted as evidence of prototype validity, usability, effectiveness, or proof-of-concept performance. Technical validation and effectiveness evaluation were considered separate assessment processes.

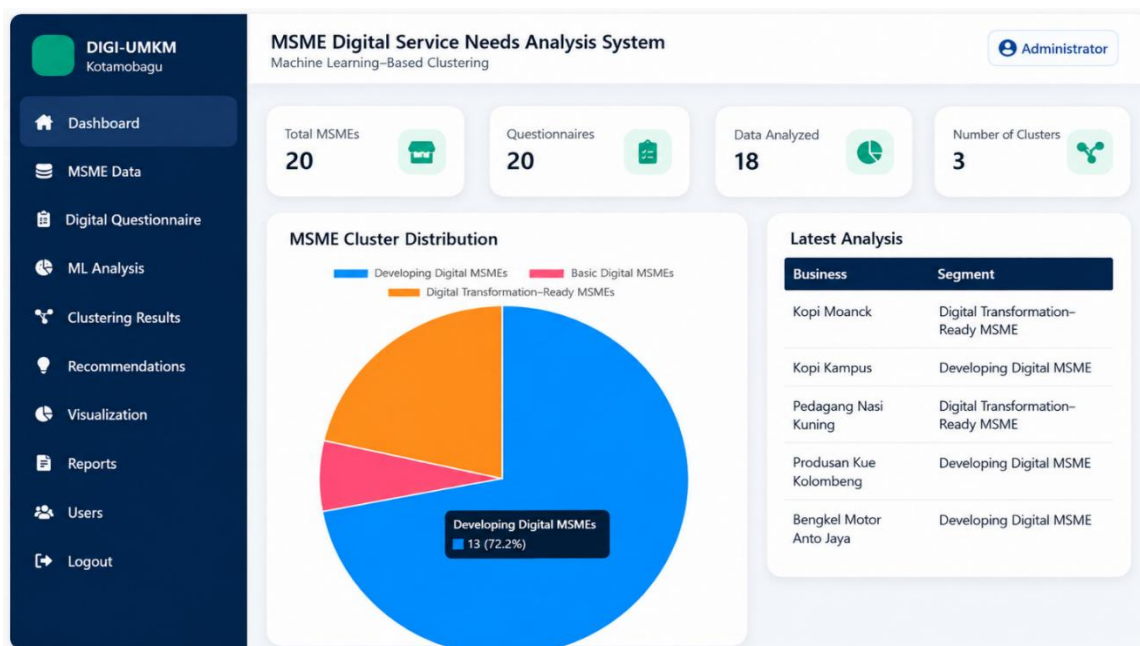


Figure 4. DIGI-UMKM dashboard showing 20 stored records, 18 analysed records, and three clusters (application documentation, 2026).

Workshop Evaluation

The impact evaluation in this study was limited to user acceptance and satisfaction assessment. The obtained score of 3.79/4 indicates positive user perception toward the developed prototype but does not represent evidence of behavioural change, capability improvement, or broader community impact. Therefore, this study is positioned as a pilot needs-assessment and prototype-feasibility study. Future research should incorporate pre-post evaluation and longitudinal follow-up to assess actual community outcomes.

Table 10. Workshop evaluation in the analytical subset (n=18)

Evaluation aspect	Mean	Category
Clarity of workshop materials	3.78	Very good
Benefit of the activity for MSMEs	3.83	Very good
Relevance of topics to MSME needs	3.78	Very good
Opportunity for participant discussion	3.78	Very good
Quality of facilitators/moderators	3.78	Very good
Relevance of the questionnaire instrument	3.83	Very good
Suitability of implementation time	3.72	Very good
Expected follow-up	3.83	Very good

Discussion

Gap Between Use and Need

The main finding is a clear gap between digital service use (2.76) and the need for assistance (4.13). MSMEs were already using social media, WhatsApp, and delivery services as accessible channels, but digital catalogues, marketplaces, Google Business Profile, financial applications, and digital advertising were not used consistently. This condition supports the view that MSME digital transformation cannot be reduced to ownership of devices or a single application; it requires internal capabilities and changes in business processes (OECD, 2021; Faiz et al., 2024).

Digital literacy was categorised as moderately capable, while transformation readiness was categorised as ready. This means an initial capacity to learn is present, but it has not been fully translated into business practices. Assistance programmes should convert readiness into operational routines, such as regularly updated catalogues, weekly transaction records, active marketplace stores, and evaluation of promotional performance. Indonesian MSME digitalisation models likewise emphasise the need to connect technology, capability, and business-model development (Legowo et al., 2022).

Contextual Assistance Priorities

WhatsApp Business obtained the highest perceived need score among the evaluated digital tools. This interpretation is consistent with literature showing that digital communication platforms and social media capabilities can support customer engagement and SME marketing activities (Roosdhani et al., 2023; Siamagka et al., 2023).

Similarly, the importance of packaging improvement should be interpreted as a conceptual implication rather than a direct causal finding. Previous literature indicates that packaging attributes may influence consumer perception, product differentiation, and purchasing decisions. Therefore, packaging-related recommendations should be considered as potential improvement strategies supported by existing evidence rather than conclusions directly proven by the current dataset.

Difficulty managing marketplaces and insufficient assistance indicate that the main problem is not merely access to platforms. Business actors need direct examples, staged assistance, and post-training support. Previous local findings also show the benefits of practical social-media marketing and QRIS outreach accompanied by contextual explanation (Maramis et al., 2025; Nugroho et al., 2025). The national expansion of digital payments needs to be connected to operational benefits and user trust so that adoption does not stop at account ownership (Bank Indonesia, 2025; Muchtar et al., 2024).

Implications of Segmentation for Service Programmes

The identified three-cluster solution provides an exploratory understanding of different user profiles based on observed characteristics. The proposed programme implications were developed by linking centroid profiles with potential needs; however, these recommendations should be interpreted as provisional rather than definitive intervention strategies. Further validation of clustering stability, centroid interpretation, and external applicability is required before implementing these programmes at a broader scale.

The clustering results should be interpreted as preliminary segmentation patterns derived from a purposive sample of 18 participants. Although the identified profiles provide initial insights into potential differences among participants, they should not be considered generalisable population segments, particularly due to the presence of a singleton cluster. These preliminary findings may inform differentiated resource planning for similar assistance contexts; however, broader validation using larger and more diverse samples is required before wider application.

Contributions and Limitations

This study contributes in three ways. First, it provides empirical evidence of the gap between digital-service use and assistance needs among participating MSMEs. Second, it integrates 74 field items into a descriptive workflow and 13 operational indicators for segmentation. Third, it translates cluster outputs into assistance recommendations that can be directly used in local programme planning.

The limitation regarding clustering validity was addressed within this study through internal validation procedures. Several clustering solutions were compared using alternative values of k , and performance was evaluated using silhouette score, Davies-Bouldin index, and Calinski-Harabasz index. Additionally, repeated K-Means runs with different initialisations were conducted to examine solution stability. These analyses provide evidence supporting the selected clustering structure; however, external validation using larger and more diverse datasets remains necessary to assess generalisability.

Conclusion

The ready category reflects a higher relative capability profile compared with other clusters within the analysed dataset. This interpretation should be understood as an exploratory classification rather than a general assessment of the broader population.

This study identified a ready category among the analysed participants. The classification provides preliminary insight into differences in transformation readiness profiles; however, it should not be interpreted as a population-level estimate due to the limited and purposive nature of the sample.

This study provides preliminary evidence that clustering-based profiling may support differentiated assistance planning within the analysed sample. The identified clusters offer exploratory insights into variations in readiness characteristics and potential support needs. However, given the purposive sample size and exploratory nature of the clustering approach, these findings should be interpreted cautiously and require further validation using larger and more diverse datasets before broader implementation.

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Declarations

Author Contributions

The instrument used in this study underwent preliminary expert/content validation to assess the relevance and clarity of measurement items. However, this process should not be interpreted as complete instrument validation, as construct validity and reliability testing were beyond the scope of this study and should be conducted in future research.

Conflict of Interest

The authors declare no conflict of interest in the research and preparation of this article.

Data Availability Statement

Aggregated data and the instrument are available from the corresponding author upon reasonable request. Individual-level data are not publicly released to protect respondent identities and business information.

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