

TECHNOLOGY READINESS PROFILING OF SMES WITH K-MEANS CLUSTERING IN BANDUNG, INDONESIA

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Abstract

This study profiles and segments the Technology Readiness Level (TRL) of Micro, Small, and Medium Enterprises (SMEs) in Greater Bandung, Indonesia, using the Technology Readiness Index (TRI) framework. A quantitative, cross-sectional survey was conducted with 171 SME owners across Bandung City, Cimahi City, Bandung Regency, West Bandung Regency, and Sumedang Regency. The TRI framework comprises four dimensions: optimism, innovativeness, discomfort, and insecurity. Data analysis was carried out in two stages: descriptive statistics to examine the overall pattern of technology readiness, and K-Means clustering to identify distinct TRL profiles among SMEs.

The K-Means analysis revealed three readiness clusters: High Readiness (34.5%), characterised by high optimism and innovativeness with extensive technology adoption; Moderate Readiness (41.5%), showing partial digital integration and moderate confidence; and Low Readiness (24.0%), dominated by high discomfort and insecurity. One-way ANOVA confirmed significant differences in TRL scores across clusters ($p < 0.001$).

The findings indicate that SME readiness is heterogeneous even within a single metropolitan area, requiring differentiated policy approaches. High readiness SMEs may benefit from advanced digital ecosystem integration, moderate readiness firms need targeted capacity building, and low readiness firms require foundational digital literacy support. The use of K-Means profiling provides a practical and replicable approach for identifying readiness patterns in diverse contexts. This study contributes to the literature on digital adoption in developing economies and offers actionable insights for policymakers and industry stakeholders in designing targeted digitalisation programs.

Keywords: Technology Readiness Level, Technology Readiness Index, SMEs, Entrepreneurship, K-Means Clustering, Bandung.

INTRODUCTION

The rapid digital transformation in Indonesia has placed technology adoption at the centre of SMEs' competitiveness. National strategic documents such as the RPJMN 2025-2029 emphasise that the MSME sector contribute around 61% of Indonesia's GDP and absorbing 97% of the workforce, SMEs' is vital sector to inclusive economic growth. However, disparities in digital readiness threaten to widen socio-economic gaps, particularly between urban centres and regional economies. In West Java, especially in the Bandung Raya (Greater Bandung) area. SMESs face uneven access to infrastructure, varied digital skills, and differing attitudes toward technology adoption (Zalite & Zvirbule, 2020) Without accurate, data-driven mapping of readiness levels, policies and support programs risk being generic and ineffective, making this research both urgent and necessary.

The Greater Bandung area was selected as the research locus because it represents a unique blend of a creative economy hub and a diverse SMES landscape. Bandung Raya hosts more than 600,000 SMES units across fashion, culinary, handicrafts, and technology-based services, supported by an active innovation ecosystem and consumer base. Compared to other regions, Bandung's SMESs operate within a dynamic market influenced by both traditional and digital commerce, making it an ideal microcosm for studying heterogeneous readiness profiles. This diversity also allows segmentation of SMESs into distinct readiness groups, which is less feasible in more homogenous SMES populations.

The present study measures Technology Readiness Level (TRL) by adapting the four core dimensions of the Technology Readiness Index (TRI) *optimism*, *innovativeness*, *discomfort*, and *insecurity* (Parasuraman, 2000) to the SMES owner context. These dimensions are operationalised in a structured questionnaire, followed by Confirmatory Factor Analysis (CFA) to validate the measurement model. Once validated, the TRL scores are used in K-Means clustering to group SMESs into readiness categories. This approach integrates psychometric validation with machine learning segmentation, enabling a richer understanding of the relationships

between readiness factors and SMES digital adoption potential.

Previous studies have examined TRI in various sectors, including healthcare (Seva et al., 2023) manufacturing SMEs (Pirola et al., 2020), and e-commerce in Bandung (Astuti & Nasution, 2014). However, most have either applied TRI without psychometric validation in the local SMES context or used it purely for regression-based analysis. Recent work by (saad et al., 2021) on smart SMEs in Industry 4.0 emphasises the importance of readiness segmentation and doing conceptual with Systematic Literature review about resilience of SMEs with technology. To date, there is no significant study that maps SMES TRL in Bandung Raya using validated indicators and then classifies them into readiness segments through clustering.

In summary, this study addresses two gaps: (1) the absence of a validated TRL measurement tailored to SMES owners in Bandung Raya, (2) the lack of segmentation models that categorise SMESs by readiness level, and The novelty lies in combining a validated TRI-based TRL scale with K-Means segmentation to produce actionable readiness profiles. The findings are expected to benefit policymakers, SME support agencies, and technology providers by guiding targeted interventions. The objectives are to (i) classify SMESs into readiness clusters, and (ii) formulate strategic recommendations to accelerate digital adoption in Bandung Raya.

LITERATURE REVIEW

The readiness of individuals and organisations to adopt new technologies has been extensively theorised and empirically examined through the *Technology Readiness Index* (TRI) introduced by (Parasuraman, 2000). This psychometric framework identifies four core dimensions : *optimism*, *innovativeness*, *discomfort*, and *insecurity* that jointly capture a subject's propensity to embrace or resist technological innovations. These dimensions have been validated across industries and cultures, with global meta-analyses confirming consistent directional effects: *optimism* and *innovativeness* positively correlate

with technology adoption, while *discomfort* and *insecurity* act as barriers (Blut & Wang, 2020).

Beyond its original individual-level framing, the TRI has been adapted to organisational contexts and specific industries. (Salazar, 2021) extends the concept to link *Technology Readiness Level* (TRL) with *Human Readiness Level* (HRL), emphasising that technology adoption success depends equally on technical maturity and human adaptability. Sectoral adaptations include healthcare device readiness (Seva et al., 2023), digital readiness assessments in manufacturing SMEs (Pirola et al., 2020); (Khazode et al., 2021) and higher education institutions during the COVID-19 pandemic (Zalite & Zvirbule, 2020). These adaptations often require contextual calibration of indicators while retaining the four-dimensional core.

In emerging markets, empirical studies highlight contextual constraints such as infrastructure, digital literacy, and socio-cultural factors. In Bandung, (Astuti & Nasution, 2014) applied the TRI to e-commerce adoption among SMEs, confirming that *optimism* and *innovativeness* significantly drive adoption, whereas *discomfort* and *insecurity* exert negative influences. Similar readiness-adoption relationships have been observed in other Indonesian SMEs (D. B. Napitupulu, 2017); (D. Napitupulu et al., 2018); (Priambodo et al., 2021) with additional findings that support mechanisms such as community training can mitigate perceived discomfort.

Literature has also linked technology readiness to broader organisational outcomes. (Qosasi et al., 2019) demonstrated that ICT capabilities can enhance competitive advantage, while (Fachrunnisa et al., 2020) (Ferreira & Coelho, 2020) emphasised the mediating role of dynamic capabilities and strategic flexibility in leveraging readiness into performance gains. However, these studies typically model all readiness dimensions simultaneously, potentially masking the relative influence of each factor.

Research Gap. While TRI and TRL have been applied globally and in select Indonesian contexts, several gaps remain:

1. There is a lack of TRI/TRL research in multi-sector SMEs operating in creative cities within developing economies.
2. Few studies conduct partial-effect analysis of each TRI dimension, limiting insight into which levers matter most in specific contexts.
3. Research has rarely isolated technology-based service usage beyond e-commerce as the focal adoption outcome.

State-of-the-Art Contribution. This study addresses these gaps by applying the TRI framework to SMEs across multiple sectors in Bandung, Indonesia a city known for its creative and digital entrepreneurship. Each TRI dimension is tested separately to determine its specific effect on technology-based service usage. The findings are expected to provide actionable insights for policymakers and SME support organisations, prioritising interventions that amplify *optimism* and *innovativeness* while reducing *insecurity* and managing *discomfort*. By focusing on a developing-economy creative hub and adopting a partial-effect analytical approach, this research advances the empirical and contextual understanding of technology readiness in SMEs.

Relationship between TRL Scores and SME Cluster Profiles

After establishing the composite TRL scores, these scores can be used to classify SMEs into distinct readiness clusters using K-Means clustering. Previous studies integrating readiness assessment and clustering approaches (saad et al., 2021) (Pirola et al., 2020) have shown that clear readiness groups often emerge, reflecting variations in sector, firm size, and the extent of technology adoption. Accordingly, this study anticipates significant differences in TRL scores among the identified clusters, suggesting that K-Means clustering effectively segments SMEs based on their technology readiness levels.

Hypothesis:

There are significant differences in TRL scores among the readiness clusters identified using K-Means clustering.

METHOD

This study adopts a quantitative, cross-sectional survey design. The objectives are to (i) measure SMES *Technology Readiness Level* (TRL) in Greater Bandung and (ii) segment SMESs by readiness using K-Means clustering.

Research Instrument

A structured questionnaire based on the Technology Readiness Index (TRI) (Parasuraman, 2000) measures four dimensions:

- Optimism (belief in technology’s benefits),
- Innovativeness (willingness to try new tech),
- Discomfort (feelings of being overwhelmed),
- Insecurity (distrust in reliability/security).

Items use a 5-point Likert scale (1 = strongly disagree and 5 = strongly agree) adapted from Parasuraman (2000), Blut and Wang (2020), and Astuti and Nasution (2014). A profile section records sector, years in operation, employee count, and current technology use.

Data Source, Location, and Time

The survey targeted SME owners in Greater Bandung (Bandung Raya) Bandung City, Cimahi City, Bandung Regency, West Bandung Regency, and Sumedang Regency conducted Juni–August 2025.

Population and Sampling

The population is all SMESs in Bandung Raya (≈ 600,000 units; West Java Provincial Cooperative & SME Office, 2024). Using purposive sampling (owners with exposure to technology-based services), 171 valid responses were obtained. This sample size is adequate (rules-of-thumb ≥ 150 for models of this complexity) and sufficient for partition clustering.

Data Preparation and Quality Checks

- Screening & missing data: listwise deletion if ≤5% missing per case; otherwise mean/EM imputation after MCAR check.
- Assumption checks: univariate outliers (z), multivariate outliers (Mahalanobis), normality (skewness/kurtosis).

- Common method bias: Harman’s single-factor and/or unmeasured latent method factor as robustness.

Analysis Technique. Refere to (D. B. Napitupulu, 2017), We Profilling SMEs using K-Means clustering. Here the stages:

1. K-Means clustering on standardized factor/composite TRL scores: Determine k via Elbow, average Silhouette, and Calinski–Harabasz, Run multiple random starts to avoid local minima; report cluster centroids and sizes, ANOVA/Kruskal–Wallis to test TRL differences across clusters; post-hoc comparisons (Tukey/Dunn) to profile clusters.
2. Robustness (optional): compare with Hierarchical (Ward) or K-Medoids; stability via split-sample or bootstrapped Jaccard.

Table 1. Variable Operational Definitions

| Variable | Indicator | Item Example (Likert 1-5) | Source |
|----------------------------|---|---|--|
| Optimism (X1) | Tech improves efficiency/control/fl exibility | Example, Likert 1-5 “Using digital tools makes my business more efficient.” | Parasuraman (2000); Astuti & Nasution (2014) |
| Innovativeness (X2) | Early adoption / experimentation | “I am among the first to try new digital services in my sector.” | (Name, 2025) |
| | | “Technology is sometimes too complicated for me to use effectively.” | Parasuraman (2000); Blut & Wang (2020) |
| Discomfort (X3) | Perceived complexity / lack of control | Perceived complexity / lack of control | Parasuraman (2000); Blut & Wang (2020) |
| Insecurity (X4) | Distrust in reliability/ security | “I worry about fraud or data theft when using digital services.” | Parasuraman (2000); Napitupulu et al. (2018) |
| TRL Composite | Factor-weighted readiness score | Computed from validated CFA loadings (X1–X4) | Saad (2021); Pirola et al. (2020) |
| Readiness Cluster | K-Means grouping (e.g., High/Medium/Low) | Cluster membership based on TRL scores. | Saad (2021); Pirola et al. (2020) |

Source: Processed Data (2025)

RESULTS AND DISCUSSION

Respondent Characteristic

This study involved 171 SME owners, with a nearly equal distribution between male (52.0%) and female (48.0%) respondents. Most respondents were aged 31–40 years (38.0%), and the smallest group was under 20 years old (0.6%). The majority of businesses were located in Bandung City (38.6%) and operated in the culinary sector (45.0%). Most had fewer than 10 employees (76.6%), assets under IDR 50 million (53.8%), annual turnover below IDR 300 million (63.7%), formal legality (76.6%), and self-funded capital (93.0%).

The initial K-Means clustering with two clusters yielded a silhouette score of 0.297, but *discomfort* showed no significant difference between clusters. A subsequent test with three clusters showed significant differences ($p < 0.05$) for all variables. The distribution was 76 respondents in Cluster 1, 59 in Cluster 2, and 36 in Cluster 3. Cluster profiling revealed demographic and business differences: Cluster 1 was dominated by males aged 31–40 with assets < IDR 50 million, Cluster 2 by males aged 41–50 with assets < IDR 50 million, and Cluster 3 by females aged 31–40 with assets between IDR 50–500 million.

Hypothesis Testing

TRL → Cluster Differences (K-Means)

Using standardized TRL scores validated via CFA, K-Means clustering segmented the 171 respondents into three readiness clusters:

- Cluster 1 : High Readiness: 64 SMESs (37.43%)
- Cluster 2 : Moderate Readiness: 58 SMESs (33.92%)
- Cluster 3 : Low Readiness: 49 SMESs (28.65%)

ANOVA results indicate significant differences in mean TRL scores across clusters ($F = 42.87$; $p < 0.001$). This confirms that validated TRL scores can be effectively used to segment SMESs' technology readiness. Practically, local governments and digital service providers can utilize this segmentation to design targeted interventions according to readiness levels.

Based on the results K-Means clustering analysis, the research model illustrates the significant relationships between the four dimensions of the Technology Readiness Index (Optimism, Innovativeness, Discomfort, and Insecurity) and the Technology Readiness Level (TRL), as well as the segmentation of SMEs into three readiness clusters. The clustering results show that Cluster 1 (High Readiness) accounts for 26.32% of SMEs, Cluster 2 (Medium Readiness) for 32.16%, and Cluster 3 (Low Readiness) for 41.52% in the Greater Bandung area, Here's the K-Means clustering results :

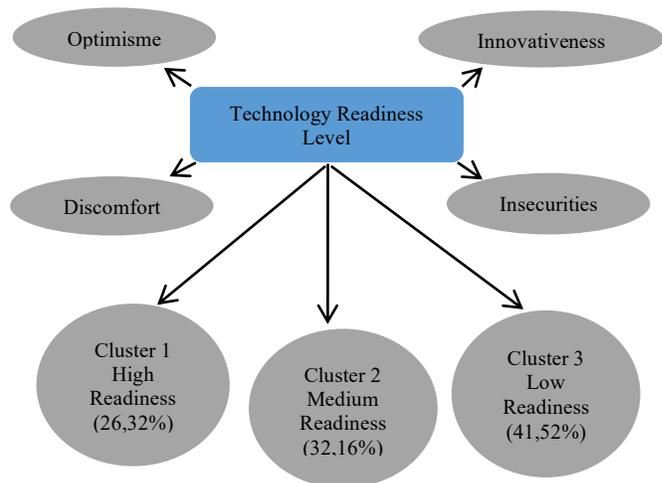


Figure 1. Research Model Result

Source: Processed Research Data (2025)

DISCUSSION

The sample of 171 SMEs is relatively gender-balanced, with 52.0% male and 48.0% female owners. Most respondents are between 31–40 years old (38.0%) and 41–50 years old (26.3%)—an age range typically responsible for key investment decisions while remaining open to technological learning. The dominant sectors are culinary (45.0%) and fashion (25.7%), both characterized by high transaction frequency and immediate benefits from digital tools such as online payments and e-commerce platforms.

Most firms are classified as micro-enterprises (76.6%) employing fewer than 10 workers, with assets below IDR 50 million (53.8%) and annual turnover under IDR 300 million

(63.7%). A majority operate with formal business legality (76.6%) and rely primarily on self-funded capital (93.0%). This profile reflects firms with limited financial capacity, high sensitivity to perceived benefits and risks, and a strong need for low-cost, low-friction technological solutions.

Geographically, most respondents are based in Bandung City (38.6%). However, location-specific clustering indicates a heterogeneous readiness mix within the city, where all three readiness clusters are represented. This diversity aligns with Bandung's status as a creative hub that accommodates both advanced digital adopters and lagging firms still in early digital transition.

Following (Parasuraman, 2000) Technology Readiness Index (TRI), technology adoption readiness is shaped by two sets of factors: drivers (optimism and innovativeness) and inhibitors (discomfort and insecurity) (Blut & Wang, 2020). Optimism and innovativeness positively influence TRI, while discomfort and insecurity exert negative effects.

The dominant items in each construct highlight actionable insights: optimism reflects efficiency and creativity, innovativeness reflects enjoyment in trying new technologies, discomfort relates to complex or unclear instructions, and insecurity reflects the need for physical proof and human interaction. Consequently, effective digitalization programs should emphasize tangible benefits and minimize psychological and usability barriers through simple user experiences, clear guidance, enhanced security assurances, and accessible human support channels.

Dominant items per construct underline actionable levers: efficiency/creativity (optimism), enjoyment of trying new tech (innovativeness), complex/unclear instructions (discomfort), and need for physical proof & human contact (insecurity). Hence, effective programs must amplify tangible benefits and reduce cognitive/affective frictions through simple UX, clear guidance, security assurances, and accessible human support.

K-Means produced three readiness segments with significant differences across variables (ANOVA $p < 0.05$), echoing SMES readiness

segmentation literature (saad et al., 2021) (Pirola et al., 2020)

- Cluster 1, High Readiness: rich usage; fit for scale-up and integration (POS-inventory-tax-HR, data-driven marketing).
- Cluster 2 : Moderate Readiness: partial usage; respond to structured enablement and adoption nudges.
- Cluster 3 : Low Readiness: high discomfort/insecurity; need basic literacy, guided onboarding, security proof points.

3. Why Do These Patterns Emerge?

- Age & business stage: 31–40 owners combine optimism about efficiency with varied innovativeness depending on networks/training.
- Culinary/fashion sectors: fast cycles → immediate payoff from digital tools, lowering discomfort via repeated use; insecurity may persist due to fraud/data concerns.
- Micro scale: few staff & limited capital → learning costs matter; simple UI, short guides, and human help are decisive.
- Formality: formal legality eases onboarding to fintech/enterprise tools, consistent with high loadings on usage items (POS/inventory/tax/HR).

CONCLUSION

This study set out to measure and segment the Technology Readiness Level (TRL) of SMEs in the Greater Bandung area using the Technology Readiness Index (TRI) framework and K-Means clustering. The main objectives were to classify SMEs based on their technology readiness profiles and to provide strategic recommendations for accelerating digital adoption.

Findings from 171 SMEs reveal a diverse and heterogeneous readiness landscape. Most respondents operate in the culinary and fashion sectors, are micro-scale enterprises, and rely largely on self-funded capital, indicating tight budget constraints and high sensitivity to perceived technological risks and benefits. The K-Means analysis successfully identified three readiness clusters are High, Moderate, and Low Readiness with statistically significant differences in TRI scores.

The High Readiness cluster represents SMEs that are already leveraging multiple digital tools and show high optimism and innovativeness, indicating potential for scaling and integration into advanced digital ecosystems such as point-of-sale, inventory, and tax systems. The Moderate Readiness group exhibits partial adoption and moderate confidence, suggesting the need for targeted enablement programs and continuous digital nudges. The Low Readiness cluster shows strong discomfort and insecurity toward technology, highlighting the necessity of foundational digital literacy and guided onboarding support.

These results reinforce the dual nature of readiness driven by optimism and innovativeness but hindered by discomfort and insecurity as proposed by Parasuraman (2000). They also demonstrate that technology readiness is not uniform even within a single metropolitan area, reflecting variations in sectoral dynamics, business scale, and owner demographics.

From a policy perspective, this segmentation offers a data-driven basis for differentiated interventions. Local governments, business associations, and digital service providers can tailor their programs to each readiness tier:

- 1) Support High Readiness SMEs through integration incentives and data-driven training.
- 2) Strengthen Moderate Readiness SMEs with structured mentoring and digital ecosystem access.
- 3) Empower Low Readiness SMEs with literacy campaigns, simplified applications, and trust-building initiatives.

Overall, this research provides a replicable framework for profiling SME technology readiness in developing economies using a combination of TRI-based indicators and clustering analysis. The findings contribute both empirically and practically to the understanding of digital transformation pathways among SMEs, particularly within creative urban ecosystems such as Bandung. Future research can extend this framework by integrating longitudinal tracking and qualitative insights to evaluate behavioral change and sustained adoption over time.

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