



Research Article

Social Sciences

Development and Validation of a Transformational Leadership Measurement Model for Community-Based Waste Separation at Source in Northeastern Thailand

泰国东北部社区垃圾源头分类变革型领导力测量模型的开发与验证

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Abstract:

This study aimed to develop and validate a measurement model of transformational leadership for community-based waste separation at source within the Middle Northeastern Region of Thailand. A sample of 401 residents was recruited via multistage stratified random sampling. Data were collected using a questionnaire comprising 12 indicators across four components of community-based transformational leadership, measured on a five-point Likert scale. Second-order confirmatory factor analysis (CFA) was conducted to assess the factorial structure and construct validity of the proposed model. The results indicated strong standardized factor loadings for all four latent constructs – Initiative and Expanding Interest (ISI), Organizational Resource Relationship (ORR), Goal Setting and Strategy (GSS), and Implementation of Strategies and Plans (ISP) – ranging from 0.948 to 0.995. The model demonstrated excellent fit with the empirical data ($\chi^2 = 51.870$, $df = 39$, $\chi^2/df = 1.329$, RMSEA = 0.029, CFI = 0.996, TLI = 0.992, and SRMR = 0.018). These findings empirically support the construct validity of the instrument, confirming its utility for assessing transformational leadership in community waste management contexts. As this study focused on psychometric validation rather than causal inference, future research should

employ structural equation modeling to examine the effects of transformational leadership on community participation, waste separation behavior, and environmental performance.

Keywords: confirmatory factor analysis; transformational leadership; waste separation at source; community-based waste management; Thailand

摘要：本研究旨在构建并验证泰国东北部中部地区社区垃圾源头分类变革型领导力测量模型。研究采用多阶段分层随机抽样方法，招募了 401 名居民作为样本。数据收集采用问卷调查，问卷包含社区变革型领导力四个组成部分的 12 个指标，采用五点李克特量表进行测量。研究运用二阶验证性因子分析（CFA）评估了所提出模型的因子结构和结构效度。结果表明，所有四个潜在结构——主动性和拓展兴趣（ISI）、组织资源关系（ORR）、目标设定和战略（GSS）以及战略和计划实施（ISP）——均具有较高的标准化因子载荷，范围在 0.948 至 0.995 之间。该模型与实证数据拟合度极佳（ $\chi^2 = 51.870$ ， $df = 39$ ， $\chi^2/df = 1.329$ ， $RMSEA = 0.029$ ， $CFI = 0.996$ ， $TLI = 0.992$ ， $SRMR = 0.018$ ）。这些结果从实证角度支持了该工具的结构效度，证实了其在评估社区垃圾管理背景下的变革型领导力方面的实用性。由于本研究侧重于心理测量学验证而非因果推断，未来的研究应采用结构方程模型来检验变革型领导力对社区参与、垃圾分类行为和环境绩效的影响。

关键词：验证性因素分析；变革型领导；源头垃圾分类；社区垃圾管理；泰国

I. INTRODUCTION

Ineffective waste management at the source is a critical driver of global warming. As organic and biodegradable wastes decompose anaerobically, they emit methane, a greenhouse gas with a global warming potential significantly exceeding that of carbon dioxide [1]. Globally, the waste sector accounts for approximately 3–5% of total greenhouse gas emissions [2]. In Asia, rapid urbanization and industrial growth have increased municipal solid waste generation by roughly 35% over the past decade [3]. [This surge, compounded by inefficient handling practices, intensifies environmental pressures and regional climate change impacts.

Thailand exemplifies this challenge. National statistics attribute an estimated 1.5% increase in overall emissions to improper source-level waste disposal [4]. The issue is particularly acute in the Middle Northeastern Region (Khon Kaen, Maha Sarakham, Roi Et, and Kalasin), where traditional management systems persist despite growing urbanization. Local studies indicate that inadequate segregation and recycling in this region significantly contribute to methane emissions [5]. For instance, Khon Kaen generates over 450 tons of municipal solid waste daily, yet household segregation remains limited due to low public awareness and inconsistent collection systems. Similarly, infrastructural deficits and lack of participation hinder effective management in Kalasin and Maha Sarakham, where open burning and dumping remain common [4,6]. In Roi Et, inconsistency between municipal and

subdistrict levels further impedes progress; although pilot programs like community waste banks exist, they often lack continuity and strong local leadership [6]. Participatory research suggests that sustained community engagement is essential for improving segregation efficiency, yet such engagement remains elusive in many areas [6].

These systemic failures highlight the urgent need for reform in source-level waste management strategies. While technical solutions are necessary, sustainable behavioral change requires effective community governance. Transformational leadership has emerged as a key factor in fostering environmental initiatives [7]. Leaders who inspire collective action, mobilize resources, and establish collaborative networks are instrumental in overcoming infrastructural and social barriers [8]. However, existing literature offers limited insight into the specific leadership components that drive success in Thai community-based waste management contexts. Classical models of transformational leadership [7] may not fully capture the nuances of local environmental governance in developing regions.

Therefore, this study conceptualizes transformational leadership as a context-specific construct tailored to community-based environmental management. Rather than adopting classical dimensions wholesale, we operationalize leadership through four practice-oriented components: initiative, resource mobilization, strategic orientation, and implementation capacity. These dimensions reflect how leadership is

enacted in local waste management settings. The primary objective of this study is to develop and validate a second-order measurement model of community-based transformational leadership specifically designed for source-level waste management in Northeastern Thailand.

II. METHODS

A. Research Design

This study employed a quantitative cross-sectional design to examine the components of transformational leadership affecting source-level waste management in the Middle Northeastern Region of Thailand. Second-order confirmatory factor analysis (CFA) was used to validate the proposed measurement model. Each of the four leadership components was measured using three observed indicators (composite scores), resulting in a total of 12 indicators derived from 40 questionnaire items.

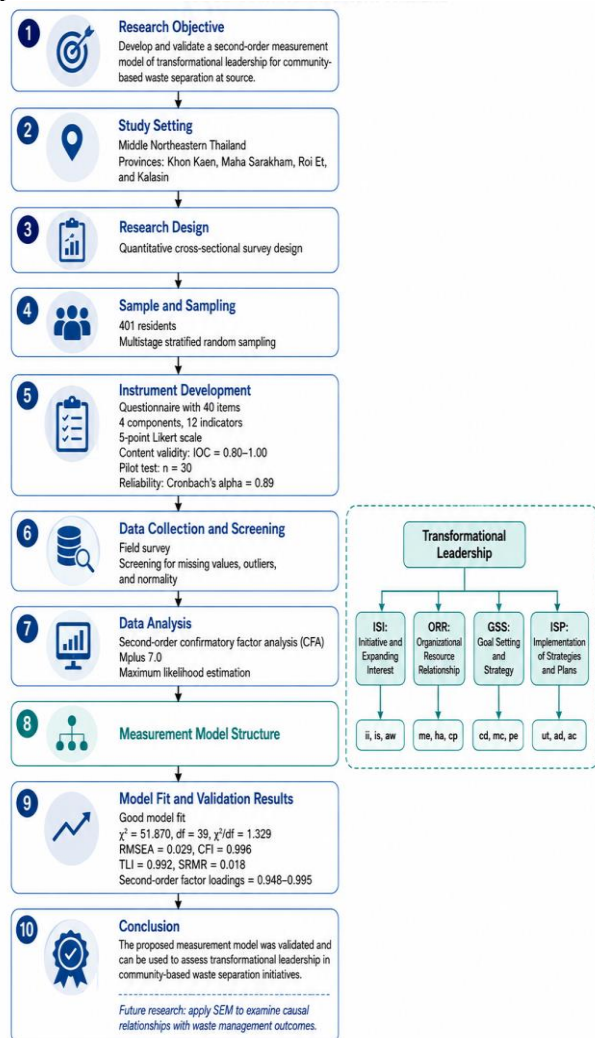


Figure 1. Research flowchart. Source: Authors' own elaboration.

Figure 1 presents the methodological sequence for developing and validating the second-order

measurement model. The flowchart outlines the key stages: research objective formulation, study setting, sampling, instrument development, content validity assessment, pilot testing, data screening, and CFA using Mplus 7.0. It also illustrates the hierarchical structure of the model, wherein community-based transformational leadership serves as a higher-order construct comprising four first-order components: Initiative and Expanding Interest (ISI), Organizational Resource Relationship (ORR), Goal Setting and Strategy (GSS), and Implementation of Strategies and Plans (ISP). The final stage confirms that the validated model demonstrates good empirical fit for assessing leadership in community-based waste separation initiatives.

B. Sample

Sample size was determined following the recommended ratio of 10–15 observations per estimated parameter [9]. With 28 parameters to be estimated, the required sample ranged from 280 to 420 participants. A final sample of 401 residents was recruited via multistage stratified random sampling. Four provinces served as strata; one district and one community were randomly selected from each province. Within each community, households were sampled randomly from administrative lists.

Although the construct is conceptualized at the community level, data were collected from individual residents as informants of perceived leadership practices. Consequently, results reflect perceived rather than objective community-level leadership. Aggregation to the community level was not performed due to the limited number of clusters ($n = 4$ communities).

C. Research Instrument

The instrument was a structured questionnaire measuring community-based transformational leadership attributes related to source-level waste management. Items were rated on a five-point Likert scale (1 = strongly disagree, 5 = strongly agree). Instrument development proceeded as follows:

Literature Review and Item Generation: A comprehensive review of theoretical frameworks identified four leadership components and 12 corresponding indicators: Initiative and Expanding Interest (ISI), Organizational Resource Relationship (ORR), Goal Setting and Strategy (GSS), and Implementation of Strategies and Plans (ISP).

Indicator Construction: To enhance model parsimony and reduce measurement error, CFA was conducted using aggregated indicators

(composite scores) rather than item-level analysis. Each indicator represents the mean score of 3–4 items. Thus, the second-order latent construct of transformational leadership (TL) comprises four first-order factors (ISI, ORR, GSS, ISP), each

measured by three observed indicators, totaling 12 indicators in the CFA model.

Table 1 presents the measurement items used in the confirmatory factor analysis.

Table 1.

Measurement items for community-based transformational leadership (compiled by the authors)

Latent Variables	Observed Variable	Description
1. Initiative and Expanding Interest (ISI)		
1.1 Idealized Influence (II)	1.1.1 Leader as a Role Model	Leaders behave in ways that followers respect and trust; they serve as role models, e.g., demonstrating proper source waste management in communities and households.
	1.1.2 Vision Communication	Leaders have a clear vision and can communicate it to followers for the common good, e.g., continuously implementing community “Waste Zero” projects.
	1.1.3 Ideological Commitment & Adaptability	Leaders possess insight, intelligence, self-confidence, and strong ideological commitment to source waste management, employing diverse strategies and problem-solving approaches in communities and households.
1.2 Intellectual Stimulation (IS)	1.2.1 Fostering Creativity	Leaders encourage followers to generate creative ideas and allow the community to participate freely in source waste management while respecting their opinions.
	1.2.2 Challenging Problem-Solving	Leaders motivate followers to perceive challenges as opportunities, supporting the community in solving source waste management issues in households and communities.
	1.2.3 Encouraging Suggestions	Leaders provide continuous opportunities for followers to propose ideas or solutions regarding source waste management in communities and households.
1.3 Awareness (aw)	1.3.1 Community Empowerment	Leaders strengthen communities to be self-reliant, aware, and protective of their local resources, e.g., communities share resources and generate income from source waste separation.
	1.3.2 Systematic Work Implementation	Leaders encourage followers to follow structured plans for source waste management in communities and households.
	1.3.3 Local Development & Resource Utilization	Leaders promote community development by creating work from local resources, e.g., arts and crafts from waste materials and household waste generating income.
2. Organizational Resource Relationship (ORR)		
2.1 Multi-Ecosystem Management (me)	2.1.1 Resource Management Ability	Leaders can manage natural resources and the environment using diverse approaches for source waste management in communities and households.
	2.1.2 Environmental Development Planning	Leaders have clear plans for environmental development in communities regarding source waste management in households and communities.
	2.1.3 Collaborative Community Work	Leaders collaborate with the community to develop the environment and seek support resources for source waste management in communities and households.
2.2 Habitat Development (ha)	2.2.1 Community Culture and Unity	Leaders build organizational culture and promote love, unity, and mutual support within the community, e.g., collaborating with the community to support “Zero Waste” initiatives in households and communities.
	2.2.2 Income Generation and Self-Reliance	Leaders and communities jointly develop habitats to generate income and achieve self-reliance through effective source waste management in households and communities.
	2.2.3 Clean and Sustainable Living Environment	Leaders promote the development of clean, hygienic, and waste-free living environments with clear policies and goals, ensuring active community participation.
2.3 Community Participation (cp)	2.3.1 Shared Vision for Community Development	Leaders establish a shared vision for community transformation in source waste management in communities and households.
	2.3.2 Community Engagement in Vision	Leaders enable the community to actively participate in creating a shared vision for community work related to source waste management.
	2.3.3 Joint Commitment to Shared Vision	Leaders and the community collaboratively develop a shared aspiration toward the common vision for source waste management in communities and households.
3. Goal Setting and Strategy (GSS)		

Latent Variables	Observed Variable	Description
3.1 Competency Development (cd)	3.1.1 Self-Development Planning	Leaders have an annual plan to develop themselves in transformational leadership affecting source waste management in communities and households.
	3.1.2 Operational Competency Development	Leaders develop their abilities to perform source waste management in communities and households effectively.
	3.1.3 Flexibility and Empowerment	Leaders demonstrate flexibility, allowing time for decision-making and encouraging communities to overcome obstacles and foster creativity in waste management participation.
3.2: Motivation & Individualized Consideration (mc)	3.2.1 Inspiring Followers	Leaders have the ability to inspire followers in source waste management in communities and households.
	3.2.2 Demonstrating Enthusiasm	Leaders demonstrate enthusiasm in waste management activities, such as continuous meetings, planning, and implementation in the community.
	3.2.3 Commitment to Vision and Goals	Leaders show dedication to goals and vision by regularly collaborating with the community to solve waste management problems in households and communities.
	3.2.4 Appropriate Task Allocation	Leaders assign tasks to community members or households based on their knowledge, abilities, and aptitudes in managing source waste.
3.3 Persuasion (pe)	3.3.1 Reasoned Persuasion	Leaders can persuade the community with logical options and conclusions to follow proper source waste management practices in communities and households.
	3.3.2 Respect for Individual Differences	Leaders accept individual differences and provide opportunities for the community to fully utilize their abilities in source waste management.
	3.3.3 Encouraging Independent Action	Leaders support and encourage followers to act independently in managing source waste in communities and households.
4. Implementation of Strategies and Plans (ISP)		
4.1 Utility (ut)	4.1.1 Maximizing Resource Utilization	Leaders are able to reduce waste at the source in communities and households, and effectively manage natural resources and the environment for maximum benefit.
	4.1.2 Socio-Economic Utilization	Leaders utilize source waste management, natural resources, and environmental management to enhance social and economic security in the community, e.g., waste banks and eco-friendly rural tourism initiatives
4.2 Action Development (ad)	4.2.1 Task Assignment	Leaders assign tasks to personnel responsible for source waste management in communities and households, including maintaining cleanliness, orderliness, and safety in the community.
	4.2.2 Capacity Building and Support	Leaders promote work development by providing training and encouragement to personnel involved in source waste management in communities and households
	4.2.3 Supporting Individual	Development Leaders support community members in self-development, respect individual differences, and accept personal readiness levels in participating in waste management activities.
4.3 Action of Delegation (ac)	4.3.1 Effective Policy Implementation	Leaders perform duties efficiently in accordance with policies and operational plans related to source waste management in communities and households.
	4.3.2 Commitment and Perseverance	Leaders carry out their responsibilities with determination, patience, and resilience under various constraints to reduce risks and ensure successful source waste management in communities and households.

Additional questionnaire sections captured individual- and community-level variables related to source-level waste management: information perception (Part 3), knowledge and understanding (Part 4), waste management behaviors (Part 5), and community participation (Part 6). These variables provided contextual support for the leadership construct and reflected broader dimensions of community engagement in waste management.

D. Measurement Model Specification

The measurement model was specified as a second-order hierarchical structure in which observed indicators loaded onto their respective first-order latent constructs, which in turn loaded onto the higher-order transformational leadership factor. Confirmatory factor analysis (CFA) was used to evaluate this structure, assessing both construct validity and overall model fit.

E. Content Validity (Expert Evaluation)

A panel of five experts (two specialists in psychometrics, one leadership scholar, and two environmental scientists) evaluated the questionnaire content validity using the Index of

Item-Objective Congruence (IOC). The acceptance criterion was set at ≥ 0.80 . All items met or exceeded this threshold (IOC range: 0.80–1.00). Items falling below the criterion were revised or removed based on expert feedback.

F. Pilot Testing and Reliability Assessment

The revised instrument was pilot-tested with 30 residents from Ban Hua Thanon Community (Mueang District, Khon Kaen Province), who were excluded from the main sample. Internal consistency was assessed via Cronbach's alpha. The overall coefficient was 0.89, indicating high reliability; subscale coefficients ranged from 0.82 to 0.91.

G. Data Analysis

CFA was conducted in Mplus 7.0 using maximum likelihood (ML) estimation to validate the transformational leadership measurement model. Prior to analysis, data were screened for missing values, outliers, and normality to verify CFA assumptions. ML estimation was deemed appropriate given the approximately normal distribution of the observed variables.

III. RESULTS

A. Respondents' Characteristics

Table 2 presents respondents' characteristics.

Table 2

Respondents' Characteristics (compiled by the authors)

Characteristics	n	%
Male	183	45.64
Female	218	54.36

B. Validation of the Community-Based Transformational Leadership Model

Symbols used in data analysis:

χ^2 : Chi-square statistic

df: Degrees of freedom

p: Probability value

RMSEA: Root Mean Square Error of Approximation

Table 3

Factor loadings and predictive efficiency coefficients for transformational leadership indicators (compiled by the authors)

Measurement Model Components	Factor Loading Indicators	b	SE	t	R ²
1. Initiative and Expanding Interest (ISI)	ii	0.783	0.023	33.766	0.613
	is	0.777	0.023	33.449	0.603
	aw	0.702	0.029	24.390	0.492
2. Organizational Resource Relationship (ORR)	me	0.599	0.035	17.019	0.358
	ha	0.701	0.028	24.926	0.491
	cp	0.802	0.022	36.835	0.643
3. Goal Setting and Strategy (GSS)	cd	0.780	0.022	35.411	0.608
	mc	0.802	0.020	39.661	0.644
	pe	0.696	0.028	24.630	0.484
4. Implementation of Strategies and Plans (ISP)	ut	0.821	0.024	34.730	0.675
	ad	0.777	0.027	29.067	0.603
	ac	0.740	0.026	28.416	0.547

Note: * $p < .0001$

CFI: Comparative Fit Index

TLI: Tucker-Lewis Index

SRMR: Standardized Root Mean Square

Residual

b: Factor loading (component weight)

SE: Standard error of factor loading

t: t-value (factor loading / standard error)

R²: Coefficient of determination (predictive power)

Transformational Leadership (TL) Components and Indicators

TL: Transformational leadership components, including ISI, ORR, GSS, and ISP

1. Initiative and Expanding Interest (ISI)

ii: Idealized Influence

is: Intellectual Stimulation

aw: Awareness

2. Organizational Resource Relationship (ORR)

me: Multi-Ecosystem Management

ha: Habitat Development

cp: Community Participation

3. Goal Setting and Strategy (GSS)

cd: Competency Development

mc: Motivation & Individualized Consideration)

pe: Persuasion

4. Implementation of Strategies and Plans (ISP)

ut: Utility

ad: Action Development

ac: Action of Delegation

1) Confirmatory Factor Analysis (CFA) Results

The confirmatory factor analysis was conducted to examine factor loadings and validate the transformational leadership indicators, as shown in Table 3. All standardized loadings exceeded the recommended threshold of 0.70, confirming that each observed indicator reliably measures its respective latent construct. The predictive efficiency coefficients further indicate strong explanatory power for all items within the model.

Building on these item-level results, Table 4 presents the overall CFA outcomes for the four first-order attributes of transformational leadership (ISI, ORR, GSS, ISP). The analysis confirms that each attribute is a distinct yet highly correlated dimension, with composite reliability

and average variance extracted values meeting or exceeding established criteria for convergent validity. This supports the structural integrity of the proposed measurement framework prior to higher-order evaluation.

Table 4

Confirmatory factor analysis results for first-order leadership attributes (compiled by the authors)

Components of the Measurement Model	b	SE	t	R ²
1. Initiative and Expanding Interest (ISI)	0.984	0.016	63.431	0.968
2. Organizational Resource Relationship (ORR)	0.995	0.001	1203.065	0.990
3. Goal Setting and Strategy (GSS)	0.995	0.001	1974.003	0.991
4. Implementation of Strategies and Plans (ISP)	0.948	0.019	50.501	0.900

Note: * $p < 0.001$

Finally, Table 5 reports the global goodness-of-fit indices comparing the hypothesized second-order model against established benchmarks [10]. The model demonstrated excellent fit across multiple criteria: $\chi^2/df = 1.329$, RMSEA = 0.029, CFI = 0.996, TLI = 0.992, and SRMR = 0.018. Collectively, these indices confirm that the second-order transformational leadership model adequately represents the empirical data and meets rigorous standards for structural validity in community-based waste management research.

Table 5

Goodness-of-fit indices for the second-order transformational leadership model (compiled by the authors based on [10])

Goodness-of-Fit Index	Fit Criteria	Model Analysis Result
χ^2 (Chi-square)	$p > 0.05$	0.0814
χ^2 / df	< 2	1.329
RMSEA	< 0.07	0.029
CFI	> 0.95	0.996
TLI	> 0.95	0.992
SRMR	< 0.08	0.018

The hypothesized second-order measurement model of community-based transformational leadership is depicted in Figure 2. The diagram illustrates the hierarchical structure wherein the higher-order latent construct (TL) loads onto four first-order factors (ISI, ORR, GSS, ISP), each measured by three observed indicators. Standardized factor loadings and standard errors are presented for all paths. As shown, all first-order factors exhibit strong loadings on the higher-order construct ($\lambda \geq 0.948$), and all observed indicators demonstrate adequate loadings on their respective first-order factors ($\lambda \geq 0.599$). The model fit indices reported in the figure caption confirm excellent empirical adequacy, supporting the proposed structural specification prior to detailed statistical evaluation in subsequent tables.

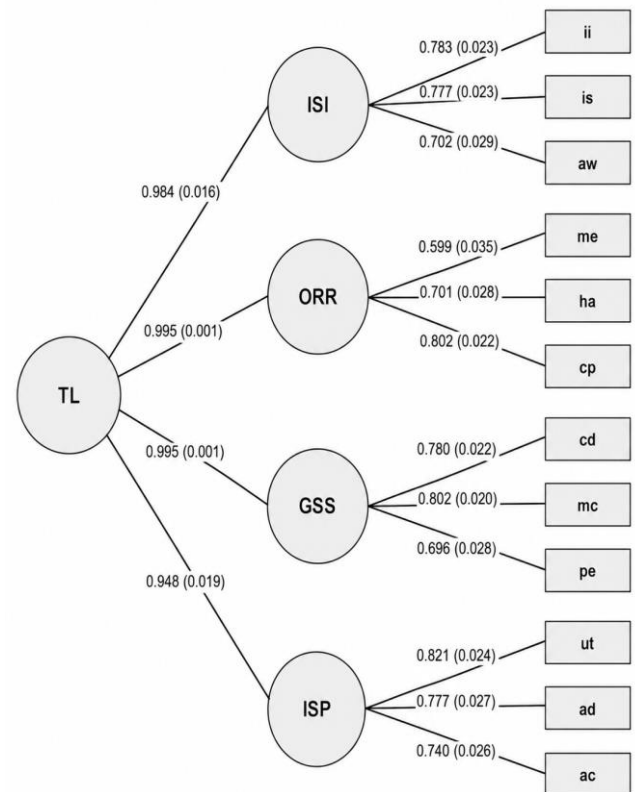


Figure 2. Second-order confirmatory factor analysis model of community-based transformational leadership.

Source: Authors' own elaboration

Note: N = 401. Estimator: Maximum Likelihood (ML). Values represent standardized factor loadings with standard errors in parentheses. Fit indices: $\chi^2 = 51.870$, $df = 39$, $\chi^2/df = 1.329$, RMSEA = 0.029, CFI = 0.996, TLI = 0.992, SRMR = 0.018. All path coefficients significant at $p < .001$. TL = Transformational Leadership; ISI = Initiative and Expanding Interest; ORR = Organizational Resource Relationship; GSS = Goal Setting and Strategy; ISP = Implementation of Strategies and Plans.

2) Convergent Validity and Reliability

Convergent validity and internal consistency were evaluated using Composite Reliability (CR) and Average Variance Extracted (AVE), calculated from standardized factor loadings in Mplus.

Table 6
Convergent Validity and Reliability

Construct	Loading Range	CR	AVE
ISI	0.702–0.783	0.80	0.57
ORR	0.599–0.802	0.74	0.50
GSS	0.696–0.802	0.80	0.58
ISP	0.740–0.821	0.82	0.61

As shown in Table 6, all constructs met the recommended thresholds ($CR \geq 0.70$; $AVE \geq 0.50$), confirming adequate convergent validity and reliability.

All constructs demonstrated acceptable reliability ($CR = 0.74$ – 0.82), exceeding the 0.70 threshold. AVE values ranged from 0.50 to 0.61; all but one construct met or exceeded the 0.50 criterion for convergent validity. The remaining construct ($AVE \approx 0.50$) was retained based on its theoretical centrality and satisfactory composite reliability ($CR > 0.70$), consistent with established guidelines that permit marginal AVE values when supported by strong reliability and substantive justification [9,11].

3) Discriminant Validity and Higher-Order Structure

Discriminant validity was evaluated using both the Fornell–Larcker criterion (Table 7) and the heterotrait–monotrait ratio (HTMT; Table 8). As shown in Table 7, inter-construct correlations were exceptionally high (0.933–0.990), exceeding the square root of AVE for all constructs. Similarly, HTMT values ranged from 0.933 to 0.990, surpassing the conventional threshold of 0.85–0.90 [12]. Notably, the HTMT ratios were identical to the latent correlations reported in Table 7, reflecting the near-perfect linear relationships among these first-order factors.

Table 7
Discriminant validity (Fornell–Larcker criterion)

	ISI	ORR	GSS	ISP
ISI	0.754			
ORR	0.979	0.707		
GSS	0.979	0.990	0.762	
ISP	0.933	0.943	0.944	0.781

Note: Diagonal elements represent the square root of AVE. Off-diagonal elements represent latent correlations obtained from Mplus.

Table 8
HTMT Ratio

	ISI	ORR	GSS	ISP
ISI	-			
ORR	0.979	-		
GSS	0.979	0.990	-	
ISP	0.933	0.943	0.944	-

Note: HTMT values exceed the recommended threshold (0.85–0.90), indicating high inter-construct correlations.

Rather than indicating a lack of discriminant validity, these results are consistent with the theoretical specification of transformational leadership as a higher-order construct. The strong inter-correlations among first-order factors (ISI, ORR, GSS, ISP) reflect their shared variance under the overarching transformational leadership dimension, thereby justifying the second-order model structure. Consequently, discriminant validity was assessed at the level of the higher-order construct rather than among its constituent first-order components.

IV. DISCUSSION

This study confirms that transformational leadership is a critical driver of effective community-based waste separation at source. The validated four-component model – Initiative and Expanding Interest (ISI), Organizational Resource Relationship (ORR), Goal Setting and Strategy (GSS), and Implementation of Strategies and Plans (ISP) – aligns with prior evidence that transformational leadership fosters sustainable environmental practices through inspiration and resource mobilization [7, 8]. This is particularly salient in developing country contexts, where leadership often compensates for infrastructural and institutional deficits [13,14].

Among the identified components, GSS and ORR emerged as the most salient dimensions, both exhibiting near-maximal factor loadings ($b = 0.995$). The prominence of GSS underscores that clear strategic objectives are foundational to environmental interventions in this context, corroborating a finding [15] that structured, goal-oriented planning is prerequisite for municipal solid waste program success in Thailand. Similarly, the high loading for ORR reflects the centrality of resource mobilization; as noted by the World Bank [2], leadership capacity to secure financial, human, and infrastructural resources directly determines sustainability outcomes. This resonates with Pariatamby and Tanaka’s [16] observation that Southeast Asian waste management projects depend heavily on leaders’ ability to attract domestic and international funding, especially given documented barriers related to limited government support in Thai communities [5]. These findings extend prior work by demonstrating that even within resource-constrained settings, targeted leadership development can overcome systemic barriers to effective waste management [2,17].

Beyond individual leadership attributes, this study reinforces the importance of collaborative networks. Effective waste management requires coordination among local governments, private

entities, and residents, a dynamic that participatory approaches have been shown to enhance in developing countries [3,6,18]. Community-driven initiatives, when supported by transformational leadership, cultivate resident ownership and responsibility, thereby improving long-term behavioral compliance and system sustainability. This aligns with global evidence that leadership-centered, participatory models outperform top-down technical interventions in achieving durable environmental outcomes [19,20].

Several limitations warrant consideration. First, the sample was restricted to the Middle Northeastern Region of Thailand; findings may not generalize to areas with different socio-economic or environmental conditions. Second, the exclusive reliance on quantitative self-report data may not fully capture the nuanced lived experiences of community members. Future research should integrate qualitative methods (e.g., interviews, focus groups) to deepen understanding of leadership dynamics and participation mechanisms, consistent with a recommendation for mixed-methods approaches in this domain [21]. Additionally, longitudinal designs are needed to establish causal pathways between leadership practices and waste management performance, addressing the cross-sectional nature of the current study [19].

In sum, this study demonstrates that transformational leadership, operationalized through strategic clarity, resource mobilization, and collaborative engagement, is essential for advancing community-level waste management. These findings reinforce international calls for leadership-centered approaches to sustainable waste systems and provide a validated instrument for assessing such leadership in similar contexts.

V. CONCLUSION

This study demonstrates that transformational leadership is a critical enabler of sustainable community-based waste separation at source. The validated measurement model identifies strategic goal-setting and resource mobilization as the most salient leadership dimensions, confirming that clear objectives and the capacity to secure financial and infrastructural resources are foundational to effective waste management in developing contexts. These findings reinforce global evidence that participatory, leadership-driven approaches yield more sustainable environmental outcomes than top-down technical interventions alone.

Several limitations warrant consideration when interpreting these results. First, the cross-sectional

design precludes causal inference; longitudinal studies are needed to establish temporal precedence between leadership practices and waste management outcomes. Second, reliance on self-report data from a single source may introduce common method bias. Third, the nested structure of the data was not modeled due to the limited number of communities ($n = 4$), and findings reflect perceived rather than objective leadership performance. Finally, the regional focus on Northeastern Thailand limits generalizability to areas with different socio-economic or institutional conditions. Future research should employ mixed-methods designs, including interviews and focus groups, to capture nuanced leadership dynamics and validate these findings across diverse contexts.

For policymakers and local leaders, this study provides a validated instrument for assessing and strengthening transformational leadership in waste management. By prioritizing strategic clarity, resource mobilization, and collaborative engagement, communities can enhance both the effectiveness and sustainability of source-level waste separation initiatives.

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DECLARATIONS

Author Contributions

Conceptualization, S.N., and C.S.; methodology, C.S., K.C., and T.L.; software, U.I., and S.N.; formal analysis, C.S., and T.L.; investigation, S.N., T.L., and C.S.; validation, C.S., and T.L.; resources, C.S., and S.N.; data curation, T.L.; writing—original draft preparation, all authors contributed equally.; writing—review and editing, C.S., and T.L.; visualization, K.C., and U.I.; funding acquisition, S.N.; supervision, C.S.; project administration, T.L. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

The data used to support the findings of this study are available from the corresponding author upon request.

Ethical Compliance

All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and / or national research committee and the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed Consent Statement

Participation in the study was voluntary and informed consent was obtained from all participants prior to their involvement.

Conflicts of Interest

The authors declare no conflict of interest.

Competing Interests

The authors confirm that no competing interests exist.

Disclaimer

The authors declare their opinion and view expressed in this manuscript are free of any impact of any organization.

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