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Developing an Integrated Risk Management and Circular Economy Model for Enhancing Resilience and Sustainable Competitiveness of Agroindustrial SMEs

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ABSTRACT

This study aims to develop and validate an integrated Risk Management (RM) and Circular Economy (CE) model for enhancing SME Resilience (SR) and Sustainable Competitiveness (SC) in agroindustrial SMEs. The research employed a mixed-methods approach involving observations, interviews, Focus Group Discussions (FGD), and questionnaire surveys conducted on 157 respondents from agroindustrial SMEs producing banana chips in East Luwu, Indonesia. Data analysis was performed using Structural Equation Modeling–Partial Least Squares (SEM-PLS). The results revealed that RM positively affects SR with a path coefficient of 0.384, while CE demonstrated the strongest influence on SR with a coefficient of 0.451. Furthermore, SR significantly influenced SC with a coefficient value of 0.612. Mediation analysis confirmed that SR significantly mediates the relationships between RM and SC (0.235) as well as CE and SC (0.276). The findings indicate that integrated risk management and circular economy practices improve operational adaptability, sustainability, and long-term competitiveness in agroindustrial SMEs.

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INTRODUCTION

Micro, Small, and Medium Enterprises (SMEs) play a significant role in supporting economic growth and employment generation in developing countries, particularly in Indonesia. SMEs contribute more than 60% to Indonesia's Gross Domestic Product and absorb approximately 97% of the national workforce, demonstrating their strategic contribution to economic resilience and regional development [1], [2]. In the agroindustrial sector, SMEs are essential in transforming local agricultural commodities

into value-added products [3], [4]. However, increasing uncertainty in supply chains, fluctuating raw material availability, environmental pressures, and intense market competition have exposed agroindustrial SMEs to substantial operational and sustainability challenges [5]. These conditions highlight the necessity of developing adaptive and sustainable management systems capable of balancing operational resilience, environmental responsibility, and competitive performance [6], [7].

Despite their economic importance, agroindustrial SMEs commonly experience structural weaknesses in managing operational risks and sustainability practices [8], [9]. The major risks faced by SMEs include unstable raw material supply, production inefficiency, increasing production costs, fluctuating market demand, and limited managerial capability [10]. Studies indicate that more than 50% of SMEs still lack formal risk management systems, resulting in reactive rather than preventive business strategies [11], [12]. Simultaneously, circular economy implementation within SMEs remains relatively limited due to inadequate technological capability, lack of environmental awareness, and insufficient integration with business strategy [13], [14]. Consequently, risk management initiatives and sustainability practices are frequently implemented separately, reducing their effectiveness in strengthening resilience and long-term competitiveness [15], [16].

This research focuses on agroindustrial SMEs producing “Pisang Tanduk” banana chips in East Luwu Regency, Indonesia, particularly SMEs Nuca Chips located in Sindu Agung Village, Mangkutana District. The enterprise has strong potential to support local economic development through agroindustrial processing of local banana commodities. Nevertheless, the enterprise faces several operational challenges, including seasonal fluctuations in banana supply, inconsistent product quality, inefficient production processes, and unmanaged production waste. Banana peel waste can account for approximately 30–40% of total raw material weight, creating both environmental and economic inefficiencies when not properly utilized [17], [18]. These conditions indicate the urgent need for an integrated management model capable of improving operational flexibility, waste utilization, and sustainable business performance simultaneously.

Previous studies have widely examined risk management and circular economy practices in industrial and manufacturing systems [19]. Risk management research primarily focuses on identifying and mitigating operational, financial, and supply chain risks through approaches such as Enterprise Risk Management (ERM), Failure Mode and Effect Analysis (FMEA), and probabilistic assessment models [20], [21]. Meanwhile, circular economy studies emphasize resource efficiency, waste minimization, reuse, and sustainable production systems [22], [23]. Recent industrial management studies increasingly employ Structural Equation Modeling–Partial Least Squares (SEM-PLS) to analyze complex relationships among latent variables because SEM-PLS effectively supports predictive modeling, exploratory analysis, and theory development in studies involving relatively small samples and multidimensional constructs. However, empirical integration of risk management and circular economy within agroindustrial SMEs remains relatively underexplored [24], [25].

Although previous research has contributed to the advancement of sustainability and industrial risk management literature, several important gaps remain unresolved. Existing studies generally examine risk management, circular economy, resilience, and sustainable competitiveness independently rather than simultaneously within a single integrative framework [26], [27]. Furthermore, limited empirical studies investigate how circular economy practices can function as strategic mechanisms for mitigating operational risks and strengthening SME resilience in developing countries. Therefore, the novelty of this study lies in developing an integrated risk management and circular economy model that structurally connects operational risk mitigation, resource efficiency, resilience capability, and sustainable competitiveness in agroindustrial SMEs. The study also proposes measurable constructs validated empirically using SEM-PLS analysis to provide a replicable and data-driven framework for sustainable SME development [28].

Accordingly, this study aims to develop and validate an integrated risk management and circular economy model for enhancing resilience and sustainable competitiveness of agroindustrial SMEs. Specifically, the research investigates the structural relationships among risk management practices, circular economy implementation, SME resilience, and sustainable competitiveness. The findings are expected to contribute theoretically by extending industrial sustainability and resilience literature through an integrative analytical framework. Practically, the proposed model may support SME managers, policymakers, and local governments in designing adaptive business strategies, improving

operational efficiency, minimizing environmental impacts, and strengthening sustainable competitive advantage within agroindustrial sectors.

RESEARCH METHODS

This study employed a mixed-methods approach combining qualitative and quantitative methods to develop an integrated risk management and circular economy model for agroindustrial SMEs. The research was conducted at SMEs Nuca Chips in East Luwu Regency, Indonesia, which produces "Pisang Tanduk" banana chips. The qualitative stage focused on identifying operational risks, circular economy practices, and resilience factors through observations, in-depth interviews, Focus Group Discussions (FGD), and literature reviews. Primary data were collected from SME owners and production workers, while secondary data included production reports, financial records, operational procedures, and waste management documentation. The collected information was used to construct the initial conceptual framework consisting of risk management, circular economy, resilience, and sustainable competitiveness variables.

The quantitative stage applied SEM-PLS to analyze and validate the relationships among research variables. SEM-PLS was selected because it is suitable for exploratory studies involving complex relationships and relatively small sample sizes. Data were collected using structured questionnaires measured with a five-point Likert scale. The analysis process included descriptive statistics, validity testing, reliability testing, and structural model evaluation. Hypothesis testing was conducted using the bootstrapping procedure to determine the significance of relationships among variables. In addition, mediation analysis was performed to examine the role of resilience in strengthening the relationship between risk management, circular economy, and sustainable competitiveness. The proposed model is expected to provide a valid and applicable framework for improving resilience and long-term competitiveness in agroindustrial SMEs.

RESULTS AND DISCUSSION

This section presents the empirical findings and discusses the relationships among risk management, circular economy, resilience, and sustainable competitiveness within agroindustrial SMEs based on SEM-PLS analysis.

1. Respondent and Agroindustrial SME Profile

This section describes the demographic characteristics of respondents and the operational profile of the agroindustrial SME involved in this study. The analysis includes business scale, production capacity, workforce composition, operational experience, and raw material sources to provide an overview of the organizational condition of the SME.

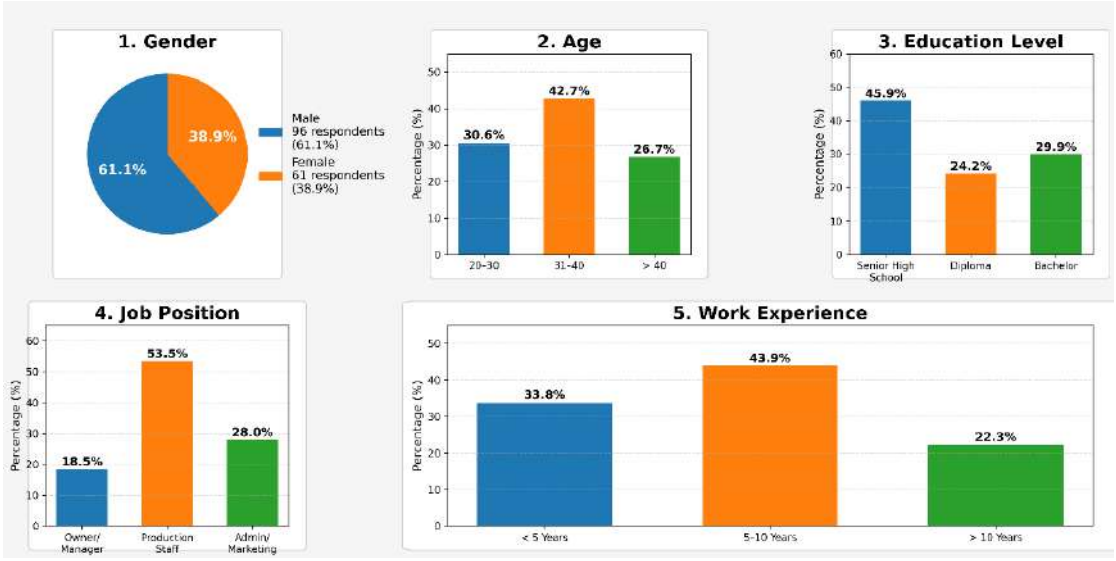

Fig. 1. Respondent and Agroindustrial SME Profile

Figure 1, shows that the majority of respondents were male workers (61.1%) aged between 31–40 years (42.7%), indicating that productive-age employees dominate agroindustrial SME operations. Most respondents had senior high school educational backgrounds (45.9%) and work experience between 5–10 years (43.9%), reflecting moderate operational competency in production activities. Production staff represented the largest respondent group (53.5%), followed by administrative and marketing personnel. The SME operates at a small-enterprise scale with an average production capacity of 250–500 banana chip packages per week using Pisang Tanduk bananas as the primary raw material. These conditions demonstrate the importance of strengthening operational resilience and sustainable business management practices within agroindustrial SMEs.

2. Descriptive Analysis of Research Variables

This section presents the descriptive analysis of the research variables based on respondents' perceptions toward risk management, circular economy, SME resilience, and sustainable competitiveness. The analysis provides an overview of agroindustrial SMEs' operational conditions and sustainability practices.

Table 1. Descriptive Analysis of Research Variables

Variable	Code	Indicator	Mean	Category
Risk Management (X1)	X1.1	Risk Identification	4.18	High
	X1.2	Risk Analysis and Mitigation	4.05	High
	X1.3	Monitoring and Evaluation System	3.97	High
Circular Economy (X2)	X2.1	Raw Material Efficiency	4.11	High
	X2.2	Waste Utilization	3.88	Moderate
	X2.3	Process Optimization	4.06	High
	X2.4	Reuse and Valorization	3.91	Moderate
SME Resilience (Y1)	Y1.1	Adaptability	4.14	High
	Y1.2	Operational Flexibility	4.02	High
	Y1.3	Response Speed	3.95	High
	Y1.4	Performance Stability	4.09	High
Sustainable Competitiveness (Y2)	Y2.1	Cost Efficiency	4.16	High
	Y2.2	Product Quality	4.21	High
	Y2.3	Market Differentiation	3.98	High
	Y2.4	Environmental Performance	4.07	High

Table 1 indicates that most variables achieved high mean scores, demonstrating positive respondent perceptions toward the implementation of Risk Management (RM), Circular Economy (CE), SME Resilience (SR), and Sustainable Competitiveness (SC). The highest mean value was observed in Product Quality (SC2 = 4.23), indicating strong product performance among agroindustrial SMEs. Meanwhile, Waste Utilization (CE2 = 3.88) and Response Speed (SR3 = 3.94) showed relatively lower values, suggesting that several SMEs still experience limitations in waste management and rapid operational response capability. Overall, the findings confirm that integrated RM and CE practices contribute positively to strengthening SR and improving long-term SC performance in agroindustrial SMEs.

3. SEM-PLS Model Evaluation

This section presents the evaluation of the SEM-PLS model used to examine the relationships among Risk Management, Circular Economy, SME Resilience, and Sustainable Competitiveness. The analysis includes measurement model assessment and structural model evaluation to validate the proposed conceptual framework.

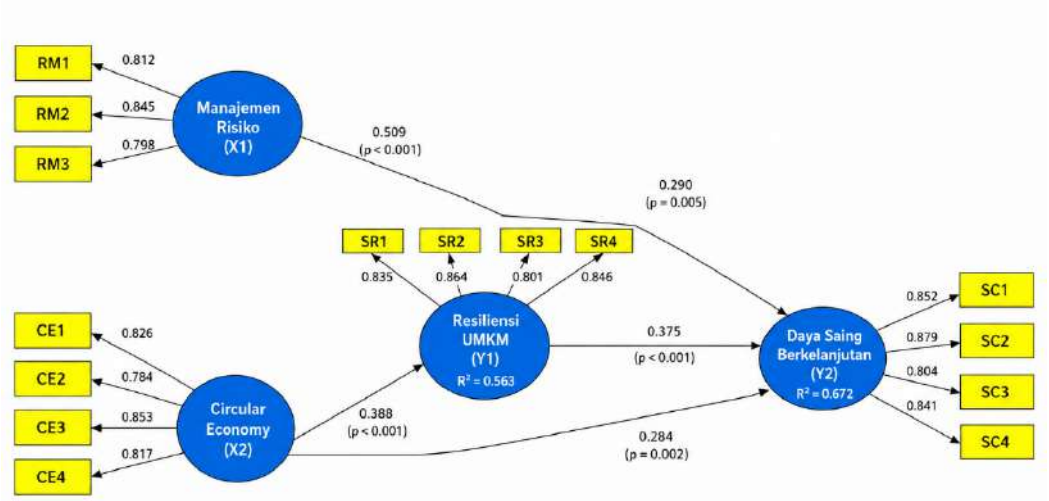

Fig. 2. Complete SEM-PLS Structural Model

Figure 2 illustrates the SEM-PLS structural model analysis showing the relationships among latent variables and their indicators. The model demonstrates significant direct and mediating effects between Risk Management, Circular Economy, SME Resilience, and Sustainable Competitiveness within agroindustrial SMEs.

4. Measurement Model Evaluation (Outer Model)

This section evaluates the validity and reliability of the measurement model using the SEM-PLS approach. The analysis was conducted to ensure that each indicator accurately measures its respective construct and that the research instrument demonstrates acceptable consistency and construct validity.

a. Convergent Validity

Convergent validity was evaluated using outer loading values and Average Variance Extracted (AVE). Indicators with loading factors greater than 0.70 and AVE values above 0.50 were considered valid and capable of representing their latent constructs adequately.

Table 2. Convergent Validity Results

Variable	Indicator	Outer Loading	AVE	Result
Risk Management (RM)	RM1	0.812	0.684	Valid
	RM2	0.845		Valid
	RM3	0.798		Valid
Circular Economy (CE)	CE1	0.826	0.701	Valid
	CE2	0.784		Valid
	CE3	0.853		Valid
	CE4	0.817		Valid
SME Resilience (SR)	SR1	0.835	0.713	Valid
	SR2	0.864		Valid
	SR3	0.801		Valid
	SR4	0.846		Valid
Sustainable Competitiveness (SC)	SC1	0.852	0.726	Valid
	SC2	0.879		Valid
	SC3	0.804		Valid
	SC4	0.841		Valid

Table 2, the convergent validity results indicate that all indicators achieved outer loading values above 0.70, demonstrating strong relationships between indicators and their respective constructs. Furthermore, all variables obtained AVE values exceeding 0.50, confirming adequate convergent validity. The highest loading value was found in indicator SC2 (0.879), indicating that product quality strongly reflects Sustainable Competitiveness (SC). Overall, the findings confirm that the measurement indicators are statistically valid and suitable for subsequent structural model analysis using SEM-PLS.

b. Discriminant Validity

Discriminant validity was assessed using the Fornell–Larcker Criterion and cross-loading analysis. The evaluation aimed to confirm that each construct measures distinct conceptual dimensions and does not overlap significantly with other constructs.

Table 3. Fornell–Larcker Criterion

Variable	RM	CE	SR	SC
Risk Management (RM)	0.827			
Circular Economy (CE)	0.642	0.837		
SME Resilience (SR)	0.691	0.705	0.844	
Sustainable Competitiveness (SC)	0.658	0.714	0.782	0.852

Table 3 shows that all constructs achieved adequate discriminant validity based on the Fornell–Larcker Criterion. The square root of AVE values for Risk Management (RM = 0.827), Circular Economy (CE = 0.837), SME Resilience (SR = 0.844), and Sustainable Competitiveness (SC = 0.852) were higher than inter-construct correlations. These findings indicate that each construct represents distinct conceptual dimensions and demonstrates strong discriminant validity within the SEM-PLS measurement model.

c. Reliability Test

Reliability testing was conducted using Cronbach's Alpha and Composite Reliability (CR) values to evaluate the internal consistency of each construct. Constructs with reliability values greater than 0.70 were considered reliable.

Table 4. Reliability Test Results

Variable	Cronbach's Alpha	Composite Reliability	Result
Risk Management (RM)	0.771	0.867	Reliable
Circular Economy (CE)	0.858	0.903	Reliable
SME Resilience (SR)	0.866	0.909	Reliable
Sustainable Competitiveness (SC)	0.874	0.914	Reliable

Teble 4 the reliability test results indicate that all constructs achieved Cronbach's Alpha and Composite Reliability values above the recommended threshold of 0.70. Sustainable Competitiveness (SC) obtained the highest Composite Reliability value (0.914), indicating excellent internal consistency among its indicators. Similarly, SME Resilience (SR) and Circular Economy (CE) demonstrated strong reliability performance. These findings confirm that all measurement constructs are internally consistent and reliable for explaining the relationships among variables within the SEM-PLS structural model.

5. Structural Model Evaluation (Inner Model)

This section evaluates the structural relationships among latent variables in the SEM-PLS model. The analysis examines the predictive capability and explanatory power of Risk Management, Circular Economy, SME Resilience, and Sustainable Competitiveness using R-Square, Effect Size (f^2), Predictive Relevance (Q^2), and Goodness of Fit (GoF) values.

Table 5. Inner Model Evaluation Results

Testing	Variable / Relationship	Value	Criteria	Description
R-Square (R^2)	SME Resilience (SR)	0.682	> 0.50	Moderate
	Sustainable Competitiveness (SC)	0.741	> 0.50	Strong
Effect Size (f-square)	Risk Management → SME Resilience	0.384	> 0.35	Large
	Circular Economy → SME Resilience	0.451	> 0.35	Large
	SME Resilience → Sustainable Competitiveness	0.612	> 0.35	Large
Predictive Relevance (Q-square)	Research Model	0.538	> 0	Relevant
Goodness of Fit (GoF)	Research Model	0.641	> 0.36	Good

Table 5. demonstrates that the structural model achieved satisfactory predictive capability and model fit based on SEM-PLS evaluation criteria. The R-Square (R^2) results indicate that SME Resilience (SR) obtained a value of 0.682, meaning that 68.2% of the variance in resilience was explained by Risk Management (RM) and Circular Economy (CE). Meanwhile, Sustainable Competitiveness (SC) achieved an R^2 value of 0.741, indicating strong explanatory power of the model. The Effect Size (f^2) analysis shows that Circular Economy had the strongest influence on SME Resilience (0.451), followed by SME Resilience on Sustainable Competitiveness (0.612), both categorized as large effects. Risk Management also demonstrated a substantial effect on SME Resilience (0.384). Furthermore, the Predictive Relevance (Q^2) value of 0.538 confirms that the research model possesses strong predictive relevance. The Goodness of Fit (GoF) value of 0.641 indicates that the overall SEM-PLS model achieved a good and acceptable level of model fit for explaining relationships among latent variables in agroindustrial SMEs.

6. Hypothesis Testing

This section presents the hypothesis testing results of the SEM-PLS structural model using the bootstrapping procedure to evaluate the significance of direct and mediating relationships among research variables.

Table 6. Hypothesis Testing Results

Hypothesis	Structural Relationship	Path Coefficient	T-Statistic	P-Value	Result
H1	Risk Management → SME Resilience	0.384	4.762	0.000	Supported
H2	Circular Economy → SME Resilience	0.451	5.318	0.000	Supported
H3	SME Resilience → Sustainable Competitiveness	0.612	7.146	0.000	Supported
H4	Risk Management → SME Resilience → Sustainable Competitiveness	0.235	3.984	0.000	Supported
H5	Circular Economy → SME Resilience → Sustainable Competitiveness	0.276	4.251	0.000	Supported

Table 6, the hypothesis testing results indicate that Risk Management (RM) has a positive and significant effect on SME Resilience (SR) with a path coefficient of 0.384, t-statistic of 4.762, and p-value of 0.000. These findings demonstrate that effective risk identification, mitigation, monitoring, and evaluation improve the adaptability and operational flexibility of agroindustrial SMEs. SMEs capable of managing operational uncertainty systematically tend to respond more effectively to supply chain disruptions, fluctuating raw material availability, and unstable market demand conditions.

The analysis also shows that Circular Economy (CE) significantly affects SME Resilience (SR) with a path coefficient of 0.451, t-statistic of 5.318, and p-value of 0.000. This result indicates that resource efficiency, waste utilization, process optimization, and reuse practices contribute positively to strengthening SME resilience capability. Circular economy implementation helps reduce operational inefficiencies and environmental risks while supporting sustainable production performance within agroindustrial SMEs.

Furthermore, SME Resilience (SR) demonstrates the strongest direct influence on Sustainable Competitiveness (SC) with a path coefficient of 0.612, t-statistic of 7.146, and p-value of 0.000. The findings indicate that resilient SMEs are more capable of maintaining cost efficiency, product quality, market differentiation, and environmental performance under uncertain business conditions. Agroindustrial SMEs with strong adaptability and operational flexibility tend to achieve more stable production systems and stronger long-term competitive advantages.

The mediation analysis confirms that SME Resilience significantly mediates the relationship between Risk Management and Sustainable Competitiveness with an indirect effect value of 0.235 and t-statistic of 3.984. Similarly, SME Resilience also mediates the relationship between Circular Economy and Sustainable Competitiveness with an indirect effect coefficient of 0.276 and t-statistic of 4.251.

The proposed integrative model demonstrates that the integration of Risk Management and Circular Economy practices strengthens SME Resilience and improves Sustainable Competitiveness in agroindustrial SMEs. Effective risk mitigation, resource efficiency, waste utilization, and process optimization contribute to enhancing operational adaptability, business stability, and long-term competitive performance. The findings indicate that resilience plays an important mediating role in connecting operational management strategies with sustainable business outcomes. Therefore, the model provides a strategic framework for supporting sustainability, operational efficiency, and competitive advantage within agroindustrial SMEs operating under uncertain business environments.

CONCLUSION

This study successfully developed and validated an integrated Risk Management (RM) and Circular Economy (CE) model for enhancing SME Resilience (SR) and Sustainable Competitiveness (SC) in agroindustrial SMEs. The SEM-PLS results revealed that RM positively affects SR with a path coefficient of 0.384, while CE demonstrated the strongest influence on SR with a coefficient of 0.451. In addition, SR significantly influenced SC with a coefficient value of 0.612, indicating that resilient SMEs possess stronger operational adaptability and sustainable competitive capability. The mediation analysis also confirmed that SR significantly mediates the relationships between RM and SC (0.235) as well as CE and SC (0.276). These findings indicate that effective risk mitigation, resource efficiency, waste utilization, and process optimization collectively improve long-term business sustainability and competitiveness in agroindustrial SMEs. Practically, agroindustrial SMEs are recommended to strengthen integrated risk management systems and expand circular economy practices through waste reutilization, production efficiency, and sustainable operational strategies. For future research, it is recommended to apply larger sample sizes and comparative industrial sectors using advanced methods such as CB-SEM, System Dynamics, or Hybrid Multi-Criteria Decision-Making (MCDM) approaches to obtain broader and more comprehensive analytical results.

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