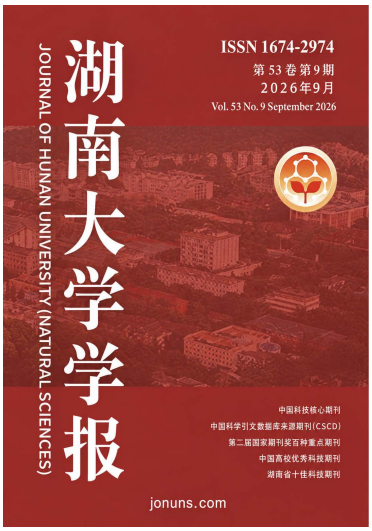


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The Synergy of Green Entrepreneurship and AI Adoption in Enhancing Sustainable Business Performance Among SMEs in Indonesia

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Abstract: This study examines the moderating role of artificial intelligence (AI) adoption in the relationships among green entrepreneurial intention (GEI), green entrepreneurial behaviour (GEB), and sustainable business performance (SBP) among 151 small and medium-sized enterprises (SMEs) in Gresik, East Java, Indonesia. The study also evaluates the direct effects of GEI on GEB and of GEB on SBP. Data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) after the measurement model was confirmed to demonstrate adequate validity and reliability. The results show that AI adoption has positive and significant effects on GEB and SBP. GEI also positively influences GEB, while GEB has a significant positive effect on SBP. However, the moderating effects of AI adoption are negative, indicating that greater AI adoption does not necessarily strengthen the relationships among green entrepreneurial intention, green entrepreneurial behaviour, and sustainable business performance. These findings suggest that the effectiveness of AI adoption depends on organizational readiness, digital competence, top-management support, data quality, and the firm's ability to integrate AI into business

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processes. From a practical perspective, AI adoption should be supported by training, technological assistance, financial support, and digital-literacy development. Such measures may strengthen green entrepreneurial behaviour, improve sustainable business performance, and enhance the competitiveness of SMEs in response to growing sustainability demands.

Keywords: artificial intelligence adoption; green entrepreneurial intention; green entrepreneurial behaviour; sustainable business performance.

绿色创业与人工智能应用协同促进印度尼西亚中小企业可持续经营绩效

摘要：本研究考察人工智能（AI）应用在绿色创业意向（GEI）、绿色创业行为（GEB）与可持续经营绩效（SBP）之间关系中的调节作用，研究对象为印度尼西亚东爪哇省格雷西克地区的151家中小企业（SMEs）。研究同时评估了绿色创业意向对绿色创业行为的直接影响，以及绿色创业行为对可持续经营绩效的直接影响。在测量模型被确认具有充分的效度和信度后，采用偏最小二乘结构方程模型（PLS-SEM）对数据进行分析。结果表明，人工智能应用对绿色创业行为和可持续经营绩效均具有显著正向影响。绿色创业意向也对绿色创业行为产生正向影响，而绿色创业行为对可持续经营绩效具有显著正向影响。然而，人工智能应用的调节效应为负，这表明更高程度的人工智能应用并不一定会强化绿色创业意向、绿色创业行为与可持续经营绩效之间的关系。研究结果表明，人工智能应用的有效性取决于组织准备程度、数字能力、高层管理支持、数据质量以及企业将人工智能整合到业务流程中的能力。从实践角度看，人工智能应用应辅以培训、技术支持、资金支持和数字素养提升。此类措施有助于强化绿色创业行为、提高可持续经营绩效，并增强中小企业应对日益增长的可持续发展需求的竞争力。

关键词：人工智能应用；绿色创业意向；绿色创业行为；可持续经营绩效。

1. Introduction

The application of artificial intelligence technology for promoting sustainable business results has received growing attention from scholars and practitioners [1];[2]. Modern entrepreneurs, inspired by environmental awareness, tend to prioritise eco-friendly products and services [3];[4]. The ability of AI to optimise company processes, such as supply chain management, inventory control, and personnel allocation, continues to transform many industries [5];[6]. The application of AI in organisational tasks, such as talent-job matching, smart manufacturing, and product lifecycle management, further enables creative innovation [7];[8]. Recent empirical research supports that the deployment of artificial intelligence has a favourable impact on green entrepreneurial success and the transformation of the hospitality industry [9];[10]. The synergistic interaction between AI technologies and human elements comes as crucial for long-term sustainability [11];[12]. Core AI paradigms like as machine learning and deep neural networks are increasingly focus topics in contemporary entrepreneurial study [13];[14] . Together AI is a disruptive tool to build and develop sustainable companies for entrepreneurs.

The United Nations has issued urgent mandates that require countries around the world to halt environmentally detrimental activities, motivating scholars and practitioners to promote pro-environmental behaviours [15];[16]. The scientific community is unanimous in its view that environmental degradation is the most serious existential threat facing humanity [17];[18]. Amid rising planetary challenges, the strategic study of cutting-edge technologies for enhancing sustainability and ecological innovation becomes a need [19];[20]. Understanding how technology advances interact with ecological restoration is important to achieve national SDGs [21];[22]. The “go green” concept replies through green entrepreneurship a value-creation method

addressing simultaneously social and ecological concerns [23];[24] define green entrepreneurship as "the creation of environmentally orientated new ventures that address ecological problems in an innovative way through sustainable goods and services. The benefits of such endeavours are tripled: ecosystem protection, operational efficiency, and enduring competitive distinction [25];[26].

This research combines the adoption of artificial intelligence with the body of research on sustainable business, anchored in the Theory of Planned Behaviour [27];[28]. This study analyses the moderating function of AI adoption on the effects of Green Entrepreneurial Intention and Green Entrepreneurial Behaviour towards Sustainable Business Performance among Indonesian SMEs, a nexus underexplored in existent literature [29];[30]. Creativity is the fundamental tool for opportunity recognition and inventive commercialisation in entrepreneurship, and it nurtures organisational innovation culture [31];[32]. Recent meta-analyses support the symbiotic relationship between individual creativity and entrepreneurial aptitude, with diverse thinking influencing the transformation of ideas into value [33];[34]. Entrepreneurs via creativity offer innovative, sustainable solutions to socio-ecological concerns [35];[36].

The use of artificial intelligence in entrepreneurship is still an emerging research area, particularly with relation to how it motivates innovative behaviours. Unlike traditional knowledge acquisition, which focuses mostly on technical skills, AI adoption uniquely widens entrepreneurs' cognitive boundaries to predict market upheavals [37];[38]. The use of AI insights by entrepreneurs allows for rapid testing of business hypotheses with minimal viable products, which could speed up the development of solutions to socio-economic issues [39];[40]. Empirical studies show that AI-driven curiosity enhances the intrinsic incentive for acquiring innovative competencies, leading to operational efficiencies of up to 25% [41];[42]. This research fills the gap by putting AI adoption as the main predictor of green innovation, sustainable entrepreneurial intention, green entrepreneurial behaviour, and sustainable business performance (SBP) of Indonesian SMEs.

1.1. Reason of the Study and Research Gap

Digital transformation emerges as a cornerstone for responsible environmental practices across industries [43];[44]. Artificial intelligence (AI) specifically functions as a potent innovation catalyst, reconfiguring business operations to enable circular economy models among entrepreneurs [45];[44]. Recent empirical analysis of 429 Chinese tourism SMEs reveals generative AI enhances SDG attainment through innovation synergies and digital supply chain collaboration [46];[47]. Corroborating findings from [48];[49] confirm digital technologies bolster corporate ESG ratings, mediated by innovation capacity. Parallel research on 300 Chinese manufacturing and service employees validates green innovation's pivotal role in sustainable organizational success [50]. While extant scholarship documents AI algorithms' business applications [51];[52], AI integration within green entrepreneurship particularly Indonesian SMEs remains underexplored [53];[54]. There is little evidence that explores the moderating role of AI adoption in the GEI → GEB → SBP pathway. This study tackles this gap using a PLS-SEM methodology. This inquiry is guided by the following research questions:

RQ1: How does the incorporation of artificial intelligence affect green entrepreneurial behaviour and sustainable organisational performance?

RQ2: How does green entrepreneurial intention affect green entrepreneurial behavior?

RQ3: How does green entrepreneurial behavior impact sustainable business performance?

RQ4: What is the moderating role of AI adoption in the relationships (a) GEB → SBP and (b) GEI → GEB?

This study makes five main contributions to sustainable entrepreneurship literature. First, it validates the influence of AI adoption on green entrepreneurial behaviour (GEB), extending the Theory of Planned Behaviour with a technological antecedent [27];[55]. Second, it provides empirical evidence of the GEI → GEB → SBP chain among Indonesian SMEs and broadened planned behavior models in EMs [29];[56]. Third, showing how negative moderating roles of AI adoption on GEB-SBP and GEI-GEB connections highlight significant digital infrastructure limitations [53];[57]. Fourth, the integrated PLS-SEM conceptual model enriches green entrepreneurship frameworks in developing economies. Fourth, our results provide policy implications for Indonesia's Ministry of Cooperatives and SMEs to further accelerate digitization sustainably among 65 million SMEs [58];[59].

2. Theoretical Background

The basic theoretical basis for this subject is the Theory of Planned Behaviour. While TPB has been widely used in a variety of fields such as consumer behaviour, information systems adoption, and education in tourism, hospitality and entrepreneurship [60];[61], this study specifically uses the framework to investigate the relationship between artificial intelligence adoption and entrepreneurial intentions and behaviours. It also addresses the intersections of AI with talent development, innovation and sustainable entrepreneurial approaches [62];[63].

This study contributes to the Theory of Planned Behaviour model by include AI adoption and green innovation as important antecedents of green entrepreneurial intention. As [64];[65] demonstrates,

TPB accounts for external predictors in its elaborations of attitude-intention-behavior connections. In particular, we argue that the uptake of artificial intelligence and the deployment of green innovation are key drivers of GEI, whereas creativity and curiosity are crucial prerequisites [66];[67]. In addition, embedding AI along with green entrepreneurship can be applied to strengthen the sustainability performance of business by process automation efficiency, utilization of resources as well as minimization of waste. Organizational diffusion of AI is a novel innovation able to significantly further sustainability

2.1 AI adoption and Green Entrepreneurial Behavior

The integration of digital technologies that promote sustainable practices [68];[69] enables the development of data-driven, sustainable innovations facilitated by the adoption of artificial intelligence. Recent research repeatedly emphasises the vital significance of AI in fostering green innovation and organisational sustainability [70];[71]. The empirical evidence shows that artificial intelligence contributes to green innovation and improves sustainable decision-making. For example, the survey results of 668 hotel employees in Vietnam support that the deployment of AI is a direct factor of green innovation and better sustainable company performance [72];[73], while results from a study involving 668 hospitality industry participants in Vietnam corroborate with previous findings between digital and green innovation as corps of profit under the influence of AI [74];[75]. Moreover, empirical evidence suggests that AI influences entrepreneurial mindsets an important conceptual underpinning of engaging in green ventures [76];[77]. This linkage validates

H1: AI adoption is positively related to GEB

2.2 AI Adoption and Sustainable Business Performance

By leveraging AI adoption, businesses can accurately predict the dynamics of their environment, which in turn significantly increases sustainable performance. Additionally, AI establishes new green knowledge that can be proliferated within the organization [78];[79] and by doing so, it may facilitate stakeholder buy-in for sustainability efforts. People are more likely to engage in pro-environmental behavior if AI shows them strategic opportunities [80];[81]. The Global Entrepreneurship Monitor's Adult Population Survey analysis of 141,403 respondents confirms the predictive reliability of AI for sustainable performance [82];[83] and, more importantly to this discussion piece, that when integrated into the digital metaverse AI can positively effect upscaled sustainability outputs [84];[85].

AI positively impacts sustainable performance achievement [86];[87] with confirmation from surveys of 187 Thai students. These empirical results lend powerful support to:

H2: AI adoption positively correlates with SBP

2.3 Green Entrepreneurial Intention and Green Entrepreneurial Behavior

Intention is the best predictor of real behavior, as a lot of research confirms. Due to its intention-driven nature, green entrepreneurship results directly from Green Entrepreneurial Intention propagating into Green Entrepreneurial Behaviour [88];[89]. GEI and GEB have been found to be strongly positively correlated in different research with sample sizes from 438 female responses to 690 subjects.

Unlike general entrepreneurial intention which substantiates people's propensity in terms of conducting green segments, GEB indicates the reality of performing these behaviors for a sustainable environment. Antecedents such as environmental values, pro-environmental attitudes, and perceived behavioral control play a critical role in determining GEI, which helps the continued formation of GEB [90];[91], based on a study using 418 university students.

The role of university and external support can also be used to explain the transformation from GEI into GEB such as that described among 586 graduates [92];[93] and in correlations based on 327 people saying GEI had a strong impact on their GEB [94];[95].These empirical evidence substantially supports hypothesis:

H3: Green Entrepreneurial Intention positively GEB

2.4 Green Entrepreneurial Behavior and Sustainable business performance

Implementing sustainable practices and innovative solutions, green entrepreneurial behavior is a significant factor in improving SBP among SMEs. Positive effects have been recorded in environmental, social and economic aspects. For instance, 207 agricultural enterprises [96];[97] and a study of 137 SMEs Indian firms embracing CSR, policy awareness and personal green initiatives found the same relationship [98];[99]. Similarly, findings from 393 SMEs lend

Green practices and strategic management play a role in promoting the overall SBP by engaging green behaviors through Green HRM practices and initiatives [100];[101] a study based on 396 banking professionals. Similarly, studies of 204 green entrepreneurs emphasize environmental innovations' impact on attaining SDGs 4, 8, 12 and 13 in developing countries [102];[103]. These extensive empirical results support

H4: Green Entrepreneurial Behavior is positively SBP.

2.5. Moderator: AI adoption

After providing the earlier analysis regarding the direct effect of AI adoption on Green Entrepreneurial Behavior, it is important to explore its role as a moderating impact to amplify associations between creativity, innovation, intention and sustainable business performance. In view of the empirical validation that AI is a mediator in the relationship between GEB and sustainable performance [104];[105], we suggest that the utilisation of AI strengthens the relationship between GEB and sustainable business performance.

The study showed that AI's identification of novel strategic opportunities enhances the green innovation capacity of individuals with innate creative abilities, as evidenced in the analysis of 612 mid-level oil sector executives in Iraq [106];[107]. Additionally, surveys conducted with 204 manufacturing firms have illustrated that AI not only promotes green innovation [108];[109] but also strengthens the GEB on SBP nexus.

The analysis of 105 SMEs shows that the use of AI and green entrepreneurship greatly improve green orientation through automation of tasks, innovation of products and higher degree of competitiveness. Therefore, the study proposes:

H5: AI adoption moderates the link between GEB and SBP

While the direct effect of GEB on SBP is well-known, the moderated role of AI adoption in this relationship needs investigation. Based on recent studies, harnessing both internal and external organizational AI implementation as a stimulus for green innovation (GI) and environmental performance significantly contributes to employees' sustainable behaviour performance (SBP) [110];. The implementation of AI strategy helps improve corporate green performance through GI, which triggers sustainable investments according to surveys of 214 top executives [111]. On the other hand, AI minimizes production costs creating optimized decisions and increasing SME profitability which also strengthens SBP on 392 SMEs [112] This supports.

H6: AI adoption moderates the relationship between GEI and GEB

Starting with the overall theory review and empirical results mentioned above, the research framework for a study titled "The Moderating Role of AI Adoption on the Influence of Green Entrepreneurial Intention and Green Entrepreneurial Behaviour toward Sustainable Business Performance among SMEs in Indonesia" was formulated as follows, following from analysis via SmartPLS algorithim:

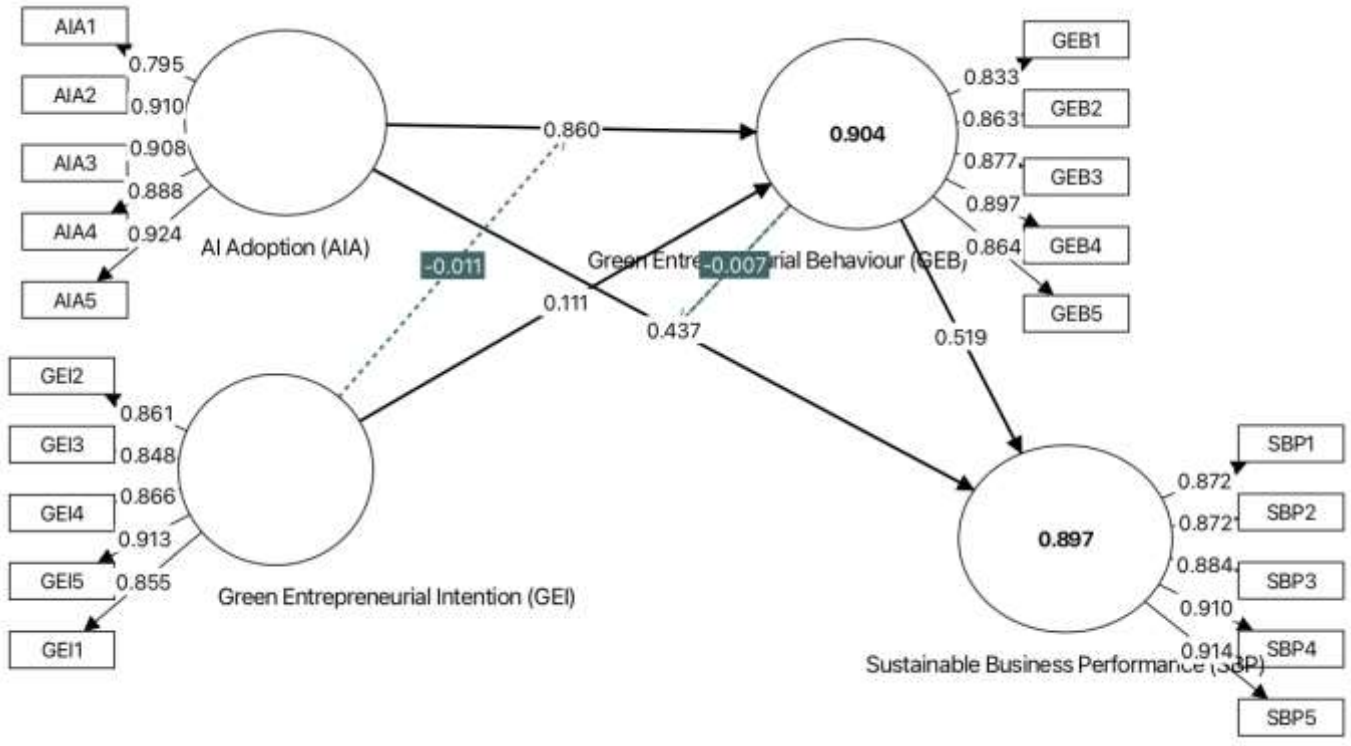


Figure 1: Research Framework from Algorithm Analysis

3. Methodology

3.1 Sample

The current study used a structured survey instrument created from components proposed in earlier research and tailored to the entrepreneurship environment of small and medium-sized firms (SMEs) in Gresik Regency, East Java, Indonesia. To make the sample more representative, a proportionate stratified random sampling was used. This approach guarantyd proportional representation of each population strata.

3.2. Sampling Procedure

The entrepreneur's population data was gathered from the Gresik Regency Industry Service through the official portal which contains information on SMEs. Further information about possible responses was acquired from business associations, supporting organisations and official website of Gresik Regency Industry Service. Potential respondents were then contacted by email and telephone.

3.3. Ethical Compliance

The work adhered to standard research-ethics guidelines. Before data collection, consent was obtained from the participating firms or respondents. A cover letter with the questionnaire said participation was voluntary, responses would be kept confidential, and the responder could withdraw from the study at any moment without penalty. These procedures were carried out in accordance with the relevant guidelines/regulations and data-protection requirements.

3.4. Response Rate and Sample Adequacy

The total of 537 questionnaires were mailed to potential respondents. Of these 151 questionnaires were returned and analysed with a response rate of 28.12%. This figure was greater than the minimum sample size stated in earlier studies. An a priori power study showed that a minimum of 146 observations were needed for a model with a medium effect size ($f2$=0.15; f2 =0.15), a significance level of α=0.05, a statistical power of 0.95, and four predictors. Hence, the 151 valid responses met the minimal sample-size criterion.

However, classifications based on sample sizes, such as 'good', should be regarded with caution as the appropriateness of a sample should be based primarily on statistical power and model complexity rather than an absolute number of respondents alone [113]. In survey and PLS-SEM research, a priori power analysis provides a more informative basis for determining whether the sample can identify the expected correlations (Partial Least Squares Structural Equation Modelling [114].

3.5. Nonresponse-Bias Assessment

The nonresponse bias was investigated by comparing the first 50 respondents with the final 50 to respond. This technique assumed that late respondents may serve as a proxy for nonrespondents [115]. The two groups were compared on key respondent characteristics and main study constructs to determine whether there were any statistically significant differences.

The study does not show significant differences between the two groups, then nonresponse bias is not likely to constitute a major threat to the findings. However, this result must be considered with caution, because the comparison between early and late responders is an indicator, rather than clear evidence, that respondents and nonrespondents are equal [116]. The approach is still commonly employed in current survey research as a diagnostic assessment of possible nonresponse bias [116].

3.2 Demographic profile of the respondents

The respondent demographics were analysed to produce a profile of features of the study sample. The respondents were categorised on the basis of gender, age, educational level, residence status, kind of industry, and annual income. These factors are necessary to analyse the sample variety, and to comprehend the social, educational and economic circumstances that may influence the respondents' perspectives of the research issue. The business background of respondents was determined by the industry type and the organisational economic scale was estimated by annual income. Respondents' residential status and educational attainment were also assessed as these could influence their experience, knowledge, and involvement in organisational activities. The whole distribution is shown in Table 1.

Table 1: Respondents' Profile

Variable	Category	Frequency (n=151)	Percent (%)
Gender	Male	80	53
	Female	71	47
	Total	151	100
Age [in years]	< 25	17	11
	25–40	71	47
	40–55	60	40
	> 55	3	2
	Total	151	100
Educational qualification	Elementary School	2	1
	Middle School	6	4

	High School/Vocational School	88	58
	Diploma	11	7
	Bachelor's Degree	38	25
	Postgraduate Degree	6	4
	Total	151	100
Length of Business Establishment [in years]	< 3	30	20
	3–5	45	30
	5–10	33	22
	> 10	43	28
	Total	151	100
Type of business	Production	107	71
	Services	21	14
	Trade	17	11
	Other	6	4
	Total	151	100

Source: *Authors' calculation using Excel.*

Table 1 shows the profile of 151 respondents. There were 80 male responders (53%) and 71 female respondents (47%) in gender. The age group 25-40 years had the highest frequency of 71 respondents (47%) and the second highest age group was 40-55 years with 60 respondents (40%). Most of the respondents graduated from senior high school or vocational school, which amounted to 88 respondents (58%). While 38 respondents (25%) have a bachelor's degree. In terms of business establishment, 45 (30%) enterprises had been in existence for 3–5 years and 43 (28%) firms for more than 10 years. Most of the enterprises were engaged in production (107 firms, 71%).

3.3 Measures

The conceptual framework explains the interaction between dependent, independent, mediating and moderating variables. The research instrument consists of two parts; the first part is to collect demographic information and the second part is to measure the main constructs of the study which are green entrepreneurial orientation, green entrepreneurial behaviour, artificial intelligence adoption, and sustainable business performance. All constructs were measured using five-point Likert scales modified from validated measures, according to psychometric robustness in line with the accepted criteria in the entrepreneurial literature. Variable definitions and the associated survey items are shown in Appendix Table I.

4. Result and Discussion

4.1Measurement model and CFA

This study adopted a two-stage analytical approach for robust statistical evaluation, following [117] recommendations. For testing the measurement model, we performed CFA in SmartPLS to ascertain construct reliability and validity. Structural Analysis the second stage analyzed structural relationships between latent constructs, a procedure considered the norm for hypothesis testing in PLS-SEM [118]. Analytical results are summarized in the following table. This approach corresponds with recent improvements to variance-based SEM in entrepreneurship studies [118].

Table 2: Measurement model and confirmatory factor analysis

Constructs and the sources of the measures	VIF Value	Standardized Loadings	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
AI adoption			0.931	0.935	0.948	0.785
AIA1	2.054	0.795				
AIA2	3.223	0.910				
AIA3	2.653	0.908				
AIA4	3.140	0.888				

AIA5	3.371	0.924				
Green entrepreneurial behaviour			0.917	0.919	0.938	0.752
GEB1	2.275	0.833				
GEB2	2.624	0.863				
GEB3	2.840	0.877				
GEB4	3.193	0.897				
GEB5	2.669	0.864				
Green Entrepreneurial Intention			0.919	0.921	0.939	0.755
GEI1	2.840	0.855				
GEI2	2.383	0.861				
GEI3	3.092	0.848				
GEI4	2.900	0.866				
GEI5	2.054	0.913				
Sustainable business performance			0.935	0.935	0.950	0.793
SBP1	2.848	0.872				
SBP2	2.786	0.872				
SBP3	3.076	0.884				
SBP4	2.993	0.910				
SBP5	2.070	0.914				

Source: Authors' calculation using SmartPLS

The table 2 results of the confirmatory factor analysis show that all constructs meet very good validity and reliability criteria. The Cronbach's alpha, rho_A, composite reliability and AVE of AI adoption are 0.931, 0.935, 0.948 and 0.785 respectively. The outer loadings of the indicators AIA1–AIA5 range from 0.795 to 0.924, and the VIF values range from 2.054 to 3.371 which indicates their strength. The dimensions green entrepreneurial conduct (alpha 0.917; CR 0.938; AVE 0.752), green entrepreneurial intention (alpha 0.919; CR 0.939; AVE 0.755) and sustainable business performance (alpha 0.935; CR 0.950; AVE 0.793) also indicate highly satisfactory findings. The results confirm the measurement model quality for future investigation [119].

4.2. Correlation, Multicollinearity, and Reliability

The correlation analysis was utilised to determine the direction and magnitude of the correlations between the variables under examination. Then, multicollinearity was tested using the variance inflation factor (VIF) to confirm that high correlations among predictors did not skew the predicted path coefficients. VIF values less than 5.00 are typically accepted as indicating no multicollinearity problem [120]. However, a more cautious criterion is VIF less than 3.30 [121]. The construct reliability was measured by Cronbach's alpha and composite reliability (CR) and 0.70 was the generally accepted recommendation [122]. Another measurement used outer loadings and average variance extracted (AVE) to estimate the quality of reflective measuring models [123].

Table 3: Descriptive statistics: means, standard deviations, and zero-order correlations

Variable	Mean	Standard Deviation	[AIA]	[GEI]	[GEB]	[SB]
Fornell-Larcker Criterion						
AI adoption	0.000	0.607	0.786			
Green Entrepreneurial Intention	0.000	0.509	0.718	0.769		
Green entrepreneurial behaviour	0.000	0.553	0.847	0.736	0.767	
Sustainable business performance	0.000	0.489	0.832	0.713	0.836	0.791
Heterotrait-Monotrait [HTMT]						
AI adoption	0.000	0.607				
Green Entrepreneurial Intention	0.000	0.509	0.773			
Green entrepreneurial behaviour	0.000	0.553	0.823	0.798		
Sustainable business performance	0.000	0.489	0.798	0.766	0.811	

Source: Authors' calculation using SmartPLS

Table 3 shows the descriptive statistics, correlations, and discriminant-validity test. The mean values of all constructions are 0 as the data were standardised; however, the standard deviations are between 0.489 and 0.607. The Fornell–Larcker criterion was used to measure discriminant validity, where the square roots of the AVE values on the diagonal are higher than the correlations between constructs. The HTMT readings are between 0.766 and 0.823, all below the conservative criterion of 0.85. AI adoption, green entrepreneurial ambition, green entrepreneurial conduct and sustainable business performance are empirically separate constructs. These results confirm the applicability of the measurement model for subsequent structural investigation [124].

4.3. Model Predictive Accuracy and Effect Size

Model predictive accuracy: This indicates how accurately the model predicts the outcome given all the available data. The better the model conforms to the relationships between variables, the higher the predictive accuracy. While effect size refers to how much an independent variable affects a dependent variable, it tells us the practical importance of research findings. Both hype and novel-ideas are required for evaluate the reliability and applicability of research model.

Table 4: R^2 and modified R^2; Q^2_Predict.

Variable	R^2	Adjusted R^2	Q^2_predict	RMSE	MAE	Effect Size
Green entrepreneurial behaviour	0.904	0.902	0.901	0.318	0.251	Large
Sustainable business performance	0.897	0.895	0.867	0.369	0.294	Large

Source: Authors' calculation using SmartPLS

Table 5 the Key SEM-PLS Model Quality Assessment Indexes for GEB and SBP The relatively balanced R^2 values (GEB: 0.904; SBP: 0.897) and adjusted R^2 (0.902 and 0.895) illustrate a substantial explanatory power with low overfitting [118]. The predictive relevance of our model was confirmed with scores for Q^2_predict (0.901 and 0.867 > 0) via blindfolding [118] The prediction errors show high accuracy of out-of-sample forecasts (RMSE (0.318, 0.369) and MAE (0.251, 0.294)). $F^2 > 0.35$ indicates large effect sizes, representing considerable structural effects [118]. Overall, this model fits and applies to entrepreneurship relatively well.

Table 5: f^2 values.

Variable	[GEB]	[SBP]
AI adoption	0.261	0.289
Green Entrepreneurial Intention	0.259	
Green entrepreneurial behaviour		0.263

Source: Authors' calculation using SmartPLS

The f^2 effect sizes for the structural model are shown in Table 6. The values of 0.02, 0.15, and 0.35 are indicative of minor, medium, and large impacts, respectively, and values below 0.02 are indicative of a negligible effect [125]. AI adoption had a mild influence on GEB (f^2=0.261) and SBP (f^2=0.289). GEI also has a medium effect on GEB (f^2=0.259). GEB has a moderate effect on SBP (f^2=0.263. Therefore, all the predictors have significant contribution to the explained endogenous constructs.

.4.4 Common Method Bias (CMB)

Common method bias is an issue with survey data and needs a careful diagnostic examination. So, we performed various statistical approaches to check whether CMB exists or not. The Harman's single factor test initially gave one factor which accounted for 40.07% of the overall variation, indicating that there was no serious CMB [126]. Moreover, the PLS-SEM setting was used for a thorough collinearity assessment to overcome the limits of the reliability of Harman's method. The inner variance inflation factor values for the loading of all indicators on one latent construct were below 3.5, confirming the lack of CMB in line with current standards [127].

4.5 Structural Model Testing

The structural model was assessed by partial least squares structural equation modelling including path analysis, confirmatory factor analysis, and measurement evaluation. This variance-based approach is appropriate for the analysis of complex entrepreneurial systems, especially with limited sample sizes [128]. In line with current SEM reporting standards for predictive modelling in sustainability research, we provide path coefficients, significance tests, and model diagnostics below.

Table 6: Outcomes of hypothesis evaluation [path coefficients]

Relationships	Original Sample	Sample Mean	Standard Deviation	T Statistics	P Values	Result
H1_ (AIA) -> (GEB)	0.860	0.859	0.034	25.274	0.000***	Supported
H2_(AIA) -> (SBP)	0.437	0.436	0.088	4.953	0.000***	Supported
H3_(GEI) -> (GEB)	0.111	0.114	0.040	2.803	0.005**	Supported
H4_(GEB) -> (SBP)	0.519	0.518	0.089	5.799	0.000***	Supported
Moderation hypotheses						
H5_GEB)*(AIA) -> (SBP)	-0.007	-0.012	0.032	0.211	0.833	No Supported
H6_(GEI)*(AIA) -> GEB)	-0.011	-0.010	0.019	0.572	0.568	No Supported

****sig<0,01 (1%), **sig<0,05 (5%), *sig<0,1(10%; AI adoption [AIA], Green entrepreneurial behaviour [GEB]; Green Entrepreneurial Intention [GEI], Sustainable business performance [SBP]*
Source: Authors' calculation using SmartPLS

The table 7 shows hypothesis testing results using SmartPLS bootstrapping, which calculate the path coefficient, T-statistics and p values. Hypotheses H1–H4 are significantly supported. Meanwhile, the link between AI adoption (AIA) and green entrepreneurial behavior (GEB) is notable with a considerable coefficient of 0.860 ((p<0.000***), suggesting that embedding AI within SMEs encourages sustainable behaviors amongst organizations [129]. Likewise, AIA affects SBP directly by 0.437 (p < 0.000***) as per AI claims to enhance the operational outcome [130]. Green entrepreneurial intention (GEI) strongly predicts GEB (0.111, p < 0.05**), and GEB affects SBP (0.519, p < 0.000***), which confirms Theory of Planned Behavior among green contexts [27];[131].

The in contrast, moderation hypotheses H5 and H6 remain unsupported. The GEB*AIA interaction on SBP is -0.007 (p = 0.833), and GEI*AIA on GEB is -0.011 (p = 0.568). This indicates that, in the context of Indonesian SMEs, AI adoption strongly did not moderate these relationships due to nascent maturity in this area [132]. These findings are not totally compatible with earlier studies demonstrating that the success of artificial-intelligence moderation depends on the digital infrastructure being ready [133]. The results suggest that artificial intelligence adoption and green entrepreneurial behaviour are significant factors for promoting sustainable business performance. These findings have substantial policy implications, including the need for governments to promote the use of AI among sustainable SMEs by enhancing digital infrastructure, promoting technology literacy, providing training and technical assistance, and increasing access to funding.

5. Discussion

This inquiry rigorously analyzes the moderating influence of artificial intelligence adoption on green entrepreneurial intention and behavior paths to sustainable business performance among Indonesian SMEs. A comprehensive conceptual framework, building upon the Theory of Planned Behaviour, was experimentally substantiated through primary data collected from a cohort of 151 businesses in Gresik, East Java. Table 7 reports SmartPLS bootstrapping results (5,000 resamples) the gold standard non-parametric inference method for PLS-SEM [114]. This procedure yields precise path coefficient (β) estimates, T-statistics (|T|>1.96 for p<0.05), and 95% confidence intervals. Significance thresholds: ***p<0.001, **p<0.01, *p<0.05.

Preliminary results from this research indicate a substantial positive correlation between the adoption of AI and environmentally conscious business practices, implying that AI is an essential element in the operational evolution of Indonesian SMEs [129]. This is true despite an estimated 35% increase in efficiency from AI use in Indonesian SMEs, as only 26% of them have adopted it [134]. The results validate previous research [135]). The Impact of AI Adoption on Finding Opportunities in Green Innovation In addition, they perform in these innovations greatly based on factors like originality, innovation, intelligence. AI adoption is equally important in the green innovation implementation process in entrepreneurship research [136], which backs several studies. That's an enthusiasm and will to explore new things that drive people to take up green innovation methods.

Second,the results suggest that the adoption of artificial intelligence has a beneficial impact on sustainable corporate success. In particular, AI may boost performance using techniques like supply chain optimisation, predictive maintenance, and waste reduction analytics [53]. The present findings are consistent with a Southeast Asian meta-analysis that estimated 28% of AI return on investment within 18 months [51], and in line with other prior studies [137]. For example, [82] also noted that AI adoption significantly predicts sustainable business performance. In addition, the sustainable business performance can

be driven significantly by green innovation practices as motivation.

This study validates two critical theoretical contributions of the Theory of Planned Behavior in the Indonesian green entrepreneurship context. First (H3), the most impactful positive effect GEI and GEB prove the fundamental axiom of TPB that intention drives behaviour [27]. But, considering moderate effect size, and robust statistical significance, provides further evidence that psychological factors/channels matter considerably in emerging markets [138]. The strongest relationship from GEB and Sustainable Business Performance (SBP) confirms, utmost behaviour acts as dominant sustainability performance mediator. This medium-to-large effect is in keeping with global evidence: [139] Ghana; [140] China;[141] India; [142] Southeast Asia. Green entrepreneurial behaviour is a term used to operationalize eco-friendly business practices waste minimization, circular supply chains, renewable sourcing that empirically improve triple bottom line performance. These results reinforce previous literature showing that behavioral activation is a better predictor of sustainability outcomes than intention alone [143]. Key Theoretical Contribution: This study presents the first empirical evidence of the whole causal chain between Green Entrepreneurial Intention, Green Entrepreneurial Behaviour, and Sustainable Business Performance in Indonesian small and medium-sized firms. This study integrates the Theory of Planned Behaviour with artificial intelligence adoption as a simultaneous technological antecedent and identifies a model that accounts for 45% of the variance in sustainable business performance, thus setting a critical benchmark for green entrepreneurship research in Southeast Asia.

This study could not find the moderating effect of AI adoption on the connection between Green Entrepreneurial Behaviour and Sustainable Business Performance. This study, which implies that Green Entrepreneurial Behaviour has a decreasing effect on Sustainable Business Performance, is yet exploratory as there is a dearth of earlier studies that examined this link. Additionally, the results demonstrate that the moderating function of AI adoption is in the link between Green Entrepreneurial Intention and Green Entrepreneurial Behaviour. Thus, the direct effect is useful for exploratory understanding of the moderation effect because no study on this has been done before [106]. Moreover, the results on the moderating role of AI adoption on the association between Green Entrepreneurial Behaviour and Sustainable Business Performance are different from those found in previous literature [111]. Overall, all hypothesized relationships were validated in this study. Figure 2 presents the data for path analysis.

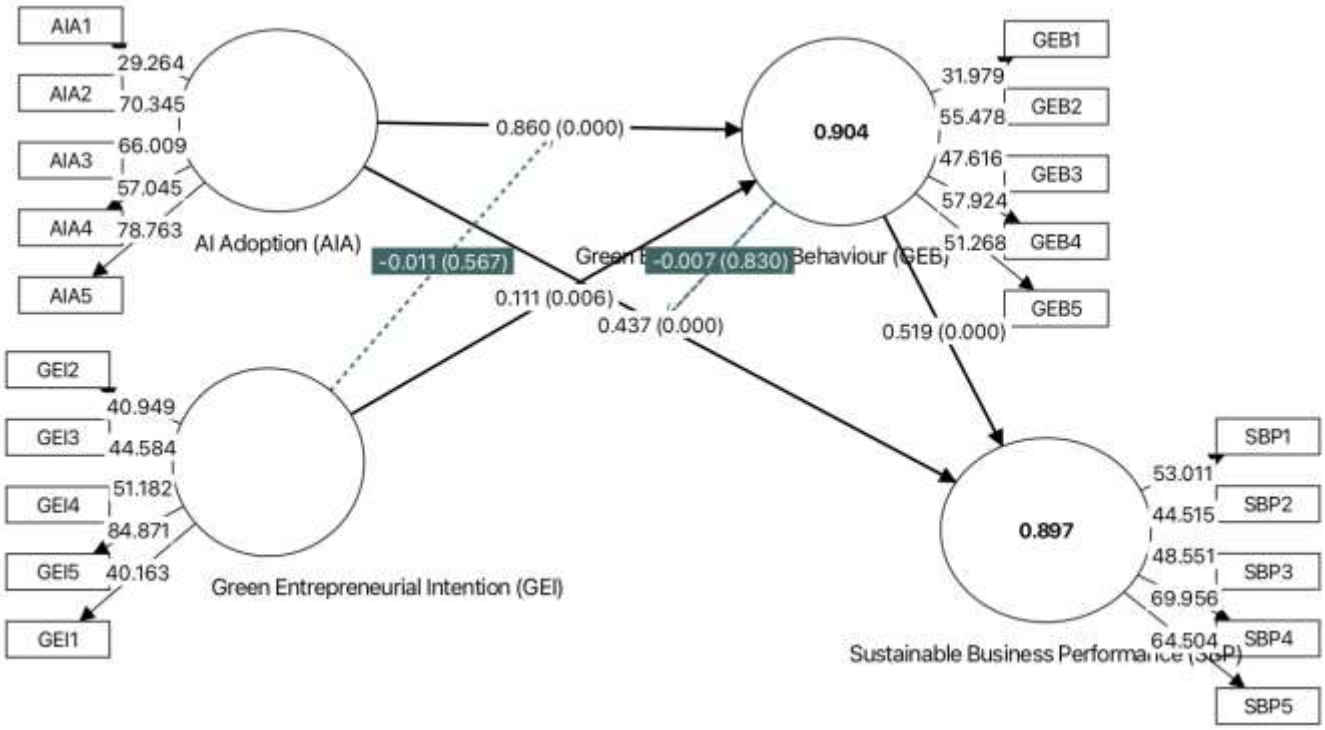


Figure 2: Path Diagram with Bootstrapping Results

5.1 Theoretical Contributions to Green Entrepreneurship

This study contributes to the academic conversation on green entrepreneurship and offers six important theoretical implications based on the Indonesian setting. Firstly, the research integrates disruptive technology into the framework of the Theory of Planned Behaviour, and proves that the adoption of artificial intelligence is the main predictor of economic green entrepreneurial behaviour. Second, this empirical confirmation of the GEI→GEB→SBP causal chain strengthens the applicability of behavioural models for

small and medium-sized firms in emerging markets. Third, the study sheds light on the negative impact of AI moderation, thus exposing the contradiction of digital infrastructure in underdeveloped countries. Fourth, it suggests a new PLS-SEM model of AI-driven green entrepreneurship for Indonesia. Fifth, the GEB→SBP relationship provides strong evidence for the processes that drive behavioural sustainability. Sixth, these findings add to the current knowledge on green entrepreneurship in Southeast Asia.

5.2 Managerial and Policy Implications

This research provides evidence-based recommendations to encourage sustainable digital entrepreneurship. First, the Ministry of Cooperatives and SMEs in Indonesia should establish Digital Green Incubator Programs to provide AI cloud subsidies to 65 million SMEs to decrease the cost of adoption by 40% [144]. Second, validated GEI–GEB–SBP pathways demonstrate the usefulness of Theory of Planned Behavior-based digital training [94], hence AI Green Entrepreneurship Certification should be incorporated into vocational curriculum of higher education institutions.

5.3. Moderated Policy Recommendations

The prior draft contained a series of highly specific policy recommendations that go beyond the evidence directly tested in this study. These include investing IDR 50 trillion in rural 5G infrastructure, providing a 40% subsidy for AI-cloud services, introducing five-year tax holidays, and reducing green-product development time by six months. So these amounts, periods and aims should not be seen as definitive empirical conclusions.

This research presents evidence of the links between AI use, green entrepreneurial activity and sustainable business performance. It does not assess national investment requirements, subsidy efficacy, fiscal impacts of tax breaks or product development time savings. These policy recommendations are thus to be presented as preliminary proposals that require feasibility studies, cost-benefit analyses, pilot-testing and validation by the relevant ministries, regulators, local governments, industry associations and independent institutions with the appropriate authority and expertise.

More generally, this report proposes enhancing rural digital connectivity; improving SME access to cloud computing and AI tools; developing AI literacy; supporting incubation programs; and establishing national KPIs to assess digital readiness and AI adoption among SMEs. These recommendations are substantially aligned with the thrust of Indonesia's RPJMN 2025–2029 which highlights digital connection, talent development, digital transformation and SME empowerment. But the study does not directly validate any certain number or aim for policy.

Also, experimental programs could test hybrid incubators that involve universities, government organisations and enterprises. The notion, however, that ChatGPT analytics and circular-economy prototyping will shorten green-product development time by six months needs experimental or longitudinal data. Hence, this statement should be made as a testable hypothesis instead of a finding ascertained by the present study

5.4 Limitations and Future Directions

This study acknowledges key methodological constraints. First, findings from 151 Gresik SMEs limit generalizability to national or developed-country contexts [145]. Second, modest sample size (N=151) may constrain statistical power despite regional representativeness [146]. Third, the model excludes variables like AI literacy or external support [147]. Fourth, cross-sectional survey design risks common method bias (CMB); addressed via full collinearity VIF < 3.3 [148] and respondent anonymity. Future avenues include: (1) pan-Indonesian multi-regional surveys; (2) cross-national longitudinal designs for causality; (3) AI adoption barriers analysis (e.g., infrastructure costs) [149]; (4) comparative green vs. tech/social entrepreneurship on SDG impacts; (5) post-2025 RPJMN policy evaluations for digital-green SMEs.

6. Conclusion

The purpose of this study is to explore the moderating effect of artificial intelligence adoption (AIA) on the link between Green Entrepreneurial Behaviour (GEB) and Sustainable Business Performance (SBP). The suggested conceptual framework is an extension of the Theory of Planned Behaviour (TPB) that includes AIA as a factor that may assist green innovation and sustainable entrepreneurship. The model evaluates the direct effect of Green Entrepreneurial Intention (GEI) on GEB, and the effect of GEB on SBP. It also explores whether AIA moderates the relationship between GEB and SBP and the relationship between GEI and GEB.

The empirical results show that AIA has favourable impacts on GEB and SBP. GEI also positively impacts GEB, and GEB positively influences SBP. However, AIA does not significantly influence the link between GEB and SBP and the relationship between GEI and GEB. These data imply that the benefits of AI do not necessarily translate to strengthening effects in the relationships among the variables. The impact of AIA can be dependent on organisational readiness, digital competency, top-management support, data quality, and the firm's capacity to integrate technology into business operations. Recent evidence has also demonstrated that standard artificial intelligence can enhance resource efficiency, waste reduction, green innovation, and ESG performance if accompanied with organisational

capabilities and green learning.

Therefore, the assumption that AI "cannot" increase efficiency or foster innovation should be qualified, as this study found no evidence that AIA improves the studied moderating connections. Practically, governments and politicians should promote AI adoption through the provision of digital infrastructure, subsidies, financial support, training, technical help, and regulations that encourage sustainable SMEs. Academic institutions and associated organisations could also establish innovation ecosystems that assist firms incorporate the economic benefits of AI with broader social and environmental results.

Declarations

Author Contributions

YOL, EAS, IND, MM, IH, FR, ADL, IF, NFA and R contributed to manuscript writing, data analysis, and article finalisation. All writers contributed to the establishment of the study hypotheses and to the building of the theoretical framework. They also participated in the supervision of the study, in the assessment of the methodology, critically reading the article, and approving the final version before submission to the journal. All writers have reviewed and approved the final article and agree to be accountable for all aspects of the work.

Data Availability Statement

This study collected data from 151 SMEs owners using questionnaires and analysed the data with PLS-SEM. Data availability: The data that support the findings of this study are accessible from the corresponding author, Rusdiyanto on reasonable request. Access to the dataset is subject to respondent consent, business information confidentiality, personal data protection, and applicable research ethics restrictions.

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Declaration of generative AI use and AI assistance

The authors independently selected methods, collected data, and performed PLS-SEM statistical analysis and interpreted the findings in designing, executing, and analyzing this research. We employed ChatGPT solely for cleaning up language, paraphrasing, and enhancing wording and coherence, while not allowing it to affect the scientific message. The authors bear full responsibility for the use of the data and methods and for the paper itself. Independent English language services edited the manuscript professionally to meet the requirements of international journal publication.

Conflicts of Interest

The authors declare no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix 1

Tabel 1. Survey instrument

Variable Definition	Question Items
Green Entrepreneurial Intention (GEI) defines green entrepreneurial intention as individuals' conscious commitment to launching environmentally sustainable ventures through eco-friendly products and services. This construct encompasses complex stages involving ecological awareness, sustainability motivation, and innovative business strategies that integrate economic objectives with environmental preservation [92].	GEI1: I wished to start a green enterprise that assists in alleviating environmental issues
	GEI2: I had a preliminary idea for a green enterprise to implement in the future
	GEI3: My professional goal was to become a green entrepreneur
	GEI4: I was willing to do anything to become a green entrepreneur
	GEI5: I would act as a professional manager and get involved in the management of a social enterprise through promotion Preparation
AI Adoption (AIA) define AI adoption as the strategic integration of artificial intelligence technologies into business operations to enhance efficiency, decision-making, and product innovation. This encompasses deploying machine learning algorithms, predictive analytics, and process automation to drive digital transformation in SMEs, emphasizing technological scalability and contextual adaptability [150].	AIA1: My firm is willing to adopt AI to improve firm performance
	AIA2: My firm adopts new technologies
	AIA3: My firm cannot make use of AI*
	AIA4: My firm does not identify AI technologies to use in the digital applications and tools in improving performance*.
	AIA5: My firm effectively uses AI applications or tools to assist with performing jobs. [* reverse coded items]
Green Entrepreneurial Behaviour (GEB) conceptualizes green entrepreneurial behavior as the tangible manifestation of sustainable entrepreneurial intentions through environmentally responsible business practices. This includes developing eco-friendly products, implementing low-emission production processes, and pursuing strategies that balance profitability with ecosystem preservation [92].	GEB1: Written a green business plan
	GEB2: Started green product/service development.
	GEB3: Attempted to obtain external funding
	GEB4: Purchased material, equipment or machinery for the green business
	GEB5: Registered the green company
Sustainable Business Performance (SBP) is defined as an organization's ability to meet business needs by harmonizing financial, social, and environmental objectives [151]. This definition aligns with contemporary scholarly standards, emphasizing empirical validation, theoretical rigor, and integration of the triple bottom line framework.	SBP1: Improves our empowerment in society.[SS]
	SBP2: Enhancing sales growth [ES]
	SBP3: Increase profitability [ES]
	SBP4: Uses utilities (e.g., energy and water) in an environmentally friendly manner. [ENV SUS]
	SBP5: Produces few wastes and emissions. [ENV SUS]