

Application of Principal Component and Cluster Analysis to Examine Factors Influencing Tourist Behavioural Intention: A Case Study of Santhei Natural Park, Manipur

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Abstract: - Community-managed parks play a significant role in the promotion of ecotourism growth by integrating local culture, tourism services and environmental conservation. However, the success of these destinations depends on several interconnected factors, such as infrastructure, cultural offerings, service quality, accessibility, and the surrounding landscape. Understanding how these factors interact to affect visitor satisfaction and behavioural intentions (such as recommendation and return) is crucial for sustainable destination management. The present study applies Principal Component Analysis, a Multivariate technique, to probe the core elements of ecotourism experiences, followed by Cluster Analysis in a study on Santhei Natural Park, Imphal, East Manipur, North East India. The study provides a PCA–SDG integrated framework linking tourist perception to actionable sustainability policy.

Key-Words: - Community Park, Ecotourism, Management, Behavioural Intentions, Principal Component Analysis, Cluster Analysis

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1 Introduction

Globally, tourism makes an important contribution to socio-economic development by increasing income, encouraging exports, and upholding cultural values. Hence, the tourist development and destination choice are prioritised by nations. The goal of India's Eco-Tourism Policy, which was created in 2018 and put into effect in 2024, is to encourage responsible and sustainable tourism in ecologically sensitive regions. Human beings engage in tourism for leisure, social merriment, education and trade [1]. Ecotourism includes contact with nature, culture, agriculture, wildlife, and adventure activities [2]. Tourist satisfaction remains a significant component of tourism sustainability [3].

Ecotourism destinations have become significant due to their efficiency in protecting the environment, supporting education, recreation, and job creation [4]. Unregulated tourism leads to nature degradation [5].

Ecotourism is a sustainable alternative to mass tourism that promotes environmental conservation, cultural preservation, and community participation, according to Tunde & Adetola [6]. Thus, ecotourism becomes a major tool for resource conservation, environmental protection and economic development.

Natural destinations that are characterised by unpolluted environments, clear water bodies, and beautiful landscapes attract tourists seeking tranquillity and authentic experiences. Ecotourism destinations require periodic impact assessment and monitoring approaches. Managers must realise the economic importance of meeting the needs of visitors and providing them with memorable experiences [7]. Hence, satisfaction is often an important goal that park managers seek to achieve [8].

Measuring the impact of various variables is important in planning so as to ensure that expenditure in ecotourism resources leads to increased monetary profits via enhanced repeat visitors [9]. Satisfaction is related to the choice

of destination, the consumption of products and services, and the decision to return [10,11,12]. Sustainable destination management needs the understanding of the working together of these elements so as to influence tourist satisfaction and behavioural intentions. The quality of the physical amenities has a significant impact on visitors' opinions and likelihood to return [13]. The quality of ecotourism services varies significantly in various eco-tourism destinations due to the management approach. Various assessment methods, focusing on qualitative and quantitative approaches, have been used in previous studies.

Manipur, North East India, is a biodiversity hotspot with enchanting landscapes and holds great potential for the development of its tourism industry. In rural Manipur, Santhei Natural Park, a community-managed park, can play a significant role in promoting ecotourism by integrating local culture, environmental sustainability, and tourism services. However, the success of such destinations depends on multiple interrelated factors, including service quality, accessibility, infrastructure, cultural offerings, and environmental attributes. This study provides a scientific basis for strategic planning of the development of the Manipur tourism industry, and practical solutions for attracting tourists to Manipur in general, and the Community Park in particular.

The objectives of this study are:

- To determine the key components of an ecotourism experience.
- To assess how these dimensions affect tourists' behaviour intention
- To suggest strategies for promoting the development of sustainable tourism

Multivariate methods like Principal Component Analysis help in figuring out the fundamental aspects of ecotourism experiences that affect tourist satisfaction and behavioural intentions like recommendation and return.

This study provides a scientific basis for strategic planning of the development of the

Manipur tourism industry, and practical solutions for attracting tourists to Manipur in general and the Santhei Natural Park in particular. India's Eco-Tourism Policy, drafted in 2018 and implemented in 2024, focuses on promoting sustainable and responsible tourism in ecologically sensitive areas.

2 Methodology

2.1 Site

Manipur, located in the Indo-Myanmar Biodiversity hotspot, is a unique state for promoting ecotourism in North-East India. Santhei Natural Park is situated in Imphal East District, Manipur, in the picturesque village of Andro. It is a tranquil ecotourism site that skilfully combines cultural legacy with natural appeal. About 21 kilometres east of Imphal, Manipur, situated at an elevation of around 2,000 feet, the park spans over 8.5 square kilometres. Santhei Natural Park is a sanctuary of grandeur preserved by nature by the traditional community of Andro, showing the reverence and passion for the preservation of nature. An artificial dam has been routed, making it enchantingly beautiful and serving as a water body cum source of public utility. For those who are adventurous, Santhei Natural Park provides plenty of opportunities for discovery and thrills, birdwatching, and leisurely walks along the trails surrounded by beautiful foliage and a serene lake. The park is particularly well-visited in the cooler months of October through March, when the scenery is most colourful, the temperature is comfortable, and the climate is salubrious. The Loi community, which is well-known for its traditional ceramics and indigenous traditions, calls Andro itself a cultural centre (Fig1A).



Fig. 1a Santhei Natural Park, Andro

Besides, the village Andro has several attractions (Fig 1b).



Fig. 1 b- Mei Mutaba (A place where fire does not extinguish), Traditional Pottery, Sacred Kaina Entrance, Mutua Museum Complex, Andro, Manipur

Some of them are Chakpa Panam Ningthou Meithoupirol Shanglen or Mei Mutaba (A place where fire does not extinguish) at Andro is a unique destination.

The Andro Traditional pottery-making is the talk of Manipur; the village is home to skilled craftspeople who use an ancient method of pottery-making without a potter's wheel. Rather, they mould clay entirely by hand.

Kaina is a beautiful hillock about 29 Kms to the east of Imphal, considered sacred as according to a legend, during the reign of King Bhagyachandra (1763-98 A.D.), the sacred idol of Lord was sculptured from the parts of a jack fruit tree grown at Kaina.

Mutua museum, a cultural complex, at the village of Andro houses multiple artefacts, highlighting the replicas of houses of different tribes and ethnic groups from all over the state, like Poumai, Kabui, Meitei, Kuki, Tangkhul, etc.

2.2 Demographic Characteristics

Data was collected through convenience sampling from 110 tourists who visited Santhei Natural Park, Imphal East, Manipur, during January 2024-December 2024. Of these, 42.7% were male tourists, whereas 57.3% were

female. The ages of tourists who visited the park were in between 20-30 years, >30-50 years and > 50 years respectively, corresponding with 41.9, 43.6 and 14.5% of tourists. The educational achievement of tourists respectively was 43.6%, Matriculates, 32.7%, Graduates and 23.7% with postgraduate degrees. Unmarried tourists were 61.8%, whereas 38.2% tourists were married. 57.3% of tourists had visited the park for the first time, 42.7% tourists visited the park at least 2 times or more.

2.3 Data Collection

Primary data was collected through structured questionnaires targeting available tourists using a convenience sampling approach. Tourists rated nine attributes (Food & Facilities, Service, Culture, Tourism Products, Digital Payment, Attraction, Transport, Return Decision, Tranquillity/Uniqueness) on a five-point Likert Scale. We utilised the above data to explore the relationships between attributes and tourists' behavioural intention. Principal Component Analysis was applied to identify the underlying dimensions that could influence tourists in the community park. Principal Component Analysis (PCA) is a widely used multivariate technique for data reduction and structure detection, employed to identify the key dimensions. PCA transforms correlated variables into a smaller number of uncorrelated components while retaining most of the variance in the dataset (Principal Component Analysis). The Kaiser-Meyer-Olkin (KMO) index and the Bartlett's test of Sphericity were used to determine if it was appropriate to perform PCA [14].

The variable loadings on the first two principal components were visualised using a biplot of component weights. It was determined that variables with comparable vector directions and magnitudes were perceptually related.

Cluster analysis was employed to sort out the natural clusters /groupings among variables. A cluster is a set of similar entities, distinct from

those in other clusters. Hierarchical cluster analysis was performed using the Nearest Neighbour (Single Linkage) method with Squared Euclidean Distance as the dissimilarity measure. The agglomeration schedule was examined to determine optimal cluster cut-off points. A dendrogram was generated to visualise the clustering process and interpret variable associations.

This combined approach allows for a comprehensive understanding of the phenomenon by both methods, characterising the variables and comparing them.

2.4 Application of PCA in Tourism Studies

PCA is widely used in tourism research to identify latent constructs influencing tourist behaviour. According to Jolliffe [15], PCA reduces data complexity while preserving variance, making it suitable for analysing multi-dimensional constructs like tourism experience. Previous studies have used PCA to identify destination attributes, group related variables and simplify decision-making frameworks.

Hussien et al [16], in their article on the Role of Statistical Modelling in Sustainable Tourism Planning, mention the use of PCA in dimensionality reduction and identification of key sustainability indicators. Mihai et al [17] used an exploratory analysis based on the principal component analysis (PCA) to reduce the dimensionality of the 23 items used to evaluate the factors that influence destination choice. The authors claim that these insights on the factors influencing tourists' decision-making process are of the utmost importance for managers and overall tourism service providers in the design of marketing and management strategies in accordance with tourists' expectations and needs. Wang et al [18] used 146 keywords related to "Beijing tourism" obtained from the Baidu index, and principal component analysis (PCA) was applied to reduce the dimensionality of keywords obtained by the Baidu index for analysing

potential tourist behaviour using PCA, taking Beijing city as an example.

2.5 Application of Cluster Analysis in Tourism Research

Cluster Analysis identifies patterns on the basis of attribute similarities and organises objects into groups or clusters. The output of clustering can be visually represented, and dimensionality reduction techniques such as the Principal Component Analysis (PCA) algorithm can be utilised to reduce the number of dimensions. Applications of clustering algorithms in tourism data analysis include destination profiling, market segmentation, customer behaviour analysis, and recommendation systems [19].

By using multidimensional statistical methods for classification, Liptáková et al [20] point out the fusion of regions of Central and Eastern Europe into clusters according to selected indicators of tourism, and differences between the clusters are defined. Wang et al [21] worked on the principal component analysis and clustering technology of the K-means clustering algorithm to analyse the tourism competitiveness of Leshan. The model shows that tourists' destination image perception is an important antecedent variable of tourists' behaviour intention, and perceived value and local attachment are two important intermediary variables. Ashraf et al [22] focus on customer segmentation based on their purchase behaviour attributes by using machine learning on the "Online Retail" dataset through various clustering algorithms.

3 Results

3.1 Principal Component Analysis

3.1.1 Components, Eigen Values, Variance

Two principal components were extracted, explaining approximately 80% of the total variance, indicating a reasonably good representation of the dataset as they capture most of the information in the data (Table 1).

The Kaiser–Meyer–Olkin (KMO) value is = 0.50, suggesting marginal sampling adequacy. However, the significant Bartlett’s Test of Sphericity ($p \approx 0.00$) indicates that the correlations between variables are statistically significant, supporting the use of PCA. These findings align with methodological guidelines proposed by Jolliffe [15], who emphasised that PCA is appropriate when variables exhibit meaningful intercorrelations.

Table 1 Analysis of Eigen Values

Component Number	Eigen Value	Variance %	Cumulative Percentage
1	5.24	58.24	58.24
2	1.95	21.70	79.94
3	0.66	7.33	87.27
4	0.57	6.35	93.62
5	0.26	2.86	96.48
6	0.19	2.07	98.55
7	0.09	1.04	99.59
8	0.03	0.35	99.94
9	0.01	0.06	100.00

3.1.2 Factor Loadings

Table 2 reveals Component Loadings, with high loadings on Component 1 for variables Tourism Products, Decision to Return, Digital Payment, Service, Uniqueness/Tranquillity, and Culture. Component 2 projects as the

Table 2 Factor Loadings on PC1 and PC2

No.	Variable	PC I	PC II
1	Food and Facilities	0.29	0.47
2	Service	0.37	0.10
3	Culture	0.34	0.14
4	Tourism Products	0.41	-0.07
5	Digital Payment	0.38	-0.30
6	Attraction	0.21	0.51
7	Transport	0.13	-0.59
8	Return Decision	0.40	-0.21
9	Tranquillity/Uniqueness	0.35	-0.07

Secondary Factor with strong positive loadings for variables Attraction, Food & Facilities, however, negative loadings for Transport (strong negative), Digital Payment and Return. Thus, this component clearly splits into the positive side representing on-site experience quality and the negative side representing Access and external convenience constraints. Component 2 reveals Nature vs Infrastructure Trade-off (Nature (tranquillity, uniqueness) vs transport (facilities)).

3.1.3 The Biplot

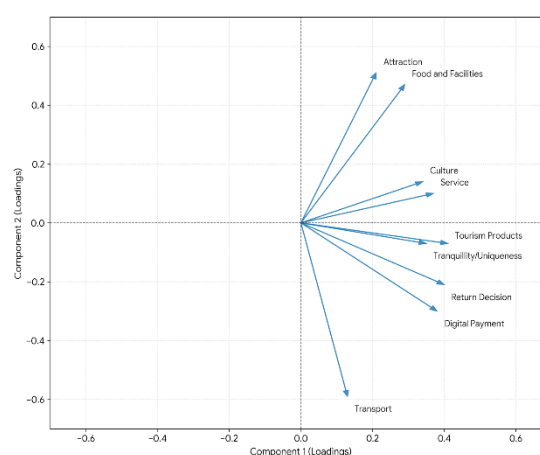


Fig. 2 PCA Biplot of Factor Loadings

In the biplot, the arrows represent variables, and the length of the arrows reveals how well the variables are represented by the two components; the longer arrows point to better representation. The small angle between arrows means strong positive correlation; however, the opposite directions (180°) justify negative correlation, and a 90° angle means little or no correlation (Fig 2).

Most variables point in a similar direction (right side) in the biplot, suggesting a strong common factor, which can be interpreted as overall Ecotourism Experience Quality. This includes Service Quality, Cultural experience, Tourism Products, Digital convenience, Emotional value (tranquillity) and Visitor satisfaction as Behavioural outcome (return & recommendation). Thus, it is obvious that visitors who rate one aspect highly tend to rate others highly too. This is Component 1

explaining the largest share of variance and exhibiting strong positive loadings across most variables, suggesting Overall Ecotourism Experience and Satisfaction. It can be interpreted that visitors who rate one aspect highly tend to rate others highly too. It is the strongest dimension as it confirms that a better experience provides higher satisfaction, leading to return intention. Component 1 is represented on the x-axis; it captures the main variation, with many variables aligning, suggesting a dominant underlying factor.

Component 2 is represented on the y-axis; it represents a secondary pattern or contrast and separates some variables from others. Component 2 reveals Attraction vs Accessibility, with attraction and food securing the positive values showing on-site experience; however, Transport and digital convenience get negative values, pointing out access and convenience on the negative side, with infrastructure being the Trade-off dimension. This introduces some separation as variables pointing upward vs downward.

Thus, PCA reveals that Ecotourism success is mainly driven by a single overall experience factor. Transport is the biggest weakness (separate and negative). Attraction and Tranquillity are strong positives. Visitors will return if the experience is good — even if access is imperfect.

3.2 Cluster Analysis

3.2.1 The Dendrogram

The dendrogram (Fig 3) reveals Attraction (6) joining Tranquillity/Uniqueness (9) at the lowest distance of 1.05, confirming their highest similarity as tourists see uniqueness as tied to attractions. Further, cluster (6+9) merges with Digital Payment (5), suggesting modern infrastructure is part of the attraction experience, followed by Culture (3), Tourism Products (4), and Service (2) at gradually increasing heights, visually forming the experience cluster with progressive grouping. As a separate branch, Food & Facilities (1)

cluster with Transport (7) at a moderate height of 5.48, showing that basic infrastructure and accessibility are linked, forming a distinct infrastructure cluster. Finally, the infrastructure cluster joins the experience

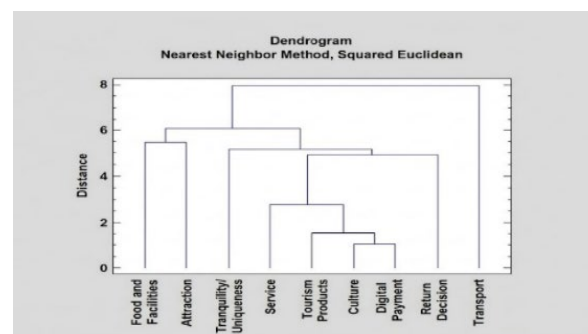


Fig. 3 Dendrogram showing the formation of clusters

at a higher level, and Return Decision (8) merges in the last at 7.95 at the greatest height. The agglomeration schedule is shown in Table 3. Thus, Cluster 1 (Experience Identity) comprises Attractions, uniqueness, digital payment, culture, products, and service elements. Cluster 2 (Infrastructure) comprises food facilities and transport. The Outcome Variable includes the return decision, influenced by both clusters. Thus, it is obvious that the return decision is not driven by one factor alone—it's the cumulative effect of experience and infrastructure. In the Dendrogram, Transport stands at the distant end, revealing it is a concern among the variables studied.

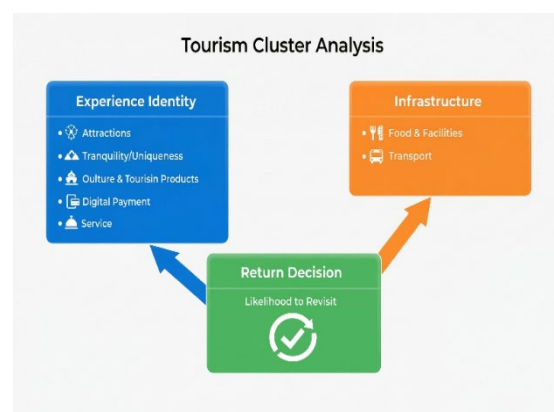


Fig. 4 Functional Interactions in Tourism Cluster Structure

Based on the dendrogram, a three-cluster structure was identified by locating the stage; before the sharp increase in linkage distance, ensuring maximum within-cluster homogeneity and between-cluster heterogeneity. Figure 4 is a three-block conceptual structure clearly revealing how the clusters map into functional categories, viz., an experience cluster (attractions, culture, services, etc.), an infrastructure cluster (food, transport) and final integration leading to overall behavioural outcome (return decision).

3.2.2 The agglomeration schedule

The agglomeration schedule (Table 3) shows a clear progression in how tourists group destination attributes. Here, the agglomeration coefficient represents the dissimilarity (or distance) at which clusters are merged, revealing that with higher values, increasingly heterogeneous clusters combine. Attraction (6) first merges with Tranquillity/Uniqueness (9) at the lowest distance (1.05), indicating strong similarity and suggesting that uniqueness is closely associated with destination attractiveness. This cluster then merges with Digital Payment (5), followed by Culture (3), Tourism Products (4), and Service (2) at increasing distances, representing together an experience cluster.

Separately, Food & Facilities (1) merges with Transport (7) at a moderate distance (5.48), reflecting the linkage between amenities and accessibility and forms an infrastructure cluster. This cluster further joins the experience cluster, while Return Decision (8) merges at the highest distance (7.95), indicating its distinct nature. The agglomeration schedule is presented in Table 3.

Overall, the agglomeration process demonstrates that tourists evaluate destinations holistically, where experiential and infrastructural components progressively combine to influence their final behavioural intention.

Table 3 Agglomeration Schedule of Clusters

Stage	Cluster 1	Cluster 2	Cluster Formation (Merge)	Distance	Interpretation
1	Attraction (6)	Tranquillity / Uniqueness (9)	6-9 → Cluster (6+9)	1.05	These two are most similar—tourists see uniqueness as tied to attractions.
2	Digital Payment (5)	Cluster (6+9)	5-(6+9) → Cluster (5+6+9)	1.52	Payment convenience links closely with attraction/uniqueness, suggesting modern infrastructure is part of the attraction experience.
3	Culture (3)	Cluster (5+6+9)	3-(5+6+9) → Cluster (3+5+6+9)	2.78	Cultural offerings integrate with attractions, uniqueness, and digital convenience—forming a broad "experience" cluster.
4	Tourism Products (4)	Cluster (3+5+6+9)	4-(3+5+6+9) → Cluster (3+4+5+6+9)	4.95	Products join culture/attractions, reinforcing the idea of a bundled tourism experience.
5	Service (2)	Cluster (3+4+5+6+9)	2-(3+4+5+6+9) → Cluster (2+3+4+5+6+9)	5.15	Service merges into the experience cluster, showing tourists view service as inseparable from culture/products/attractions.
6	Food and Facilities (1)	Transport (7)	1-7 → Cluster (1+7)	5.48	Food and transport cluster together—basic infrastructure and accessibility are linked.
7	Cluster (1+7)	Cluster (2+3+4+5+6+9)	(1+7)-(2+3+4+5+6+9) → Cluster (1+2+3+4+5+6+7+9)	6.10	Core Infrastructure (food, transport) merges with the broader experience cluster.
8	Return Decision (8)	Cluster (All others)	8-(1+2+3+4+5+6+7+9) → Cluster (All = 1+2+3+4+5+6+7+8+9)	7.95	Finally, return decision joins last, meaning loyalty depends on the combined effect of all prior clusters.

4 F'kewukqp''

Responsible travel to wilderness areas that preserve the environment and enhance the quality of life for the local community is emphasised by ecotourism. According to Honey [23], ecotourism encompasses community benefits, cultural respect, and environmental sustainability and further highlights how service quality, cultural authenticity, and environmental quality all work together to influence visitors' satisfaction. The sample strategy takes into account the realities of doing tourism research in a conflict zone, where respondent safety and accessibility become crucial methodological concerns. The high cumulative variance (79.94%) and significant Bartlett's test of Sphericity ($p < 0.001$) support the validity of the PCA result, even though the KMO values indicate moderate adequacy, particularly in exploratory contexts and field-based studies in constrained and conflict-affected regions. According to Pine II and Gilmore's Experience Economy Theory [24], contemporary tourists are more interested in immersive and memorable experiences than in standard offerings. Supporting our results obtained on the first component, which indicates that memorable and immersive experiences are significant in creating tourism value rather than discrete services. Moirangthem et al [25] developed a model to explain tourists' profiles towards ecotourism in Keibul Lamjao National Park,

Manipur, the only floating park in the world. The study suggested that overall satisfaction was driven by nature-based experiences and tourism offspring, while logistical and experiential shortcomings in transport and activities reduced satisfaction. Natural beauty (tranquillity, distinctiveness), cultural authenticity, and service quality are all components of ecotourism settings that together influence the overall tourism experience. Both tangible and intangible elements, such as service quality, attractions, cultural experiences, facilities, and infrastructure, have an impact on tourist satisfaction.

Tourism in rural areas largely depends on the successful promotion of its beautiful landscapes and cultural heritage [26]. Moiranthem et al [27] express that through ancestral customs and cultural practices, the Meiteis (inhabitants of Manipur) have established a cultural foundation for sustainable conservation, integrating traditional wisdom and modern strategies for a more sustainable future.

According to Chan et al. [28], service quality has a significant and positive impact on satisfaction, which drives the review intentions. There are several factors identified across different studies, with a certain degree of similarity among them. Significant factors identified are Nature and Culture [29,30,31,32], Infrastructure [33, 32], and Service quality [29,30,28,32].

Tourism research indicates that satisfaction is a key predictor of loyalty behaviours such as revisit intention and recommendation. General satisfaction influenced the intentions to return to the destination; similar results are reported in several studies [34,35,32]. In addition, general satisfaction affected the intentions to recommend the destination [36,37].

An all-encompassing experience comprises both tangible and intangible elements like service excellence, cultural exposure, distinctive natural features, and auxiliary infrastructure like digital payment systems. As

the factor behavioural intention (choice to return) also loads strongly on this component, it implies that visitor satisfaction is intimately connected to the entire quality of experience. The findings suggest that ecotourism in the park is largely driven by a unified experience dimension, where improvements in one aspect (e.g., service or attractions) are likely to positively influence others. The inclusion of tranquillity and uniqueness highlights the importance of preserving the park's natural and unpolluted environment, which is central to ecotourism appeal.

Moirangthem and Gupta [38] in a study on 'Application of Principal Component Analysis in understanding Tourist Behaviour Intention-A case study from Manipur found that attraction, a component of a destination's appeal, is orthogonal to others, i.e. statistically independent and not influenced by factors like transport or culture, suggesting that heritage is strong enough as perceived and valued independently of external factors. Attractive places attract more tourists, as per Mutinda & Mayaka [39], destination image positively influences destination choice and intention to return [40]. Accessibility is a big concern, as evidenced by the substantial negative loading of transport. However, the current research shows that accessibility—especially transportation—has a major detrimental impact on visitor behaviour. This implies that although attraction is still a powerful and self-sustaining element of destination appeal, infrastructure constraints limit its transformation into positive behavioural outcomes, like the intention to return. This finding is particularly relevant in ecotourism settings, since attractions are often located in remote or impoverished areas. Research also shows that visitors may be able to tolerate small accessibility issues due to the high calibre of the natural experiences, but improved transit infrastructure might significantly improve overall satisfaction. In a study in Zhalong National Nature Reserve, China, Xu et al. [31] identified a high degree of

satisfaction with the natural environment of the study area; however, they recorded a relatively low satisfaction with the biodiversity, facilities, and services of the scenic place.

Aizen's [41] Theory of Planned Behaviour holds that favourable views created around an experience lead to favourable intentions of revisit and recommendation in a destination, which is supported by the strong loading of "determination to return" in our study.

Component 2 reveals Accessibility versus on-Site Experience. Thus, the second component reveals a contrasting structure, with positive loadings for attraction and food & facilities, and negative loadings for transport, digital payment, and (to a lesser extent) return intention.

This paradox has been well established in tourism studies. Cooper [42] says that a destination's competitiveness depends on its infrastructure and accessibility as much as on its attractions. The substantial negative loading of transport we get in the PCA study reflects a widespread issue, as ecotourism destinations are often located in remote or environmentally fragile areas. Weaver [43] opines that limited accessibility can both protect and impede the expansion of ecotourism.

Our results also support the push-pull theory in tourism, which is proposed by Crompton [44]. Pull elements include scenic beauty, tranquillity, and attractions. whereas the factors like Infrastructure restrictions and accessibility are examples of push limits. Travellers may choose these destinations based on attraction despite the accessibility concerns because of the natural beauty and uniqueness of a destination.

4.1 Geqvwtko 'Uwncldkls{, Behaviour Intentions and Sustainable Development Goals (SDG)

Understanding tourist behaviour is crucial for stakeholders to refine and enhance the destination elements to better cater to this loyal

market segment [45]. Measuring the impact of various variables is crucial in planning to ensure that investments in ecotourism resources lead to increased monetary profits through enhanced repeat visitors [46]. Identifying key factors that boost interest in repeat visits can help the cost-efficient redevelopment of ecotourism assets [47]. Furthermore, visitors' perceptions and chances of returning are greatly influenced by the physical facilities' quality [48, 21]. Planning remains uncertain without evaluating the sensitivity of these components, hindering advancements in ecotourism sustainability metrics. Assessing revisited intents is essential for long-term planning and sustainability of the tourism industry in any region [49].

Our PCA-validated ecotourism model for the community park directly provides a policy brief, emphasising community-led conservation in unpolluted landscapes while linking to India's SDG commitments (Table 3). Important PCA elements and Sustainable Development Goals (SDGs) influence the development of policy briefs illustrating how the SDGs framework balances the social, economic, and environmental aspects of sustainable tourism. SDG 15.1 encourages biodiversity conservation efforts and is closely associated with PC1 through Tranquillity and attractiveness. SDG 8.9 links to local economic growth by directing visitor spending into local communities for Sustainable Tourism. SDG 11.6 emphasises the need for environmentally friendly mobility in relation to transportation constraints in PC2. SDG 9.c encourages the use of effective digital payment methods for ease and transparency. Last but not least, SDG 12.b promotes frequent PCA-based surveys to track visitor satisfaction, supporting sustainable tourism management. Similar to our community park study (PC1 core experience, PC2 logistics, 80% variance), PCA analysis in ecotourism appears in sustainable tourism literature. It offers a methodology and a policy brief for SDG integration that helps in

Table 4: SDG, PCA Scores, and Policy Brief

SDG Target	PCA Linkage (Loadings)	Policy Integration
SDG 15.1 (Biodiversity)	PC1: Tranquillity (0.35), Attraction (0.51 PC2)	Protect the Core Zone of the park as "No-Impact Core" for crystal clear water/landscape; track via PC1 scores
SDG 8.9 (Sustainable Tourism)	PC1: Service/Culture/Products (0.37-0.41)	Tourist spending should go to locals through community cooperatives for food and crafts
SDG 11.6 (Sustainable Transport)	PC2: Transport barrier (-0.59)	Bike trails and eco-shuttles minimise access dissatisfaction.
SDG 9.c (Digital Infrastructure)	PC2: Digital Pay (-0.30 supportive)	UPI ticketing platform; transparent revenue for SDG reporting
SDG 12.b (Tourism Monitoring)	Intentions (0.40 PC1)	Annual PC-score surveys tracking satisfaction → loyalty

translating statistical insights into practical policy, as per India's 2030 agenda for securing funding while achieving sustainability, jobs, and conservation. Moirangthem and Pathak [50] examine the alignment of ecotourism with sustainable development principles and cover frameworks for evaluating ecotourism potential, including infrastructure, accessibility, and attractions. Like our PC1/PC2 reduction of visitor satisfaction criteria, global research of 136 sites by Kim et al [51] employed PCA to weight sustainability indicators into unified rankings. SDG 8.9 strategy for similar destinations was directly influenced by PC1's emphasis on "natural assets + services" and PC2's emphasis on "infrastructure gaps" (transport/digital). Another study on China's scenic spots [52] integrated PCA with multi-criteria decision models to measure sustainable capacity, extracting tourism economy/society/resources components. PC1 "visitor experience/resources"

loadings drove capacity limits; applied to zoning like our tranquillity cores (SDG 15.1).

In a study on Vietnam [conducted by Hussien et al [53] key sustainability drivers were identified across medical/leisure tourism. The application of PCA helped in reducing 20+ indicators to 2-3 components explaining 75-85% variance. It has parallels with our study service/products (our PC1) vs. transport/access (PC2 negative)—guided national policies prioritising natural attractions over infrastructure, SDG 12.b monitoring. These parallels confirm our approach's rigour, where 80% variance explanation exceeds typical tourism PCA thresholds (60-75%), KMO=0.50 aligns with marginal-but-significant cases, and PC1 for policy mapping. Protected Area Equity Review [54] synthesises 100+ studies and revealed that community involvement metrics align with ecological equity. Madumalai Tiger Reserve (MTR) literature by Bhattacharya et al [55], though,

does not have direct PCA applications on visitor satisfaction like our community park study; however, the study points out the parallel ecotourism insights through Ecodevelopment Committees, visitor economics, and sustainability assessments that mirror our study as PC1 (experiential drivers) and PC2 (logistics gaps).

The study by López-Sanz et al. [56] demonstrates how loyalty, translated into repeated visits to a tourist area and the recommendation to third parties, promotes and encourages the sustainable development of rural areas, generating several benefits for the tourist destination.

The Framework (Fig 5) explains the different types of variables, exhibiting their elements.

- Core Drivers: Attraction, service, culture, products, tranquillity
- Mediating Variable: Overall experience → satisfaction
- Outcome Variables: Return intention and recommendation
- Constraint Variable: Transport (negative influence) and
- Support Variables: Digital payment and Food facilities

The framework demonstrates how the overall ecotourism experience is shaped by attraction, culture, service, tourism products, and tranquillity/uniqueness, leading to Tourists' satisfaction. This satisfaction leads to the intention of returning and recommending. The transport problem is a constraint, but digital

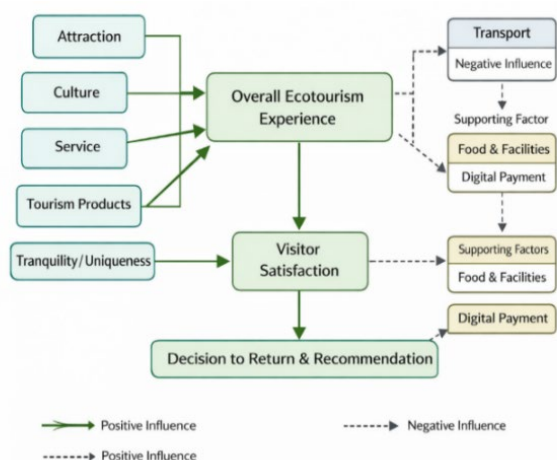


Fig 5: Conceptual Framework for ecotourism experience and visitor satisfaction

payments, food, and comforts increase satisfaction. It generally emphasises how visitor satisfaction and loyalty are affected by core experiences and auxiliary infrastructure (Fig 5).

This study integrates PCA-derived components with Sustainable Development Goals (SDGs) that are further converted into actionable policy interactions; thus, the present study goes beyond the statistical interpretation, unlike the earlier studies, which are generally descriptive in nature. Further, the analysis is done in the data-deficient part of North East India, where safety and accessibility pose significant methodological challenges.

5 Conclusions & Recommendations

Application of PCA and Cluster Analysis provides insights and statistical rigour to develop effective strategies for sustainable tourism.

Our research shows that two key dimensions influence ecotourism experiences:

1. Holistic Ecotourism Experience and satisfaction, and
2. Accessibility vs. On-Site Experience.

Even while the park offers a satisfying ecotourism experience, improving accessibility, particularly in terms of transportation, is essential for boosting overall tourist satisfaction and sustainability. Hence, the following recommendations are emphasised.

1. Improve the fundamental components of the experience (attractions, service, culture, tourism products) besides preserving the site's uniqueness and tranquillity.
2. Transportation infrastructure to be upgraded without sacrificing the component of sustainability.

3. Supporting infrastructure, food, facilities, and digital systems need improvement so as to boost satisfaction.

4. Capacity building of local communities for improving experience and service quality

5. For boosting tourist satisfaction, return visits, and favourable recommendations, a thorough strategy incorporating infrastructure development, community involvement, and experience quality is required.

The study provides stakeholders (Department of Tourism, Government of Manipur, policymakers, government agencies and tourism practitioners) a deeper understanding

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that can strengthen the tourism development policies in shaping the destination's future while linking to India's SDG commitments.

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