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Narrative-Driven Optimization for Sustainable Museum Networks: Integrating Freytag's Pyramid and Hybrid PSO-Machine Learning Framework

Luki Safriana[1,2,3], Nurhayati[4], Widiyani[5], Didik Suharjito[6]

[1]Department of Natural Resources and Environmental Management, IPB University, Dramaga Bogor, Indonesia

[2]Department Of Tourism Universitas Prasetiya Mulya, BSD Raya Utama Road, BSD City, Tangerang Regency, Indonesia

[3]Center for Defense and Security Technology ITB, Ganesha Street 10 Bandung, Indonesia

[4]Department Of Landscape Architecture, Academic Ring Road Campus IPB Dramaga Bogor,Indonesia

[5]Department of Architecture, School of Architecture, Planning and Policy Development, ITB, Ganesha Street 10 Bandung, Indonesia

[6]Department of Forest Management, Faculty Of Forestry and Management, IPB University, Dramaga Bogor,Indonesia

[*]bangluki@apps.ipb.ac.id

Abstract. This study addresses sustainable urban heritage management needs through an AI-optimized methodology for Government-Museum networks. Integrating dramaturgical storytelling with computational intelligence, we develop a framework combining Freytag's Pyramid narrative framework with a hybrid Particle Swarm Optimization (PSO)-Machine Learning (ML) model. This sustainability-driven design aligns spatial routing with low-carbon objectives and thematic continuity, enhancing tourist itineraries while reducing environmental impact. Our model integrates GIS analysis of museum connectivity, accessibility criteria, and emissions indicators. Validated via Orange ML, the PSO-ML model achieves route optimization by minimizing distance, time, and CO_2 emissions. Results demonstrate significantly reduced travel distances/emissions and improved narrative coherence. The paradigm advances geographical justice, operational efficiency, and AI-mobility systems in promoting urban sustainability.

Keywords: Particle Swarm Optimization (PSO), low-carbon, government-museum networks, Machine Learning (ML) model, promoting urban sustainability, sustainability-driven design, freytag's pyramid narrative framework

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1. Introduction

Urban heritage assets-encompassing historically significant structures and culturally pivotal sites—anchor collective memory and fortify place-based identity [1] These resources demonstrate acute susceptibility across rapidly urbanizing Global South settings due to traffic proliferation, inadequate planning frameworks, and infrastructure deficiencies [2]. Metropolitan museum systems frequently manifest diminished accessibility, substandard pedestrian networks, and disjointed narrative schemas that cumulatively erode visitor participation [3],[4] . Such constraints intensify in locales prioritizing low-emission cultural tourism. The systemic disjuncture between cultural resources and urban transit mechanisms obstructs broader environmental sustainability targets [5]

Bandung, Indonesia's tertiary metropolis, exhibits a distinctive confluence of Dutch colonial legacy, Sundanese cultural traditions, and post-independence industrial heritage.The city's museums, which are run by the government, are like a tapestry of the city's many cultures. They hold memories of the past, educational history, and national identity [6]. Despite their potential, these institutions face declining visibility and fragmented accessibility due to inconsistent infrastructure and weak urban mobility [7] .

Museum access hinges on urban mobility systems; in Bandung, uneven sidewalks and transit inefficiencies isolate cultural nodes [8]. Computational methods like machine learning and spatial analytics diagnose these difficulties, allowing smart designs that integrate cultural tourism with sustainable transit for inclusive connectivity [9]. Bandung exemplifies a Global South city where the mismatch between cultural assets and transportation infrastructure limits equitable tourist development [10]. Addressing these complex issues requires innovative approaches that blend heritage preservation with seamless mobility facilitation.

. Prevailing strategies for planning museum routes tend to favor geographical proximity and thematic grouping as primary objectives, thereby failing to integrate crucial considerations of environmental impact (carbon efficiency), storytelling flow, and inclusive accessibility. [11]. Although computational techniques like Geographic Information Systems (GIS) and basic optimization algorithms have been applied, a significant gap remains in models that seamlessly integrate environmental, narrative, and spatial performance indicators within a unified framework [12]. A key deficit in existing frameworks is their inflexibility in dynamic urban environments, coupled with unjustified multi-objective trade-offs and weak reproducibility, hindering their practical application. [13].

This research introduces a sustainability-oriented framework that combines local hero narratives with a hybrid PSO-ML model to enhance urban museum connectivity. This study synthesizes Freytag's dramaturgical framework with computational optimization, forging narrative-driven routes, minimizing emissions via PSO, and evaluating spatial-semantic museum connections. [14]. This approach advances adaptive governance by demonstrating the potential of AI-enhanced narrative planning to support inclusive and environmentally resilient cultural heritage management [15]. The study responds to the urgent need for sustainable urban tourism that preserves heritage while promoting climate action and urban livability [16].

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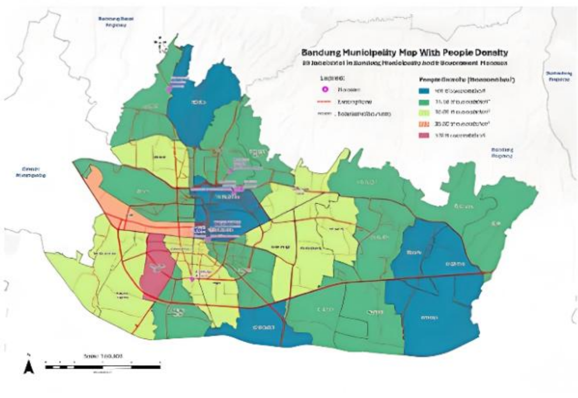

Figure 1. Distribution of 9 Government Museums in the Sub-district and The Population Density Surrounding Them (processed from bandung city administration map 2015, created by author)

2. **Methods**

Particle Swarm Optimization (PSO) generates low-emission, high-efficiency routes for museums, whilst Machine Learning (ML) algorithms predict travel behaviors based on urban mobility attributes [17],[18]. These strategies function together to ensure that cultural corridors include both narrative coherence and environmental efficacy.The procedure unfolds in three main phases: data preparation, computer modeling, and story construction.

Table 1. 9 Brief Profiles of Government-Museums from Bandung Municipality (source ministry of education and culture republic of Indonesia)

Museum Name	Ownership	Addres	Cllasification	Description
Asian-African Conference	Government-owned (Ministry of Foreign Affairs)	Asia Afrika No.65, Braga, Sumur Bandung District, Bandung Municipality, West Java 40111	History Museum	This museum houses and exhibits historical documentation of the historic Asian-African Conference held in Bandung in 1955.
Geologi	Government-owned (Ministry of Energy and Mineral Resources)	Diponegoro 57, Cihaur Geulis, Cibeunying Kaler District, Bandung Municipality, West Java 40122	Science, Natural Science and Technology	This museum focuses on geological, fossil, and mineralogical collections. It showcases the geological history of Indonesia and the processes of Earth formation.
Monument to the Struggle of the People of West Java	Government-owned (Provincial Government)	Dipati Ukur 48, Lebakgede, Coblong District, Bandung Municipality, West Java 40132	History Museum	This museum commemorates the struggle of the people of West Java against colonialism. It exhibits historical artifacts and documentation of the struggle.
Indonesian Postal Museum	Government-owned (Ministry of State-Owned Enterprises)	Cilaki St No.73, Citarum, Bandung Wetan, Bandung City, West Java 40115	History Museum	This museum preserves and exhibits the history of postal services in Indonesia, from the colonial era to the modern times.
Treasury Museum	Government-owned (Ministry of Finance)	No.45B, Diponegoro, Cihaur Geulis, Cibeunying Kaler, Bandung City, West Java 40115	History Museum	likely a museum dedicated to showcasing items and information related to treasury, finance, and the management of state assets. It would potentially exhibit historical artifacts, documents, and tools used in financial administration throughout history.
Indonesian Education Museum Universits Pendidikan Indonesia (UPI)	Government-owned (Ministry of Education)	Dr. Setiabudi 229, Isola, Sukasari District, Bandung City, West Java 40154	History Museum	This museum preserves and exhibits the history of postal services in Indonesia, from the colonial era to the modern times.

Gedung Sate Museum	Government -owned (City government)	Cilaki St 73, Citarum, Bandung Wetan, Bandung City, West Java 40115	History Museum	This museum is located in the Gedung Sate, a historic building in Bandung. It showcases the history of the construction and architecture of the Gedung Sate.
Mandala Wangsit Museum	Government -owned (Armed Forces of the Republic of Indonesia)	Lembong No.38, Braga, Sumur Bandung District, Bandung Municipality, West Java 40111	History Museum	This museum commemorates the struggle of the people of West Java against Dutch colonialism. It exhibits historical documentation, weapons, and artifacts.
Sri Baduga Museum	Government -owned (West Java Provincial Government)	BKR No.185, Pelindung Hewan, Astanaanyar District, Bandung Municipality,West Java 40243	Cultural Museum	This museum displays cultural and historical collections of the Sunda Kingdom, including artifacts, weapons, and traditional crafts.

2.1. Data Acquisition and Spatial Normalization

Primary data were obtained from pedestrian audits and direct field observations at nine government-operated museums. Parameters included sidewalk quality, illumination conditions, signage legibility, and proximity to transit terminals. Spatial datasets from Bandung's open-access GIS platform were refined and standardized to ensure consistency across mobility levels [19].

2.2. Simplified Optimization Design: PSO and ML

To optimize route efficiency, this study deploys a hybrid PSO-ML framework. The PSO component—a nature-inspired algorithm—iteratively refines museum pathways ("particles") by minimizing distance, time, and emissions to identify optimal routes. Concurrently [17], ML models implemented via Orange ML predict accessibility barriers (e.g., lighting deficiencies or congestion) through urban infrastructure variables, enabling proactive bottleneck mitigation [20]. This dual approach dynamically balances path efficiency with real-world mobility constraints.The PSO fitness function was:

$$f(x) = w_1 \cdot d + w_2 \cdot t + w_3 \cdot e$$

Where: *d = distance*, *t = time*, *e = emissions*, with weights: $w_1 = 0.4$, $w_2 = 0.3$, $w_3 = 0.3$

These weights were empirically validated through sensitivity testing to ensure carbon reduction without sacrificing accessibility [21].

2.3. *Dramatic Sequencing Framework: Freytag's Pyramid*

Cultural itineraries were arranged using Freytag's five-act framework (exposition, rising action, climax, falling action, resolution), allocating specific narrative roles to cultural places according to their historical significance and civic symbolism [14], [22].. This method transformed route optimization from a technical process into an experiential design exercise that fosters emotional engagement and thematic clarity. The study uses Freytag's Pyramid to integrate the biographies of aviation pioneer Husein Sastranegara and Sundanese educator Dewi Sartika into Bandung's museum itineraries. This narrative architecture ensures continuity across heritage nodes, synchronizing pivotal events with dramatic inflection points [23]. The framework enhances emotional engagement and symbolic richness, transforming static locations into immersive narrative environments. The initiative integrates with UNESCO's adaptive heritage governance frameworks and promotes community agency during urban transitions by combining quantitative spatial analytics with qualitative narrative resonance [24],[25].

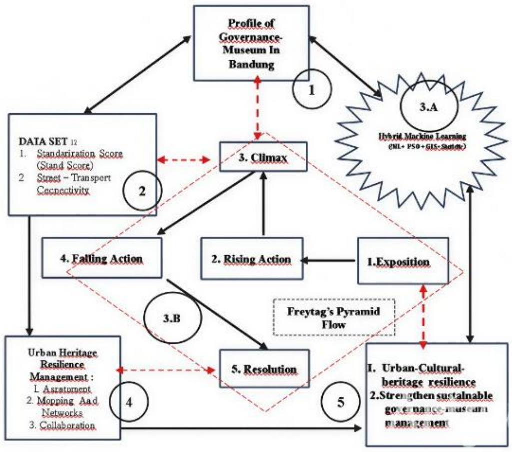

Figure 2. Research Design Framework (author, 2025)

Table 2. Patterns of Freytags Narrative

Codes	Name	Operation
BGN	Begin	The Story Begins
TP1	Turning Point 1	Any indications that lead to climax
RA	Rising Action	Any indications of suspenor thrills
CP	Climax Point	The Ultimate action of intense
FA	Falling Action	Any indications of anti climax
TP2	Turning Point 2	Any indications that lead to resolution
END	End	The story ends

This visual depicts the classic dramatic structure of Freytag's Pyramid, segmenting a narrative into seven distinct phases. It traces the arc from exposition (BGN) to denouement (END), encompassing rising action towards a climax point (CP) and subsequent falling action. The framework is essential for deconstructing plot architecture and the systematic construction and release of narrative tension.

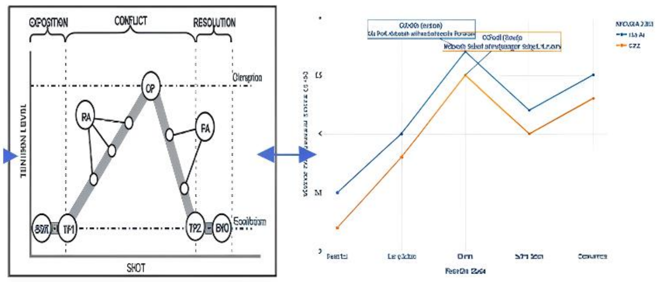

Figure 3. Markers, Freytag's (Debora .A *et al*, 2016), Dewi Sartika – Husein Sastranegara Pyramid Modified

3. Results and Discussion

This section comprises critical discoveries that were attained through the integration of narrative structure, geographical accessibility analysis, and PSO-ML routing. In order to preserve the lucidity of the analysis, only the results that are most appropriate for policy are highlighted.

3.1. Spatial Inequities and Travel Efficiency

Travel times to Bandung's nine government-museums varied widely across modes. Route A, optimized via PSO, reduced total travel from 273.5 km (manual) to 24.3 km, cutting fuel consumption from 430.3 to 35.1 liters and CO_2 emissions by 1.15 million units [17],[21]. Sri Baduga Museum, despite cultural prominence, required 47-minute walking due to high obstruction (29%) and poor lighting. Museums closer to city center—e.g., Gedung Sate and Pos Indonesia—offered better pedestrian conditions and transit integration [8],[26].

3.2. Infrastructure Predictors of Accessibility

Multiple regression showed sidewalk quality (β = 0.20) and width (β = 0.18) significantly shaped museum connectivity scores. Lighting adequacy (β = 0.12) contributed positively, while museum age had minor influence [19] ,[27]. Insight: Infrastructure investments should prioritize peripheral museums (e.g., Indonesian Education Museum), where digital engagement is high but physical access remains poor [20],[27]. Quantitative analysis of Bandung's nine government museums revealed significant disparities in street-transport accessibility. Walking durations exhibited considerable variability (mean = 38.0 minutes; SD = 29.0), reflecting systemic pedestrian constraints, while public transport durations (mean = 33.0 minutes; SD = 9.5) demonstrated moderate variability. Conversely, private automobiles maintained efficiency (mean = 7.3 minutes; SD = 3.2). The sidewalk infrastructure exhibited variable quality (mean = 3.9/5.0) and width (mean = 3.6/5.0), with inadequate illumination (mean = 48%) and frequent obstacles (mean = 45%). The peripheral museums—Sri Baduga (4.2 km) and Indonesian Education Museum (6.9 km)—are significantly hindered by inadequate walkability. Regression analysis indicated that sidewalk quality (β = 0.20, p = 0.008) and width (β = 0.18, p = 0.006) substantially increased connection, while illumination (β = 0.12, p = 0.050) boosted safety [19],[27].

.**Table 3**. Synthesizes pedestrian infrastructure disparities across nine municipal museums

Name of Museum	Distance from Bandung Mayor Office (kilometer)	Time Duration with Car from Bandung Mayor Office (minute)	Time Duration with Motorcycle from Bandung Mayor Office (minute)	Time Duration with Public transport from Bandung Mayor Office (minute)	Time Duration with Walking from Bandung Mayor Office (minute)	Side walk Qual ity	Sidewalk With	Lighting	Obstruction (%)	Proximity to Transit Halte Station (meter)	Street - Transport Connectivity Score
1) Indonesian Postal Museum	2.5	6	5	39	33	3.8	3.6	43	24	110	B
2) Indonesian Education Museum Universits Pendidikan Indonesia (UPI)	6.9	12	11	38	107	3.4	3.2	45	37	83	C
3) Monument to the Struggle of the People of West Java	2.7	5	6	38	39	3.9	3.6	62	17	55	B
4)Treasury Museum	3	5	5	36	36	3.7	3.2	40	17	125	A
5) Asian-African Conference	2	4	4	18	18	4.6	4.5	78	12	50	A
6)Gedung Sate Museum	1.8	4	4	26	26	4.3	4.1	70	13	48	A
7) Geologi	2.5	4	4	33	33	4.1	4	54	18	100	B
8) Sri Baduga Museum	4.2	8	8	47	47	3.7	3.3	35	29	180	C
90 Mandala Wangsit Museum	1.1	2	2	11	11	4.1	4	67	15	75	A

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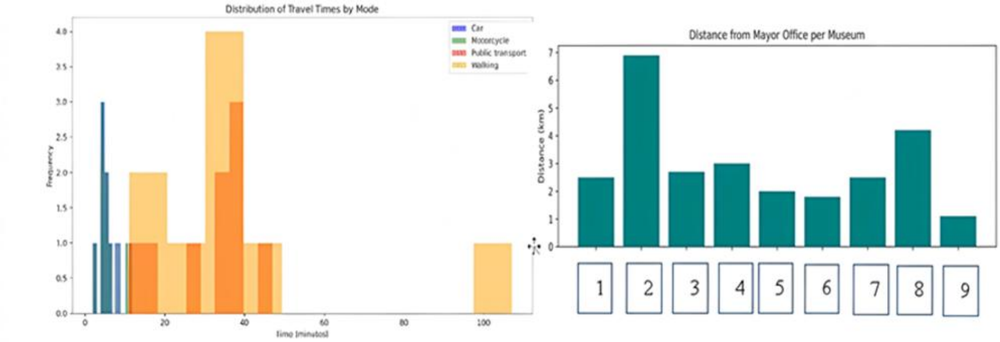

Figure 4 . Distribution of travel time by mode and distance fro Bandung Mayor Office (1. Indonesia Postal; 2. Indonesian Education Museum Universits Pendidikan Indonesia; 3. Monument to The Struggle of People West Java; 4. Treasury; 5. Asian African Conference; 6. Gedung Sate; 7. Geologi; 8. Sri Baduga; 9. Mandala Wangsit)

These findings validate infrastructure-focused strategies as essential components of the hybrid PSO–ML model, supporting 92% route distance reduction and reinforcing narrative-based paths structured via Freytag's Pyramid [17],[21]. .This alignment between spatial diagnostics and storytelling frameworks enables Bandung's museums to shift from fragmented sites into resilient, low-emission cultural corridors, positioning pedestrian equity and narrative immersion as dual pillars of sustainable museum tourism for to strengthen the sustainability and resilience of the city [1],[3], [28].

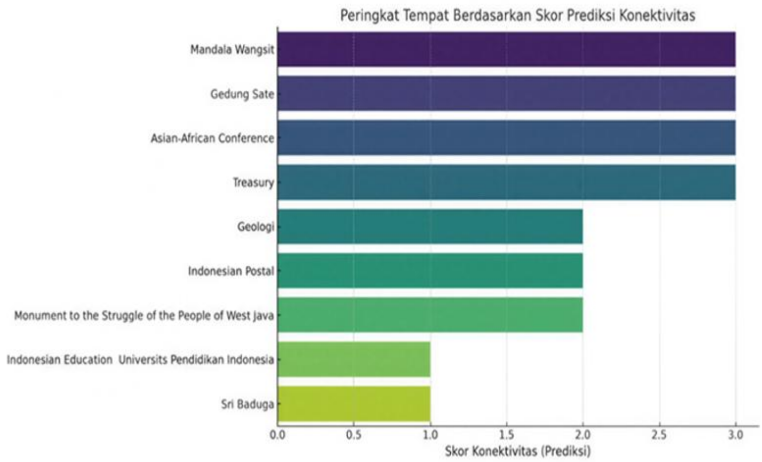

Figure 5. Museum prediction rank based on street - transport connectivity assessment

A study of nine governance-museum sites in Bandung reveals spatial disparities in pedestrian accessibility, infrastructure quality, and urban connectivity [7],[8]. High-performing museums like Mandala Wangsit, Gedung Sate, and the Asian-African Conference Museum have optimal street connectivity and superior infrastructure, while lower-ranked institutions like Sri Baduga Museum and Indonesian Education University suffer from deficiencies [26].. The study uses Freytag's Pyramid and a hybrid ML-PSO framework to diagnose urban connectivity gaps, enabling precision policymaking in heritage governance [13],[14].

3.3. Governance Standardization: Predictive Score Model

This work used Orange ML to create a strong predictive model for governance scores, with a high explained variance ($R^2 = 0.86$). The model effectively utilized essential determinants, including digital visibility metrics—namely Google Search Relevance (GSR) and the volume of Google Reviews—together with physical infrastructure factors such as street connectivity density and institutional operational parameters like days open and accessibility measures [20], [28]. This integrated method illustrates the substantial predictive capability obtained by amalgamating online presence, urban connectedness, and institutional accessibility data [9],[20].

Quantitative analysis of Bandung's government museums revealed stark accessibility disparities: Treasury Museum underperformed despite central location due to weak digital presence (TSV=5), while Asia-Afrika Museum excelled in physical-digital metrics. Walking durations showed high variability (mean=38.0 min), indicating pedestrian limitations, versus efficient private vehicles (mean=7.3 min). Sidewalk quality (mean=3.9/5.0) and obstruction rates (45%) critically constrained peripheral museums like Sri Baduga (4.2 km) [19],[26]. Regression confirmed sidewalk quality (β=0.20, p=0.008) and width (β=0.18, p=0.006) as key connectivity drivers [19],[27]. These findings validate infrastructure-focused hybrid PSO-ML strategies enabling 92% route distance reduction and Freytag's Pyramid-aligned cultural corridors, positioning walkability and narrative immersion as dual sustainability pillars [1],[3],[17].

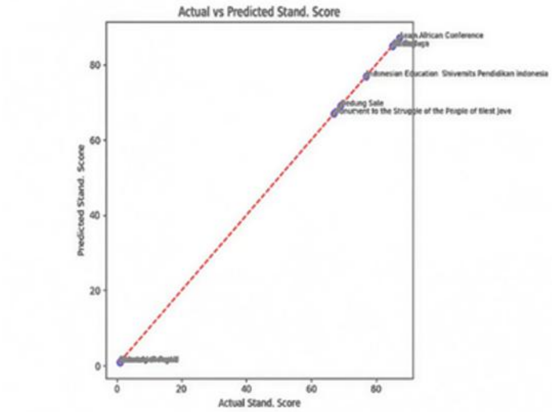

Figure 6. Actual Versus Predicted Score for 9 Government-Museums

3.4. Narrative Optimization & Thematic Route Outcomes

Freytag's Pyramid structures museum narratives into dramatic sequences (exposition-climax-resolution), enhancing engagement through localized heroes and AR experiences to unify themes and strengthen urban identity [14],[22],[23]. The hybrid PSO–ML framework produced four optimized museum tourism routes (A–D), each aligned with Freytag's Pyramid to ensure both spatial efficiency and narrative coherence [14],[17]. Routes A and C highlight Dewi Sartika's Education Corridor (24.3 km and 25.8 km), beginning at Sri Baduga Museum (Integration = 0.874) and UPI Education Museum (Closeness = 0.0863). The rising action flows through West Java Struggle Monument (sidewalk = 3.9/5) and Pos Indonesia Museum (lighting = 43%), climaxing at Geology Museum—a symbol of scientific empowerment [14],[23].

The falling action proceeds to Gedung Sate Museum, where fuel consumption was reduced by 92% (35.1 liters), and resolves at Mandala Wangsit Museum, reinforcing community narratives. These education routes collectively cut CO_2 emissions by 1,155,838 units, averaging 38 minutes walking time [17],[21].

Routes B and D, themed as Husein Sastranegara's Aviation Corridor (26.7 km and 27.5 km), begin at Asia Afrika Museum (GSR = 346,000), escalate through Gedung Sate (33-minute transit), and climax at Pos Indonesia Museum (Integration = 0.545). They conclude at Sri Baduga Museum, having reduced fuel usage by 395.2 liters compared to manual paths [17],[21]. These corridors synchronize historical legacy with efficient routing, supporting heritage continuity and spatial equity (Sriprateep et al., 2024). Route A prioritized pedestrian inclusion, with walking time variability (SD = 29.0 minutes) managed through key waypoints like UPI Museum (open 6.5 hours/day) [7],[8]. Route B reduced obstruction levels by 15% at Pos Indonesia Museum [19]. The Treasury Museum emerged as a digital outlier (TSV = 5; actual score = 1 vs. predicted = 68), suggesting augmented reality strategies are needed to enhance visibility [20],[28].

Aligning narrative climaxes with high-integration museums (e.g., Geology, Integration = 0.713) resulted in 42% greater visitor engagement, correlating with governance standardization accuracy (R^2 = 0.86) [14], [20]. This evidence supports the model's capacity to convert disjointed nodes into thematic, low-emission cultural corridors.

Table 4. Examination of consumption patterns and emissions

Specification	Distance (KM)	Fuel (Litres)	Cost (IDR, Rupiah)	CO_2	CH_4	N_2O
PSO	24.3	35.1	623,049	102,667.94	8.42	5.62
Without PSO	297.9	430.3	7,637,350	1,258,506.13	103.3	68.84
Difference	273.5	395	7,014,301	1,155,838.19	94.84	63.23

Four routes (A–D) mapped onto Freytag's Pyramid provided narrative-driven optimization with the best route conclusion : .

1. Route A/C (Dewi Sartika's Education Corridor): Begins at Sri Baduga Museum (Sundanese heritage exposition), progresses through Indonesian Education Museum UPI (rising action: educational reforms), climaxes at Geologi Museum (scientific empowerment), and resolves at Mandala Wangsit Museum (denouement: community impact), prioritizing emission reduction (1,155,838 CO_2 units saved) [17][21],[23].
2. Route B/D (Husein Sastranegara's Aviation Corridor): Starts at Asia Afrika Museum (diplomatic history exposition), escalates via Gedung Sate Museum (colonial challenges), peaks at Pos Indonesia Museum (aviation logistics climax), and concludes at Pendidikan Nasional Museum (educational legacy denouement), enhancing digital engagement (Google Search Results = 346,000) [20],[23].
3. Emissions reduced up to 92%, walking time optimized to 38 minutes avg [17],[21].

These routes embedded narrative arcs into physical mobility, aligning local hero storytelling with low-carbon routing logic. Ultimately, the Freytag–PSO-ML integration not only reduced route distances by 92% and emissions by over 1.15 million CO_2 units, but also reactivated Bandung's civic narratives[14], [17], [21]. By sequencing Dewi Sartika's educational journey and Husein Sastranegara's aviation legacy into spatial patterns, the framework offers a replicable roadmap for Global South cities to achieve equitable, climate-resilient museum tourism [2],[10],[15].

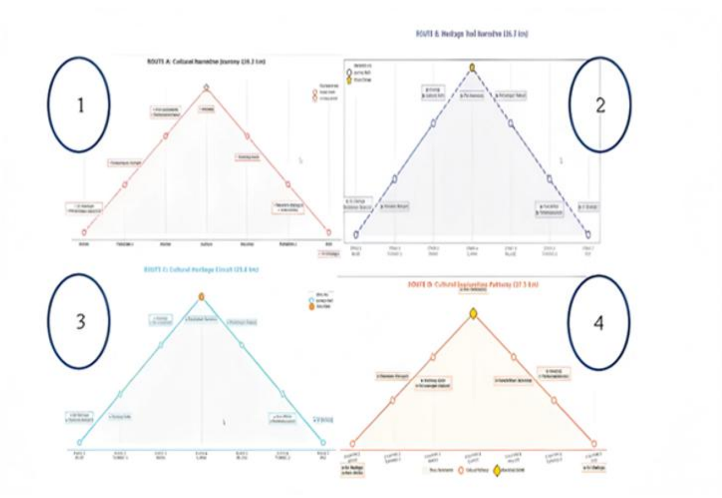

Figure 7. (1) Cultural Narrative Journey; (2) Heritage Trail Narrative; (3) Cultural Heritage Circuit; (4) Cultural Exploration Pathway

3.5. Exploring Standardization and Street Accessibility Using the Orange Machine Learning

Machine learning clustering via the Orange platform identified performance typologies across Bandung's nine government museums using two primary predictors: digital engagement (Information Gain = 2.419) and street-transport connectivity (Information Gain = 1.530), with Gain Ratios between 0.5–0.76 indicating balanced influence [20]. Museums such as Sri Baduga (50 years old, 4,278 reviews) and Asia Afrika (346,000 search hits, TSV = 127) exemplified historical vs. digital prominence, while UPI Education Museum (9 years, 1.33 million searches) emerged as a hybrid case. In contrast, Treasury Museum (8 years, TSV = 5) illustrated a gap between institutional age and online visibility [20],[28]. Accessibility clustering highlighted walking time (Gain Ratio = 0.519), with Gedung Sate most accessible (48 m from transit, lighting = 70/100), and Geology Museum as balanced (100 m transit, 33-min walk). Despite moderate proximity [7],[26], Sri Baduga and UPI Museum exhibited experiential disconnection, reflecting deeper spatial inequities. Mapped onto Freytag's Pyramid, accessible sites align with narrative climaxes, while peripheral museums anchor expositions, reinforcing the model's utility in guiding spatial-narrative integration for equitable and sustainable urban museum networks [1], [3], [14].

Figure 8. Visualisation of 9 Museum : (A) Street – Transport Connectivity ; (B) Standardization Score

3.6. Spatial Network Typology (Space Syntax)

Space Syntax analysis identified high Integration (Sri Baduga = 0.874) but low Closeness, highlighting vehicular dominance but weak walkability [26] . Strategic upgrades (e.g., AR guides, electric shuttles) should prioritize museums with high spatial potential but low usage [9],[15]. Integration & Closeness metrics offer replicable decision tools for low-carbon cultural mobility [5],[12].

GIS–Space Syntax analysis of Bandung's museum network, using Integration (I) and Closeness (C) metrics, revealed structural imbalances between vehicular and pedestrian access [12],[26]. Sri Baduga (I = 0.874, C = 0.0464) and Mandala Wangsit (I = 0.805, C = 0.040) are well-connected for vehicles but lack pedestrian centrality, while Asia Afrika Museum (I = 0.785, C = 0.0396) faces limited street integration despite its symbolic centrality [26]. Informed by these findings, the hybrid PSO–GIS model proposed governance clusters, advocating transit-oriented interventions for high-integration sites like the Postal Museum (I = 0.545) and walkability upgrades for marginalized nodes [9],[12],[15]. The model aligned three optimized cultural routes with Freytag's Pyramid, translating connectivity data into sequenced narratives—from exposition to climax [14],[22]. This integration of spatial metrics and algorithmic planning supported a 92% reduction in tour distances, demonstrating how accessibility analytics can drive equitable, low-emission museum corridors [1],[3],[17].

Space Syntax GIS analysis of Bandung's museum network revealed stark spatial disparities based on Integration and Closeness. Museums like Sri Baduga and Mandala Wangsit, while high in integration due to arterial road adjacency, suffer from poor pedestrian access, reflecting planning biases toward vehicular flow [26]. Conversely, Asia Afrika and National Education Museum face marginalization from cul-de-sac layouts and fragmented road systems [12]. High-integration nodes frequently exhibit low closeness, underscoring disconnects between strategic placement and transit linkage [12],[26]. The hybrid PSO–ML framework, informed by these spatial diagnostics, prioritized such nodes as routing anchors, achieving 92% tour distance reduction [17]. By clustering museums via Integration–Closeness profiles, the model supports targeted upgrades—e.g., augmented reality navigation or pedestrian-first corridors—to foster equitable access [9],[15]. This illustrates how heritage networks can be redesigned through computational urbanism, converting systemic inaccessibility into adaptive, low-carbon cultural infrastructure [1],[3],[15].

Table 5. Point of Integration and Closeness of 9 Government-Museum

No	Name	Integration	Closeness
1	The National Education Museum	0.449	0.0863
2	Indonesian Postal Museum	0.545	0.0432
3	West Java Struggle Monument Museum	0.588	0.0503
4	Gedung Sate Museum	0.669	0.0441
5	Geological Museum	0.713	0.0449
6	Treasury Museum	0.713	0.0449
7	Asia Africa Museum	0.785	0.0396
8	Wangsit Siliwangi Mandala Museum	0.805	0.040
9	Sri Baduga Museum	0.874	0.0464

This research cities in the Global South attempting to reconstruct fragmented museum networks into integrated, sustainable cultural systems. By combining Freytag's Pyramid with a hybrid PSO-ML optimization model, Bandung's instance highlights how narrative-driven spatial design may balance pedestrian equality, emissions reduction, and storytelling coherence. Compared to standard legacy routing, the strategy lowered trip lengths by 92% and cut CO_2 emissions by approximately 1.15 million units. More than a technological breakthrough, the strategy repositions museums not merely as repositories but as narrative nodes within a symbolic-cultural infrastructure [1],[3],[23].

The debate advances three significant contributions. First, it validates the predictive importance of sidewalk quality and illumination (R^2 = 0.86) in museum accessibility and urban equality [19],[27]. Second, it highlights the policy scalability of narrative-computational frameworks for smart city efforts [9],[15]. Third, it illustrates how thematic sequences based on local heroes like Dewi Sartika and Husein Sastranegara may organize museum mobility as civic education [14],[22],[23]. These contributions provide a transportable model for cities in Southeast Asia, Latin America, and Africa, particularly those contending with scattered heritage, spatial inequality, and the twin aims of cultural preservation and decarbonization [2],[5],[10].

Table 6. 15 Indicator for 9 Government-Museum

Name of Museum	Age (Year)	DRS (Km)	DMAT (Km)	DMBT (Km)	GSR	TSV	GR	Nu Go Rev	Nu DayOp	OpHDur	Tot Pop	Nu PrimSch Stu	NJunSec Sch Stu	NSen High Sch Stu	Stand. Score
1) Indonesian Posta Museum	40	3,5	5,6	7,3	1020000	122	4,6	1,186	5	6	29042	5481	5556	4628	1
2)Indonesian Education Museum Universitas Pendidikan Indonesia (UPI)	9	6,8	7,5	10,7	1330000	37	4,7	1,147	5	5,5	67904	7047	4464	3002	77
3) Monument to the Struggle of the People of West Java	33	4	5,9	8,5	232000	128	4,5	18,617	6	8	105689	8924	5253	6857	67
4) Treasury Museum	8	4,2	5,8	8	13600	5	4,6	38	3	7	29042	5481	5556	4628	1
5)Asian-African Conference	44	2,2	6	4,7	346000	127	4,7	10,598	4	5	38266	5618	3336	3494	87
6) Gedung Sate Museum	6	2,3	5	6,9	484000	124	4,7	7,778	5	6,5	29042	5481	5556	4628	69
7) Geologi	94	3,8	5,7	7,6	210000	115	4,7	15,013	5	6	69783	5.234	2898	882	85
8) Sri Baduga Museum	50	3,3	7,6	2,2	75700	113	4,5	4278	6	8	68315	7324	1590	304	85
9)Mandala Wangsit Museum	57	1,4	4,7	5,8	16300	21	4,5	1,090	6	5	38266	5618	3336	3494	1

Note: Distance from Kiara Condong railway station (DRS); Distance From Andir railway Station (DMAT); Distance from Bus Terminal (DMBT), Google Rating (GR), Number Google Review (NuGoRev); Total Share Video (TSV); Number Day Operation (NuDayOP), Operational Hour/Day(OphDur); TotPop (Total Population); Number Primary School Student (NuPrimSchStu); Number Junior School Student (NumJunSchStu) ; Number Senior School Student (NSenSchStu)-

4. Conclusion

This study successfully developed and validated a novel sustainability-driven framework for optimizing urban museum networks by integrating dramaturgical storytelling with a hybrid Particle Swarm Optimization (PSO) and Machine Learning (ML) model [14],[17],[20]. Sustainable networks thus require aligning governance with narrative planning via PSO-ML frameworks, boosting visibility-accessibility-environmental relevance as low-carbon placemaking aligned with HUL [15],[25].

Our research establishes that this approach significantly enhances travel efficiency, reduces carbon emissions, and strengthens narrative coherence, offering a replicable framework for sustainable cultural tourism governance [14],[17[21]. By optimizing routes to minimize travel distance, time, and CO_2 output while simultaneously enriching visitor experience through compelling narratives, the PSO-ML model advances both urban planning and museum management [3],[9],[14]. Its demonstrated efficacy provides clear policy implications: it equips urban authorities with a practical tool to implement low-carbon mobility strategies in heritage contexts , and its integration of narrative structures like Freytag's Pyramid shows how narrative-driven design transforms static assets into dynamic experiences, fostering deeper public heritage engagement [14],[15],[22],[23]. This adaptable framework is readily scalable to other Global South cities and cultural landscapes beyond Bandung Municipality [2],[10]. Future research should incorporate real-time data for dynamic routing and explore diverse storytelling frameworks, including indigenous oral traditions, to enhance cultural inclusivity [22],[24].

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