A Thematic Analysis of Green Commuting and Accessibility in Urban Historic Districts

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ABSTRACT

Urban heritage districts, which preserve rich cultural, architectural, and social histories, often face the dual challenge of protecting their historical value while accommodating modern mobility needs driven by urbanization and changing lifestyles. However, there is a growing disconnect between mobility infrastructure and actual accessibility has emerged in urban heritage districts, particularly affecting vulnerable groups. This thematic review aims to analyze the key challenges related to mobility and accessibility in urban heritage districts, with a focus on elderly individuals, persons with disabilities, parents with strollers, and those with limited mobility. It also seeks to review existing literature on mobility and accessibility in urban heritage districts, and identify conceptual and empirical research gaps that need to be addressed. Additionally, this study proposes future research directions aimed at supporting more inclusive and sustainable mobility planning in historic urban environments. Based on a thematic analysis of 21 selected research papers, five key themes were identified: sustainable mobility and green transport, walkability and accessibility, transport infrastructure and planning, socioeconomic and behavioral factors, and urban heritage and cultural preservation. The findings show that while there is growing support for green commuting, major gaps remain in infrastructure, policy integration, and stakeholder engagement. Conflicts between heritage preservation, inclusive mobility needs, underdeveloped accessibility infrastructure, fragmented planning, and lack of participatory approaches also limit progress. This research highlights the urgent need for better policy coordination, inclusive planning, reliable data collection, and cross-sectoral strategies to balance modern mobility needs with heritage preservation in order to create more accessible, resilient, and sustainable environments.

Keywords: Green commuting, thematic analysis, active mobility, accessibility, historic district

INTRODUCTION

The acceleration of global urbanization has brought increasing challenges to cities, particularly in historic districts that hold cultural, architectural and social value. These areas were originally designed for pedestrians and cyclists with the features of narrow streets and compact layouts. While their design naturally supports active mobility, modern urban development, driven by car-centric planning, has introduced automotive infrastructure that, in contrast, undermines walkability and disrupts the historical fabric [2].

Recent urban renewal efforts frequently emphasize pedestrianization and car-free zones as strategies to promote sustainability. However, these approaches do not always account for the diverse needs of all user groups, especially the elderly, people with disabilities, parents with strollers, and those with injuries or limited mobility [19], [23], [28], [31], [33]. In some contexts, complete pedestrianization may lead to accessibility challenges or insufficient transportation alternatives, particularly in cities where public transit systems are underdeveloped. This has led to a growing disconnect between mobility infrastructure and actual accessibility. Instead of one-size-fits-all solutions, heritage districts require more balanced mobility strategies. These are approaches that are equitable (addressing the needs of vulnerable users), sustainable (supporting environmentally friendly transport), and historically sensitive (preserving the cultural and spatial integrity of heritage areas), aiming to meet diverse mobility needs, ensure equitable access, enhance sustainability, and preserve cultural identity.

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BACKGROUND

Although many historic districts are well-suited for walking and cycling, current mobility policies often prioritize environmental benefits over user diversity. Studies have shown that while pedestrianization can reduce emissions and increase tourism appeal, it may also create unintended complications if not supported by comprehensive planning and inclusive design [30], [34]. Moreover, research on sustainable mobility in heritage areas tends to focus on environmental outcomes or aesthetic improvements, rather than accessibility for all road users [5], [6], [18], [24]-[25], [28]. There remains a significant gap in frameworks that integrate green commuting strategies, including improved public transport, walkable street design, and cycling infrastructure, while also accounting for heritage preservation and social inclusivity. Existing integrated mobility frameworks, such as the Sustainable Urban Mobility Plan (SUMP), provide valuable guidance on combining various transport modes for environmental and functional efficiency. However, their application in heritage contexts may be limited, as they often lack sufficient sensitivity to cultural preservation constraints and the unique spatial challenges of historic urban environments. This study aims to fill these gaps by exploring how green commuting strategies can be integrated into historic districts to support the accessibility and mobility of all road users, while also preserving and promoting cultural heritage.

Research Problem

Many urban renewal projects in heritage districts focus on improving green commuting options like walking and cycling. Despite this growing emphasis on sustainable transportation, these initiatives still struggle to balance modern mobility needs with the preservation of cultural heritage [23]. While pedestrian-friendly areas and cycling infrastructure are often promoted as solutions, they tend to apply general approaches that overlook the unique features of heritage areas [2], [8] and the needs of vulnerable groups, such as the elderly, people with disabilities, parents with strollers and those with injuries or limited mobility [17], [31]. This creates challenges in integrating modern transportation options without compromising the cultural and historical value of these districts. It also creates a significant gap in understanding how sustainable transportation can improve accessibility for all while protecting the historical integrity of these areas. This research aims to explore how green commuting strategies can be more effectively integrated into urban heritage areas, ensuring better access for people of all mobility levels while preserving the area's unique historical character.

Research Gaps

While green commuting has gained attention, there is limited research on its application in historic districts, particularly regarding the integration of walking, cycling, and public transport. Existing studies often overlook the specific needs of vulnerable groups, such as the elderly and disabled, and fail to address how green commuting can be balanced with the preservation of cultural heritage. This study aims to bridge these gaps by exploring how sustainable mobility can be effectively implemented in urban heritage areas while ensuring accessibility and heritage conservation.

Research Objectives and Questions

Key research question of the study:

How are mobility and accessibility addressed in urban historic districts, particularly in relation to the needs of elderly individuals, persons with disabilities, and those with limited mobility, and what gaps and implementation challenges remain in the current body of research?

This study aims to achieve the following objectives:

1. To analyses the key challenges and issues related to mobility and accessibility in urban historic districts, with a focus on elderly individuals, persons with disabilities, parents with strollers and those with limited mobility.

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2. To review existing literature on mobility and accessibility in urban heritage districts and identify conceptual and empirical research gaps.

3. To propose future research directions aimed at supporting more inclusive and sustainable mobility planning in historic urban environments.

Theoretical Framework

This research is grounded in theories of sustainable mobility [1], urban heritage preservation [22], and social equity [14], [16]. These frameworks are integrated to examine how green commuting strategies can support environmental sustainability and cultural preservation in urban heritage areas. The theoretical framework guides the exploration of how various green commuting practices, such as walking, cycling, and improved public transportation, can be adapted to balance mobility needs with heritage conservation. Specifically, the sustainable mobility theory [1] is applied to assess the environmental effectiveness and modal integration of green commuting options within historic districts. The urban heritage preservation framework [22] informs the evaluation of how mobility interventions interact with spatial configurations, historical streetscapes, and conservation principles. Meanwhile, the social equity perspective [14], [16] is used to analyze the extent to which green commuting strategies address the mobility needs of vulnerable populations, ensuring inclusivity and equitable access across demographic groups.

Research Contribution

This study contributes to a deeper understanding of how green commuting strategies can be effectively integrated into urban heritage districts, with a particular focus on balancing accessibility, sustainability, and cultural preservation. It highlights the challenges of accommodating diverse user needs, particularly vulnerable groups, while safeguarding the unique characteristics of heritage areas. The findings offer practical insights for urban planning and policy development aimed at fostering sustainable mobility solutions in sensitive, historically significant urban environments.

While the integration of green commuting and accessibility into urban planning is critical for sustainability, its application within the context of urban heritage areas remains underexplored. This thematic analysis synthesizes existing global literature, identifying key patterns, challenges, and opportunities for future research. The study not only provides a comprehensive review of literature trends but also lays the groundwork for further investigation into sustainable mobility solutions in heritage-based urban contexts.

LITERATURE REVIEW

This chapter presents a thematic literature review with a focus on sustainable mobility [1], green commuting [9], accessibility [11], and heritage conservation [22] in historically sensitive urban environments. The purpose of this review is to synthesize key findings from existing studies. It also aims to highlight critical research gaps and establish an analytical framework for understanding how green commuting can be implemented in heritage districts. This implementation is particularly important for addressing the mobility needs of elderly individuals, persons with disabilities, and others with limited mobility [20], [23]. The review is structured around five thematic areas. These areas were identified through a manual thematic analysis of 21 peer-reviewed journal articles and conference papers. A detailed description of the literature search strategy, including databases used, inclusion and exclusion criteria (e.g., publication year, keyword focus, language), and any limitations such as regional bias or publication type, should be provided to clarify methodological rigor. The analysis is guided by three core theoretical frameworks: sustainable mobility [1], urban heritage preservation [22], and social equity [14]. These frameworks provide a lens for examining the intersections between transport planning, inclusivity, and cultural conservation in urban contexts.

Green Commuting in Urban Contexts

Green commuting refers to sustainable and environmentally friendly travel options such as walking, cycling, and public transportation, and carpooling. It aims to reduce carbon emissions and promote healthier urban living [9].

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In the context of urban heritage areas, these forms of mobility are increasingly promoted to balance environmental sustainability with the preservation of historical character.

Cities have adopted Sustainable Urban Mobility Planning (SUMP) to guide green transport initiatives [7] around the world. Scholars like [1] and [12] argue that green commuting contributes to loveable cities by reducing car dependency. However, as highlighted by [22] and [30], implementation in heritage zones remains complex due to spatial constraints, cultural preservation concerns, and limited transportation infrastructure. This indicates a tension between the goals of sustainable mobility, as defined by Sustainable Mobility Theory [1], and the realities of heritage space constraints, suggesting a need for more localized application of theory.

Most green commuting strategies in historic districts are developed and widely implemented in Western contexts, while studies in Southeast Asia are still lacking. [8] and [2] emphasize the rapid motorization and inadequate public transport systems present additional barriers to promoting sustainable modes in historic cores. This regional bias also reflects a limitation in the existing literature pool, which may influence the applicability of findings across different socio-cultural and spatial contexts.

Characteristics and Challenges of Historic Districts

Historic urban areas exhibit distinct spatial characteristics such as narrow streets, pedestrian-oriented layouts, and limited traffic capacity. While these traits align with walkability goals, they often present challenges for modern transportation planning [33]. As both [22] and [27] argue, spatial configurations are not solely logistical in nature but are embedded with cultural and symbolic meanings shaped by the authorized heritage discourse and conservation-planning practices. In many historic towns, the existing infrastructure is inadequate to meet the demands of modern tourism, yet upgrading is often constrained by conservation policies aimed at preserving the historic character [21]. In Southeast Asia, George Town and Melaka have adopted partial pedestrianization models; however, their implementation is often oriented toward tourism rather than inclusive daily mobility [13], [19], [31].

The key challenge is balancing transport needs with heritage preservation. Green commuting infrastructure may compromise cultural values or inadequately address community needs in the absence of context-sensitive planning. This reveals a misalignment between policy objectives and user-centered inclusivity—especially when viewed through the lens of Social Equity theory [14], [16].

Accessibility and Inclusive Mobility in Heritage Areas

Accessibility is about reaching key destinations easily [11], while inclusive mobility ensures all user groups can navigate urban environments effectively [16], including the elderly, disabled, children, parents with strollers, those with injuries, and low-income residents.

Although equity is gaining attention in transport planning, heritage areas often neglect the needs of vulnerable groups. In George Town, Penang, studies highlight significant barriers for people with disabilities, such as narrow sidewalks and a lack of accessible facilities, which limit mobility and social participation [31]. Research on elderly travel behavior also shows the need for transport systems that address age-related mobility challenges [17]. Smart city studies further stress the importance of spatial design that improves accessibility and navigation for all users [23]. This aligns with Social Equity theory [14], particularly the concept of 'transport justice' as mentioned in which emphasizes the moral obligation to ensure equal access in urban systems [16]. However, few studies critically evaluate how these principles are operationalized in Southeast Asian heritage towns [2], [8]. Therefore, promoting equitable access not only supports the rights of marginalized groups but also enhances the sustainability and inclusivity of urban mobility.

Integrating Green Commuting and Heritage Preservation

Integrating green mobility strategies with heritage conservation requires a delicate balance between sustainability, inclusiveness, and cultural sensitivity. Several studies highlight this challenge but offer limited solutions.

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Common limitations include:

1. Over-idealization of pedestrian zones with limited focus on vulnerable groups, mixed traffic conditions, accessibility to public transport, and multimodal integration;

2. Heritage regulations that require more targeted, inclusive, and context-specific research to guide sustainable transport planning in heritage areas;

3. Green commuting and transport in historic cities - lack of long-term impact assessments, real-world evidence, and analysis of user satisfaction

In recent years, frameworks such as Sustainable Urban Mobility Plans (SUMPs) have been successfully implemented across many Western cities [7]. However, these approaches remain largely underutilized in Southeast Asia and other vehicle-oriented regions. This contrast underscores a critical framework gap—the inability to adapt global best practices to local heritage contexts with differing spatial, social, and cultural dynamics. This highlights the need for context-sensitive approaches that integrate sustainable mobility with the protection of tangible and intangible heritage values in historic urban settings.

Thematic Gaps Identified in Literature

Building on the literature review, four key thematic gaps emerge: regional, framework, equity, and policy-practice. These gaps are interrelated and collectively hinder the development of inclusive green mobility in heritage contexts. Table 1 summarizes each gap and its implications for inclusive and sustainable transport planning in historic urban contexts, while Figure 1 visually illustrates their interconnections to support a more integrated understanding of the research landscape.

Table I Thematic Research Gaps In Literature On Green Commuting In Heritage Districts

Type of Gap	Definition	Implications
Regional Gap	Lack of empirical research in Southeast Asian heritage cities.	Limits the understanding of how green commuting works in rapidly motorizing, culturally sensitive contexts.
Framework Gap	Absence of integrated frameworks combining green mobility and heritage values.	Weakens policy coherence and reduces the effectiveness of context-sensitive transport strategies.
Equity Gap	Neglect of vulnerable groups in mobility planning.	Leads to social exclusion and fails to uphold principles of inclusive access and transport justice.
Policy-Practice Gap	Misalignment between sustainable mobility policies and actual implementation.	Creates barriers in translating planning ideals into effective, inclusive on-ground actions.

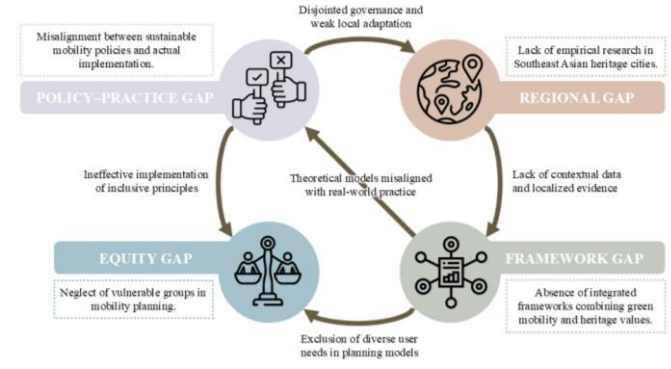

Fig. 1 Interrelations among research gaps in green mobility and heritage planning

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This diagram illustrates the interconnections among four key gaps in the literature: regional, framework, equity, and policy–practice. The regional gap underpins and amplifies the others by limiting contextual relevance. It contributes to inadequately localized frameworks, which in turn exclude vulnerable groups and deepen the equity gap. Disconnections between policy and practice further exacerbate both equity and regional issues. Arrows represent influence paths, highlighting a cyclical pattern of weak contextualization, ineffective implementation, and social marginalization within Southeast Asian heritage towns. These gaps highlight the need for a context-sensitive approach to planning that addresses both environmental and social dimensions of mobility, especially within heritage zones.

Theoretical and Analytical Frameworks

This study is grounded in three interrelated frameworks that guide the analysis of green commuting and accessibility in historic districts: Sustainable Mobility Theory, Urban Heritage Preservation, and Social Equity:

1) *Sustainable Mobility Theory:* Sustainable mobility promotes transport systems that reduce environmental impacts and support active travel like walking and cycling [1]. However, its implementation in historic districts requires sensitivity to spatial constraints and cultural context.

2) *Urban Heritage Preservation:* Heritage conservation today is increasingly integrated with urban regeneration. Ref. [22] and [27] argue that conservation is not static, but can be an agent of sustainable change. This perspective is essential when adapting historic districts for modern mobility without compromising cultural values.

3) *Social Equity and Inclusive Access:* Transport justice and social equity theories stress that everyone, regardless of age, ability, or income, should have equal access to transportation. Ref. [14] discusses how lack of access leads to social exclusion, while [16] provides a framework for ensuring fair access. These ideas are important for addressing the needs of vulnerable groups in green transport initiatives.

4) *Analytical Framework:* This study uses three key frameworks (Sustainable Mobility, Urban Heritage Preservation, and Social Equity) to guide the research on mobility and accessibility in historic districts, with a focus on vulnerable groups:

1. Sustainable mobility focuses on reducing emissions, encouraging walking and cycling, and promoting environmentally friendly transport in urban areas.

2. Urban heritage preservation considers the need to respect the cultural and historical aspects of heritage districts while incorporating modern transport solutions.

3. Social equity ensures equal access to mobility for all, especially vulnerable groups like the elderly and disabled, by emphasizing inclusive planning.

These frameworks help identify challenges and gaps in current mobility planning, while also pointing to ways to make mobility in historic areas more inclusive and sustainable.

METHODOLOGY

This study adopts a qualitative thematic analysis approach [3] to examine existing research on green commuting and accessibility in urban heritage areas. As a flexible method for identifying and interpreting patterns across textual data, thematic analysis is well-suited to this research. It enables the exploration of complex, overlapping issues drawn from multiple domains—such as urban mobility, heritage preservation, and inclusive access—while allowing for the integration of theoretical and practical insights across diverse case contexts.

Research Design and Justification

This study adopts a qualitative thematic synthesis approach 29 to analyze academic literature on green commuting and accessibility in urban historic districts. Unlike meta-analyses or statistical reviews, thematic

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synthesis allows the researcher to interpret complex, context-dependent issues by identifying recurring patterns, contradictions, and policy tensions within textual data.

Thematic analysis, particularly the six-phase framework proposed by [3], was chosen for its flexibility and suitability in exploring socially constructed phenomena such as mobility equity, heritage preservation, and urban inclusivity. Alternative methods like content analysis or meta-synthesis were considered but found less appropriate, as they either rely heavily on frequency counts (content analysis) or are better suited to synthesizing empirical data (meta-synthesis) rather than theoretical and conceptual arguments.

Literature Selection Strategy

A purposive sampling strategy was employed to select academic journal articles that best address the research questions concerning sustainable mobility, walkability, and inclusive access in historic urban environments. While not a systematic review, this approach ensured relevance, conceptual richness, and contextual diversity in the selected studies.

Database and Scope

The primary source of literature was the Scopus database, chosen for its broad coverage of peer-reviewed journals across urban studies, transport planning, heritage, and environmental disciplines. A preliminary search using the Boolean strings was used to identify a pool of relevant studies as shown in Table 2. The search was conducted in March 2025, covering the period from 2010 to 2024, and restricted to English-language peer-reviewed journal articles.

Table 2 Preliminary literature search results based on Boolean string queries and relevance screening

Boolean Strings	No. of Documents
("green commuting" OR "active mobility" OR "sustainable transport") AND ("historic district" OR "heritage city" OR "urban heritage") AND ("accessibility" OR "mobility" OR "walkability")	3
("historic district" OR "heritage city" OR "urban heritage") AND ("accessibility" OR "mobility" OR "walkability")	118
("green commuting" OR "active mobility" OR "sustainable transport") AND ("accessibility" OR "mobility" OR "walkability")	1945

Inclusion and Exclusion Criteria

The literature included in this study was selected based on several clear criteria:

1. Focused on urban historic districts, or heritage cities, or historically significant area
2. Addressed issues of sustainable commuting, green mobility, walkability, or accessibility
3. Contained conceptual, empirical, or policy discussions relevant to the intersection of accessibility, mobility, and heritage

Exclusion criteria included:

1. Studies focused solely on rural or non-heritage areas
2. Articles dealing only with general tourism (e.g. tourism mobility) or real estate without mobility content
3. Publications lacking adequate methodological or contextual information

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All of the sources were found through academic databases, Scopus, using Boolean keyword searches. Studies with a clear and direct focus on green mobility and accessibility in urban heritage areas were included in the final review. This ensured that the selected literature closely aligned with the goals of the review and provided meaningful insights into sustainable transport and inclusive access within historically significant urban contexts.

Final Selection

From an initial set of 2066 articles, 21 were selected based on their alignment with the research objectives and their conceptual depth in exploring mobility-heritage tensions. While no formal quality appraisal tool was applied, articles were assessed for scholarly credibility (indexed journals, peer-reviewed), relevance to the themes, and conceptual contribution. Although coding was conducted independently, input and feedback were sought from two senior academic colleagues to enhance reliability.

Data Management and Coding Tools

Although no specialized software was used, the data was carefully organized using several manual tools to keep the analysis clear and systematic:

1) *Structured Reading Notes:* These notes captured important information from each article (e.g., author, year, country, research method) and supported the early stages of coding. As they contain preliminary interpretations, they are therefore not shared publicly.

2) *Manual Coding Sheet:* This document was used to collect and organize the initial codes. It helped to group and refine ideas during the analysis.

3) *Thematic Table:* The final table summarizes the main themes, along with definitions and representative studies as references. While CAQDAS was not used, traceability was maintained through consistent file naming, cross-referenced summaries, and coding logs stored in versioned spreadsheets.

These tools helped in ensuring consistency, traceability, and transparency of the analysis process.

Analytical Framework and Coding Process

Braun and Clarke's six-phase framework [3] is adopted to conduct thematic analysis in this study. Although the analysis was performed manually (without the use of CAQDAS software, such as NVivo), it was done in a systematic, structured, and reflective way to ensure analytical depth and consistency. A brief overview of each phase is outlined below in Table 3.

Table 3 A Detailed Breakdown of The Thematic Analysis Process Conducted in This Study

Phase	Description	Actions Taken in This Study
Phase 1: Familiarization	Reading and re-reading the data to become deeply familiar with its content.	All 21 selected articles were read thoroughly. Notes were taken on research purpose, key focus area, findings, implications, etc.
Phase 2: Generating Initial Codes	Systematically identifying and coding interesting features of the data.	Open coding was applied manually using structured notes to tag key ideas such as transport modes, user groups, and urban planning factors.
Phase 3: Searching for Themes	Collating codes into potential themes based on similarity and relevance.	Codes were clustered into potential themes like 'walkability', 'accessibilities, and 'heritage districts. A preliminary theme list was developed.

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Phase 4: Reviewing Themes	Refining themes to ensure internal coherence and distinctiveness.	Themes were compared across all sources to validate their consistency. Some themes were merged or split based on content depth.
Phase 5: Defining and Naming Themes	Finalizing the specifics of each theme and naming them.	Themes were clearly defined and labelled. For example, 'Accessibility' included both physical access and user experience in heritage zones.
Phase 6: Producing the Report	Writing the final analysis with narrative, examples, and implications.	Themes were synthesized into structured sections of the literature review, supported by quotes and insights from the studies.

All 21 articles were imported into EndNote, thoroughly read and manually annotated in structured reading notes. Key details, such as research focus, methodologies, research scope, and key findings, were noted to build a strong understanding of the data set. Figure 2 shows the excerpt from structured literature review reading notes, detailing how each article was annotated for research focus, methodology, scope, and key findings.

Structured Reading Notes

This structured reading notes compiled during the literature review phase of the study. Each selected article was reviewed and summarized using a consistent format to capture key information. These notes formed the foundational layer for the initial familiarization and data extraction in the thematic analysis process.

Title		
Author		
Year	ID	
Journal/Publisher		
Abstract		
Keywords		
Research Purpose		
Research Background		
Study Location		
Study Type		
Focus Area		
Key Metrics		
Transport Mode		
Usage Change		
Key Factors		
Key Findings		
Key Theory/Concept		
Research Methods/Approach		
Research Gaps		
Implementation Success		
Evaluation		
Novelty	Research Results	
The novelty lies in	The results indicate...	
Significance And Inspiration		
Significance	Inspiration	
This study contributes to		
Summary/Conclusion		
The analysis highlights		
Quotes from article		

Fig. 2 An Example of Structured Reading Notes Used for Article Analysis

Although CAQDAS software like NVivo was not used, a structured manual process was adopted to ensure traceability. Files were labelled and cross-referenced through a code matrix spreadsheet, and version-controlled folders were used to maintain audit trails. Notes and thematic memos were also recorded to capture reflexive insights during the coding process.

Codes were developed through an inductive process, focusing on issues such as pedestrian accessibility, car-free planning, equity barriers, and the negotiation between heritage preservation and modern mobility. A manual coding sheet was used to identify and organize recurring patterns across the reviewed literature. These initial codes, derived from the structured reading notes, were refined through multiple rounds of comparison and reflection. Each code was linked to specific excerpts, forming the basis for the development of preliminary themes and subthemes. Figure 3 presents an excerpt from the coding sheet to illustrate this analytical process.

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Manual Coding Sheet

This the manual coding sheet used to identify and organize recurring patterns across the reviewed literature. Codes were generated inductively based on the content of the structured reading notes and refined through multiple rounds of comparison and reflection. Each code was assigned to specific excerpts, contributing to the development of preliminary themes and subthemes in the analysis.

ID	Title	Authors	Year	Research Purpose	Research Area	Research Location	Research Methodology	Key Focus Areas	Key Findings	Research Gaps
1	**Traffic Structure Optimization in Historic Districts Based on Green Transportation and Sustainable Development Concept**	Qiuping Wang, Hao Sun	2019	Optimize historic district traffic to balance limited supply and growing demand, emphasizing green transport and sustainability	Green transportation, sustainable development	Academy Street, Zhengzhou city, China	Travel diary methos, sample size 455 diaries, statistical analysis, descriptive analysis, Poisson regression	Environmental sustainability, Traffic issues, Heritage conservation Accessibility in heritage area	Travel frequency, transportation preferences, trip purposes, sociodemographic influences, perceptions of public transport, activity participation	o Current research more on Historic Urban Traffic Optimization, o lack of Empirical Validation in Historic Districts, o need Quantification of Transportation Costs for Soft Modes, o Standardized Protection for Historic Blocks, o need future Research on Multimodal Trip Traveler Mode Shares
2	**Feasibility Study on Walkable City Through Implementation of Car-Free Zones in Georgetown, Penang Using GIS Network Analysis**	A.H. Salleh, M.S.S. Ahamad, G.W.W. William	2020	Explore the feasibility and impact of car-free zones in Georgetown, Penang, on traffic and walkability.	Urban planning, pedestrian-friendly environment, car-free zones	Georgetown, Penang, Malaysia (UNESCO heritage area)	GIS network analysis, data preparation, traffic mapping, spatial and network analysis	Car-free zones, impact on traffic movements, walkability enhancement	Feasibility of car-free zones, traffic dynamics Concentration of attractions, sustainability benefits	o Long-Term Impacts of car-free zones, o User Satisfaction and Willingness on car free zones
3	**Pedestrianization and Walkability in A Fast-Developing UNESCO World Heritage City**	Rosilawati Zainol, Chen Wang, Azlan Shah Ali, Faizah Ahmad, Abdul Wafey Mohd Azipin, Hafez Salleh	2016	Assess pedestrianization attributes and evaluate walkability and citizen satisfaction in in Georgetown, Penang.	Walkability, pedestrianization, historic urban environment	Georgetown, Penang, Malaysia (UNESCO heritage area)	Structed interview 170 respondents, targeted streets, evaluation framework, statistical analysis (RII)	Physical attributes and effectiveness of pedestrian infrastructure	Inadequate walkability, satisfaction levels, overall evaluation, quality of walking environment, recommendations for improvement	o Needs of Integration of Community Activities, o Understanding Local Consumption Habits
4	**Active mobility in historical centres - towards an accessible and competitive city**	Carmela Gargiulo, Sabrina Sgambati	2022	Analyse active mobility's role in accessibility and heritage preservation in historic districts.	Active mobility, historic centre, urban regeneration	Pizzofalcone, Naples, Italy	Case study approach, matrix classification, SWOT analysis, GIS mapping	Active mobility, accessibility, redevelopment of historical districts	Improves connectivity, health and wellbeing, economic competitiveness, practical solutions for marginality, potential for urban regeneration	o Need of Empirical Evidence on Active Mobility, o gap between Quantitative Effects on Accessibility and Competitiveness, need Longitudinal Outcome Exploration
5	**Auditing a Central Area Transit (Cat) bus service in Malaysia's world heritage site - A case study of Georgetown, Penang**	Rosilawati Zainol	2016	Evaluate the effectiveness of Georgetown's CAT bus service in meeting passenger needs and overall experience.	Transportation management, sustainable urban mobility, heritage site management, tourism and accessibility	Georgetown, Penang, Malaysia (UNESCO heritage area)	Qualitative approach, participant observation, audit list	Evaluation of public transport, passenger experience,	Overall satisfaction, areas for improvement, reliability and timeliness, information dissemination, customer care	o Need Availability of Customer Care, Environmental Impact, and Information o Public Transport Usage by Disabled People o Attention to Vulnerable Groups' Needs o Systematic Benchmarking of Public Transport Quality
6	**Feasibility Study on Walkable City Through Implementation of Car-Free Zones and its Effect on Traffic Movement in Georgetown, Penang Using GIS Network Analysis**	Abdul Hakim Salleh, Nabilah Naharudin, Maisarah Abdul Halim, Nurfadhilah Ruslan	2021	Assess the feasibility of car-free zones in Georgetown, Penang, and their impact on traffic using GIS to enhance walkability and reduce car dependence.	Walkability, car-free zones, traffic movement, sustainable and urban environment	Georgetown, Penang, UNESCO heritage core zone	Identification of suitable areas, data collection (georeferencing and digitalization, traffic data acquisition), GIS methodology (Kernel density analysis, traffic mapping, simulation of traffic diversion, spatial and network analysis)	Car-free zones implementation, impact on traffic movement, tourism enhancement, environmental sustainability	Feasibility confirmed, traffic rerouting effects, tourism impact, overall urban improvement	o Need Long-term Effects and Community Feedback o lack of Stakeholder Involvement and User Satisfaction

Fig. 3 Partial View of the Manual Coding Sheet

Example of Theme Development

An initial code such as "environmental sustainability", "accessibility and travel behavior", and "transport demand-supply balance", identified during the manual coding process, was progressively refined into a broader theme titled "Sustainable Mobility Strategies in Heritage Districts". These initial codes emerged from the structured reading notes and manual coding of individual studies, serving as the foundation for thematic development. Through iterative comparison and synthesis, recurring patterns across cases (e.g., Penang, Henan, and Naples) were abstracted into higher-level themes and subthemes.

To illustrate how information from each reviewed article contributed to the development of themes, Figure 3 presents a summary of the refined themes and subthemes, their descriptions, and the supporting article IDs. This table demonstrates the analytical process used to link raw data (from coding) to conceptual categories in the literature review.

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Developed Themes and Subthemes

Article ID	Assigned Theme	Subthemes
1	Sustainable Mobility Strategies in Heritage Districts	Environmental sustainability, accessibility and travel behaviour, transport demand-supply balance
2	Car-Free Zone Implementation in Heritage Areas	Car-free zone feasibility, walkability enhancement, spatial and network impacts
3	Evaluating Walkability and Citizen Satisfaction	Pedestrian infrastructure assessment, citizen satisfaction, walking environment quality
4	Active Mobility and Urban Regeneration	Accessibility and connectivity, health and wellbeing, revitalizing marginalized areas
5	Public Transport Effectiveness in Heritage Areas	User satisfaction, transport accessibility, service quality and equity
6	GIS-Based Planning for Walkability & Traffic Management	Car-free zones, GIS planning, traffic diversion, tourism enhancement
7	Tourist Satisfaction and Urban Walkability	Tourist satisfaction, pedestrian walkways, urban planning for walkability
8	Elderly Mobility and Accessibility	Elderly travel patterns, transport reliability, age-inclusive planning
9	Sociodemographic Factors and Mode Choice	Travel behaviour, mode choice, GHG emission reduction, demographic influences
10	Transport and Public Health Outcomes	GHG reduction, health impact, transport policy
11	Urban Form and Environmental Quality	Urban geometry, air/noise pollution, spatial design and sustainability
12	Tourism Transport and Modal Accessibility in Melaka	Multimodal transport, tourism-related accessibility, underused transport options
13	Sustainable Commuting and Behaviour Change	Commuter incentives, LCA, environmental impact, long-term behavioural outcomes
14	Low-Cost Mobility and Community-Led Transport	Railway reuse, cycling paths, sustainable local transport
15	Community Engagement and Active Mobility	Social inclusion, environmental benefits, long-term behavioural shifts
16	Accessibility for Persons with Disabilities (PwDs)	Built environment barriers, inclusive design, pedestrian access in heritage areas
17	Smart Traffic Management and Simulation	ABM, mixed traffic, congestion modelling, diverse mode simulation

Fig. 4 Partial View of Theme Development Process

The final themes were then synthesized into a coherent narrative that forms the core of the study's findings. These themes structured the literature review, with each section supported by relevant quotes and insights from the reviewed studies.

Final Theme Selection Criteria

Themes were finalized based on the following criteria:

1. Recurrence across at least 3–10 different studies
2. Relevance to the core research objectives (sustainability, accessibility, heritage negotiation)
3. Conceptual richness, i.e., the extent to which a theme reflected a complex or under-explored tension

Each theme was further mapped to one or more theoretical frameworks, including:

1. Sustainable mobility theory [1], to interpret modal shifts and green transport promotion
2. Heritage preservation theory [22], to understand spatial constraints and conservation conflicts
3. Social equity frameworks [14], to interpret uneven access and marginalized mobility

This integrative step ensured that themes were not only empirically grounded but also theoretically interpreted, addressing critiques of under-theorization.

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Theme Refinement and Finalization

The preliminary themes were re-evaluated and refined through cross-checking with the original sources to ensure conceptual accuracy and alignment with the research objectives. Overlapping categories were merged or clarified to improve thematic clarity. The final five themes were selected based on their recurrence across multiple studies, their relevance to the research questions, and their contribution to the core objectives of inclusivity, sustainability, and heritage-sensitive planning:

1. Sustainable Mobility and Green Transport
2. Walkability and Accessibility
3. Transport Infrastructure and Planning
4. Socioeconomic and Behavioral Factors
5. Urban Heritage and Cultural Preservation

In order to illustrate how these themes were finalized, Figure 5 presents the final thematic table, summarizing each theme and its subthemes, supported by specific article IDs, brief descriptions, and identified research gaps. This table demonstrates how the analysis progressed from initial codes to synthesized themes, contributing directly to the core findings of this study.

Thematic Table

This table presents the final thematic table that summarizes the main themes and subthemes identified through the thematic analysis. Each theme is supported by representative codes and linked to the relevant literature. The table illustrates how the analysis progressed from initial coding to theme generation, and ultimately to the synthesis of insights addressing the study's research objectives.

Theme	Sub-theme	Supporting Evidence / Article ID	Brief Description / Key Points	Research Gaps
1. Sustainable Mobility and Green Transport	a. Sustainable Behaviour, Incentives & Long-Term Impact	13, 15	Examines social impacts of green mobility and the role of incentives in encouraging sustainable behaviour in heritage contexts.	Emphasized sustainability initiatives and commuter behaviour change, but lacks targeted policies, long-term impact evaluations, and effective incentives. Need better understanding of social impacts and adaptability to future urban development.
	b. Infrastructure Reuse & Localized Green Transport	14	Highlights reuse of heritage infrastructure to support eco-friendly, local transport systems.	Highlighted the need for targeted policies, long-term evaluations of sustainability initiatives in urban areas, and exploration of commuter incentives to support infrastructure reuse and localized green transport
	c. Car-Free Zones, Walkability & Urban Spatial Impact	2, 4	Discusses car-free strategies and walkability improvements within spatially constrained heritage settings.	lack of real-world evidence on the long-term impacts and road users' satisfaction with car-free zones; Future studies measuring accessibility, competitiveness, and longitudinal outcomes of active mobility in urban contexts
	d. Travel Behaviour, Accessibility & Demand Balance	1	Explores balance between tourism, local travel demands, and conservation in active transport.	Emphasized the need for real-life studies of travel behaviour in historic urban districts, standards for protecting historic areas from traffic and pollution, and further exploration of multimodal trip shares
2. Walkability and Accessibility	a. Pedestrian Infrastructure and Walkability Evaluation	3, 7, 21	Focuses on walkability assessments, citizen/tourist satisfaction and planning impacts	lack of context-specific and long-term studies on how walkability infrastructures impact both residents and tourists
	b. Inclusive Mobility for Vulnerable Groups	8, 16	Elderly and PwD mobility needs, inclusive and age-friendly design	need for more focused and practical research that looks at how well current infrastructure works for vulnerable groups, what their specific needs are, and whether public transport really meets those needs
	c. Spatial Accessibility and Urban Equity	20	Space syntax, urban equity, access inequality	explore mobility inequality in Asian cities, using mixed-method approaches to capture both human experiences and spatial data analysis
3. Transport Infrastructure and Planning	a. User Behaviour, Service Quality & Accessibility Equity	5, 19	Investigates how service quality shapes user behaviour and equitable access.	Lack of studies on customer care, accessibility for vulnerable groups, the impact of parking on public transport, and long-term sustainability and service quality assessments.
	b. Parking Behaviour, Urban Form & Heritage Impact	18, 19	Discusses parking infrastructure, urban form, and their effects on transport habits in heritage zones.	Mentioned the need comparative studies on parking retrofits in historic city centers, long-term sustainability assessments, and the influence of parking policies on public transport in heritage areas
	c. Traffic Management Behaviour & Mode Choice Simulation	6, 17	Explores how traffic management and simulation tools influence transport decisions.	Limited exploration of mixed traffic conditions, the need for improved models that account for various transportation modes, long-term effects of transport changes
4. Socioeconomic and Behavioural Factors	a. Travel Behaviour & Demographic Factors	9	Analyses how age, income, and education shape transport preferences in Malaysian cities.	Lack of deeper understanding of travel mode choices in Malaysia, the impact of sociodemographic factors on urban travel behaviour, and limited exploration of sustainable transport alternatives and their long-term effects
	b. Policy Impacts on Health & Environment	10	Reviews how sustainable transport policy improves public health and environmental conditions.	Lack of studies on the combined impacts of transport modes and health outcomes in Asian countries, Need further exploration of health impacts across all road user populations
	c. Multimodal Access vs. Utilization Gap	12	Investigates underutilization of available transport modes and causes for the gap.	Limited studies on Melaka's transport system, underutilization of air travel, and a lack of data on e-hailing services
5. Urban Heritage and Cultural Preservation	a. Sustainable Urban Form & Environmental Health	1, 10, 11	Studies transport design impacts on air quality, spatial layout, and ecological health in heritage areas.	Mentioned the need of studies on the impacts of transport modes, traffic optimization, and pollution mitigation strategies in historic districts and Asian cities
	b. Pedestrianisation & Walkability in Heritage Contexts	2, 3, 7	Analyses how pedestrianisation enhances heritage experiences, tourism, and community life.	Lack of studies on long term impacts of car-free zones, road users' satisfaction, walkability in heritage areas Need studies on the effects of walkable environments on local sustainability, community activities, and tourist satisfaction
	c. Accessibility, Connectivity & Livability	4, 5	Focuses on maintaining mobility and livability in heritage spaces through public and active transport.	Emphasized the need for studies on public transportation use by vulnerable groups, active mobility, accessibility, and competitiveness
	d. GIS & Traffic Management in Historic Zones	6	Highlights the use of GIS for monitoring traffic and supporting heritage conservation.	Lack of studies on the long-term effects of transport changes, community feedback, and the involvement of stakeholders and user satisfaction in proposed traffic management strategies for historic zones
	e. Multimodal Tourism & Cultural Access	12	Discusses integrating diverse transport modes to improve cultural accessibility and sustainable tourism.	Lack of research on Melaka's transport system, the underuse of air travel, and insufficient data on e-hailing services, Limited understanding of multimodal tourism and its impact on cultural access

Fig. 5 Final Thematic Table

Ethical Considerations

As this study involved analysis of published literature, no ethical approval was required. Nevertheless, academic integrity was ensured through accurate citation, transparency of selection, and reflective awareness of the researcher's positionality during theme development.

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FINDINGS

This chapter presents the findings of the thematic analysis based on 21 existing literatures using the Braun and Clarke [3] approach. A detailed review identified five main themes: (1) Sustainable Mobility and Green Transport, (2) Walkability and Accessibility, (3) Transport Infrastructure and Planning, (4) Socioeconomic and Behavioral Factors, and (5) Urban Heritage and Cultural Preservation. Each theme is explored with supporting evidence from the reviewed articles, highlighting current knowledge, research gaps, and implications for future planning and policy.

Theme Overview

Table 2 Themes and Subthemes Overview of Thematic Analysis

Theme	Subtheme	Description	Representative References
1. Sustainable Mobility and Green Transport	Sustainable Behavior, Incentives & Long-Term Impact	Examines social impacts of green mobility and the role of incentives in encouraging sustainable behavior in heritage contexts.	[4], [6]
	Infrastructure Reuse & Localized Green Transport	Highlights reuse of heritage infrastructure to support eco-friendly, local transport systems.	[8]
	Car-Free Zones, Walkability & Urban Spatial Impact	Discusses car-free strategies and walkability improvements within spatially constrained heritage settings.	[10], [24]
	Travel Behavior, Accessibility & Demand Balance	Explores balance between tourism, local travel demands, and conservation in active transport.	[31]
2. Walkability and Accessibility	Accessibility, User Satisfaction & Equity	Focuses on transport equity and satisfaction for vulnerable users in heritage zones.	[19], [32], [33]
	Car-Free Zones & Parking Retrofit for Walkability	Looks at transforming car-dominated zones and retrofitting parking to enhance walkability.	[17], [31]
	Parking Policy & Multimodal Accessibility	Examines the integration of parking policy and multimodal systems for accessibility.	[23]
3. Transport Infrastructure and Planning	User Behavior, Service Quality & Accessibility Equity	Investigates how service quality shapes user behavior and equitable access.	[5], [33]
	Parking Behavior, Urban Form & Heritage Impact	Discusses parking infrastructure, urban form, and their effects on transport habits in heritage zones.	[2], [5]
	Traffic Management Behavior & Mode Choice Simulation	Explores how traffic management and simulation tools influence transport decisions.	[19], [25]
4. Socioeconomic and Behavioral Factors	Travel Behavior & Demographic Factors	Analyses how age, income, and education shape transport preferences in Malaysian cities.	[18]

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	Policy Impacts on Health & Environment	Reviews how sustainable transport policy improves public health and environmental conditions.	[15]
	Multimodal Access vs. Utilization Gap	Investigates underutilization of available transport modes and causes for the gap.	[13]
5. Urban Heritage and Cultural Preservation	Sustainable Urban Form & Environmental Health	Studies transport design impacts on air quality, spatial layout, and ecological health in heritage areas.	[15], [28], [30]
	Pedestrianization & Walkability in Heritage Contexts	Analyses how pedestrianization enhances heritage experiences, tourism, and community life.	[19], [24], [34]
	Accessibility, Connectivity & Livability	Focuses on maintaining mobility and livability in heritage spaces through public and active transport.	[10], [33]
	GIS & Traffic Management in Historic Zones	Highlights the use of GIS for monitoring traffic and supporting heritage conservation.	[25]
	Multimodal Tourism & Cultural Access	Discusses integrating diverse transport modes to improve cultural accessibility and sustainable tourism.	[13]

Theme Analysis

This section introduces the key themes and subthemes identified through the analysis, supported by relevant articles and evidence. These themes illustrate the intersections between sustainable mobility, urban heritage, and accessibility, with a focus on the needs of vulnerable groups and the role of transportation infrastructure.

Theme 1: Sustainable Mobility and Green Transport:

This theme highlights how sustainable mobility initiatives, such as walking, cycling, and reduced car usage, are being adapted within the context of historic urban areas. The subthemes reflect various strategies and challenges related to implementing green transport while respecting the cultural and spatial uniqueness of heritage zones.

1. Sustainable Behavior, Incentives & Long-Term Impact

Promoting sustainable mobility in historic areas goes beyond infrastructure which involves encouraging long-term behavioral change. Strategies like parking management and public transport incentives can help shift daily habits by reducing car dependency, lowering emissions, and improving the overall quality of urban life [6]. At the same time, initiatives such as the GRAB project show how cycling and walking can bring wider benefits—not just for the environment, but also for public health, social interaction, and the revitalization of neglected urban spaces [4]. These examples highlight how well-designed incentives and user-focused planning can support a shift toward greener mobility, while also contributing to more inclusive and resilient cities over time.

2. Infrastructure Reuse & Localized Green Transport:

Supporting sustainable transport in historic areas requires sensitivity to both regional challenges and the unique qualities of each local setting. Ref. [8] points out that many historic cities, particularly in Southern Europe, are seeing population decline as residents move toward better-connected outskirts. This shift, along with increasing tourism and traffic pressures, has placed added strain on the cultural fabric of inner cities. Reusing existing infrastructure in thoughtful ways rather than introducing disruptive new developments, can help cities in creating

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localized, environmentally friendly transport systems that support accessibility without compromising heritage value.

3. Car-Free Zones, Walkability & Urban Spatial Impact

Thoughtfully designed pedestrian networks can improve access to services and heritage sites, attract visitors, and contribute positively to the social dynamics of the urban fabric. Ref. [24] highlight that car-free zones in historic areas aim to reduce the negative impacts of car dependency (e.g. congestion, safety risks, and environmental degradation) while enhancing urban livability. Ref. [10] emphasize that walkability and active mobility not only support environmental and health outcomes but also enhance the perception of safety and cultural value in historic spaces.

4. Travel Behavior, Accessibility & Demand Balance

In historic districts, travel behavior is closely linked to urban form and land use, both of which influence mode choice. Ref. [30] emphasizes the importance of balancing heritage conservation with contemporary mobility needs. However, planners must acknowledge the practical limitations of fully pedestrianizing historic areas, which may not be realistic. Therefore, non-motorized transport should be prioritized, while moderate accommodation of motorized access is recommended.

Theme 2: Walkability and Accessibility

This theme emphasizes the critical role of walkability and inclusive access in historically sensitive urban environments. It covers a wide range of user needs from general pedestrian infrastructure and tourist satisfaction to specific accessibility requirements of elderly individuals and persons with disabilities. The subthemes reflect how infrastructure quality, spatial planning, and equity considerations interact within heritage urban mobility strategies.

1. Pedestrian Infrastructure and Walkability

Urban design significantly influences walkability, public satisfaction, and overall quality of life in historic districts. Limited pedestrian infrastructure, such as narrow, poorly connected, and obstructed pathways reduces both usability and appeal [19], [33]. Moreover, poor physical conditions and lack of continuity weaken walkability outcomes [32]. In developing contexts, walkability is often overlooked due to the prioritization of cars as status symbols, further degrading pedestrian environments [33]. Improvements must go beyond infrastructure to include street life and safety, benefiting both locals and tourists, while supporting sustainability and local economies [32].

2. Inclusive Mobility for Vulnerable

Ensuring inclusive mobility remains a critical challenge in heritage cities particularly for the elderly and persons with disabilities (PwDs). Ref. [17] reveal in the study that elderly residents face limited mobility options due to poor health, car dependency, and inadequate public transport infrastructure. This restricts their participation in daily activities and impacts long-term sustainability. Despite urban heritage preservation efforts, the built environment often neglects the specific needs of vulnerable groups. In George Town, for instance, the lack of elderly- and disability-friendly infrastructure hampers access, contributing to social exclusion [31]. The current design still prioritizes private vehicles, undermining walkability and equitable access.

3. Spatial Accessibility and Urban Equity

Ref. [23] shows that accessibility in heritage areas is often uneven. In George Town, the mix of old irregular grids and modern planned streets improves walkability but reduces vehicle access. This creates a gap in mobility that affects different groups unequally. The study highlights mobility inequality as a key issue for spatial justice. It suggests that urban planning should balance both pedestrian and vehicle needs to support fair and inclusive access for all.

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Theme 3: Transport Infrastructure and Planning

This theme explores how the design, quality, and management of transport infrastructure shape mobility behaviors, accessibility equity, and urban experiences within heritage contexts. It also highlights the importance of adaptive planning strategies to accommodate multimodal needs.

1. User Behavior, Service Quality & Accessibility Equity

Infrastructure quality can shift user behavior and promote more sustainable travel. Ref. [33] points out that poor service quality, such as long waits, lack of information, and lack of facilities for disabled users reduce public transport use and effectiveness. Accessibility issues especially affect vulnerable groups, yet their needs are often overlooked. Ref. [5] adds that better planning, like clear pedestrian routes and parking control, can ease congestion and improve mobility, especially in historic areas.

2. Parking Behavior, Urban Form & Heritage Impact

Retrofitting parking infrastructure and urban form on transportation patterns in heritage areas can affect accessibility, user preferences, and the preservation of cultural character. Ref. [2] highlights that limiting surface parking in historic areas, like Bath, helps maintain walkability and preserves the character of the area. Ref. [5] suggests that limiting parking and improving pedestrian routes can ease congestion and support better transport choices while preserving urban character. Highlighting the importance of finding a balance between accommodating modern transport needs and preserving the integrity of historic districts.

3. Traffic Management Behavior & Mode Choice Simulation

Different traffic management strategies influence commuters' mode choices. Ref. [25] points out that over-reliance on private cars has led to congestion, pollution, and safety issues. Car-free or pedestrian-friendly zones are proposed to shift travel behaviors, but long-term success depends on reducing vehicle access, not only depends on adding infrastructure. Ref. [26] adds that traffic is made up of many different vehicle types, and driver behaviors strongly affects congestion. Current simulations often don't reflect this complexity. This shows the need for better models to understand how traffic policies influence people's travel choices in mixed-use and heritage areas.

Theme 4: Socioeconomic and Behavioral Factors

This theme looks at the intersection between individual travel behaviors and broader socioeconomic dynamics. It emphasizes the role of demographics, policy, and infrastructure in shaping the effectiveness and acceptance of sustainable mobility options.

1. Travel Behavior & Demographic Factors

Commuter's behavior patterns can affect the success of green commuting initiatives. Ref. [18] highlights that travel behavior is significantly shaped by sociodemographic factors such as education, income, and vehicle ownership. Individuals with higher socioeconomic status tend to rely on private vehicles. Therefore, suggesting targeted policies are needed to encourage shifts toward sustainable travel.

2. Policy Impacts on Health & Environment

Ref. [15] demonstrates that active transport policies can significantly reduce greenhouse gas emissions (GHGE) and improve public health outcomes. However, to fully realize these benefits, the study emphasizes the importance of mitigating risks to pedestrians and cyclists through safety-focused infrastructure. A combined strategy of promoting active travel, reducing vehicle miles, and adopting low-carbon vehicles is essential for improving urban air quality and reducing traffic-related harm.

3. Multimodal Access vs. Utilization Gap

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Despite the presence of multiple transport options, there is often a gap between access and actual usage. Ref. [13] points out that although transport networks in cities like Melaka are available, there are still gaps in connectivity, accessibility, and service satisfaction limit their effective use in heritage tourism areas. Traffic congestion and inadequate public transport reduce mobility and affects both residents and tourists. This highlights the need for more user-centered, integrated transport planning to bridge the access–utilization gap.

Theme 5: Urban Heritage and Cultural Preservation

This theme focuses on balancing environmental sustainability with cultural preservation in urban heritage districts. It highlights that protecting heritage districts requires limiting car use, making walking easier, and improving active transport options to support both cultural preservation and better city living.

1. Sustainable Urban Form & Environmental Health

Ref. [30] argues that historic cities face environmental and mobility degradation due to car dominance and ineffective traffic management. Emphasizing that limiting motor vehicle flow and prioritizing non-motorized modes like cycling can significantly enhance ecological conditions and service levels in heritage areas. Ref. [15] supports this view with highlighting that active transport not only reduces greenhouse gas emissions but also improves public health. Ref. [28] mentioned that historic urban forms which characterized by narrow roads and dense intersections can naturally limit traffic volumes. It helps lower noise and air pollution. These studies show that limiting car use and promoting active modes can both preserve cultural identity and enhance environmental sustainability, supporting healthier, more resilient heritage zones.

2. Pedestrianization & Walkability in Heritage Contexts

Multiple studies have emphasized the critical role of pedestrianization in enhancing the cultural and tourism value of heritage areas. Ref. [24] highlights the potential of car-free zones in Georgetown to promote walkability, though notes a lack of real-world validation and calls for further research into long-term impacts. Ref. [34] underscores that walkability is more than physical infrastructure—it requires continuous, safe, and engaging pedestrian routes to support both local and tourist use. Ref. [19] emphasized that weak connectivity between heritage sites in Penang deters exploration, calling for a more integrated pedestrian network to sustain cultural tourism and heritage preservation.

3. Accessibility, Connectivity & Livability

Emphasizes the importance of maintaining strong connectivity while preserving historical integrity. Active transport like walking and cycling not only reduces pollution but also boosts public space safety and quality of life. Ref. [10] highlights integrating active mobility into urban regeneration can improve accessibility, enhance urban competitiveness, and preserve cultural heritage, making historical districts more attractive and livable. In contrast, [33] discusses public transport improvements in Georgetown can address traffic congestion, reduce carbon emissions, and improve the livability of heritage areas by promoting sustainable transport options.

4. GIS & Traffic Management in Historic Zones

Ref. [25] demonstrates how GIS can be effectively used to model and visualize the implementation of car-free zones in George Town, offering a data-driven approach to managing traffic in heritage areas. The study emphasizes that reducing vehicle dominance through walkable, pedestrian-oriented planning not only improves safety and environmental quality but also supports heritage conservation by mitigating the pressures of over-tourism and motorized congestion.

5. Multimodal Tourism & Cultural Access

Multimodal strategies that integrate public transport, walking, and cycling play a key role in maintaining accessibility while preserving historical integrity. Ref. [13] emphasizes that despite Melaka's rich cultural appeal, its reliance on private vehicles due to inadequate public transport and congestion during peak seasons

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undermines tourist mobility. While accessibility within the core heritage zone is relatively high, areas beyond suffer from limited connectivity. This reflects a pressing need for an integrated multimodal transport system that combining walking, cycling, public transit, and e-hailing to support sustainable tourism and ensure cultural sites remain accessible to a broader population.

A. Interpretation of Themes and Analytical Insights

While the thematic analysis presents detailed findings, the following section provides interpretive insights that delve deeper into the patterns, contradictions, and implications emerging from the reviewed studies. The themes were interpreted in relation to the main research question:

How are mobility and accessibility addressed in urban historic districts, particularly in relation to the needs of elderly individuals, persons with disabilities, and those with limited mobility, and what gaps and implementation challenges remain in the current body of research?

The thematic analysis highlights the multifaceted nature of mobility and accessibility in historic urban districts, particularly in relation to vulnerable groups such as older adults and persons with disabilities. Several key insights were derived from the themes:

First, one of the most pressing challenges is the tension between modern mobility upgrades and the preservation of historical character. Across multiple studies, the introduction of pedestrian zones [10], [24], traffic management plans [25], and infrastructure retrofitting [2] often risks compromising the cultural and architectural integrity of heritage sites [2]. While car-free zones and green transport initiatives are increasingly proposed, their implementation can lead to cultural dilution or conflict with local stakeholder values.

Secondly, the issue of inclusive design emerged as a central concern. Despite growing attention to walkability and public transportation, there is a persistent lack of infrastructure that caters to people with limited mobility—particularly the elderly and persons with disabilities [17], [23], [31]. In practice, urban design in heritage zones often remains exclusionary, with physical barriers, poor signage, and limited consideration of sensory or cognitive accessibility [5], [19], [34]. In cities like George Town and Melaka, the lived experiences of vulnerable users reflect ongoing barriers to equitable access and participation in public life [13], [19], [33].

Third, the findings underscore significant institutional and policy-level barriers. Many cities struggle with regulatory misalignment, where heritage protection frameworks conflict with modern urban mobility plans [8]. These tensions often slow or fragment implementation efforts, especially in Southeast Asia, where complex governance structures and siloed policy domains complicate coordination between transport, heritage, and planning authorities.

From a geographical perspective, the thematic patterns also reflect a divide between Southeast Asian and European research approaches. The literature review summarizes what has been explored and highlights significant gaps. Among the 21 reviewed studies, 14 originated from Asian contexts, with 12 focusing specifically on Southeast Asia. Although Southeast Asia contributes a growing body of literature, particularly in countries like Malaysia, these studies often focus on single-dimension issues such as traffic congestion, pollution, or tourism management. In contrast, European studies, though fewer in number, tend to adopt integrated frameworks, connecting active mobility, environmental sustainability, and social inclusion in a more cohesive manner. This divergence reveals a critical research gap: while interest in mobility within historic urban districts is expanding in Southeast Asia, the conceptual integration of inclusive and sustainable mobility with heritage preservation remains underdeveloped. Few studies provide frameworks that simultaneously address the intersectional needs of diverse users alongside environmental and cultural goals [13], [19], [23]-[24], [33].

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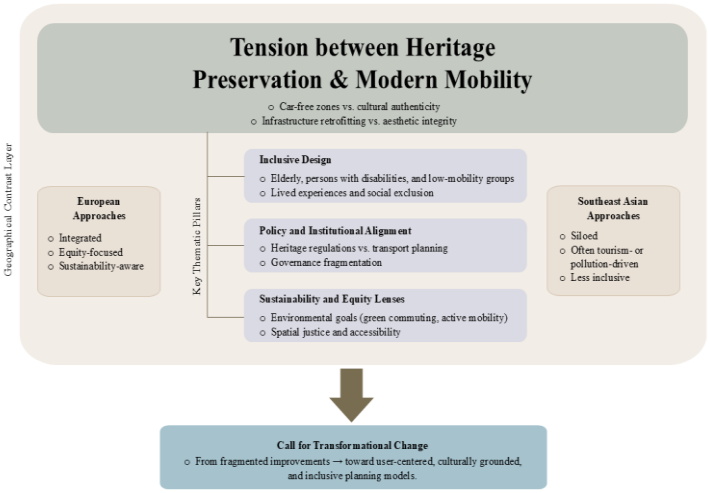

Fig. 6 Conceptual Framework of Interpretation of Themes and Analytical Insights

Figure 6 shows a Conceptual Framework of the tension between heritage preservation and modern mobility in urban historic districts. These themes collectively point toward the need for transformational, not merely incremental, change. Addressing mobility and accessibility in historic urban districts [8] requires planners and policymakers to move beyond physical infrastructure and consider behavioral realities, identity, spatial justice, and cultural sensitivity. Rather than imposing generic transport solutions, future planning should be user-centered and context-sensitive, grounded in the lived experiences of vulnerable populations, and aligned with heritage values and long-term sustainability goals.

Overall, this analysis serves to synthesize fragmented knowledge, identify persistent tensions, and inform future research and policy directions that promote a more inclusive, equitable, and sustainable vision of mobility in heritage-rich urban environments.

B. Interrelationship Among Themes

The themes presented in the previous sections are deeply interconnected, reflecting the multifaceted nature of sustainable mobility in historic urban environments. Understanding these intersections is essential for developing integrated strategies that promote environmentally sustainable, socially inclusive, and culturally respectful transport systems in historic urban areas.

Sustainable Mobility and Green Transport (Theme 1) intersects significantly with Walkability and Accessibility (Theme 2). Both themes emphasize the importance of reducing car dependency and promoting non-motorized transport modes such as walking and cycling. Initiatives like car-free zones not only contribute to environmental goals but also enhance the pedestrian experience within heritage areas, as highlighted by [24] and [10]. These car-free zones create spaces that improve the quality of life for both residents and tourists while contributing to environmental and health [4], [15]. However, the implementation of such green transport initiatives needs to consider accessibility for vulnerable groups, which brings the two themes into closer alignment. [17] and [31] emphasize the importance of ensuring that elderly individuals and persons with disabilities can also benefit from improved infrastructure, something that must be addressed when designing walkable heritage areas.

Additionally, Transport Infrastructure and Planning (Theme 3) provides the practical foundation for both sustainable mobility (Theme 1) and walkability (Theme 2). Infrastructure choices, such as pedestrian routes and parking management, can directly impact travel behavior and accessibility outcomes. Ref. [33] and [25] discuss how thoughtful infrastructure planning, including the reduction of parking spaces and the improvement of pedestrian networks, can ease congestion and foster more sustainable travel choices. As Ref. [30] point out, a key challenge lies in striking a balance between modern infrastructure improvements and the need to preserve the historical character and integrity of urban heritage areas. Thoughtful design is necessary to avoid conflicts between modern mobility needs and the preservation of cultural heritage.

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The intersection between Socioeconomic and Behavioral Factors (Theme 4) and the other themes also plays a crucial role in shaping the effectiveness of green mobility strategies. Demographics, income levels, and car ownership habits significantly influence travel behavior [18]. This is particularly relevant in heritage areas, where socioeconomic status can determine whether individuals opt for sustainable transport options or rely on private vehicles. Moreover, policies aimed at reducing greenhouse gas emissions, such as those advocating for active transport [15], must consider these demographic factors to be effective in diverse contexts. These considerations also tie into the idea of Urban Heritage and Cultural Preservation (Theme 5), where integrating sustainable transport with cultural preservation efforts must take into account the local socioeconomic conditions and behavior patterns.

Finally, the preservation of cultural heritage (Theme 5) is intimately connected to sustainable mobility (Theme 1). As discussed by [24] and [28], prioritizing non-motorized transport like walking and cycling in historic areas not only reduces environmental degradation but also helps preserve the historical identity of these areas by reducing traffic congestion and pollution. This aligns with the need for adaptive planning strategies, as emphasized by [2], to ensure that transport infrastructure is designed in a way that both supports accessibility and protects the cultural value of heritage sites.

This review identified five key themes shaping sustainable transport in heritage areas: sustainable mobility, walkability and accessibility, infrastructure planning, social and behavioral factors, and heritage preservation. The need to balance modern mobility with cultural and social needs is highlighted. Improving walkability and inclusive access especially for vulnerable groups is essential. At the same time, transport plans must respect local heritage, adapt to user behaviors, and ensure fairness in service and design. In short, creating sustainable transport in heritage areas requires thoughtful, people-centered approaches that respect both place and community.

DISCUSSION

A. Mobility and Accessibility in Urban Heritage Districts

This study examined how mobility and accessibility are handled in urban heritage districts, with a focus on the elderly, people with disabilities, and those with limited mobility. Through thematic analysis, five major themes were identified, shedding light on current efforts, challenges, and missed opportunities in promoting inclusive mobility in heritage-rich environments.

B. Interpretation of Key Themes

1. Conflict Between Heritage Preservation and Mobility Improvement

A clear tension emerged between preserving the historical character of urban spaces and making them accessible. Many heritage districts prioritize aesthetic and cultural authenticity, which can restrict necessary upgrades like ramps for wheelchairs and stroller. This ongoing conflict calls for creative, balanced solutions that respect heritage while meeting modern mobility needs.

In cities like Barcelona and Edinburgh, planners have adopted modular or reversible infrastructure, such as retractable ramps or temporary tactile paving, which can be installed without permanent alteration to heritage fabric. These examples show how sensitivity to both preservation and accessibility can coexist with proper design innovation

2. Underdeveloped Accessibility Infrastructure

Although awareness of inclusive design is growing, many heritage areas still lack essential infrastructure. Features like safe crosswalks, wheelchair-friendly transit, or clear and consistent wayfinding are often missing. This gap limits mobility for elderly, disabled individuals, and parents with strollers, and highlights the disconnect between planning intentions and practical execution.

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As an example, George Town, Penang, although a UNESCO site, still lacks continuous wheelchair-accessible pathways or pedestrian signals with auditory support in many key zones. In contrast, Bologna has made significant strides with their "pedestrian priority zones," where traffic calming, signage, and level pavements support universal design.

3. Lack of Participatory Approaches Involving Vulnerable Users

Another key issue is the limited involvement of vulnerable groups in mobility planning. When the voices of those directly affected are not included, the solutions often fail to reflect their actual needs. A more participatory approach would help create systems that are user-centered, functional, and inclusive.

Cities like Melbourne and Copenhagen have implemented "walkshops" and co-design labs where elderly, children, and wheelchair users lead walking audits to assess real-world challenges and propose solutions. These approaches have led to context-aware design improvements such as curb cuts, seating spots, and adjusted slope gradients in sidewalks.

4. Inadequate Policy Frameworks and Fragmented Planning

The study found that policies on mobility and heritage preservation often lack alignment. Many operate in silos, with poor coordination between conservation authorities and urban transport planners. As a result, accessibility efforts are fragmented and inconsistent, pointing to the need for a more unified, cross-sectoral planning approach.

One successful model comes from Ljubljana, Slovenia, where the city created an integrated urban mobility plan (SUMP) that explicitly included heritage-sensitive areas and linked them with the city's public transport and cycling policies. This model demonstrates the importance of policy harmonization and unified governance in inclusive urban development.

5. Data Gaps and Monitoring Challenges

There is also a shortage of data on studies on long term impacts and how well accessibility measures are working in heritage districts. Without proper monitoring and feedback loops, it's difficult to evaluate what's effective and what needs to change. Reliable data collection and regular evaluation are essential for meaningful progress.

For example, Amsterdam uses pedestrian heat-mapping, mobility satisfaction surveys, and injury tracking to evaluate and adapt walking and cycling infrastructure. Heritage districts should consider developing similar KPI dashboards or performance frameworks, particularly focusing on equity-based metrics like "mobility equity score" or "access-to-destination time."

C. Theoretical and Practical Implications

From a theoretical perspective, this study highlights the need to integrate accessibility and social inclusion more deeply into the discourse on sustainable mobility. Green commuting is not just about reducing car dependency; it is about ensuring that all urban residents, regardless of age, ability, or income, can participate in and benefit from these initiatives.

In practice, the study suggests that successful green commuting in heritage districts requires collaborative policy-making, stakeholder engagement and data-driven decisions. Local governments should work with communities, heritage experts, and transportation planners to design solutions that are both inclusive and respectful of the district's cultural values. Moreover, heritage districts should embrace multi-modal transport systems that prioritize walking and cycling, while ensuring proper integration with public transport networks.

Cities like Freiburg (Germany) and Kyoto (Japan) have achieved this by integrating walkability, heritage preservation, and mobility rights through multi-stakeholder charters and community-led monitoring boards. These cases show that it is possible to promote green mobility without compromising cultural integrity. Moreover, heritage districts should embrace multi-modal transport systems that prioritize walking and cycling, while ensuring proper integration with public transport networks. For example, Vienna's Ringstrasse area

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supports pedestrian activity while offering seamless transitions to tram, bus, and paratransit options—serving both tourists and local elderly residents efficiently.

D. Policy Implications and Practical Recommendations

The following policy recommendations are proposed to translate these findings into actionable change:

1. Establish Integrated Planning Committees: Encourage cross-sector collaboration by forming integrated task forces that include heritage, transport, and community development agencies.

2. Adopt Context-Sensitive Infrastructure Design: Use reversible or low-impact accessibility interventions (e.g., modular ramps, temporary wayfinding signs) that do not damage heritage value but improve inclusivity.

3. Mandate Participatory Design: Institutionalize the involvement of vulnerable users through public consultations, co-design sessions, or walkability audits led by elderly and disabled residents.

4. Pilot Multi-Modal Transport Nodes: In car-dependent heritage areas, trial "green mobility hubs" that combine pedestrian paths, bike-sharing, and shuttle services adapted to limited-mobility users.

5. Enhance Monitoring and Evaluation Systems: Introduce key performance indicators (KPIs) such as accessibility satisfaction scores, travel time for disabled users, or pedestrian injury rates to assess and adjust policies regularly.

6. Offer Financial Incentives for Retrofits: Provide grants or tax relief to property owners who retrofit entrances or pathways in ways that improve accessibility while preserving heritage character.

These actions provide a framework for cities to balance mobility and preservation without sacrificing inclusivity or sustainability.

E. Limitations of the Study

This study has several limitations:

1. Analytical Tool Limitation: While the manual analysis approach allowed for greater researcher immersion and contextual sensitivity, the absence of CAQDAS tools may have limited the scalability, audit trail clarity, and reproducibility of the thematic process. Future studies could integrate CAQDAS to balance immersion with systematic rigor.

2. Geographic and Contextual Limitation: The study is not location-specific. It may not instantly apply to specific regions or cultural contexts.

3. Data and Methodology Limitation: The analysis relies only on existing literature, and does not include primary data collection. It may overlook emerging or localized practices not yet documented in research.

4. Scope Limitation: Since the study focuses on urban heritage districts. The findings may not be applicable to other areas with different characteristics.

F. Recommendations for Future Research

Future research should explore the following areas:

1) Participatory Research Methods: Involve local communities through surveys, interviews, and participatory planning to better understand the mobility needs of different groups.

2) Interdisciplinary Approaches: Combine expertise from heritage conservation, urban planning, and transportation to develop more holistic solutions.

3) Testing Multi-Modal Systems: Conduct case studies on how integrated transport systems (walking, cycling, and public transport) can be effectively implemented in heritage areas.

4) Long-Term Studies: Monitoring accessibility initiatives over time would help assess their real-world impact and sustainability.

5) Technology Integration: Future studies could explore how digital tools and assistive technologies can enhance mobility without compromising heritage values.

G. Research Contribution

This study highlights the urgent need to incorporate green commuting strategies into heritage management in urban heritage districts. The findings emphasize that measures like car-free zones, better public transport, and improved pedestrian pathways are crucial for achieving both environmental sustainability and social equity, all while preserving cultural heritage. However, fully pedestrianized solutions may not be the best choice in vehicle-oriented regions, where balancing mobility needs is essential. In order to make this work, urban planners, policymakers, and local stakeholders need to collaborate and adopt a more inclusive approach.

As cities continue to evolve and face growing environmental challenges, urban heritage districts are increasingly affected by negative impacts from rapid urbanization and development. It is crucial to find solutions that balance modern needs with the preservation of cultural heritage. Future research should focus on long-term studies, identify best practices from various heritage areas, and develop models for engaging stakeholders. This approach will help cities manage urban growth while safeguarding their cultural and environmental integrity, benefiting both the community and the environment.

CONCLUSION

This study examined how mobility and accessibility are addressed within urban heritage districts, with a specific focus on the needs of elderly individuals, persons with disabilities, and those with limited mobility. Through a thematic analysis of existing literature, five key themes were identified: sustainable mobility and green transport, walkability and accessibility, transport infrastructure and planning, socioeconomic and behavioral factors, and urban heritage and cultural preservation.

The findings reveal that while there is growing attention to inclusive mobility in heritage contexts, significant challenges remain. These include conflicts between conservation and accessibility, fragmented policies, underdeveloped infrastructure, lack of stakeholder engagement, and insufficient data for monitoring progress. Importantly, the analysis highlights a need for more integrated, inclusive, and context-sensitive approaches that respect both heritage value and human mobility needs. Overall, the study emphasizes the urgency of rethinking how urban heritage districts are planned and managed to support more equitable, accessible, and sustainable environments for all users. Urban planners should prioritize co-designed, multi-modal mobility systems that preserve heritage while ensuring access for vulnerable groups.

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