*Research Paper*

# A fuzzy approach for critical quality assessment of neighbourhood risk factors in historic city centres

## Empirical evidence from Kolkata, India

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### Abstract

*Historic city centres, which are essential socio-economic and cultural assets, are increasingly being threatened due to rapid urbanisation, climate change, and inadequate development, management, and conservation practices. This research made an empirical assessment of the compounding risks present in historic city centres by taking the case of Kolkata, India. A fuzzy approach was employed to quantify the critical qualities of the physical, functional, environmental, economic, and social dimensions, elucidating how these inherent characteristics govern the riskscapes in historic city centres. The findings revealed the presence of physical degradation and socio-economic decline in the selected study areas, which exacerbate their vulnerabilities and increase their overall risk. This research puts forward a stratified risk assessment approach using factors that are intrinsic to historic city centres and thus provides comprehensive knowledge about their ground realities. The research offers a pragmatic framework aiming to guide evidence-based decision-making to foster a more resilient and sustainable future for heritage management and urban development.*

### Keywords

*Historic city centre, risk assessment, vulnerability, intangible heritage, built-environment*

## 1. Introduction (800)

Industrialisation and technological advancements have steered a massive outflow of population, where people from rural hinterlands are rapidly migrating to urban centres in search of job opportunities and better quality of life. The world urban population has increased fourfold, from 0.8 billion in 1950 to 4.2 billion in 2018, and is expected to account for more than half of the total global population by 2050 (United Nations 2018). The impacts of rapid urbanisation are experienced in the form of changing demographic, spatial, and functional dynamics that inadvertently introduce significant transformation in the social, economic, and environmental base of a country (Bodo, 2019; Kuddus, Tynan and McBryde, 2020). The multifaceted urban challenges are predominantly concentrated in historic city centres in the form of housing shortages, inadequate and ageing infrastructures, overcrowding, congestion, environmental deterioration, and other socio-cultural and public health challenges, exceeding the carrying capacity of these historic centres (Picard, 1939; Hemer *et al.*, 2003).

Urban heritage, largely concentrated in historic districts, constitutes a vital asset for socio-economic development in rapidly evolving global cities. These districts hold great symbolic importance for city

dwellers and are pivotal in determining the liveability, well-being, and quality of life of residents (UNESCO, 2010). However, the tangible and intangible heritage inherent to these historic centres is being increasingly altered due to rapid urbanisation and globalisation, which introduces several risks in these sensitive areas. These historic areas are being subjected to additional pressures due to ineffective development, management, and conservation practices, exposing them to various degrees of vulnerability and compounding risks, thereby restricting their tourism and future development potential. These factors significantly diminish the potential of these invaluable heritage assets, further threatening their resilience and sustainability (Ferreira and Ramírez Eudave, 2022).

To elevate the cultural experiences in historic areas and promote their tangible and intangible heritage for sustainable development, it is vital to have high-quality and well-rounded development in these areas. Historic centres are dynamic in nature, where multiple stakeholders converge to shape their physical, environmental, social, and economic developmental trajectories. As such, successful management of historic districts mandates institutional frameworks and regulatory assessment tools. However, the intricate and constantly changing dynamics among the various urban components complicate empirical assessments in historic districts (Quesada-Ganuza *et al.*, 2021). There is a need for pragmatic approaches that combine qualitative and quantitative narratives to explore the systemic risks underlying these vulnerable historic areas. Therefore, this research aims to assess the criticality of historic neighbourhoods and identify their risks, extending a comprehensive understanding of the present urban dynamics in these historic centres. By taking the case of Kolkata, which is also known as the cultural capital of India, this study explores the various intensities of risk associated with the spatial, environmental, economic, and social conditions of these historic districts. This research puts forward an approach for quantitative risk assessment of historic districts using factors that are intrinsic to historic areas and thus provides comprehensive knowledge about their ground realities. The fuzzy risk assessment of historic areas underscored in this research took cognizance of the perturbations resulting from various socio-economic, physical, and infrastructural conditions. The findings of this research provide crucial insights for decision-makers to identify gaps in the functionality of municipal services and the quality of spatial, environmental, and socio-economic aspects. The theoretical and practical contribution of this research will assist in understanding the potential future threats and thereby guide evidence-based decision-making for streamlining heritage development towards a more resilient and sustainable future.

The remainder of the study has been structured as follows: Section 2 presents a brief background of the existing literature. Section 3 explains the methodology and selected study areas for the research, followed by section 4, which presents the result and discusses the research outcome. Section 5 presents the final inferences and conclusion of the research and describes the scope of future research.

## 2. Background

The *International Council on Monuments and Sites (ICOMOS)* has recognised historic city centres as human settlements that have a historical blueprint of their past physical structures and way of life, reflecting the spatio-temporal evolution of the settlement. These historic centres have a high concentration of business, cultural, recreational, and residential functions with buildings and structures of significant historic and cultural values (Asian Development Bank, 2008). These centres are cauldrons where physical, social, and functional attributes interact and influence each other to form an integral part of everyday city life. As a result, these centres hold profound symbolic and emotional significance for the city dwellers, as they extensively showcase the rich historical backdrop of the cities and their intangible heritage, accumulated over the years in the form of diverse traditions, values, and cultural practices

(UNESCO, 2010). These historic centres have distinct morphological, physical, functional, social, perceptual, and visual characteristics and nuanced shades of temporal evolution, fostering a unique urban identity and enriching the genius loci of these places (UNESCO, 2016; Shehab El-Deen, Aboulsaadat and Nour, 2024). The United Nations has previously recognised the importance of historic cities in advancing socio-economic development (UNESCO, 2010). They are an invaluable part of the socio-cultural and economic assets of countries and play a pivotal role in shaping the sustenance of societies and communities at large. In addition to their monumental values, these centres have social and community attributes that contribute towards the development of cultural capitals (Romão and Bertolin, 2022). Along the same line, previous literature has noted their significance in driving sustainable and inclusive development and boosting the economy of a country by promoting tourism opportunities (Deacon, 2018; UNESCO, 2023).

However, the unprecedented rate of population expansion and uncontrolled urban densification have subjected these historic city centres to pressures of varying degrees. The rapid commercialisation, market exploitation of these sensitive areas, and overexploitation of their tangible and intangible resources for promoting mass tourism have exponentially increased the vulnerabilities of these areas (Castronuovo, 2023; Shehab El-Deen, Aboulsaadat and Nour, 2024). Moreover, these historic centres often undergo natural ageing and dilapidation in addition to experiencing climate-induced disasters, contributing to significant depreciation in the natural adaptive capacities of these historic centres. The impacts of these externalities extend beyond the built environment, bearing considerable ramifications on the cultural landscape of these areas by inducing profound shifts in socio-economic dynamics, thereby resulting in dilution of community cohesion and increased fragmentation, marginalisation, and gentrification (Castronuovo, 2023; Fu *et al.*, 2023). Owing to these profound anthropogenic pressures and climate-induced challenges, the debate over resilient planning, development, and preservation of historic centres and their heritage assets have intensified over the decades. Global forums on heritage conservation like *ICOMOS* and *UNESCO* have been persistently focusing on addressing these challenges threatening the integrity and sustenance of these heritage assets (Quesada-Ganuza *et al.*, 2021). The *Recommendations on Historic Urban Landscape* was formulated by the *UNESCO World Heritage Committee* in 2003 followed by the *Vienna Memorandum* in 2005 to collectively align heritage conservation approaches with urban development aspirations (Francini and Rozochkina, 2024). The *European Union* similarly manifested a cultural heritage risk assessment through their *EU Work Plan for Culture 2019-2022* (Quesada-Ganuza *et al.*, 2021). However, risk assessment in historic areas often proves to be challenging, given the intricacies and the presence of overlapping physical, environmental, economic, and social dynamics (Ferreira and Ramírez Eudave, 2022). Existing studies on risk assessment of historic city centres have predominantly focused on hazard and vulnerability assessments within the context of disaster risk and climate change. Studies on the inherent attributes of these historic city centres, which play a crucial role in shaping their vulnerabilities and adaptive capacities, remain underexplored. There is a distinct gap in addressing how these intrinsic characteristics influence the overall risk associated with these sensitive areas, independent of external hazards. Thus, this research aims to critically evaluate the inherent characteristics of historic city centres by taking the case of historic city centre of Kolkata, the cultural capital of India. By employing a fuzzy approach, this research undertakes a multi-level and multi-factorial risk assessment of the selected study areas to better inform decision-makers about the diverse challenges present in these areas. The risk profiling incorporates both tangible and intangible attributes of the study areas, offering a comprehensive overview of their combined vulnerabilities.

The contributions of this study are twofold. Firstly, this study presents a participatory approach by integrating multiple stakeholders in the quality assessment of the study areas. This bottom-up methodology ensures that the place-based concerns and the subjective perceptions of key stakeholders

are adequately reflected in the overall risk assessment, as these aspects are often undermined when relying solely on census-based data. Secondly, the proposed framework enables policymakers to identify lacunae in existing development plans and policies, thereby fostering evidence-based policy initiatives.

## 3. Methodology

Data collection for this research was conducted in two parts consisting of expert opinion surveys and stakeholders' perception mapping using structured questionnaires. The stakeholders' perception mapping was conducted in two wards of Kolkata, which are parts of the historic centre of the city and a total of 160 samples were collected. A multi-factor and multi-level risk assessment was then conducted at three levels by employing fuzzy logic. In the first level, the critical quality assessment of individual risk factors within each subsystem was undertaken followed by the criticality assessment of the subsystems in the second level. Finally, the overall risk scores of the study areas was computed based on the values obtained in the first two levels. To determine the weights of the factors for the risk assessment, an expert opinion survey was conducted using structured questionnaire. A panel of 15 experts were invited for the expert opinion survey to rate the relevance of the selected indicators in 5-point Likert Scale and the final weight of the indicators was obtained using the normalised mean method as per the following equation:

$$w_i = \frac{M_i}{\sum_{i=1}^{n} M_i}\ , 0 < w_i < 1 \text{ and } \sum_{i=1}^{n} w_i = 1 \qquad \text{(Eq. 1)}$$

where, $w_i$ is the weight of the factors/subsystems, $M_i$ is the mean score of each factor/subsystem . The critical quality scores of the individual risk factors in each subsystem were calculated as the membership function (MF) using the following equation:

$$MF_i = \frac{x_1}{LT_1} + \frac{x_2}{LT_2} + \frac{x_3}{LT_3} + \frac{x_4}{LT_4} + \frac{x_5}{LT_5} \qquad \text{(Eq. 2)}$$

where, $x_1$ to $x_5$ are the percentage of responses received under the five linguistic terms and $LT_1$ to $LT_5$ are the grade alternatives adopted for the linguistic terms in the Likert scale. The fuzzy matrix was then computed for the criticality assessment of the subsystems in the second level as follows:

$$S_i = \begin{bmatrix} MF_1 \\ MF_2 \\ MF_3 \\ \dots \\ MF_m \end{bmatrix} = \begin{bmatrix} C_{11} & C_{21} & C_{31} & C_{41} & C_{51} \\ C_{12} & C_{22} & C_{32} & C_{42} & C_{52} \\ C_{13} & C_{23} & C_{33} & C_{43} & C_{53} \\ \dots & \dots & \dots & \dots & \dots \\ C_{1m} & C_{2m} & C_{3m} & C_{4m} & C_{5m} \end{bmatrix} \qquad \text{(Eq. 3)}$$

where, $S_i$ is the fuzzy matrix showing the membership functions of the factors, $C_{11}$ to $C_{5m}$, within a defined subsystem.

The fuzzy evaluation matrix $D_i$ was calculated as:

$$D_i = W_i \circ S_i = \{w_1, w_2, w_3, \dots, w_n\} * \begin{vmatrix} C_{11} & C_{21} & C_{31} & C_{41} & C_{51} \\ C_{12} & C_{22} & C_{32} & C_{42} & C_{52} \\ C_{13} & C_{23} & C_{33} & C_{43} & C_{53} \\ \dots & \dots & \dots & \dots & \dots \\ C_{1m} & C_{2m} & C_{3m} & C_{4m} & C_{5m} \end{vmatrix} \qquad \text{(Eq. 4)}$$

where, $D_i$ is the degree of membership of the grade alternative for a given subsystem (Wuni *et al.*, 2022). The scores of the critical quality of the subsystems in the second level was calculated as the product of the fuzzy evaluation matrix ($D_i$) of the subsystem and the grade alternatives adopted for the linguistic terms ($LT$) in the Likert scale. The critical scores of each subsystem were given by:

$$C_i = \sum_{i=1}^{5} (D_i \times LT) \qquad \text{(Eq. 5)}$$

The overall risk scores (*$RS_{sa}$*) of the study areas were calculated using the fuzzy evaluation matrices of the subsystems and their associated total weights.

$$R = \begin{bmatrix} MF_{S_1} \\ MF_{S_2} \\ MF_{S_3} \\ \dots \\ MF_{S_n} \end{bmatrix} = \begin{vmatrix} s_{11} & s_{21} & s_{31} & s_{41} & s_{51} \\ s_{12} & s_{22} & s_{32} & s_{42} & s_{52} \\ s_{13} & s_{23} & s_{33} & s_{43} & s_{53} \\ \dots & \dots & \dots & \dots & \dots \\ s_{1n} & s_{2n} & s_{3n} & s_{4n} & s_{5n} \end{vmatrix} \quad \text{(Eq. 6)}$$

The final fuzzy evaluation matrix *($D_{sa}$)* for the study areas were computed as:

$$D_{sa} = W \circ R = \{W_1, W_2, W_3, \dots, W_n\} * \begin{vmatrix} s_{11} & s_{21} & s_{31} & s_{41} & s_{51} \\ s_{12} & s_{22} & s_{32} & s_{42} & s_{52} \\ s_{13} & s_{23} & s_{33} & s_{43} & s_{53} \\ \dots & \dots & \dots & \dots & \dots \\ s_{1n} & s_{2n} & s_{3n} & s_{4n} & s_{5n} \end{vmatrix} \quad \text{(Eq. 7)}$$

where, *W* is the weight of the subsystems $S_1$ to $S_n$.

$$RS_{sa} = \sum_{i=1}^{5}(D_{sa} \times LT) \quad \text{(Eq. 8)}$$

### 3.1. Study Area

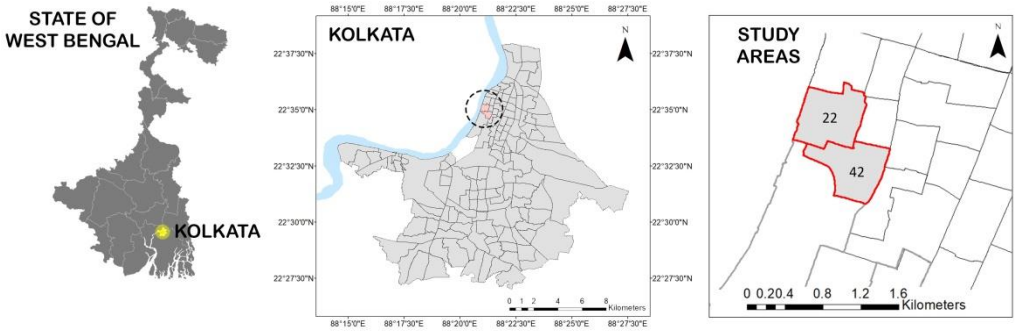


**Figure 1. Location of the study areas. Source: Authors**

The city of Kolkata, situated on the eastern bank of River Hoogly, is the business and financial hub of eastern India. The city is presently the 7th largest city in the country, with a population of approximately 45 lakhs (Directorate of Census Operation West Bengal, 2011). As the capital of British India until 1911, it developed as a port city, and the earliest settlements came up in the northern and central parts. Known as the cultural capital of India, this city has a diverse demographic population and an urban fabric that reflects the historical and cultural evolution. The historic centre of the city has rich colonial architectural heritage and a unique sense of place, deeply rooted in traditions and cultural practices. However, since the last few decades, the historic centre of the city is undergoing rapid decline due to population exodus from these areas. The city centre is more than 300 years old and has started exhibiting significant signs of ageing and degradation (Chakraborty and Dey, 2024a). The Kolkata Municipal Corporation has estimated that the city has presently more than 2000 dilapidated buildings, out of which 721 buildings pose a serious threat to the lives of the inhabitants.

**Figure 2. Condition of the study areas. Source: Authors**

Wards 22 and 42, which are parts of the earliest settlement of the city, were selected as study areas for this research. The census data revealed a high proportion of unemployed population, indicating signs of economic decline in these wards. Similarly, these wards have more than 70% rented buildings and 10% of the buildings are vacant (Figure 3), proving the exodus of the original inhabitants from these historic centres. As shown in Figure 2, these wards are undergoing severe functional and physical depreciation owing to ageing infrastructure and housing, and associated socio-economic decline, which compromises the adaptive capacity of the residents and further increases their vulnerabilities. In the presence of these multiple threats, these wards were realised to be the right case examples for carrying out a comprehensive risk profiling to elucidate how these inherent factors govern the riskscapes in historic city centres. The overlapping socio-cultural dynamics and the physical fabric of the built environment provides an ideal setting for assessing the resulting risks, as the interaction between socio-cultural capitals with the physical environment of these wards significantly impacts their adaptive capacities.

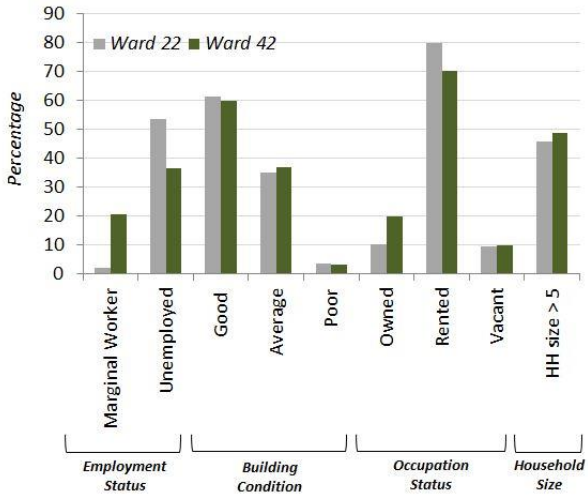


**Figure 3. Demographics of the study areas. Source: Census of India, 2011**

## 4. Results and Discussions

The results of the risk analysis were computed based on the data collected from expert opinion surveys and stakeholder perception mapping. The weights of the risk factors, deduced from the expert opinion surveys using the normalised mean method, show the relative importance of the identified factors (Table 1).

**Table 1. Weights of the factors and subsystem. Source: Authors**

| Risk Factors | Mean Score of the Factors | Factor Weights | Total Mean Score of each Subsystem | Subsystem weights |
|---|---|---|---|---|
| ***Physical Quality*** | | | 38.212 | 0.307 |
| **P1** Abandoned buildings | 4.358 | 0.114 | | |
| **P2** Vacant plots | 2.860 | 0.075 | | |
| **P3** Degraded building conditions | 4.290 | 0.112 | | |
| **P4** Presence of demolished buildings | 3.569 | 0.093 | | |
| **P5** Substandard and unsanitary living conditions | 4.067 | 0.106 | | |
| **P6** Temporary structures made of makeshift materials | 2.783 | 0.073 | | |
| **P7** Graffiti | 2.357 | 0.062 | | |
| **P8** Overgrown vegetation and weeds | 3.286 | 0.086 | | |
| **P9** High building density | 2.783 | 0.073 | | |
| **P10** Abandoned vehicles on streets | 4.072 | 0.107 | | |
| **P11** Poor visual appearance | 3.787 | 0.099 | | |
| ***Functional Quality*** | | | 17.213 | 0.138 |
| **F1** Decline in public health | 4.285 | 0.249 | | |
| **F2** Nonconformity with byelaws | 2.782 | 0.162 | | |
| **F3** Poor road infrastructure | 3.572 | 0.208 | | |
| **F4** Parking problems | 2.786 | 0.162 | | |
| **F5** Inadequate and poor public infrastructural services | 3.788 | 0.220 | | |
| ***Environmental Quality*** | | | 14.929 | 0.12 |
| **EN1** Environmental contamination | 3.787 | 0.254 | | |
| **EN2** Degraded outdoor areas | 3.784 | 0.253 | | |
| **EN3** Improper waste disposal | 4.215 | 0.282 | | |
| **EN4** Air pollution | 3.143 | 0.211 | | |
| ***Economic Quality*** | | | 14.354 | 0.115 |
| **EC1** High rate of mortgage foreclosure | 3.643 | 0.254 | | |
| **EC2** Low per capita income | 3.425 | 0.239 | | |
| **EC3** Low property values | 3.643 | 0.254 | | |
| **EC4** Tax delinquency | 3.643 | 0.254 | | |
| ***Social Quality*** | | | 39.782 | 0.32 |
| **S1** Feeling of exclusion | 3.855 | 0.097 | | |
| **S2** Less sense of community | 3.146 | 0.079 | | |
| **S3** Contested notion of safety and security | 3.787 | 0.095 | | |
| **S4** Social stigmatization | 3.856 | 0.097 | | |
| **S5** Antisocial behaviour and immoral activities | 3.426 | 0.086 | | |
| **S6** Conflicting land ownership | 3.07 | 0.077 | | |
| **S7** Socio-economic segregation | 3.497 | 0.088 | | |
| **S8** Lack of social cohesion | 3.072 | 0.077 | | |
| **S9** Violence and crime | 4.287 | 0.108 | | |
| **S10** Social unrest | 4.216 | 0.106 | | |
| **S11** Population exodus | 3.57 | 0.09 | | |

Based on the commonality between the factors, they were grouped under five subsystems, namely *physical, functional, environmental, economic*, and *social*, to represent distinct qualities of the study areas. According to the computed weights, the most important risk factors were identified to be *abandoned buildings (P1)*, *degraded building conditions (P3)*, *violence and crime (S9)*, *decline in public health (F1)*, *social unrest (S10)*, *improper waste disposal (EN3)*, *abandoned vehicles on streets (P10)*, and *substandard and unsanitary living conditions (P5)*. This indicates that physical and social dimensions have the most important role in determining risks in historic city centres.

**Table 2. Membership function of ward 22. Source: Authors**

| *Risk Factors* | *Factor Weights* | *Membership Function (Level 1)* | *Membership Function (Level 2)* |
|---|---|---|---|
| ***Physical Quality*** | | | ( 0.06 0.27 0.19 0.38 0.09 ) |
| **P1** Abandoned buildings | 0.114 | ( 0.00 0.21 0.10 0.60 0.09 ) | |
| **P2** Vacant plots | 0.075 | ( 0.00 0.06 0.09 0.40 0.46 ) | |
| **P3** Degraded building conditions | 0.112 | ( 0.20 0.36 0.14 0.24 0.06 ) | |
| **P4** Presence of demolished buildings | 0.093 | ( 0.00 0.07 0.04 0.73 0.16 ) | |
| **P5** Substandard and unsanitary living conditions | 0.106 | ( 0.07 0.36 0.17 0.39 0.01 ) | |
| **P6** Temporary structures made of makeshift materials | 0.073 | ( 0.00 0.10 0.21 0.60 0.09 ) | |
| **P7** Graffiti | 0.062 | ( 0.07 0.50 0.30 0.13 0.00 ) | |
| **P8** Overgrown vegetation and weeds | 0.086 | ( 0.01 0.40 0.26 0.33 0.00 ) | |
| **P9** High building density | 0.073 | ( 0.27 0.36 0.34 0.03 0.00 ) | |
| **P10** Abandoned vehicles on streets | 0.107 | ( 0.00 0.20 0.14 0.46 0.20 ) | |
| **P11** Poor visual appearance | 0.099 | ( 0.09 0.36 0.39 0.17 0.00 ) | |
| ***Functional Quality*** | | | ( 0.11 0.39 0.40 0.11 0.00 ) |
| **F1** Decline in public health | 0.249 | ( 0.20 0.46 0.26 0.09 0.00 ) | |
| **F2** Nonconformity with byelaws | 0.162 | ( 0.00 0.23 0.64 0.13 0.00 ) | |
| **F3** Poor road infrastructure | 0.208 | ( 0.10 0.51 0.39 0.00 0.00 ) | |
| **F4** Parking problems | 0.162 | ( 0.19 0.34 0.24 0.20 0.03 ) | |
| **F5** Inadequate and poor public infrastructural services | 0.220 | ( 0.03 0.33 0.50 0.14 0.00 ) | |
| ***Environmental Quality*** | | | ( 0.11 0.43 0.41 0.05 0.00 ) |
| **EN1** Environmental contamination | 0.254 | ( 0.01 0.29 0.54 0.16 0.00 ) | |
| **EN2** Degraded outdoor areas | 0.253 | ( 0.16 0.49 0.36 0.00 0.00 ) | |
| **EN3** Improper waste disposal | 0.282 | ( 0.11 0.47 0.39 0.03 0.00 ) | |
| **EN4** Air pollution | 0.211 | ( 0.19 0.49 0.33 0.00 0.00 ) | |
| ***Economic Quality*** | | | ( 0.03 0.25 0.37 0.34 0.02 ) |
| **EC1** High rate of mortgage foreclosure | 0.254 | ( 0.00 0.13 0.16 0.67 0.04 ) | |
| **EC2** Low per capita income | 0.239 | ( 0.07 0.26 0.36 0.27 0.04 ) | |
| **EC3** Low property values | 0.254 | ( 0.00 0.27 0.49 0.24 0.00 ) | |
| **EC4** Tax delinquency | 0.254 | ( 0.04 0.33 0.47 0.16 0.00 ) | |
| ***Social Quality*** | | | ( 0.01 0.17 0.49 0.30 0.03 ) |
| **S1** Feeling of exclusion | 0.097 | ( 0.00 0.11 0.39 0.46 0.04 ) | |
| **S2** Less sense of community | 0.079 | ( 0.03 0.31 0.59 0.07 0.00 ) | |
| **S3** Contested notion of safety and security | 0.095 | ( 0.01 0.24 0.57 0.17 0.00 ) | |
| **S4** Social stigmatization | 0.097 | ( 0.03 0.26 0.39 0.29 0.04 ) | |
| **S5** Antisocial behaviour and immoral activities | 0.086 | ( 0.00 0.17 0.34 0.44 0.04 ) | |
| **S6** Conflicting land ownership | 0.077 | ( 0.00 0.00 0.30 0.57 0.13 ) | |
| **S7** Socio-economic segregation | 0.088 | ( 0.00 0.04 0.59 0.37 0.00 ) | |
| **S8** Lack of social cohesion | 0.077 | ( 0.06 0.39 0.54 0.01 0.00 ) | |
| **S9** Violence and crime | 0.108 | ( 0.00 0.11 0.67 0.21 0.00 ) | |
| **S10** Social unrest | 0.106 | ( 0.00 0.13 0.59 0.27 0.01 ) | |
| **S11** Population exodus | 0.09 | ( 0.00 0.16 0.34 0.44 0.06 ) | |

The membership function of the risk factors and their associated subsystems were computed based on the data collected using stakeholder perception mapping (Table 2 and Table 3). These membership functions gave the primary inputs for estimating the critical qualities of the risk factors and their subsystems in *level 1* and *level 2* respectively, which were then used to estimate the overall risk scores of the study areas in *level 3*. Conducting the stakeholder perception mapping was pivotal in determining the criticality of the study areas in real time, as historic city centres often undergo transformations that remain unnoticed by external observers. As such, data collected from the primary stakeholders enabled an in-depth understanding of the intrinsic conditions of these areas based on community knowledge, collective memories, and lived experiences of the inhabitants.

**Table 3. Membership function of ward 42. Source: Authors**

| *Risk Factors* | *Factor Weights* | *Membership Function (Level 1)* | *Membership Function (Level 2)* |
|---|---|---|---|
| ***Physical Quality*** | | | ( 0.07 0.19 0.25 0.41 0.08 ) |
| **P1** Abandoned buildings | 0.114 | ( 0.00 0.17 0.03 0.69 0.11 ) | |
| **P2** Vacant plots | 0.075 | ( 0.00 0.00 0.14 0.63 0.22 ) | |
| **P3** Degraded building conditions | 0.112 | ( 0.16 0.32 0.17 0.33 0.02 ) | |
| **P4** Presence of demolished buildings | 0.093 | ( 0.00 0.03 0.11 0.68 0.18 ) | |
| **P5** Substandard and unsanitary living conditions | 0.106 | ( 0.10 0.32 0.21 0.34 0.02 ) | |
| **P6** Temporary structures made of makeshift materials | 0.073 | ( 0.01 0.14 0.21 0.60 0.03 ) | |
| **P7** Graffiti | 0.062 | ( 0.17 0.40 0.29 0.14 0.00 ) | |
| **P8** Overgrown vegetation and weeds | 0.086 | ( 0.00 0.14 0.41 0.43 0.01 ) | |
| **P9** High building density | 0.073 | ( 0.38 0.21 0.38 0.03 0.00 ) | |
| **P10** Abandoned vehicles on streets | 0.107 | ( 0.00 0.06 0.33 0.34 0.27 ) | |
| **P11** Poor visual appearance | 0.099 | ( 0.07 0.32 0.48 0.13 0.00 ) | |
| ***Functional Quality*** | | | ( 0.17 0.26 0.48 0.07 0.01 ) |
| **F1** Decline in public health | 0.249 | ( 0.32 0.20 0.32 0.16 0.00 ) | |
| **F2** Nonconformity with byelaws | 0.162 | ( 0.01 0.30 0.60 0.07 0.02 ) | |
| **F3** Poor road infrastructure | 0.208 | ( 0.14 0.28 0.57 0.01 0.00 ) | |
| **F4** Parking problems | 0.162 | ( 0.24 0.28 0.33 0.12 0.02 ) | |
| **F5** Inadequate and poor public infrastructural services | 0.220 | ( 0.09 0.29 0.61 0.01 0.00 ) | |
| ***Environmental Quality*** | | | ( 0.12 0.30 0.56 0.03 0.00 ) |
| **EN1** Environmental contamination | 0.254 | ( 0.01 0.24 0.68 0.07 0.00 ) | |
| **EN2** Degraded outdoor areas | 0.253 | ( 0.13 0.30 0.53 0.03 0.00 ) | |
| **EN3** Improper waste disposal | 0.282 | ( 0.09 0.39 0.52 0.00 0.00 ) | |
| **EN4** Air pollution | 0.211 | ( 0.27 0.26 0.48 0.00 0.00 ) | |
| ***Economic Quality*** | | | ( 0.03 0.22 0.31 0.42 0.02 ) |
| **EC1** High rate of mortgage foreclosure | 0.254 | ( 0.00 0.07 0.30 0.60 0.03 ) | |
| **EC2** Low per capita income | 0.239 | ( 0.04 0.26 0.29 0.37 0.04 ) | |
| **EC3** Low property values | 0.254 | ( 0.01 0.20 0.29 0.50 0.00 ) | |
| **EC4** Tax delinquency | 0.254 | ( 0.07 0.36 0.36 0.21 0.01 ) | |
| ***Social Quality*** | | | ( 0.01 0.18 0.46 0.32 0.04 ) |
| **S1** Feeling of exclusion | 0.097 | ( 0.00 0.08 0.36 0.49 0.08 ) | |
| **S2** Less sense of community | 0.079 | ( 0.03 0.31 0.53 0.11 0.01 ) | |
| **S3** Contested notion of safety and security | 0.095 | ( 0.01 0.26 0.58 0.14 0.01 ) | |
| **S4** Social stigmatization | 0.097 | ( 0.03 0.28 0.23 0.41 0.04 ) | |
| **S5** Antisocial behaviour and immoral activities | 0.086 | ( 0.00 0.21 0.41 0.36 0.02 ) | |
| **S6** Conflicting land ownership | 0.077 | ( 0.00 0.01 0.52 0.36 0.11 ) | |
| **S7** Socio-economic segregation | 0.088 | ( 0.00 0.10 0.50 0.39 0.01 ) | |
| **S8** Lack of social cohesion | 0.077 | ( 0.00 0.32 0.54 0.12 0.01 ) | |
| **S9** Violence and crime | 0.108 | ( 0.00 0.09 0.64 0.26 0.01 ) | |
| **S10** Social unrest | 0.106 | ( 0.01 0.28 0.48 0.23 0.00 ) | |
| **S11** Population exodus | 0.09 | ( 0.00 0.03 0.28 0.58 0.11 ) | |

The critical quality assessment of the risk factors, computed using the membership functions, highlights the present condition of the subsystems, as shown in Figure 4. The research findings suggest that the *physical* quality, *social* quality, and *economic* quality in ward 22 and ward 42 have surpassed the average critical value of 2.5, indicating that the present state of these subsystems is quite critical. Using equation 8, the overall risk score of ward 22 was found to be *2.975* while the risk score of ward 42 was *3.023*, suggesting that ward 42 poses more risk as compared to ward 22. The critical quality assessment of the risk factors highlights that these historic city centres are significantly experiencing the risk of physical decay and socio-economic decline. This can be attributed to the fact that these wards have been experiencing exodus of the original inhabitants over the last few decades, leading to housing abandonment and renting of these centuries-old buildings. The basic amenities in these historic areas are presently in a deplorable state, resulting in low rental charges in these areas and thereby attracting tenants from the economically weaker section of society. In the absence of the original caretakers, these areas undergo further decay and decline due to lack of maintenance and upkeep (Chakraborty and Dey, 2024b). Furthermore, the frequent change in tenancy often destabilises the neighbourhood cohesion in these areas and contributes to segregation and exclusion, significantly lowering the sense of community and social quality of these areas.

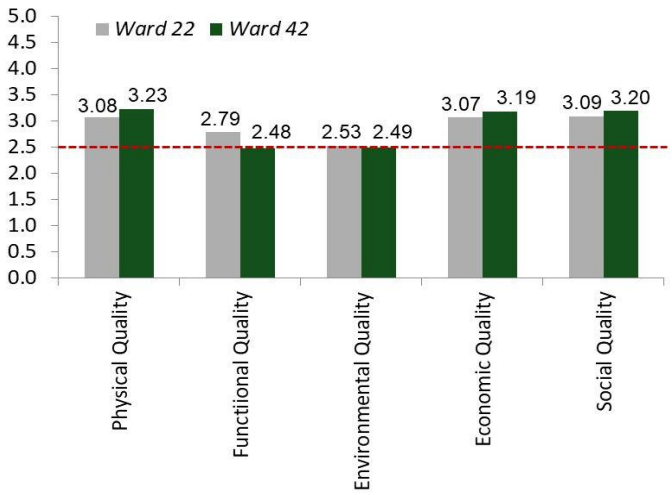


**Figure 4. Critical Quality Assessment of the Subsystems. Source: Authors**

Previous literature has highlighted that the presence of these factors often make historic centres susceptible to urban blight, which might trigger the exodus of affluent people from the historic core, contributing to building abandonment and further decline in the social structure of these areas. The presence of these factors inevitably lowers the tourism potential of the historic cores in addition to impacting their socio-economic growth. Moreover, the ineffectiveness in maintenance and conservation practices often exacerbates the existing vulnerabilities in historic city centres, thereby necessitating an integrated effort to safeguard these areas. In line with this, the findings of the research extended a nuanced understanding of the various vulnerabilities and risk profiles of the study areas, resulting from the present state of their intrinsic physical, functional, spatial, and socio-economic conditions.

## 5. Conclusion

Historic city centres and landscapes are reflections of tangible and intangible heritages. They have buildings of exemplary architectural values, showing traditional ways of construction and living and simultaneously showcasing the socio-cultural identities of these places embedded in their traditions, values, and cultural practices. The tangible and intangible assets present in historic urban centres are invaluable in advancing sustainable economic development alongside fostering social cohesion and uplifting community well-being and liveability of urban dwellers. It thus becomes crucial to preserve not just these tangible assets but their intangible counterparts as well, retaining their connection to the past that are pivotal for the sustenance of these historic precincts and communities living therein. However, rapid urbanisation and frequent threats due to climate change have destabilised these sensitive historic centres and further exacerbated their vulnerabilities and limited their adaptive capacities, necessitating a comprehensive analysis of the various dynamics that govern the riskscapes of these sensitive areas. The inherent complexities and challenges present in these historic centres demand an integrated approach that combines the built environment analyses with the socio-economic dimensions.

This research thus made an attempt to underscore the various physical, functional, environmental, economic, and social factors that determine the overall risk in historic city centres. A stratified fuzzy approach was used to evaluate the criticalities of the identified risk factors and overall risks of the selected areas resulting from the combined effects of these risk factors. The research methodology integrated expert opinion surveys with stakeholder perception mapping to derive insights into the local conditions of these areas. The stakeholder perception mapping enabled a participatory approach to understand the subjective and objective attributes associated with these historic areas, predominantly reflecting the aspects that are vital for their healthy functionality and sustenance. It further provided a new perspective on the lived experiences of the residents in these historic neighbourhoods by capturing the social-spatial factors that define and shape the vulnerabilities and management in these areas. The research findings highlighted the current state of these wards alongside the prevailing lacunas in developmental and socio-economic conditions, providing a discourse on prioritising developmental needs based on empirical evidence drawn from the fuzzy analysis.

This research puts forward an empirical approach to assess risks associated with historic city centres based on their inherent conditions and characteristics. The research concludes that risk assessment should be at the centre of policy discussions concerning the preservation and development of historic centres. The intrinsic characteristics of the historic districts, both tangible and intangible, should be carefully incorporated into the overall risk profile of cities to better prepare them for unprecedented events. Future development efforts should carefully address the preservation of these tangible and intangible resources, which are vital assets that enrich the historic identity and spirit of these places and are an important aspect of community development. Future research should conduct similar investigations into the multifaceted risks in historic city centres, enabling policymakers to take informed decisions for redirecting cities towards a more sustainable future, where new development will co-exist alongside historical heritage.

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