# GIS-Based Accessibility and Safety Assessment in Small Historic Centres in Inner Areas. Pilot Application in Stigliano and Interoperability with a Digital Twin

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**Abstract.** The high vulnerability and exposure to environmental risk of most historic villages in Italian inland areas, together with the poor accessibility, the degradation imposed by abandonment, and the increase in the elderly population, make interventions for the functional rehabilitation or reconversion of the built heritage and related public space complex and controversial. This opens questions also with respect to the evaluation and identification of possible actions to improve territorial and local accessibility emphasizing the need to consider among the priority the redevelopment, transformation and securing of the public space. Within this framework, the article experiments with a possible decision-supporting evaluation process in the minor historic center of Stigliano (MT), the lead municipality of the inner area Montagna Materana and currently the site of an experimental inter-university research project on digital twin implementation. The contribution gives a first reading of information collected through digital survey and GIS-based collaborative data collection techniques and set up a methodology to plan and prioritise interventions aimed at improving accessibility and safety. The methodology is based on a set of indicators for evaluating usability, walkability, and vulnerability. The objective is twofold: on the one hand, to ensure accessibility and safety of the routes that provide access to services and relational nodes within the historic center, with particular attention to daily use and the most fragile users; on the other hand, to make tourist usability more attractive, comfortable and inclusive.

Future developments of the research are aimed at exploring the potential of new digital technologies, like the digital twin, to improve the implemented decision support tool, efficiently informing planning and management processes, as well as improving spatial (not only physical) accessibility and the enhancement of landscape, environmental, cultural, historical and community resources.

**Keywords:** accessibility · safety · minor historic village · public space · digital twin

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## 1 Accessibility as a Key Issue for Local Development, Heritage Valorisation and Social Resilience

Italian inner areas are characterised by fragile situations, exacerbated by relentless depopulation and the consequent weakening of territorial presidium. Their progressive marginalisation has acceleratedthe loss of services and resources, a trend that began with the concentration of economic and human capital in the main urban and metropolitan centres.

Various cohesion policies at both the European and Italian level have been activated to address the increasing territorial disparities and attempt to reverse the processes of human capital loss, population aging, economic stagnation and cultural heritage deterioration. Many of these policies, including Next Generation EU, the National Recovery and Resilience Plan (PNRR), and the Italian National Strategy for inner areas (SNAI) 2021–2027, focus a significant portion of funding resources on the system of villages and minor historical centres. Hamlets**,** indeed, remain the historical territorial armoury of rural and mountainous areas, preserving a heritage of exceptional cultural, landscape, architectural and artistic value as well as a fundamental economic and social resource capable of reconciling production, trade, conviviality and a sense of community. Despite their fragility, these areas draw strength from these historic settlements where people, services, and cultural assets (tangible and intangible) are still concentrated [1]. Unfortunately, the effects of marginalisation and human capital erosion also affect the built heritage, which is often in a state of neglect and degradation. Furthermore, the high vulnerability and exposure to environmental risk in inner areas, especially to hydrogeological risk, together with poor accessibility conditions both at the territorial and urban scale, make any hypothesis of functional recovery/reconversion of the built heritage other than 'musealisation' complex.

The valorisation of the built heritage starts primarily by reconsidering the issue of accessibility [2]. Many studies in the literature focus on improving territorial accessibility which is, indeed, crucial for making inner areas more attractive for potential new residents [3]. Some approaches analyse how to enhance accessibility by acting both on mobility supply and local territorial capital, bringing back services, knowledge, and forms of interaction [4], and sometimes investigating the applicability of technological innovations without altering the historical memory of the place [5]. In certain cases, research has explored the specificity of the concept of proximity in low-density contexts, introducing specific indices [6].

All these approaches are certainly relevant but pay less attention to the issue of internal accessibility in small historic centres. In these contexts, the methodologies applied to large or medium-sized non-marginal towns [e.g. 7, 8] can hardly be adapted. Only a few studies use rigorous and quantitative methods for developing local accessibility indices [9, 10] and specific decision-support tools to orient redevelopment, transformation, and securing of public spaces. Ensuring the full usability of public spaces for all social categories and guaranteeing access to an essential set of services, especially in mountain sites, are indeed crucial aspects not only for resident population, considering the high incidence of the elderly [11], but also for fostering more inclusive forms of cultural tourism. Sustainable cultural tourism is indeed one of the pillars for local development of inner areas, as emphasised by several scholars [i.a. 12].

There have been some documented experiences in Italy regarding accessibility and inclusivity within minor historic centres, implemented by public authorities at regional and local levels, as well as by private or nonprofit associations. Some of these initiatives promote the improvement of remote accessibility through virtual reality or digital twins[1] [13, 14]. Unfortunately, awareness of the actual effectiveness of these initiatives in producing physical transformations of public spaces is still limited.

Few existing studies also attempt to integrate local accessibility levels with the crucial issue of built heritage vulnerability to environmental risks, i.e., seismic risk [15] or hydrogeological risk. While there is extensive literature on the rehabilitation and securing of the built heritage, including the use of advanced technologies [i.a. 16], there are few studies focusing on open space (paths, squares, public parks, etc.).

It is notable a GIS-based method to assess accessibility levels in synergy with the built heritage seismic vulnerability developed as a support tool for the reconstruction plan of the small historic centres of Navelli (AQ) affected by the 2009 earthquake in Abruzzo (Italy) [17]. Building on this last study, the present contribution refines the methodological approach to support the planning of interventions aimed at improving accessibility for all and securing public spaces. It considers all potential users of the site, primarily the still-residing population and potential tourists. The framework of this study is the PRIN project GO-IN! [18] aimed at testing the effectiveness of a 3D GIS model, based on digital twin technology, in supporting the planning and management of historic heritage in inner areas, with a specific focus on accessibility. The project is still ongoing, and the case study for experimentation is a portion of the historic centre of Stigliano (Basilicata, Italy), a leader municipality of the Inner Area 'Montagna Materana'.

The methodology applied in the pilot area aims to become a replicable decision-support protocol for contexts with similar characteristics and dynamics. The article presents in Sect. 2.1 the methodological framework for assessing accessibility and safety in open spaces within minor historic centres. Subsequently, Sects. 2.2 and 2.3 introduce the case study and the GIS-based analytical model. Section 3 presents the main results of the application to the pilot case, while Sect. 4 discusses the findings and outlines potential advancements of the research through an enhanced exploitation of digital twin technology tested within the GO-IN! project.

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## 2 Materials and Methods

### 2.1 Methodological Framework for Accessibility and Safety Assessment as Decision-Making Support Tool

Improving the heritage usability in small historic centres requires balancing inclusive accessibility and safety. In small historic villages, it is still notably challenging to apply the principles of 'accessibility for all' while ensuring a network of usable spaces for a wide variety of users – not only residents but also potential tourists [19, 20] – while respecting the historical character of the place.

Improving walkability emerges as a crucial operational concept to facilitate mobility [21], especially for people with limited motor abilities. This is particularly important in steep areas, where slopes, stairs, and uneven paving make movement difficult. Ensuring accessibility to key public facilities, outdoor gathering places, and sites of historical and architectural significance could be relevant both for settled communities and for promoting forms of cultural tourism. The various field inspections also revealed the great role played by public spaces in the pilot area (streets and squares in particular) for people gathering and sociality.

With regard to safety – understood as the prevention of potential damage to people and property in public spaces [22] – the vulnerability levels of the built environment, particularly concerning abandonment dynamics, degradation, and geological instability, emerge as key issues to be assessed. Open spaces are also directly affected by the conditions of surrounding buildings and the degree of space usage, which directly correlates with an increase in exposure value [23].

Considering these aspects, the proposed analytical methodology, aimed at identifying intervention priorities in minor historic villages, considers a series of indicators to assess:

1. *Usage Intensity (Ui),* defined as the potential of spaces to enhance human capabilities by supporting autonomy, active mobility, and functional, recreational, and social activities. To calculate the usage intensity indicator, factors such as access to relevant services or functions, spatial configuration (continuous or enclosed), density of in-use buildings facing the public space, the presence of tourism-related routes, social streets and social hotspots [24] – i.e., elements that encourage gathering and serve as meeting points for the local community – are evaluated.
2. *Walkability (Wi)* refers to the quality and practicability of spaces that support walking. This indicator is calculated by assessing factors such as the geometric and structural characteristics of pathways (slope, dimensions, elevation changes, surface type, and maintenance state), architectural barriers (presence of stairs, obstacles, or discontinuities), and potential pedestrian-vehicle interferences even if, evidently, this appears less relevant in small historic centres.
3. *Vulnerability (Vi)* is a key component for determining potential damage, indicating the predisposition of a system to be affected. The vulnerability indicator is calculated by evaluating the presence of structural degradation signs in buildings, cracks or subsidence in pavements, and possible failures in retaining walls.

Open spaces are treated as key urban components and divided into minimum operational units characterised by 'homogeneity' in relation to orography, morphology, use

and paving materials. Each minimum unit is analysed through a set of qualitative and quantitative attributes, pertaining to both intrinsic and extrinsic characteristics (related to configurational properties and the features of the surrounding built environment).

By combining these attributes, scores are assigned to assess the factors involved in each indicator evaluation, as illustrated in the following tables (Tables 1, 2 and 3).

**Table 1.** Factors of the Usage intensity indicator (Ui) – qualitative and quantitative assessment.

| Factors | Qualitative and qualitative assessement | |
|---|---|---|
| u1 – Access to specialised buildings with relevant public and cultural services | Present/museum, social-cultural or religious facilities; | 3 |
| | Present/administrative buildings or other facilities of public interest; | 2 |
| | Present/buildings of historical value; | 1 |
| | Absent | −1 |
| u2 – Density of abandoned buildings | No abandoned buildings; | 2 |
| | Less than 25%; | 1 |
| | 25%–50%; | −1 |
| | More than 50% | −2 |
| u3 – Social hotsposts (density of recreational, commercial or public street level activities) | More than 50%; | 3 |
| | 25% – 50%: | 2 |
| | Less than 25%; | 1 |
| | No street level activities | −1 |
| u4 – Route characteristics | Continuous in both directions; | 2 |
| | Continuous with final widening; | 1 |
| | Temporarily interrupted; | −1 |
| | Cul-de-sac | −1 |
| u5 – Social streets (paths that spontaneously become contact and meeting points) | Mixed traffic (carriageway-pedestrian) and presence of seating; | 3 |
| | Pedestrian traffic (width greater than 1.5 m) and presence of seating; | 2 |
| | Roadway and presence of seating; | 1 |
| | Absence of seating along the route | −1 |
| u6 – Tourist route | Present; | 1 |
| | Absent | −1 |

**Table 2.** Factors of the Walkability indicator (Wi) – qualitative and quantitative assessment.

| Factors | Qualitative and qualitative assessement | |
|---|---|---|
| w1 – Car/pedestrian interference | Pedestrian way; | 2 |
| | Roadway with pavement; Mixed roadway-pedestrian traffic and road width greater than or equal to 4.25 m; | 1 |
| | Mixed roadway-pedestrian traffic and road width less than 4.25 m; | −1 |
| | Roadway and no pavement | −2 |
| w2 – Pedestrian practicability | Roadway with pavement or pedestrian way larger than or equal to 1.50 m; | 2 |
| | Mixed roadway-pedestrian traffic and no pavement; | 1 |
| | Roadway with pavement or pedestrian way 0.90 m to 1.50 m wide; | −1 |
| | Roadway with pavement or pedestrian way less than 0.90 m; | −2 |
| | Stairway | −3 |
| w3 – Change in level / longitudinal slope | Longitudinal slope lower than 4%; | 2 |
| | Longitudinal slope between 4% and 8%; | 1 |
| | Longitudinal slope higher than 8%; | −1 |
| | Stairway | −2 |
| w4 – Discontinuity/obstacles | Absent; | 1 |
| | Present | −2 |
| w5 – Paving material | Asphalt; | 2 |
| | Brick or stone slabs; | 1 |
| | Gravel, dirt road, uneven paving, wasteland or lawn | −2 |
| w6 – Paving maintenance level | Excellent; | 2 |
| | Good; | 1 |
| | Sufficient; | −1 |
| | Poor | −2 |

Indicators are computed using the following formulae (Eq. 1–3), and results are then normalized from 0 to 1 based on the minimum and maximum values each indicator can assume (Table 4).

$$Ui = \frac{\sum_1^n u_n}{n} \tag{1}$$

**Table 3.** Factors of the Vulnerability indicator (Vi) – qualitative and quantitative assessment.

| Factors | Qualitative and qualitative assessement | |
|---|---|---|
| v1 – Density of buildings with signs of structural deterioration | No deteriorated buildings; | 1 |
| | Less than 25%; | −1 |
| | 25% – 50%; | −2 |
| | More than 50% | −3 |
| v2 – Spatial configuration/degree of space enclosure | Open on four sides; | 2 |
| | Open on three sides; | −1 |
| | Open on two sides; | −2 |
| | Open on one side | −3 |
| v3 – Density of buildings with poor roof maintenance | No deteriorated roofs; | 1 |
| | Less than 25%; | −1 |
| | 25% – 50%; | −2 |
| | More than 50% | −3 |
| v4 – Presence of retaining walls | Absent or present without signs of deterioration; | 1 |
| | Present with signs of deterioration | −1 |
| v5 – Downhill slope to the space | Absent; | 1 |
| | Present | −1 |
| v6 – Pavement cracking | Absent; | 1 |
| | Present | −1 |

$$Wi = \frac{\sum_1^n w_n}{n} \tag{2}$$

$$Vi = \frac{\sum_1^n v_n}{n} \tag{3}$$

**Table 4.** Indicators rankings of normalized values.

| Ui | Wi | Vi |
|---|---|---|
| 0.00 – 0.20 very low | 0.00 – 0.20 poor | 0.00 – 0.20 very low |
| 0.21 – 0.40 low | 0.21 – 0.40 modest | 0.21 – 0.40 low |
| 0.41 – 0.60 average | 0.41 – 0.60 average | 0.41 – 0.60 average |
| 0.61 – 0.80 high | 0.61 – 0.80 good | 0.61 – 0.80 high |
| 0.81 – 1.00 very high | 0.81 – 1.00 very good | 0.81 – 1.00 very high |

Through these indicators and rankings, an *Accessibility Index (AI)* can be determined as the product of Ui and Wi. Additionally, a *Potential Harm Index (HI)* can be obtained by multiplying again Ui by Vi. These are calculated using the following formulae and evaluation matrices (Tables 5 and 6).

**Table 5.** Accessibility index (AI): formula and evaluation matrix.

| Accessibility Index $AI = Ui \times Wi$ | | Wi good (1) | sufficient (2) | modest (3) | poor (4) |
|---|---|---|---|---|---|
| Ui | very high (1) | 20 | 15 | 10 | 5 |
| | high (2) | 16 | 12 | 8 | 4 |
| | avarage (3) | 12 | 9 | 6 | 3 |
| | low (4) | 8 | 6 | 4 | 2 |
| | very low (5) | 4 | 3 | 2 | 1 |
| Accessibility ranking | | Minimal 1-3 | Medium 4-9 | High 10-20 | |

**Table 6.** Potential harm index (HI): formula and evaluation matrix.

| Potential harm Index $HI = Ui \times Vi$ | | Vi very high (5) | high (4) | avarage (3) | low (2) | very low (1) |
|---|---|---|---|---|---|---|
| Ui | very high (5) | 25 | 20 | 15 | 10 | 5 |
| | high (4) | 20 | 16 | 12 | 8 | 4 |
| | avarage (3) | 15 | 12 | 9 | 6 | 3 |
| | low (2) | 10 | 8 | 6 | 4 | 2 |
| | very low (1) | 5 | 4 | 3 | 2 | 1 |
| Potential Damage ranking | | Minimal 1-2 | Low 3-5 | Medium 6-10 | High 12-16 | Very high 20-25 |

## 2.2 Case Study: A Pilot Area in the Historical Village of Stigliano (MT)

The methodological framework is then tested on a pilot area. Stigliano is an Italian municipality located in the Basilicata Region (province of Matera), covering an area of approximately 210 km$^2$. It lies within the Lucanian Apennines at an altitude of 909 m above sea level. Stigliano serves as the lead municipality of the Montagna Materana inner area [25], which includes 7 other municipalities[2] considered ultra-peripheral with

[2] Accettura, Aliano, Cirigliano, Craco, Gorgoglione, Oliveto Lucano, and San Mauro Forte.

typical demographic decline, coupled with a rapid population aging [26]. Despite being the most populous (about 3,500 inhabitants on December 31, 2023), Stigliano has experienced a significant population loss over the last two decades (−14%). The geographic position, orographic configuration, infrastructure conditions, and distance from major urban centres (80 km from Matera, and 100 km from Potenza) limit access to essential services such as education, healthcare, and social support. Additionally, the area's geological and geomorphological characteristics make it highly susceptible to landslides. The built-up area lies along the slopes of Monte Serra, bordering the fragile *calanchi* landscape, and is surrounded by areas with varying degrees of risk. Recently, the village has been affected by a significant landslide that caused the collapse of a hillside in the northern sector of its urban expansion area.

The pilot area selected for this project contains historically and architecturally significant features and a street network with medium-to-high slope due to orographic configuration. The urban fabric, originally dense and stratified, has progressively thinned over time due to targeted demolitions of degraded buildings. In fact, the area partly falls within the perimeter of a "Transfer Plan" (*Piano di Trasferimento*) established in 1973 following a disastrous hydrogeological event. Since then, much of the built environment has been subject to depopulation and deterioration. Recent geological studies suggest the hydrogeological risk may be lower than previously assessed, opening the possibility of removing the constraint. However, years of neglect have significantly increased the site vulnerability (Fig. 1).

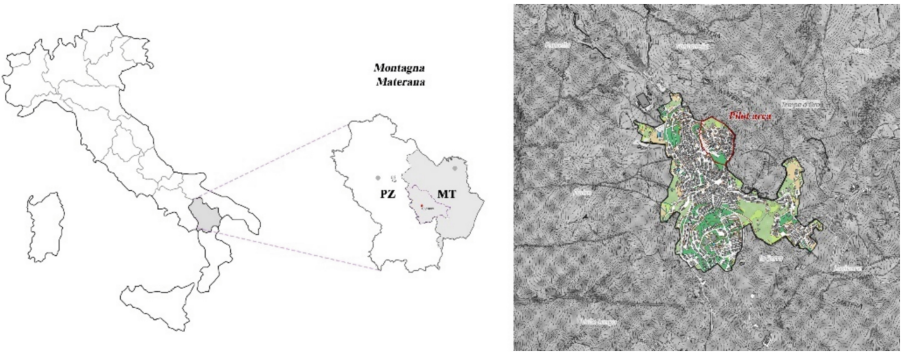


**Fig. 1.** Territorial framework of the pilot area in Stigliano (MT), Italy (authors' elaboration, based on spatial data from Istat.it and the Basilicata Region Geoportal)

Despite these challenges, the area has not been completely abandoned. Several key landmarks remain near the transfer zone, such as the Church of Santa Maria, the Museum of Rural Civilization, the Farmer's House, and the main market square (Fig. 2).



**Fig. 2.** The historic village of Stigliano, within the pilot area (authors' photos).

### 2.3 The GIS-Based Data Model and Data Collection Platform

Data required to assess intensity of use, walkability, and vulnerability of open spaces in the pilot area were analysed using a Spatial Information System (SIS), applying GIS techniques for data-modelling, collection, and management. Firstly, a GIS data model was developed by refining and expanding previous research conducted at the University of Parma [27]. The GIS data model was constructed using a vector-based data structure, enabling an in-depth analysis of the historical built environment, represented by three main semantically organised and correlated feature classes: buildings, fronts and open space. These main feature classes are complemented by housing numbers and cadastral information to help associate each building/space with a specific address, land regime and property (Fig. 3).

Secondly, a data collection protocol was set to populate the feature classes. Along with detailed cataloging and GIS mapping of the built environment elements, this approach involved a structured on-site audit through collaborative data collection. For this purpose, a GIS platform was configured based on the data model, using ArcGIS Pro and ArcGIS Online. Survey forms were set up for each feature class and networked through the ArcGIS Survey123 application. A four-day field survey, conducted by eight trained auditors divided into three teams, enabled systematic data collection through mobile survey forms for each feature class.

All feature classes were then populated according to the data model semantic structure, collecting qualitative and quantitative information aimed at assessing the intensity of use, walkability, and vulnerability of open spaces.

Finally, data management and processing, supported by the correlation of feature classes within the GIS database, produced new information associated with each open space unit. This resulted in the qualitative and quantitative assessment used to assign scores to the factors involved in the computing of Ui, Wi, and Vi indicators (as illustrated in Tables 1, 2 and 3).

## 3 Results

GIS data processing produced thematic maps showing: the open space intensity of use (Fig. 4), based on activity density and social factors; walkability (Fig. 5), assessing how well spaces support users with different mobility levels; and vulnerability (Fig. 6), highlighting damage and deterioration in both built and open areas and their spatial

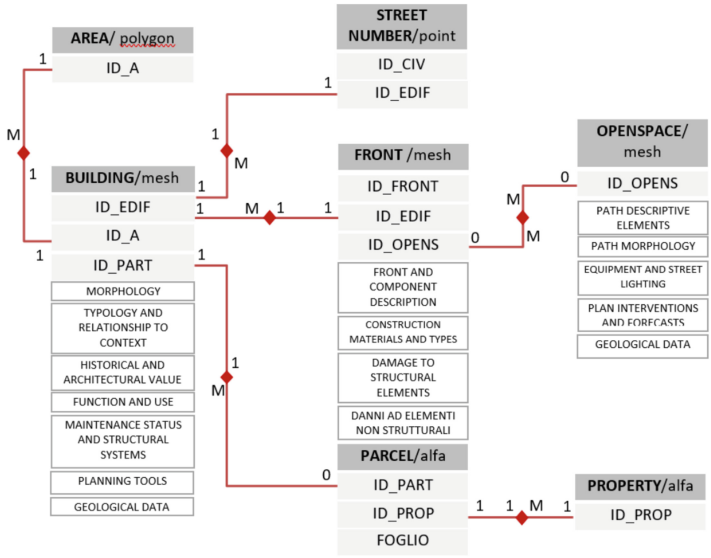


**Fig. 3.** GIS data model (authors' elaboration)

relationships. Overall, all three representations confirm that the southeastern sector of the built environment, characterized by steeper terrain, presents critical issues. The pathway system in this area is marked by slopes often exceeding 8% and is structured as networks of stairways and steps. This likely contributes to the high percentages of buildings in a state of abandonment and poor maintenance conditions observed in this area. Critical issues are also evident in the northwestern portion of the built environment, between Largo Fieramosca and Villa Marina. The primary concern here is the area's heightened vulnerability, evident from clear signs of instability linked to hydro-geological problems.

The vulnerability affects both accessibility and the presence of social hotspots, even in areas that, despite having favourable walkability characteristics, are not immune to these challenges. The historic core around the Church of Santa Maria, despite low usage intensity due to widespread building abandonment and a lack of social hotspots, shows more favorable walkability conditions.

By combining the results of the accessibility, walkability, and vulnerability indicators, as previously mentioned, the values for the Accessibility Index (Fig. 7) and the Potential Harm Index (Fig. 8) were obtained.

The thematic maps, not only confirm previous findings, but also reveal a network of moderately accessible routes that, with targeted interventions, could improve access to several areas of the historic centre. However, these pathways exhibit relatively high-risk exposure, making it necessary to integrate the data to gain a clear understanding of the nature of the interventions required for both public spaces and the adjacent buildings.

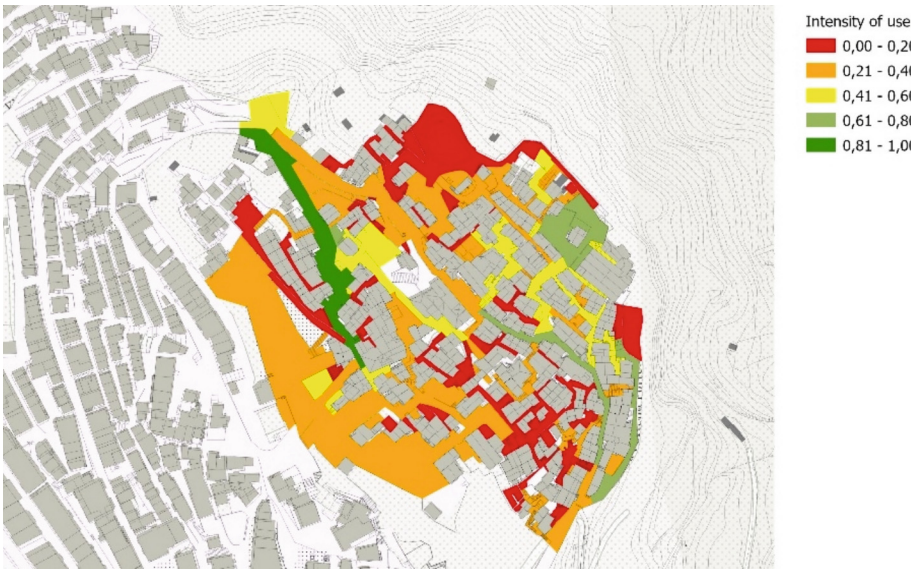


**Fig. 4.** Map of the usage intensity indicator (Ui). Authors' elaboration

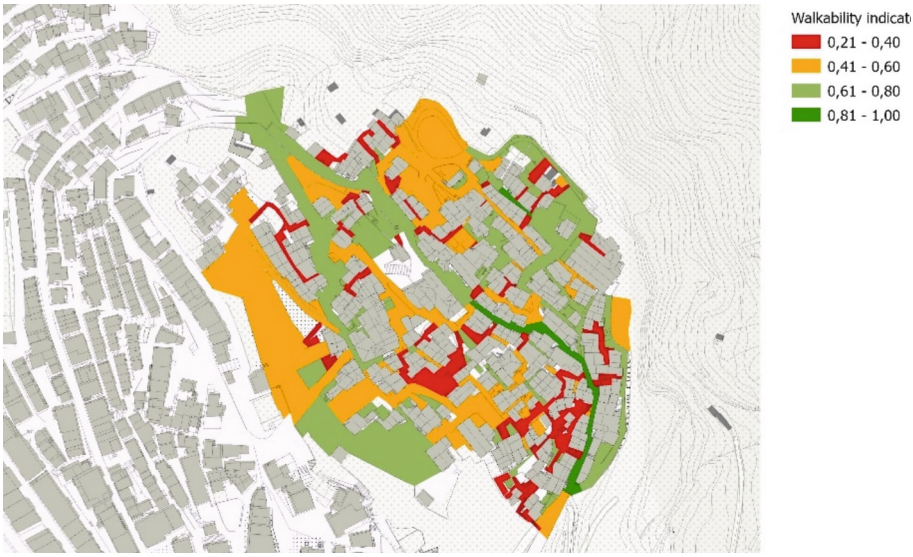


**Fig. 5.** Map of the walkability indicator (Wi). Authors' elaboration

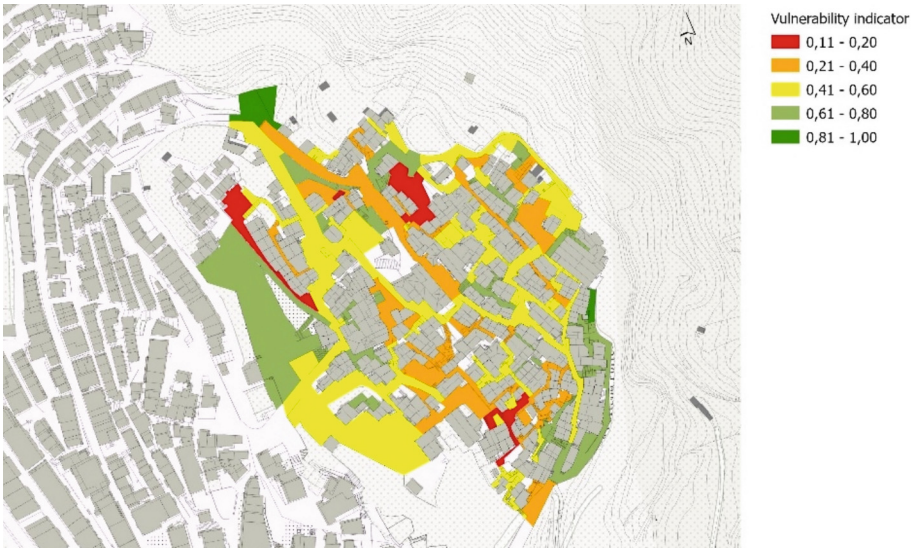


**Fig. 6.** Map of the vulnerability indicator (Vi). Authors' elaboration

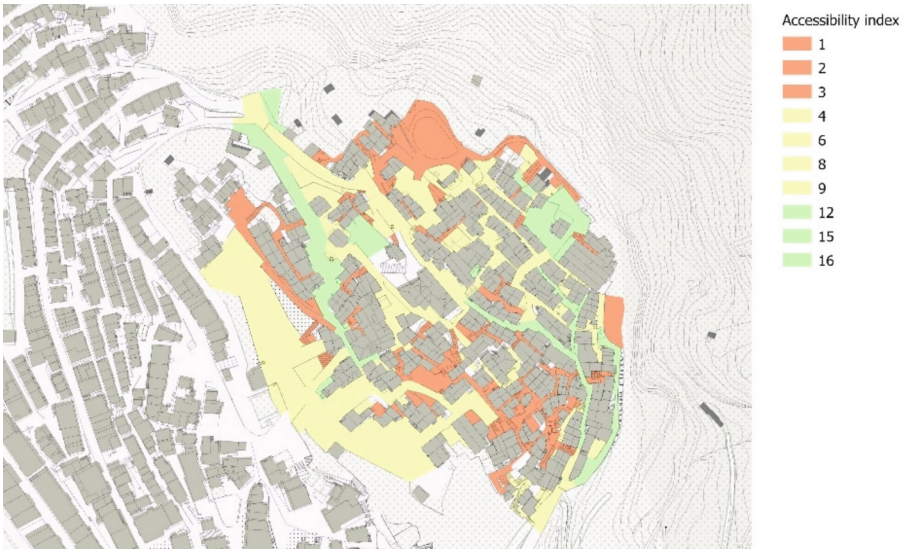


**Fig. 7.** Map of accessibility index (AI). Authors' elaboration

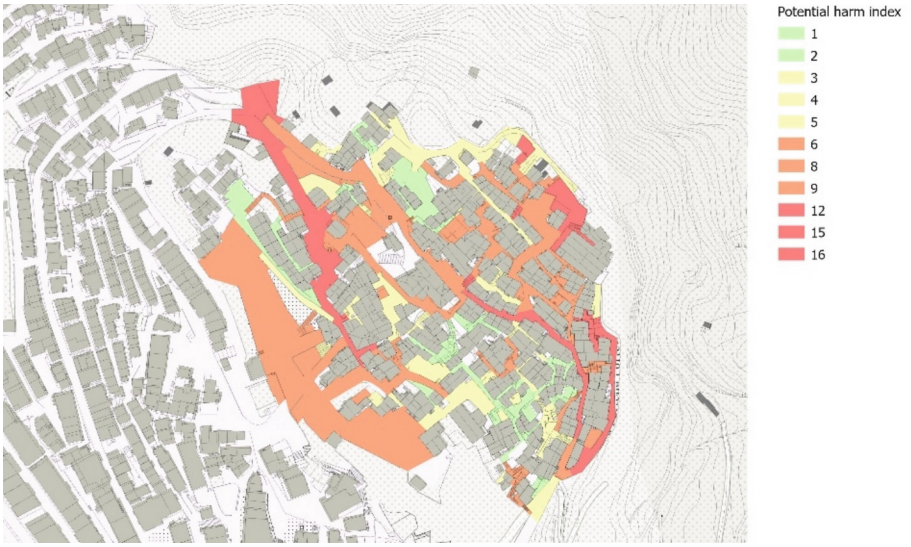


**Fig. 8.** Map of the potential harm index (HI). Authors' elaboration

## 4 Discussion and Conclusions

The article has illustrated the application of a GIS-based quantitative methodology in a pilot area of the village of Stigliano (MT) to facilitate knowledge acquisition aimed at supporting decision-making processes for improving accessibility for all and ensuring the safe usability of the built heritage.

There are still few experiments involving specific analytical methodologies for these historic settlements, which are often marginal but where it is crucial to maintain adequate levels of safety and accessibility. This built environment serves both as the daily living space for the remaining residents and as valuable cultural heritage attractive for potential tourists. The desire to promote the small centres from a tourism perspective further underscores the importance of enhancing the inclusivity and safety of the historic fabric, which is typically the most attractive area for visitors.

The methodology effectively evaluates various quality and safety factors related to pathways and open spaces – primarily public ones – by correlating them with the characteristics of the surrounding built environment. The developed and tested method is rigorous yet accessible, even for technicians working in municipal administration offices. The direct interaction with local authorities within the GO-IN! project has enabled a continuous exchange on the methodological approach.

The results of the analyses provide initial data useful for selecting priority interventions for public space redevelopment, safety enhancement, or simply pathways and open space local improvements. However, to proceed to the operational identification of intervention strategies, the addition of a survey on the potential 'transformability' of spaces could further improve the methodological approach. In fact, defining concrete intervention strategies requires a deeper understanding of space usability and level of 'transformability' based on several key factors, i.e., public/private ownership (which is not

always easy to determine in these contexts), previous urban transformations (demolition or redevelopment operations), the need for structural interventions, and the historical-testimonial value of spaces (determining the constraint level). Because this additional information is often hard to obtain, direct involvement of local administration and communities is essential. The ongoing nature of the project provides an opportunity to further explore these aspects.

Experimental validation of the results has in any case confirmed the effectiveness of the method. However, some limitations can be identified. Firstly, the indicators rely on a specific set of attributes whose selection, though grounded in previous research and field validation, remains partially context dependent. Certain variables – such as the presence of social hotspots or building frontage continuity – may carry different weight or significance in other urban settings. Moreover, the pilot area of Stigliano presents a distinct morphological and territorial configuration, with steep orography, hydrogeological risks, and a legacy of targeted demolition. These characteristics may have influenced both the performance of the indicators and the data collection process. The application of the same methodology in other small historic centres with different morphological, demographic, or infrastructural conditions may be essential to assess its robustness and potential broad replicability.

Secondly, the indicators are built on proxies and spatial characteristics, which are useful for objective analysis but may not fully capture the subjective perception of accessibility or safety experienced by users. In this sense, initiating public involvement actions would help to integrate the flow of information.

Finally, the 'cost' of extensive field surveys necessary to update the Spatial Information System (SIS), ensuring adequate knowledge of historic heritage, might not be sustainable from a technical and financial point of view. However, it should be emphasised that the SIS was built according to semantic interoperability with a 3D digital model derived from the innovative integration of topographic and photogrammetric survey. The interoperability allows to easily integrate the two technologies and resulting databases. Completing the prototype will provide an opportunity to better test the potential for automated information acquisition relevant to usability, walkability and vulnerability analyses, directly from the 3D digital model.

It is important to specify that the 3D digital model created and still expandable currently serves only as a foundation for developing a full digital twin of Stigliano. The digital twin technology under development could lead to automated documentation processes, facilitating the scalability to the entire historic centre and its replicability in similar contexts [28] – provided that the necessary financial resources and expertise are available. For instance, based on the results of specific thematic maps related to severe structural damage, targeted surveys could be conducted at regular intervals to update the system accordingly. Alternatively, sensors could be installed in the public space to enable real-time simulations. The data collected by these sensors could then be integrated into the 3D digital model, generating a wide range of information. The potential of this product is certainly significant. However, considering the specific urban context (both in terms of territorial morphology and depopulation conditions), it would be more effective to test the first strategy, before proceeding with the installation of sensors (Fig. 9).

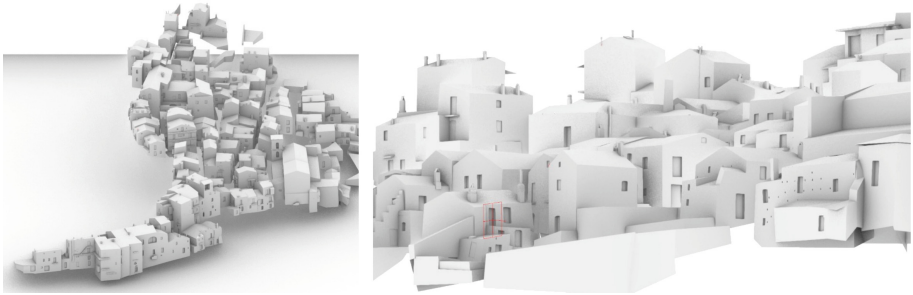

**Fig. 9.** 3D model of the pilot area in Stigliano – macro-modelling (Image produced by DadaLab, University of Pavia).

As a further future development of the project, the developed prototype will soon be shared with the municipality's technical office to assess its functionality in supporting knowledge-building processes, urban planning and management. Stigliano was chosen as pilot area also because its administrative and technical office is more structured compared to nearby hamlets of the Montagna Materana area. In addition, the project will also provide for capacity-building activities to train technicians in using and querying the 3D digital model integrated with the SIS.

As a further future development, the prototype will also be made accessible through a virtual platform enriched with informational content about local and territorial resources [29], aiming to trigger virtuous processes for local development. Accessibility can drive renewed tourism appeal, drawing on local cultural resources and enhanced by remote access systems based on new technologies and widespread mass communication channels (social media, web, smartphone apps). These tools hold the potential not only to increase tourist appeal by enabling a more inclusive experience of both tangible and intangible cultural resources but also to promote new economic sectors and supply chains. However, for remote accessibility to be truly effective, it should not remain confined to the digital world but foster long-range relational dynamics and encourage online visitors to physically experience the territory.

Therefore, promoting remote accessibility should go hand in hand with a fundamental preventive effort to improve the physical access to cultural heritage and safety in small historic centres. Despite the risk of progressive abandonment, these actions are essential for preserving identity, fostering sustainable development, and reinforcing the role of hamlets as living, resilient places rather than mere relics of the past.

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