

RESEARCH

Open Access



Digital reactivation of territories through geospatial cultural itineraries: the VIDA-HTL web application

Francisco M. Hidalgo-Sánchez^{1,6}, Rebeca Merino-del-Río^{2,6}, Emilio J. Mascort-Albea^{3,6*}, Ignacio Ruiz-Moreno³, Mercedes Linares-GómezDelPulgar^{4,6} and Antonio Tejedor-Cabrera^{5,6}

Abstract

The significant imbalances between human settlements and their surrounding environments, stemming from sector-specific policies and urban regional planning tools, constitute a primary factor in the resilience and responsiveness of territories in crisis scenarios. Within this context, the promotion of territorial heritage values emerges as a crucial means for the reactivation of vulnerable areas. Furthermore, the utilisation of technological resources, such as Geographic Information Systems (GIS), has proven to be highly effective in managing cultural landscape areas. This contribution aims to enhance the valorisation of territorial heritage through the geolocation of a system of architectural and archaeological assets of public interest, and by enabling the flexible design of cultural itineraries within the framework of slow tourism. For this purpose, a replicable methodology for the construction of a Web-GIS application has been proposed. This methodology has been put into practice in the territorial area of the lower Guadalquivir River in Spain, which encompasses 73 municipalities and one UNESCO World Heritage Site, all interconnected by rural areas. A four-stage plan has been followed for the construction of the VIDA-HTL web application: (1) conceptualisation; (2) development; (3) technical verification; and (4) social viability. The fundamental approach of the web application is based on the comprehensive integration of subsystems related to cultural heritage on one hand, and to tourist and environmental services on the other. Two main functions for the exploration of cultural assets and designing cultural routes have been designed, which complement other capabilities implemented in the web application. As a result of a detailed standardisation process, 981 cultural assets and 43 supplementary data layers have been georeferenced and included in the web application, with customised itineraries available for planning within the study area. Additionally, 49 thematic cultural itineraries are proposed. Finally, the web application is complemented with the development of a collaborative hub, which encourages its use and enhances its capabilities. It is concluded that digital tools, such as that proposed, foster knowledge and valorisation of territorial cultural heritage, while contributing to greater local development. In this way, they function as a counterbalance to the development of metropolises and the global economy, thereby improving levels of regional resilience.

Keywords Digitisation, Heritage systems, Slow tourism, 2D-3D geospatial modelling, Interactive route design, Cultural itineraries

*Correspondence:

Emilio J. Mascort-Albea
emascort@us.es

Full list of author information is available at the end of the article



© The Author(s) 2024. **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>. The Creative Commons Public Domain Dedication waiver (<http://creativecommons.org/publicdomain/zero/1.0/>) applies to the data made available in this article, unless otherwise stated in a credit line to the data.

Introduction

This section introduces the problems related to the valorisation of territorial heritage and the role of new technologies therein. The state of the art is analysed through a systematic review of the scientific literature on geospatial tools that focus on territorial reactivation. The case study of the territory of the lower Guadalquivir (Seville, Spain) is then analysed, while focusing on the threats and opportunities for the implementation of a web application such as that proposed. Subsequently, a summary is provided of the fundamental research on which the conceptual formulation and product design project is based.

Geospatial technologies for the reactivation of territorial heritage

The potential of culture economics to foster local development in the most socially, economically and culturally vulnerable territories has been widely analysed by the scientific community and is at the basis of this approach [1]. The irruption and generalisation of ICTs inaugurated a line of research focused on evaluating and exploiting the potential of ICTs applied to heritage sciences. In the early twenty-first century, a significant body of research was published on the 3D digitisation of cultural heritage and the application of Geographic Information Systems (GIS) in heritage sciences [2–4]. A substantial number of titles focused on the specific application of GIS in archaeology [5, 6]. In relation to GIS, its capability to work with different sources and formats provides a flexible framework for the representation and analysis of complex changing realities. This enables a better understanding of their essential heritage values, which is useful for policymakers, urban planners and tourism stakeholders [7]. In recent years, the exponential growth of case studies and compilations on the application of geomatics to the conservation, management and exploitation of cultural heritage demonstrate the growing interest of the scientific community and the pertinence of a study such as the one proposed here [8–12].

Nevertheless, the use of GIS for the assessment of cultural landscape values in the territory has yet to be fully explored [13]. Not only do the spatial analysis capabilities of GIS enable the precise identification of regions of interest based on a wide range of constraints [14, 15], but they also enable the historical evolution of the territory to be studied through the detection of spatial and temporal patterns [16–18]. Invisible networks are thereby revealed that provide alternative readings regarding the articulation of the territory [19]. Beyond identification and documentation, the use of GIS also provides tools to assess factors that put the detected heritage values at risk

[20, 21], and even integrate citizen participation into the policy management processes of the territory [22, 23].

In this context, the design of cultural itineraries emerges as an effective strategy for the reactivation of cultural landscapes that are closely linked to the concepts of sustainable and slow tourism [24, 25]. Various approaches are possible for the implementation of GIS-based methodologies for this purpose. In general, heritage itineraries are planned in relation to existing historical infrastructures, such as roadways, railways, and ancient paths [26, 27]. In this regard, a special mention should be made regarding the proposals for adapting abandoned railways into greenways in Italy [28, 29], and the definition of a ‘Spatial Quality Index of Slow Routes (SQISR)’ for the evaluation of slow-tourism itineraries through GIS spatial analysis [30]. In other cases, cultural routes are proposed in order to connect different regions of interest without necessarily having a previous accessible infrastructure. The literature review shows a particular interest in this domain for implementation in areas with a relevant geological heritage [31–34]. Similarly, for the various cases mentioned, GIS tools have been employed to evaluate parameters that facilitate decision-making regarding their suitability and feasibility. To this end, the implementation of Multi-Criteria Analysis (MCA) and Analytic Hierarchy Process (AHP) combined with GIS spatial analysis is common [35–38].

In terms of cultural landscape conservation, the dissemination of these itineraries is essential. The use of web-based platforms therefore constitutes a highly useful resource for accessing information in an open and platform-independent way. In particular, WebGIS platforms enable easy management of geographic data by means of appropriate user interfaces. This information may come from various sources, but fundamentally WebGIS platforms provide a way of creating access to the information contained in institutional repositories [39], while also allowing potential users to add their own information [40]. Moreover, it is possible to apply various tools to customise the cultural itineraries defined [41], and to create 3D views for the spatial understanding of the landscape [42, 43]. Lastly, the integration of these WebGIS platforms with technologies such as VR provides a new dimension of knowledge regarding cultural landscapes through immersive experiences [44]. It can be concluded that proposals with a dual approach, such as those for research and dissemination, are of particular interest [45]. In this respect, constant technological evolution allows the exploration of proposals with a comprehensive approach, where the conservation of the territorial heritage is linked to its reactivation through sustainable tourism supported by innovative spatial tools such as the VIDA-HTL web application.

Case study and background

The geographical scope of the research and the VIDA-HTL web application covers the territory of the Guadalquivir Valley between Palma del Río and Sanlúcar de Barrameda (Fig. 1). This includes a wide swathe of the province of Seville around its capital, where there are multiple landscape areas with different potentials and features. The Guadalquivir River structures this territory, which consists of 73 municipalities, with an area of 8927 km², and one UNESCO World Heritage Site (WHS).

This geographical scope is an extension of the scope of the Smart Architectural and Archaeological Heritage (SMARCH) national project. The SMARCH project, funded by the Spanish Ministry of Economy and Competitiveness, is at the basis of this conceptual formulation and product design project. It was aimed to advance in the definition of innovative strategies for the integrated management of heritage, landscape, and tourism. As a result of multiple investigations [19, 46–49], it was concluded that one of the most suitable strategies for the promotion of the integrated management of heritage, landscape, and tourism includes the design of cultural itineraries [50]. The geographical scope of this previous research was limited to the metropolitan area of Seville and nearby rural areas where, despite the existence of a large number of architectural and archaeological assets of public interest, the cultural landscape is increasingly less recognisable, and tourism remains concentrated in the capital.

The extension of the geographical scope responds to the need for diversification required by the proposed web application. The scope of the VIDA-HTL project encompasses rural territories beyond the limits of the metropolitan area of Seville, to which the SMARCH project was mainly circumscribed. On the one hand, the extension makes it possible to broaden the sample of assets of public interest that are subject to search, making the product more viable. On the other hand, it allows the research to focus on the resolution of other regional problems such as the depopulation of rural areas or the strong polarisation of the settlement system. The map produced by the team, using GIS-based software, depicts all the above aspects. The dashed line represents the work area outline of the SMARCH project. The black solid line represents the work area outline of the VIDA-HTL project, which comprises the 73 municipalities detailed below. In this way, the increased geographical scope is highlighted. Priority is given to the representation of the Guadalquivir River, in yellow solid line, which makes it easier to recognise its vertebral character in the study area.

The VIDA-HTL study area stands out for the wealth of its heritage, both in quantitative and qualitative terms, which belies the intensity of the relationships between

the different municipalities in the territory [51]. Since the mid-twentieth century, as part of a generalised globalisation process [52, 53], this territory has suffered a process of degradation of its territorial heritage [54], which has in turn affected the different landscape areas. Consequently, this destruction and undermining of its heritage have unbalanced this area and put its future sustainability at serious risk [55, 56]. In order to reactivate a process of territorial regeneration and to reduce future risks, new actions should focus on cultural and natural heritage systems [57].

In this context, the Andalusian Historical Heritage Institute (IAPH in Spanish)¹ has carried out various initiatives for the valuation of the Territorial Heritage of the area [58, 59]: the I and the II General Plan for Cultural Heritage (1989, 1995), the digitisation of the historical cartography of Andalusia (1996), the Historical Heritage Information System (2000), the Cultural Landscape Laboratory (2008), and the guides of the Cultural Heritage of Andalusia (2012, 2019).

Data presented in the Andalusian tourism year-end report [60] shows that approximately 32.52 million tourists visited Andalusia in 2019, of which about 19.9 million were Spanish and 12.62 million were foreigners. These are the latest figures recorded before the pandemic, for which data for 2020 and 2021 is disregarded due to the substantial impact incurred by the imposition of travel restrictions. These figures suggest a considerable number of potential users for the VIDA-HTL app and support its suitability and social acceptability as a product. The VIDA-HTL app seeks to reactivate the territory through a double strategy of valorisation and use of the natural, architectural, and archaeological heritage.

Aim and methodology of the research

This article proposes a replicable methodology for the construction of web applications for the digital reactivation of the vulnerable territories. The main objective is to contribute to the valorisation of the territorial heritage through the geolocation of a system of architectural and archaeological assets of public interest, thereby providing the flexible design of cultural itineraries. The methodology has been applied to the case study of the territory of the lower Guadalquivir, which is the geographical scope of the VIDA-HTL web application.

¹ The Andalusian Historical Heritage Institute (IAPH) was created in 1989 as an institution under the Ministry of Culture of the Regional Government of Andalusia. The main responsibilities of the Institute include: to produce knowledge on cultural heritage; to strengthen the capacity to create value; to make this knowledge circulate and to manage it, with a view to both promoting its own capacities and supporting other producers of knowledge in the field, regardless of whether they be public, private, or civil society organisations.

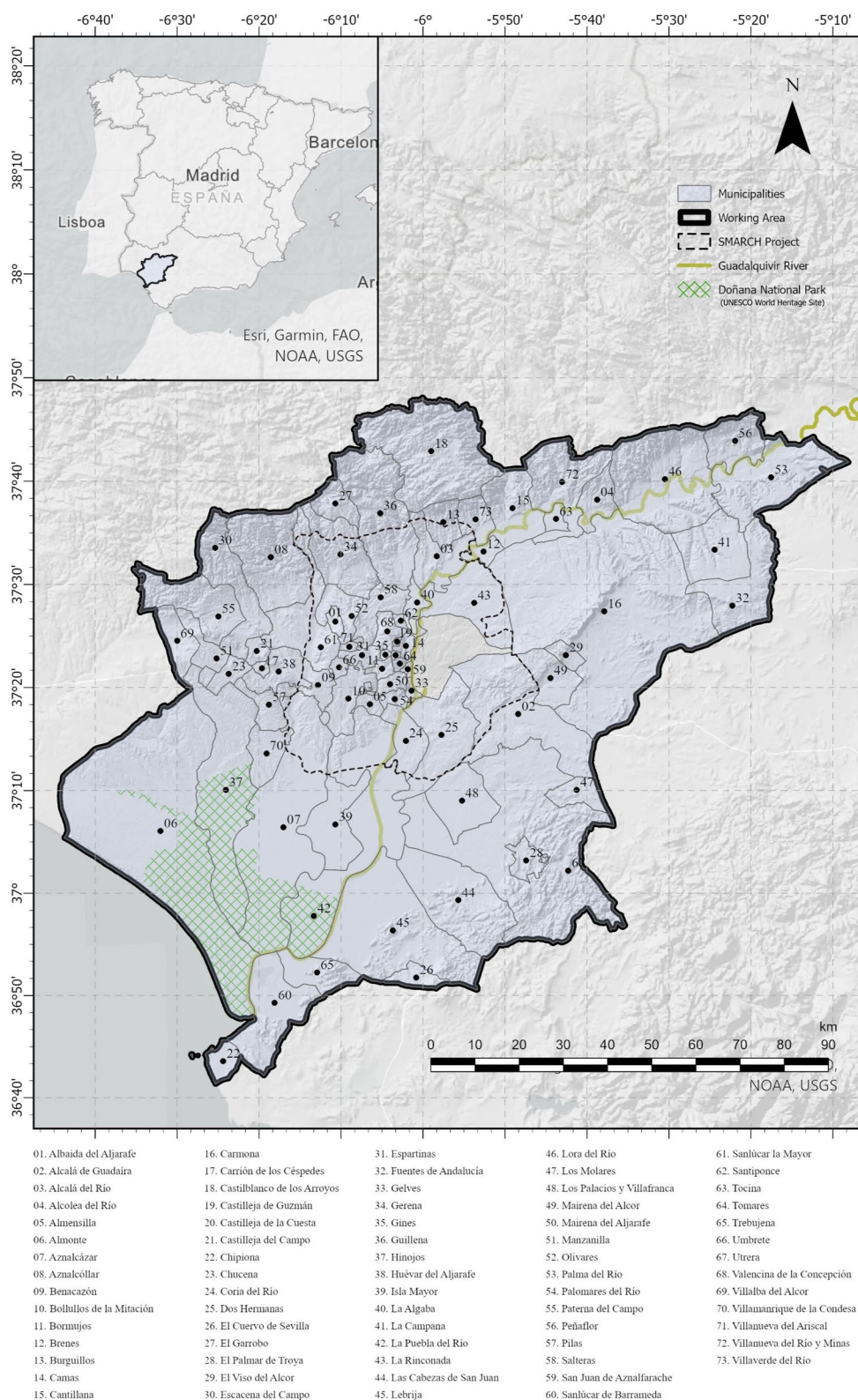


Fig. 1 Geographical scope of VIDA-HTL

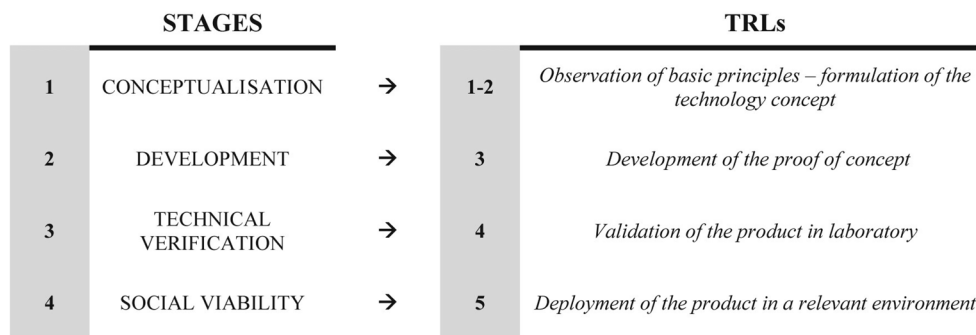


Fig. 2 Relationship between plan stages and TRLs

A four-stage plan was followed for the construction of the web application (Fig. 2). The stages determine a linear development process and are consistent with the Technology Readiness Levels (TRL) employed by the EU as the official innovation policy tool [61]. The first stage focuses on the conceptualisation of the web application (TRL 1 and TRL 2). The second stage consists of its computer development (TRL 3). The third stage focuses on technical verification (TRL 4). Finally, the fourth stage consists of verifying the social viability of the application (TRL 5).

The following section focuses on Stages 1 and 2, and describes the actions proposed for the construction of the web application: task flow and mock-up design, data gathering, database systematisation, and computer development. The third section focuses on Stages 3 and 4, whereby the development is analysed as achieved by both the fundamental research and the conceptualisation and product design project. To this end, the web application is evaluated in a specific area of the lower Guadalquivir. As a result of this critical review, conclusions, possible improvements, and future lines of research have been presented.

VIDA-HTL app: design of contents and structure

This section develops the methodological criteria that concern the design and construction of the WebGIS application.

Web app conceptualisation

The actions comprising this stage are the conceptualisation and visual development of the VIDA-HTL web application, and the analysis of existing applications focused on improving the heritage knowledge of an area and the designing of cultural routes.

Approach and scope of the web application

The VIDA-HTL web application is based on an integration of the subsystems from cultural heritage and tourist

services. This is carried out by integrating data on accessible architectural and archaeological heritage, environmental information, and tourist resources. Functions for the search for cultural assets and for the calculation of heritage routes were designed to promote the heritage values which are necessary for the digital reactivation of the territory (Fig. 3).

Task flow and storyboard for conceptual design

In this step, the visual design of the working of the application was developed through a task flow diagram and a schematic storyboard. These were used as a guide for the subsequent computer development of the WebGIS app.

The benefits of working based on task flow diagrams have been stated by numerous authors [62–64]. A task flow diagram represents the ordered sequence to perform a task by means of symbols. Its creation prior to programming is recommended because it facilitates decision-making regarding the process, the organisation of teams and tasks, and the early identification of deficiencies in the design. In the diagram below (Fig. 4), the arrows display the order of the tasks leading to a particular action.

The conceptual design of the application focuses on the implementation of the two main functions that were considered necessary for an interactive use, namely the heritage assets search engine and the cultural route calculator. These two functions are complemented by secondary operators that grant the user flexibility in the use of the application, by offering various alternatives according to their interests and priorities. Furthermore, the cultural heritage search and route calculation functions are linked. The functions allow the user to move from one function to another in an intuitive way. In this respect, there is the option of saving the results from the searches, both assets and routes, as favourites for their later use.

Decisions regarding the design of the interface are based on the specific literature [65–67], and always seek to enhance accessibility to the content by people with

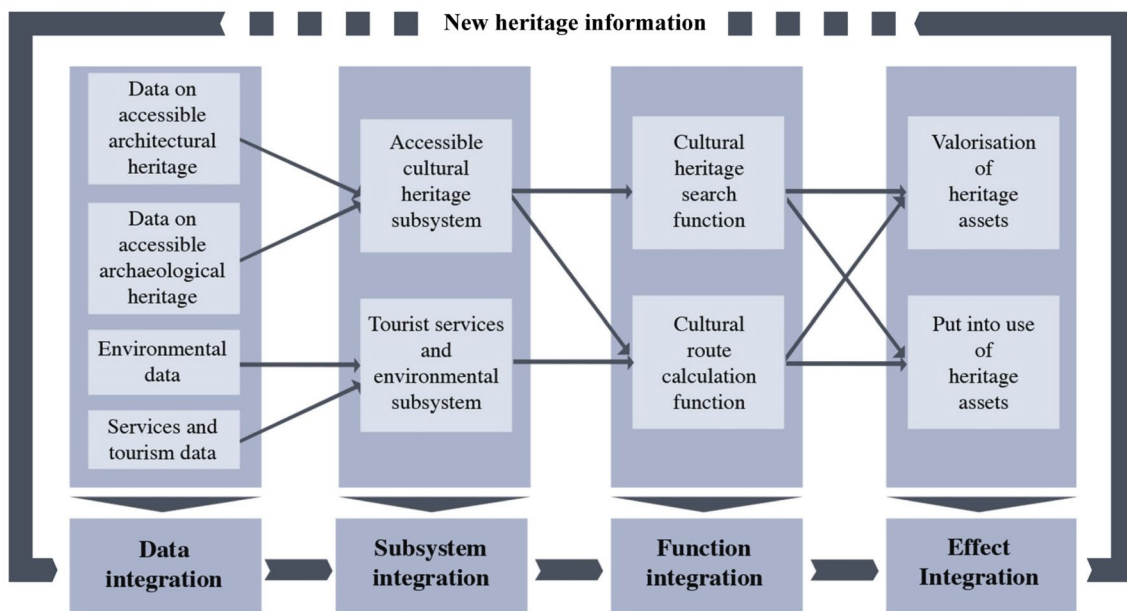


Fig. 3 Content and function schema for the digital activation of territories

different profiles. The application has been designed in such a way that the VIDA-HTL interactive map, built on the basis of a topographic base map, holds a prominent position. The homepage of the web application consists of this map and a menu sidebar. The map displays the assets comprising the accessible cultural heritage dataset, which are clustered and classified in terms of their topic: archaeology, architecture, and infrastructures (Fig. 5).

Analysis of similar apps

In order to verify the degree of innovation of the proposal, the functional capabilities of WebGIS applications have been analysed with a similar approach. This comparative analysis has been conducted for a list of applications covering different geographical scopes: regional, national, and international (Table 1).

The result of this comparison shows that there are almost no precedents that combine the two main functions around which the VIDA-HTL web application is organised. Most of these web applications act only as a repository of cultural assets and predefined routes. Although a number of the precedents enable the configuration of customised routes, they lack the advanced spatial tools and additional information useful for route planning that have been incorporated in the proposed web application.

Web app development

The second stage consists of the computer development of the web application. The actions comprising

this development include the migration of the data produced in the framework of the SMARCH project to be employed in the generation of the geodatabase, its revision and enlargement, the standardisation of the spatial data to feed the web application, and the development and implementation of the prototype.

Data acquisition and refinement

The subsystems of accessible cultural heritage and environmental tourism services that comprise the application are formed by the integration of data from various repositories and complementary actions.

Data on the accessible cultural heritage in the study area, with information on its location, mainly comes from the inventory of heritage assets created by the IAPH [72]. The data is open in the form of shapefile datasets upon the submission of a reasoned request. The number of initial records in this database is 831.

A revision of the elements that comprise this initial database has been conducted. Since the aim of the application is to facilitate accessibility to the cultural heritage in the study area, it was decided to eliminate those assets that are not visible and are not susceptible to being included in the cultural itineraries (e.g., hidden archaeological records and recently demolished assets). Duplicate assets have also been removed from the database. To this end, a total of 73 of the 831 initial records have been eliminated. On the other hand, the information contained in the attribute table of the initial database has been verified, and it has been necessary to

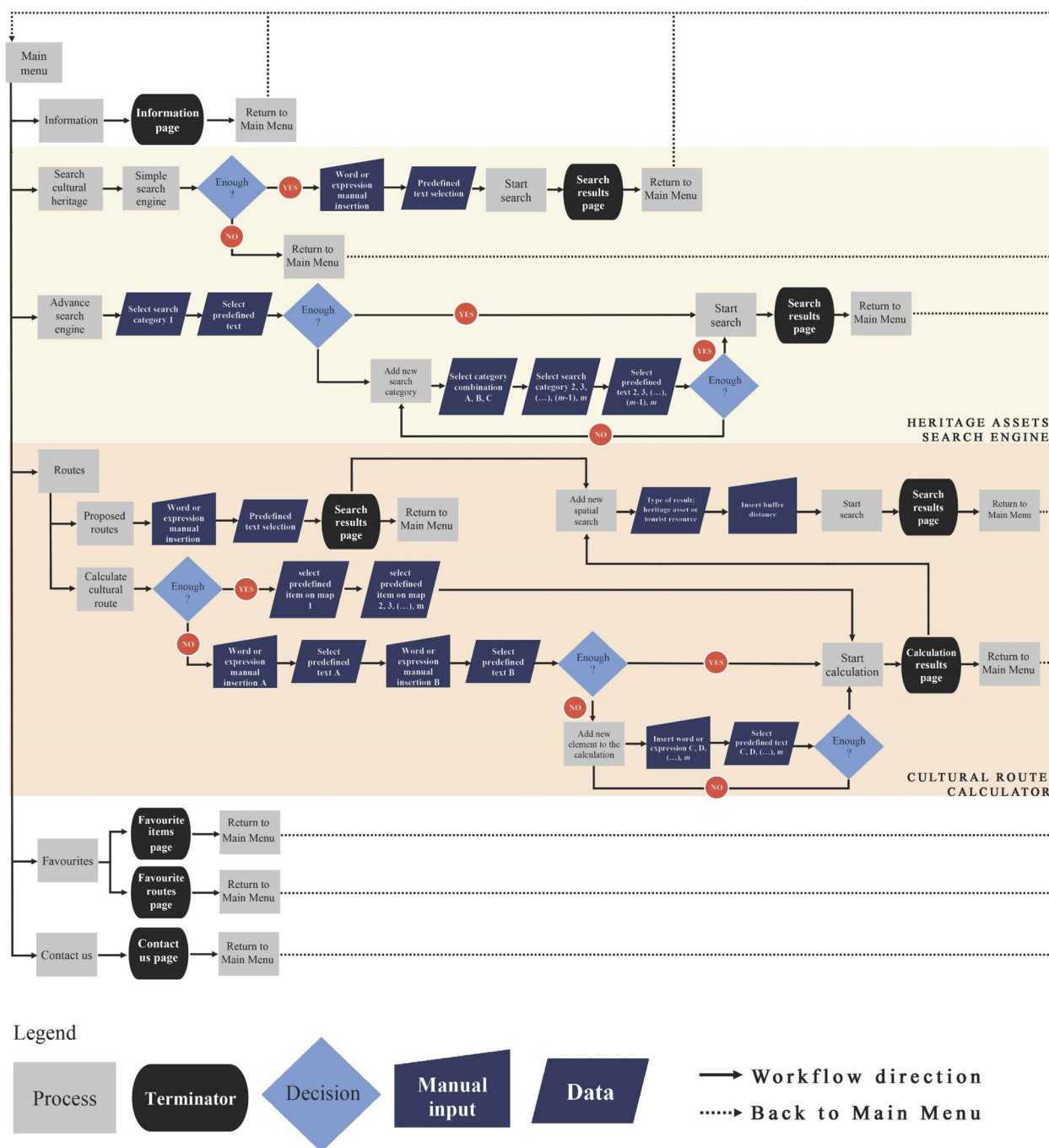


Fig. 4 Task flow diagram of the VIDA-HTL app

modify data on 388 of 831 records. In addition, 225 new heritage assets have been added manually to complete the database that feeds the web application, thereby resolving the absence of relevant records in the initial database. For this purpose, individual studies in each of the municipalities of the working area have been conducted and documents of a variety of natures have been

reviewed, such as archaeological maps, urban planning, and specific catalogues and inventories. As a result of this refinement process, the final number of assets registered in the database for the working area is 981.

The environmental and tourist services subsystem mainly includes open data from public repositories of

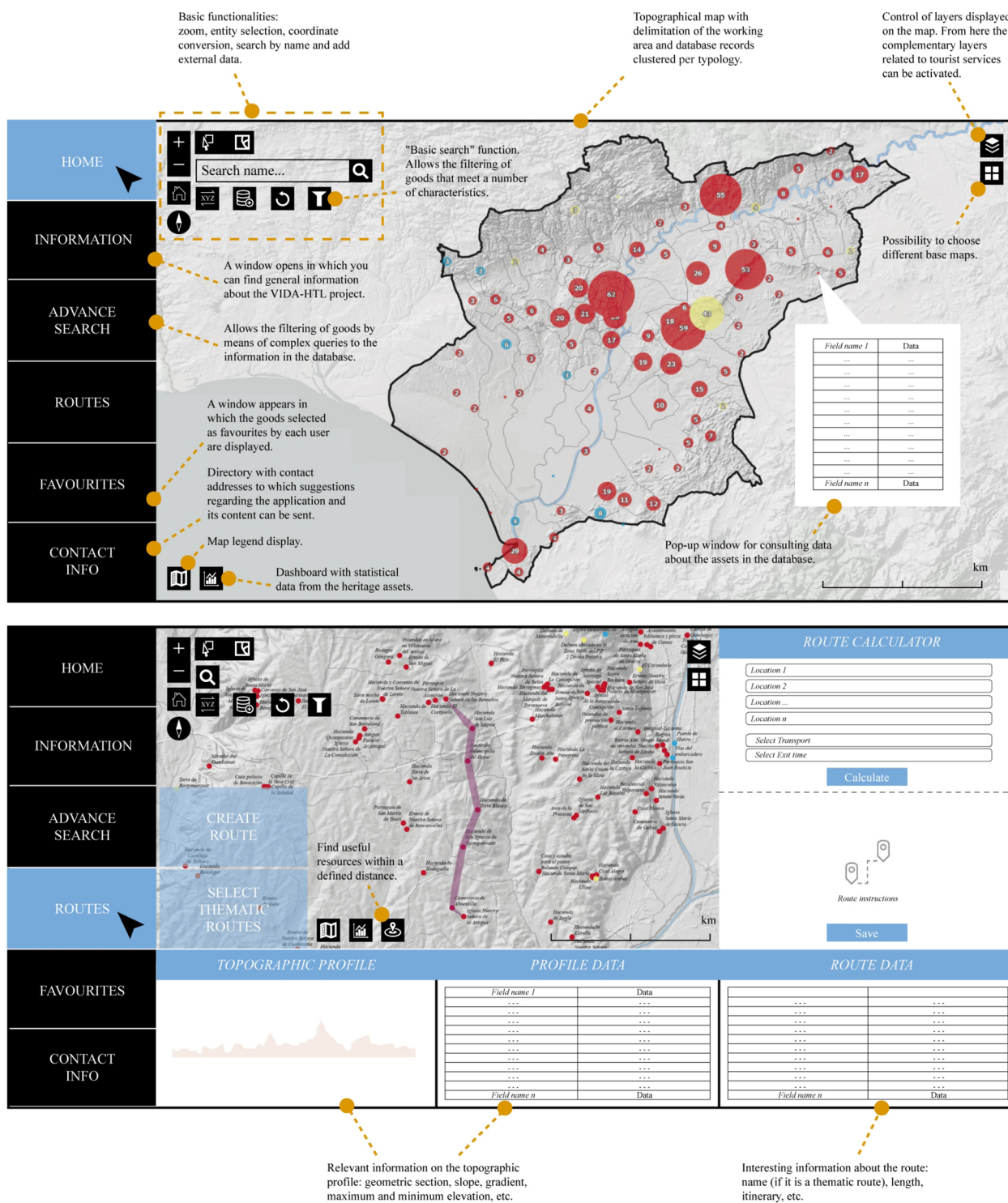


Fig. 5 Schematic mock-up of the VIDA-HTL web application

Table 1 Functional analysis of similar web applications

References	Name	Scope	Cultural heritage search function	Cultural route calculator function
[39]	G.A.L. COLLINE JONICHE ^a	Regional (Italy)	x	–
[40]	VIAS PECUARIAS DE MEDINA DE RIOSECO [Link]	Regional (Spain)	x	–
[41]	KALAMATA ACTION MAP [Link]	Regional (Greece)	x	–
[42]	CULTURAL AND NATURAL HERITAGE OF THE UNESCO SITE OF MATERA ^a	Regional (Italy)	x	–
[43]	MOUNT LUSHAN CULTURAL LANDSCAPE HERITAGE SITE ^a	Regional (China)	x	–
[45]	CORREDOR N-340: EL EJE HISTÓRICO DEL LITORAL ANDALUZ [Link]	Regional (Spain)	x	–
[68]	C-GUIDE [Link]	International	x	–
[69]	CAMINO DEL HIERRO [Link]	Regional (Spain)	–	–
[70]	VENTANA DEL VISITANTE. ESPACIOS NATURALES DE ANDALUCÍA [Link]	Regional (Spain)	x	–
[71]	DOCOMOMO IBERICO. GEOPACK [Link]	National (Spain)	x	x
[72]	GUÍA DIGITAL DEL PATRIMONIO CULTURAL DE ANDALUCÍA [Link]	Regional (Spain)	x	–
[73]	ARQUITECTURA CATALANA [Link]	Regional (Spain)	x	–
[74]	CAMINOS VIVOS [Link]	Regional (Spain)	x	x
[75]	WIKILOOC [Link]	International	x	–
[76]	VÍAS VERDES [Link]	National (Spain)	x	–
[77]	TOURER.IT [Link]	Regional (Italy)	x	–
[78]	HISTORICAL HIKING TRAILS OF THE HOLY SITE OF METEORA ^a	Regional (Greece)	x	–

^a Web applications without an access link available

the Spatial Data of Reference of Andalusia (DERA),² the National Centre for Geographic Information (CNIG),³ and the Spatial Data Infrastructure of the Province of Seville (IDEASevilla).⁴ Layers where the data is organised bring together information of interest on administrative boundaries, proposed routes, the network of roads and livestock trails, the location of tourist facilities, cultural services, service stations, etc. (Additional file 1: Table S1).

Data standardisation

The construction of the spatial database that supports the web application has required an elaborate process of standardisation of its contents while taking into account the thematic, terminological, and spatial components

of the data [79]. This section develops the standardisation criteria established for the case study. Likewise, the spatial data in this contribution were created in accordance with the European INSPIRE directive [80], to ensure compatibility with future publication of information in Spatial Data Infrastructures of regional (IDEAndalucia) and national scope (IDEE).

Thematic and terminological standardisation The thematic standardisation is aimed at defining and categorising the fields that make up the spatial database. The gathered datasets contain mainly descriptive information on the historical and heritage values and on the level of protection of the cultural assets. This systematisation addresses the objective of recording and protecting the historical heritage, and hence it was necessary to modify the table of attributes of the gathered datasets and adapt it to facilitate the valorisation of the heritage. As a result, a total of 18 information fields have been defined, organised into 3 blocks (Table 2):

- (A) Identification: data relating to the location of the asset.
- (B) Categorisation: information to identify the asset from a heritage and historical perspective.
- (C) Dynamisation: attributes regarding the state of conservation and accessibility.

² The DERA repository is a website where digital files of a geographical nature generated by the Andalusian Institute of Statistics and Cartography (IECA) can be downloaded free of charge. Data is presented in thematic blocks (relief, hydrography, transport and communications, administrative divisions, etc.) which allow centralised access to information from very different sources with guaranteed updating, geometric coherence, and territorial continuity.

³ The Download Centre (CdD) is a website of the Autonomous Body of the CNIG from which digital files of a geographic nature generated by the General Directorate of the National Geographic Institute (IGN) can be downloaded free of charge.

⁴ IDEASevilla makes the geographic information produced by the Provincial Council of Seville available to citizens and companies through standard services defined in accordance with the specifications of the Open Geospatial Consortium (OGC).

Table 2 Thematic and terminological standardisation of the spatial database

Block	Field name (Alias)	No. of terms	Examples
(A) Identification	ID_UNIQ (Id)	981	'VIDA_CT_SP_01'
	ID_NAME (Name)	981	Fuente Arkena; Oratorio de la Soledad; etc.
	ID_MUNI (Municipality)	73	Albaida del Aljarafe; Alcalá de Guadaíra; etc.
	ID_UTMX (Coord. X)	981	245643; 249535; 242435; 252965; 242297; etc.
	ID_UTMY (Coord. Y)	981	4127748; 4127504; 4123716; 4135086; etc.
	ID_GEOM (Spatial Geometry)	3	Point; line; polygon
(B) Characterisation	CH_CRON (Time Period)	6	Prehistory; protohistory; Roman age; middle ages; modern age; contemporary age
	CH_CLAS (Basic classification)	3	Archaeological heritage; architectural heritage; infrastructure heritage
	CH_TIPG (General typology)	11	Human settlement; mobility infrastructure; extractive infrastructure; hydraulic infrastructure; agricultural and livestock heritage; civil heritage; defensive heritage; funerary heritage; industrial heritage; religious heritage; residential heritage
	CH_TIPS (Specific typology)	97	Aqueduct; cistern; cellar; chapels; churches; etc.
	CH_ACTV (Activity)	54	Commercial activity; legal activity; military activity; etc.
(C) Dynamisation	CH_PRST (BIC protection status)	2	Yes; no
	DI_COST (State of Conservation)	4	Good; bad
	DI_ACCS (Accessibility)	2	Yes; no; visual
	DI_ACCT (Accessibility type)	4	Free access; concerted access
	DI_CONT (Contact)	981	(+34) 959415370; (+34) 955833701
	DI_LINK (Web Link)	981	https://www.turismo-olivares.es/museo-de-la-vera-cruz/
	DI_IMAG (Image)	981	File path (JPG, TIFF, PNG format; 200 × 150pp)

It is considered that these attributes are sufficient to illustrate the capacity of the registered assets to be used in the dynamics of social and tourist reactivation. Likewise, the design of these attributes responds to the premise of optimising the implementation of the asset search and route calculation functionalities of the web app. In this way, the structure of the database allows filters to be established and spatial queries to be conducted efficiently.

On the other hand, terminological standardisation establishes a single criterion for the completion of the database attributes. Two types of fields can therefore be distinguished depending on whether their content is categorised (e.g., typology or time period) or descriptive (e.g., name or coordinates). In this regard, problems were detected in relation to the categorisation of the information in the initial dataset, which rendered the queries from the web application more complex. The reason lies in the terminology employed, which is derived from the thesaurus of the Andalusian Historical Heritage [81]. This document, based initially in other international thesaurus like The Art and Architecture Thesaurus (AAT) from Getty Institute [82], contains an extensive range of specific terminology for the complete definition of cultural heritage, but no simplifications are assumed that would be useful for spatial database management. The

main problems identified, and the proposed solution are outlined below:

- Excessive specificity. Records in which the detail of their terminological definition is excessive for the purpose of the web application. Terms defining records of a similar nature have therefore been unified.
- Duplication of terms for the same concept. Same concept denominated with different terminology, or even with variances of singular and plural for the same term.
- Drafting error. Terms were found whose duplication results in spelling errors or the appearance of spaces at the end of the word, and are hence recognised as different terms by the web application's search engine.

As a result of this process, a significant reduction in the number of standardised terms included in the database has been achieved, thereby facilitating the user's interaction with the contents hosted in the web application. The synthesis conducted regarding two attributes stands out: 'CH_TIPS (Specific typology)', reduced from 203 to 97 terms; and 'CH_ACTV (Activity)', from 144 to 54 terms. Table 2 shows the number of different terms recorded in each information field, as well as a sample of such terms.

Spatial standardisation Spatial standardisation enables the heritage assets to be contextualised in relation to different geographical scales. Each of these scales is defined as a Unit of Logical Analysis (ULA) and is composed of a set of georeferenced information units of different nature [79]. Four geographic scales were established (ULA-0 to ULA-3), ranging from the entire working area of the VIDA-HTL project to the delimitation of the asset itself (Fig. 6). A correlation of belonging is established between the different ULAs, which is visible in the identification code of the spatial entities that comprise them. The criteria for spatial standardisation are exemplified for the archaeological site of Itálica. Likewise, this asset and its surroundings have been used for the functional and social assessment of the web application, due to the importance of its heritage as a candidate to becoming a UNESCO World Heritage Site since 2018.

- ULA-0. Working Area (VIDA_). This corresponds to a single spatial entity that represents the entire working area of the VIDA-HTL project. The criteria for its delimitation are set out in the first section of the paper.
- ULA-1. Cultural Landscape Area (VIDA_XX_). The project area is subdivided into 17 zones based on their landscape characterisation. This characterisation comes from the demarcation made in the Landscape Map of Andalusia [83], created in 2004 by the regional government and periodically updated up to the present day. The landscape area in which Itálica is located is called ‘Campo Tejada, CT’. Its identification code is ‘VIDA_CT_’.
- ULA-2. Municipalities (VIDA_XX_YY_). A total of 73 municipalities comprise the working area of the project. Moreover, certain municipalities may be included in different landscape areas. Itálica belongs to the municipality of ‘Santiponce, SP’. Its identification code is ‘VIDA_CT_SP_’.
- ULA-3. Cultural Heritage Asset (VIDA_XX_YY_ZZ). This scale corresponds to the asset and its urban-territorial context. This ULA enables the identification of other nearby heritage sites and complementary tourist services. Likewise, ULA-3 enables a sufficiently detailed territorial approach to define the surrounding geographical area by using 3D models of the terrain and buildings. The code inherited from the previous ULAs is completed in detail for each property. In the case of Itálica, this is ‘VIDA_CT_SP_01’.

The different ULAs are also applicable to the hierarchisation of cultural itineraries. In this respect, they

can be taken as a reference for planning routes of various geographical scopes, thereby providing a range of visions and approaches to the territory from the spatial–temporal dimension.

Spatial database construction

The gathered and standardised spatial data (initially in shapefile format) has been exported as feature classes of a single local geodatabase created for the VIDA-HTL project. These feature classes have been grouped within the geodatabase into three specific feature datasets according to their nature (Table 3). The first includes the feature class of the 981 architectural and archaeological heritage records inventoried in the working area. The second groups the feature classes of each of the information layers of the environmental and tourist services subsystem (Additional file 1: Table S1). The third dataset includes the feature classes employed as a reference for the spatial organisation in ULAs of the database. Furthermore, a raster dataset is included in the geodatabase corresponding to the topographical base map used. This raster file is the result of processing and unifying all the sectorised Digital Terrain Models (DTM) that comprise the working area, downloaded as open data from the National Centre of Geographic Information (CNIG).

The various datasets have been included as independent layers in a local GIS project. Their geometry can therefore be visualised on a map and the symbology can be modified to suit the interface of the web application. Colour criteria, visualisation scales, and semantic labels have all been established. All these processes have been conducted using ESRI ArcGIS Pro desktop software. The coordinate system used for the geodatabase is Web Mercator on ellipsoid WGS84.

Output data and online dissemination

The implementation of the web application consisted of two steps. The first of these was the publication of its content on a GIS-cloud platform and its subsequent integration in the web application developed according to the described functionalities.

Geographic web services publication The content of the local geodatabase has been published on a GIS Cloud portal in the form of various geographic services. The portal used, ESRI ArcGIS Online, allows the hosted information to be shared as open data. A specific workspace has been set up in the portal for the VIDA-HTL project to manage the publication of the geographic web services.

The publishing and updating process has been conducted directly from the local GIS project created in

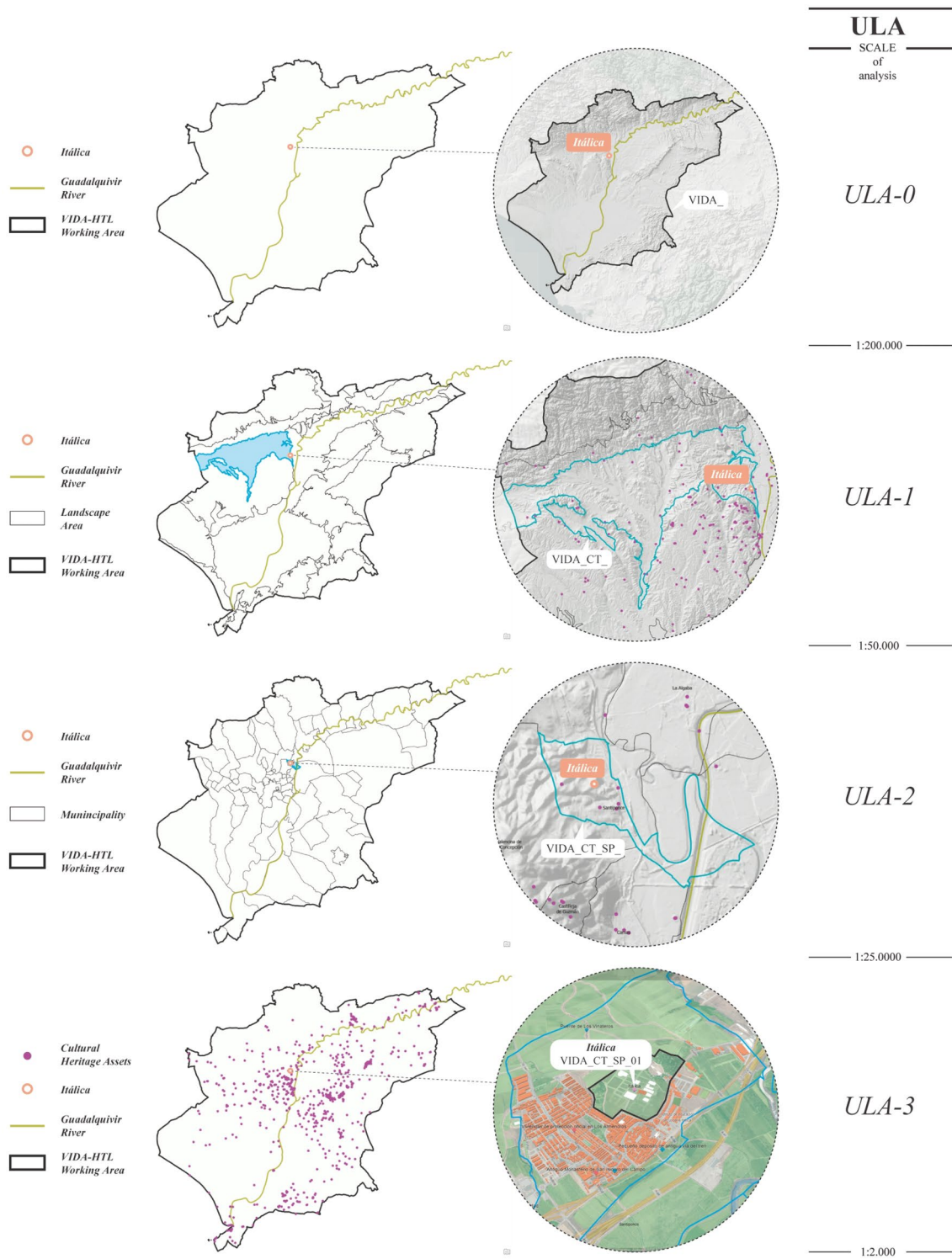


Fig. 6 Spatial hierarchy for the multiscale contextualisation of the assets

Table 3 Detailed description of the contents of the spatial database created for the VIDA-HTL project

Geodatabase contents				
Feature dataset	Feature class	Spatial feature	Geometry type	Source format
Vectorial data				
VIDA-HTL catalogue	Cultural heritage assets	981	Point; polygon	Shapefile (.shp)
Environmental and tourist services	See Additional file 1: Table S1	5444	Point; line; polygon	Shapefile (.shp)
ULA_Spatial reference	ULA-0_VIDA-HTL working area	1	Polygon	Shapefile (.shp)
	ULA-1_Landscape area	17	Polygon	Shapefile (.shp)
	ULA-2_Municipalities	73	Polygon	Shapefile (.shp)
Dataset	Raster	Cell size	Raster bands	Source format
Raster data				
Topographical base map	27 sectorial DTMs corresponding to the working area	25×25 m	1	ASCII (.asc)

ArcGIS Pro, thereby preserving the customised visualisation options. The datasets of the local geodatabase are therefore published in ArcGIS Online as attribute web services, with the status of hosted layers: feature layers for vector datasets and tile layers for raster datasets. These services integrate the semantic content of the VIDA-HTL web application. Once published, a web map is created on the portal, in which the datasets are included as interactive layers. Finally, this web map constitutes the cartographic base of the web application.

WebGIS application development The web application has been developed using the ArcGIS Experience Builder platform, based on the conceptual criteria established in Stage 1. This tool allows the creation of GIS-based web applications using pre-configured templates without the need for programming. However, the functionalities of these templates are limited, since it was necessary to implement a specific module that extends and customises the templates according to the requirements of each project. This module, used in the research, is based on the programming library ‘ArcGIS API for JavaScript’.

The aforementioned functions in the web application were generated by using configurable and sharable functional units called widgets. A total of 24 widgets have been implemented, which are organised into six categories (Additional file 2: Table S2): map-centric; data-centric; page-element; menu and toolbar; layout; and section. The capabilities of several of the predefined widgets have been edited through the extensibility framework ‘JIMU’, integrated with the ArcGIS API for JavaScript. These widgets include functions of different natures: the ‘Map’ widget, which allows the integration of the created web map into the application; the ‘Search’ and ‘Filter’ widgets, for the different search options in the database; the ‘Near me’ widget, for the location of nearby heritage assets and services; and the ‘Directions’ widget, for the calculation

of cultural itineraries. Regarding the latter, its operation is based on the geoprocessing tool ‘Network Analysis’. For its configuration, it was necessary to use a transportation network dataset, that is, an undirected navigable network that includes the entities of the existing transport system such as streets, paths, roads, and railroads. Having verified that the calculation results are acceptable (see “[Functional and social assessment](#)” section), it was decided that the predefined ESRI multimodal network dataset should be used.

Moreover, other complementary tools have been implemented in the web application: in particular, an interactive tutorial has been developed to illustrate the use of the app; a dashboard which compiles and enables real-time statistics to be consulted on the spatial data included; and a collaborative Hub, which enhances the user interaction with the data and the interaction between users.

Functional and social assessment

This section includes the evaluation of the technical development and social viability of the materialised proposal.

Web app technical verification

This action consists of the development of a series of functional and non-functional control tests of the application, both to verify its technical feasibility and to ensure its quality. The evaluation focuses on the two main functions of the application: the asset search engine and the cultural route calculator.

Heritage assets search engine

The selection of the “Search cultural heritage” function, accessible from the “Home Page”, activates by default a simple search engine in which the manual insertion of a word or expression and the selection of a predefined text

leads to a page with the search results. If this function does not suit the user's needs, it is possible to activate the "Advanced search" function. This function enables thematic queries based on the information fields included in the database. In particular, the user combines different search filters by selecting the attributes of interest. Three complementary filter types can be used (Fig. 7a):

- Simultaneous conditions, to select assets that match the selected attributes.
- Optional conditions, to add assets that meet certain attributes to the above selection.
- Excluding conditions, to eliminate from the selection the assets that correspond to the selected attributes.

In this respect, the web application works as a heritage inventory where the user can identify assets located in a specific municipality, corresponding to a particular chronological period, or related to a certain activity, among other options.

The result of the advanced search is displayed on the interactive map of the web application, from which it is possible to consult the heritage information of each of the assets in a pop-up window. Furthermore, statistical graphs are displayed that enable a quantitative and qualitative analysis of the selected group of heritage assets (Fig. 7b). The final selection of assets can be modified manually at the end of the search. This selection can be saved and later used as reference points for the calculation of a cultural itinerary.

Data-driven analysis of heritage assets The process of verifying and expanding the inventory of assets has resulted in an updated list of cultural assets within the study area. In total, 981 architectural and archaeological heritage records have been georeferenced with associated data, which represent an increase of 15.4% over the initial number of 831.

The content of the attributes that comprise the database has enabled statistical analyses to be conducted for an exhaustive verification of the data (Fig. 8). These analyses are divided into the following categories: (A) Identification, (B) Characterisation and (C) Dynamisation. The data is available through a dashboard integrated in the main window of the web application.

The municipalities with the highest concentration of heritage assets are Carmona (111) and Alcalá de Guadaíra (98), followed by a second group containing the municipalities of Lebrija [69], Utrera [50], Sanlúcar de Barrameda [49], Villanueva del Río y Minas [45], and Dos Hermanas [41]. These seven municipalities account for 47.2% of the heritage buildings in the study area, which is made up of a total of 73 municipalities. In turn, these

seven municipalities account for 30.4% of the total surface area of the working area. This shows an unequal distribution of assets in the study area, with a greater concentration in the eastern side.

On the other hand, the analysis reveals a greater number of assets identified as architectural heritage (795; 81.0%) compared to archaeological heritage (60; 6.1%). The minimal presence of the latter in the web application is due to the shortage of archaeological sites in appropriate conditions to ensure that their consideration as a tourist resource exerts no negative effect on their preservation. Regarding the chronological period of the assets, it is evident that a greater number of assets belonging to the Contemporary Age (556; 56.7%) and Modern Age (223; 22.7%) have been preserved to date. This circumstance is related to the building typology and their related activities. A third of the assets are linked to the exploitation of the territory from a productive perspective, with buildings such as plantations and farmhouses belonging to the agricultural sector (317; 32.3%). Religious heritage also has a major presence in the study area (192; 19.6%).

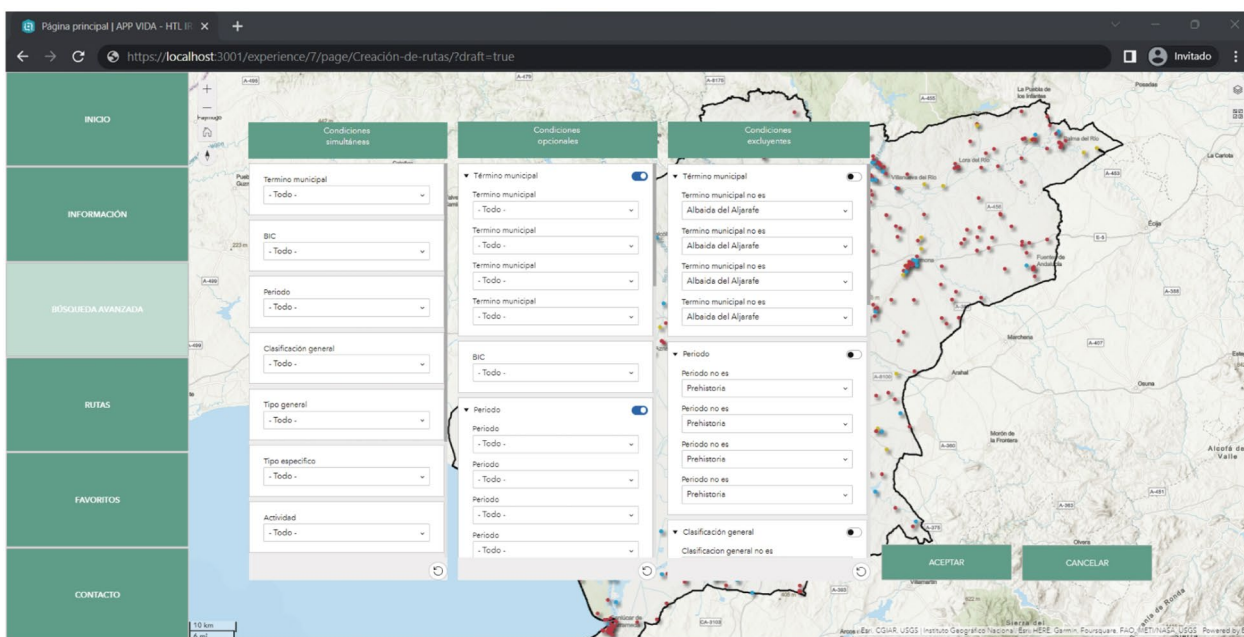
With respect to the protection status of the registered heritage, one fifth (203; 20.7%) is catalogued as an Asset of Cultural Interest (BIC in Spanish), which is the most important status of heritage protection granted in Spain. Likewise, the correct general state of conservation of most of the registered assets (763; 77.8%) is worthy of mention, regardless of whether they command any type of protection status. Finally, it has been verified that more than three quarters of the inventoried assets are physically or visually accessible (798; 81.3%), including contact information on the database.

This analysis provides exhaustive knowledge of the quantification and categorisation of the existing heritage in the working area. Many of these assets do not appear in any kind of inventory or have no protection status assigned. Consequently, it is a useful tool for both general users and stakeholders involved in territorial and heritage management.

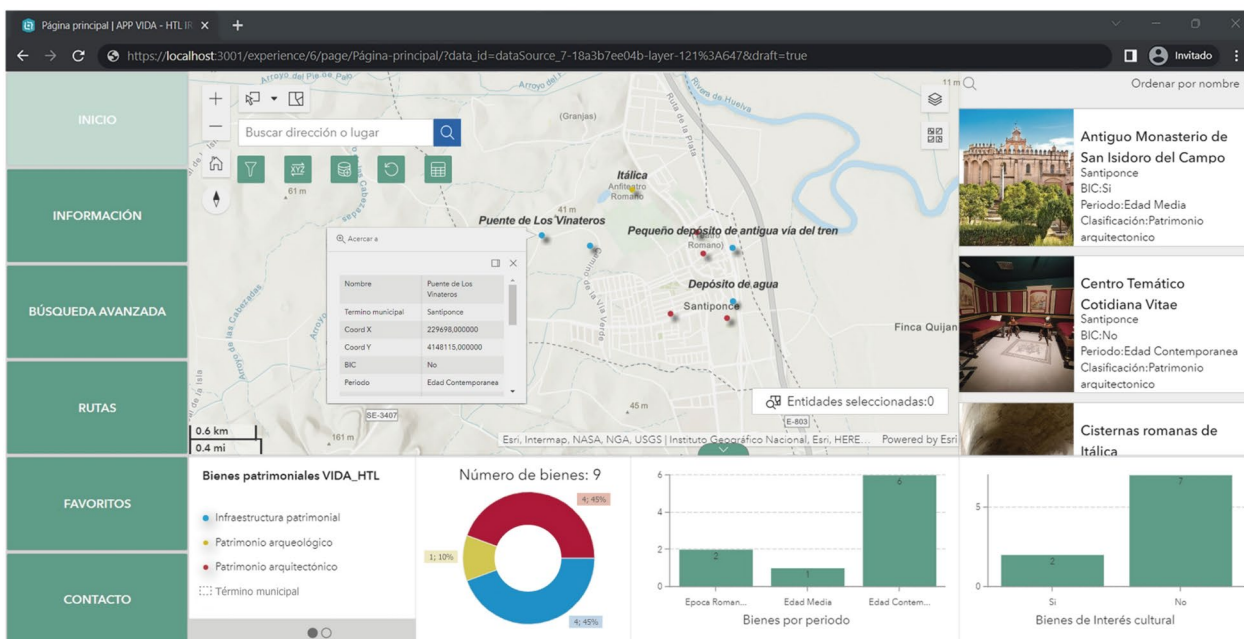
Cultural route calculator

Regarding the implementation of the route calculation function, the selection of the function "Create Route", accessible from the "Home Page", leads to a simple tool, which works by either selecting on the map or by manual text insertion of a minimum of two heritage assets for the calculation. The route can be configured according to the mode of travel: on foot or by motorised transport. Calculated routes can be exported in different formats for offline use.

The advanced search tools can be utilised to filter the detailed assets included in the route. In this respect, the feature dataset 'ULA_Spatial Reference' is useful, by



(a)



(b)

Fig. 7 a Advanced search filters available in the web application. b Search result on the interactive map with listing, statistical information, and pop-up window for individual queries

means of which spatial selection filters can be established to calculate routes corresponding to different geographical areas, from ULA-0 to ULA-2 (Fig. 9).

Alternatively, the selection of a set of thematic routes is enabled without requiring the configuration of the user. This is the “Proposed routes” option (Fig. 9). Specifically,

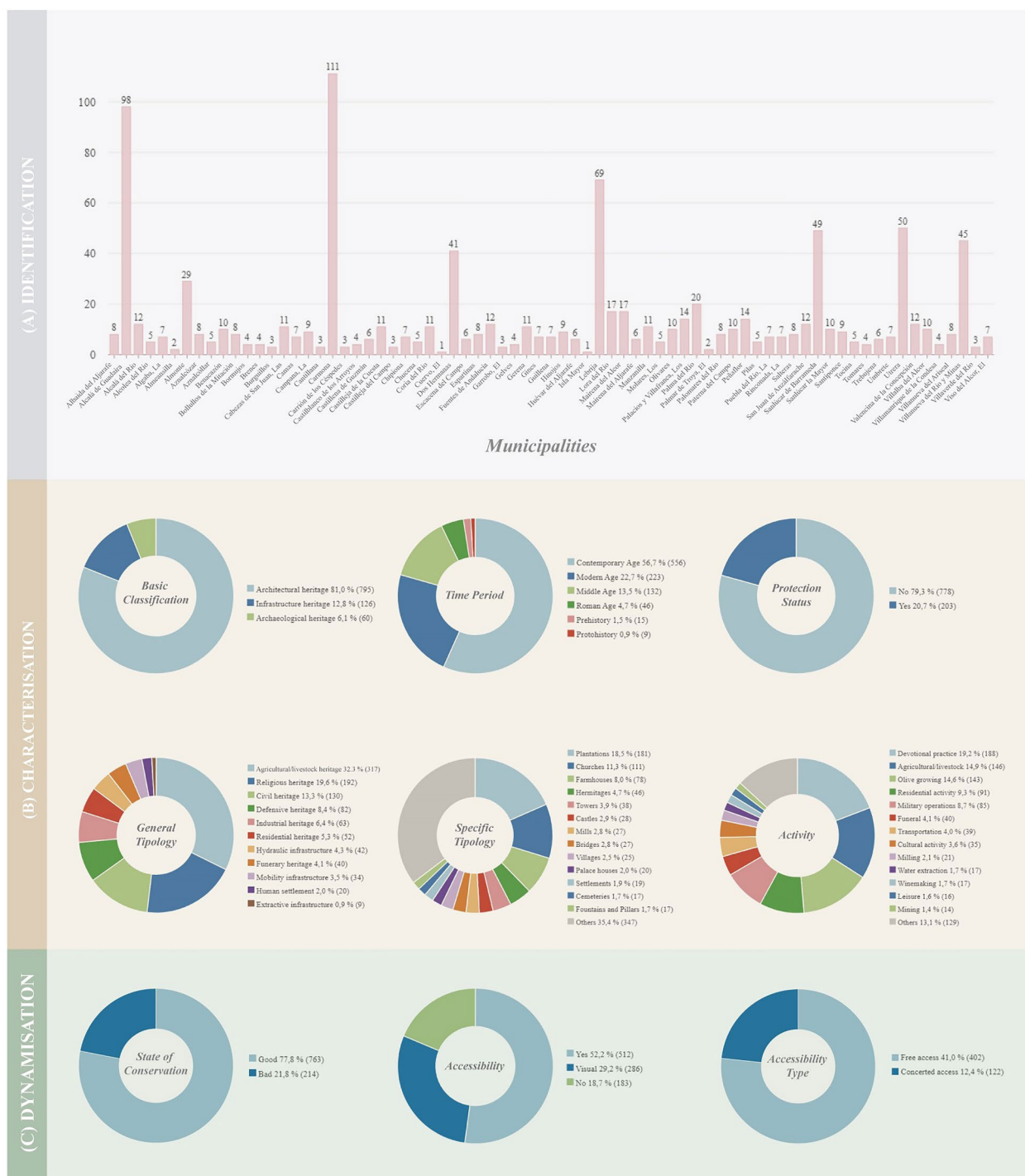


Fig. 8 Categorised analysis of the information stored in the database

a total of 49 routes have been introduced as part of the feature dataset ‘Environmental and Tourist Services’.

Lastly, the web application provides specific information on the routes. Spatial tools have been implemented to obtain the topographic profile and the calculation of

other specific parameters associated with the route, such as the distance, slope, and average gradient (Fig. 9). Likewise, the attributes associated with the thematic routes from their original data source can be consulted on the interactive map.

In order to complement the search results, the “Advanced spatial search” function enables the detection of heritage assets or services located at a certain distance from a selected route. To this end, a route is selected for use as a reference for the calculation and the result to be visualised is indicated as heritage assets, nearby services, or both. Finally, the calculated distance from the selected reference is specified. This shows the results in the map, which significantly helps in the planning of cultural itineraries (Fig. 10). The data sources employed are the feature datasets ‘VIDA-HTL Catalogue’ and ‘Environmental and Tourist Services.’

Validation of calculated cultural routes Given the difficulty involved in the geospatial control of routes in a rural environment, a verification has been conducted of the correct performance of the multimodal navigable network implemented in the web application. The evaluation was conducted in a ULA-3 geographical area, specifically in the municipality of Santiponce. The ULA-3 enables the delimitation of a working area of feasible dimensions to verify the results accurately.

In this way, 21 routes connecting different cultural assets belonging to the municipality of Santiponce have been evaluated. To this end, a series of indicators have been established to assess the response levels of two selectable modes of travel: pedestrian and motorised vehicle. For the evaluation of the pedestrian routes, eight levels of response are defined in gradual order, with acceptable results being those between levels A and D, and unacceptable results being those between levels E and H. The evaluation of the motorised vehicle routes is based on seven levels of response which compare the calculated route with the result for the same route in a pedestrian route. In this case, those between A and D are considered acceptable, and those between E and G are considered unacceptable (Fig. 11).

The study conducted on this representative sample shows that the navigable network implemented provides acceptable results in more than 75% of the cases for either mode of travel. The unacceptable results are mainly due to three factors:

- The complex geographical location of assets located in a rural environment. This results in the definition of itineraries that fail to lead directly to the access area of the asset (Fig. 12a).
- Lack of cartographic data of accessible rural roads that can be included in the navigable network. This results in itineraries that fail to consider existing roads, and instead propose longer and inefficient routes (Fig. 12b).

- Incorrect definition of the connection nodes between roads in the navigable network. This results in the non-detection of intersections connecting roads of different types (Fig. 12c).

Web app social viability

This section focuses on the interaction with spatial data within a community of users. In this regard, the development of a collaborative web environment through the ‘ArcGIS Hub’ extension, within the ArcGIS Online framework, has provided a series of complementary capabilities that favour the use of the web application. The latter and all content hosted on ArcGIS Online is accessible through the VIDA-HTL Hub.

Regarding branding and user engagement, the Hub interface includes identity elements of the VIDA-HTL research project and other components that favour user navigation and participation (Fig. 13). This content is mostly audio-visual (logos, specific colour palette, typography, project information, images representative of the working area, etc.). A language translator has also been implemented to ensure access to information for people of different nationalities.

In quantitative terms, up to 10,000 users can create personal accounts and store in them the content generated through the web application. This is considered a sufficient number of users to verify the long-term performance of the application. Furthermore, users can be grouped into teams, and share content amongst their members, with other teams, or publicly (Fig. 13). To encourage interaction between users, the Hub includes the capability of creating events and sharing them with different levels of publicity in the user community (Fig. 13). Moreover, events can be shared on social networks to achieve wider dissemination. This capability is particularly relevant in encouraging the extensive use of the web application.

The data included in the application can be accessed and downloaded from the Hub, which is linked to the ArcGIS Online root storage (Fig. 13). In this regard, the Hub acts as an open data portal from which the user can download spatial information in different formats (CSV, KML, Shapefile, GeoJSON, and GDB). Moreover, this data can be used directly online to create custom web maps using ArcGIS Online resources, which can then be stored in each user’s account within the Hub. This capability enables the creation of content that complements the main functionalities of the web application for planning cultural itineraries.

Registered users have the capability of evaluating cultural assets and itineraries within the application using forms which have been generated for this purpose. In

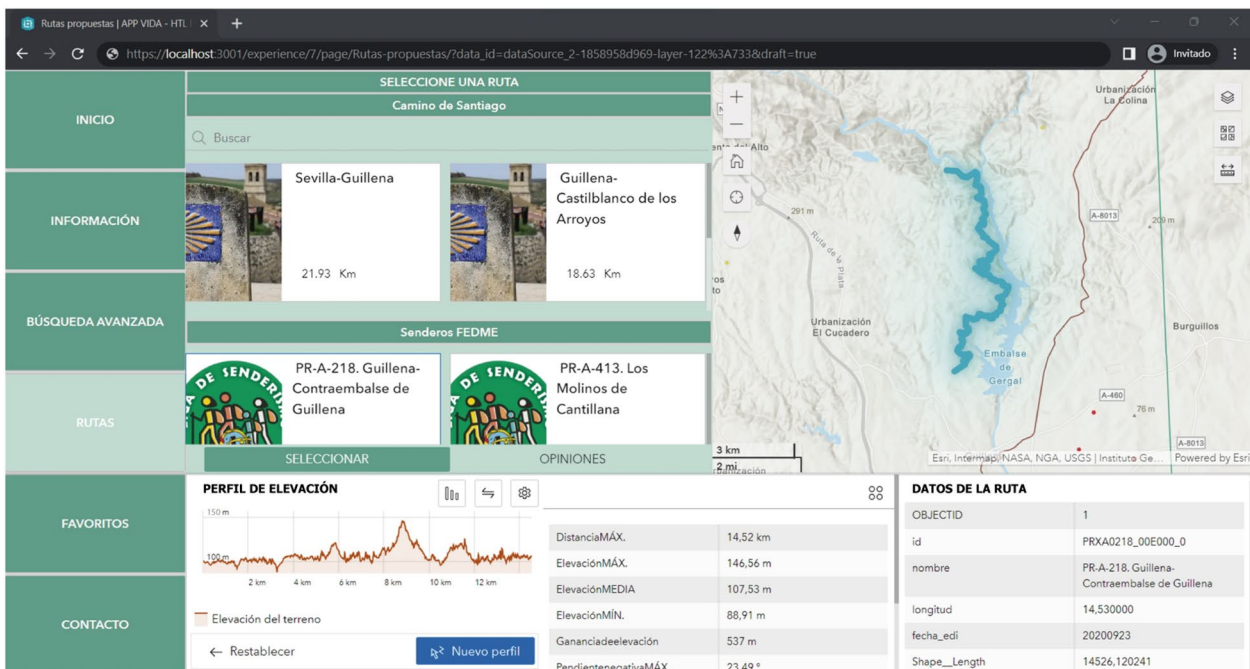
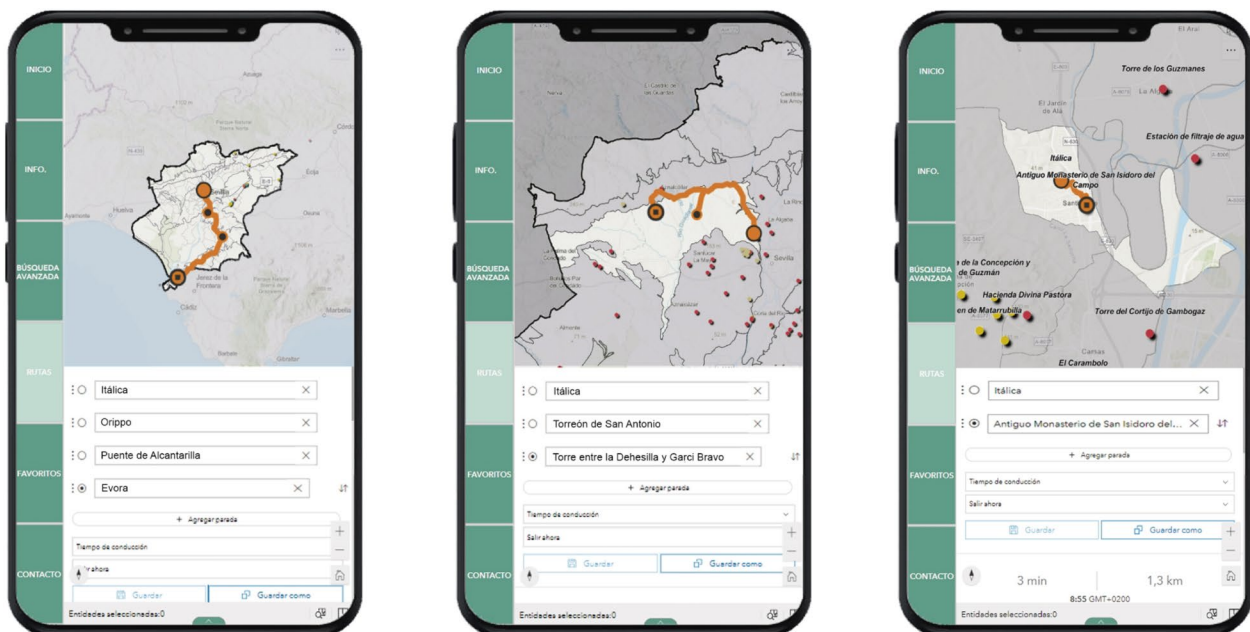


Fig. 9 Creation of routes taking as reference geographical areas corresponding to the different ULAs (top). Selection of thematic route and display of route-linked data (bottom)

addition to a numerical rating, they can provide feedback and create discussion forums with other users of the application. The user can also suggest modifications to the existing information, as well as the inclusion of new content. These suggestions are considered by the web application managers, through an evaluation process

of its quality, accuracy, and relevance. Figure 14 shows a discussion generated subsequent to the detection of an obstacle on one of the proposed routes. These discussions can be georeferenced, and an image can be attached. It also shows the form included for the assessment of the

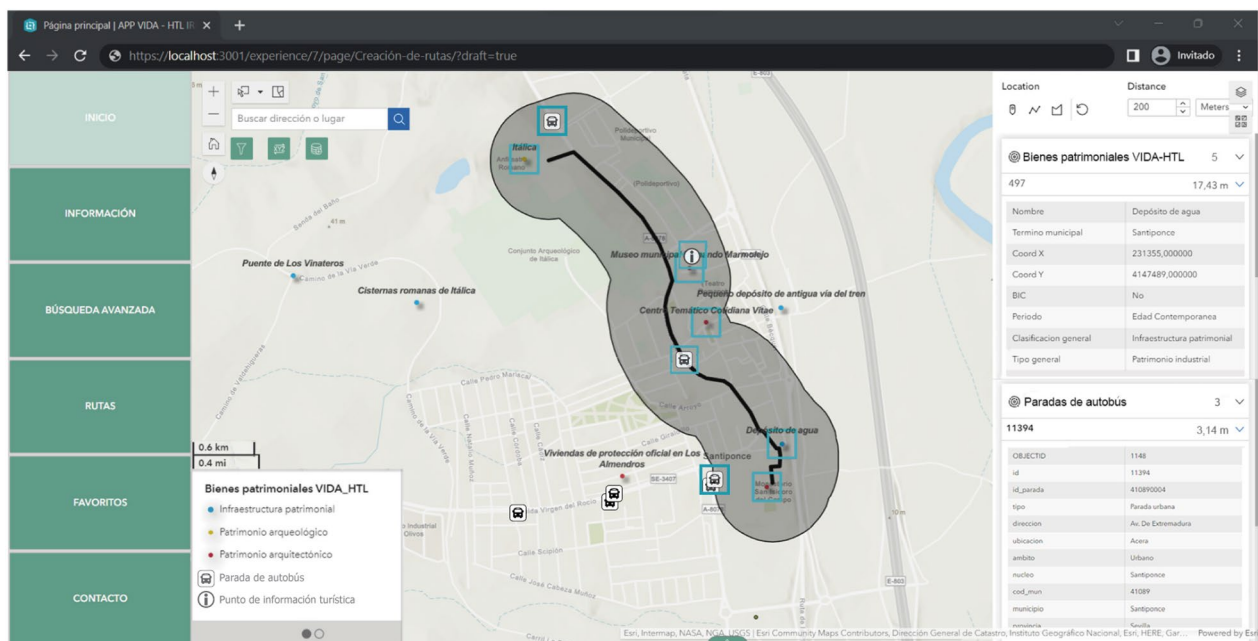


Fig. 10 Search results for heritage assets and additional resources near a calculated route

contents. The collected results are visible when using the search engine for cultural assets and routes.

Finally, web traffic analysis is conducted by the app managers using monitoring tools within the VIDA-HTL Hub (Fig. 15). It is therefore possible to observe the behaviour of users in relation to its contents. This resource is useful in numerous ways, including for ascertaining the time spent by users planning a route, and for recognising in which time slots the app is most used. Based on this data, the web application can be modified to improve the user experience. Figure 15 shows peaks of user activity concentrated at weekends, as well as an average usage time of approximately 30 min in the released version of the web application.

Conclusions

The article presents the VIDA-HTL web application as a tool to address the strong imbalances between human settlements and the environment resulting from sectoral policies and urban and regional planning instruments in the area of the lower Guadalquivir. These imbalances are the main cause of territories becoming less resilient and increasingly less responsive in crisis situations. Our proposal seeks to exploit the potential of architectural and archaeological heritage to address inequalities and reactivate those territories that remain less developed. The valorisation and use of these cultural assets, promoted by the VIDA-HTL web application, contributes to greater local development, which acts as a counterbalance to the

development of metropolises and the global economy and improves levels of regional resilience.

The web application construction is part of a conceptual formulation and product design project that has its origin in previous basic research. As a whole, the project follows an action-research method of systematic enquiry where the theoretical research is aimed at deciding on an intervention to improve or solve a critical problem, in this case, the development of a web application for the digital reactivation of the territory of the lower Guadalquivir. To establish the phases of the methodology, information related to technology maturity levels (commonly used in the assessment of the development of proofs of concept) has been gathered, synthesised, and organised following a review of the scientific literature. The implementation of these actions to the case study has enabled a series of results to be extracted. An analysis of these results in terms of the established objectives using statistical methods allows us to verify the level of achievement of these objectives and to make proposals for improvements to be considered in future phases of the technology review.

Regarding the degree of development of the application, subsequent to the technical verification of the results and of the contents that have been introduced in the application, Stage 4 has been reached in terms of technology readiness levels. In this respect, the implementation of the collaborative web environment

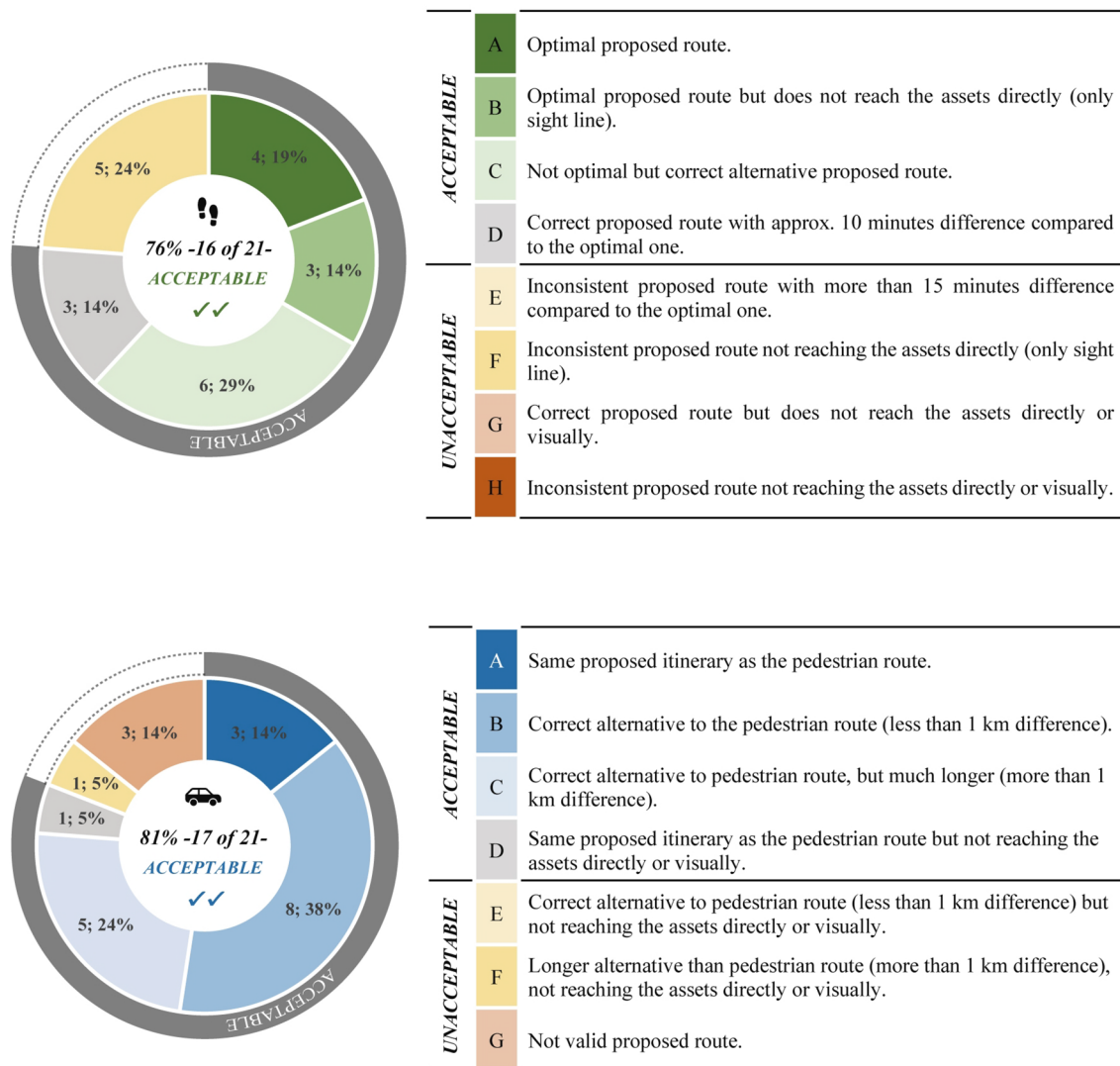


Fig. 11 Assessment results of the navigable network used in the web application. Evaluation of walking routes (top). Evaluation of routes by motorised transport (bottom)

‘VIDA-HTL Hub’ enables a comprehensive analysis of the application’s potential and of its areas for improvement, and even of how it contributes to redefining the social pact on territorial governance.

Concerning the potential of the application, it is demonstrated how the main functions of cultural heritage search and route calculation are integrated, thereby complementing other capabilities which are not jointly implemented in other similar proposals.

With a focus on the benefits of the web application, on the one hand, the function of searching for cultural assets promotes a greater knowledge of the architectural and archaeological heritage in the study area. This increased knowledge can foster an economy of culture

that contributes to local development. On the other hand, the route calculation function promotes slow tourism, an alternative to mass tourism which, in the case study, is concentrated in the city of Seville. Given the pressing problems arising from over-tourism and mass tourism, it is pertinent to explore feasible alternatives to that which is considered to be “normal” travel, characterised by its speed and intensity. One such alternative is slow tourism. This favours the valorisation and use of rural cultural heritage, which can lead to the strengthening of local economies and the reactivation of territories currently at risk.

While the web application can be a viable tool for the valorisation and use of architectural and archaeological

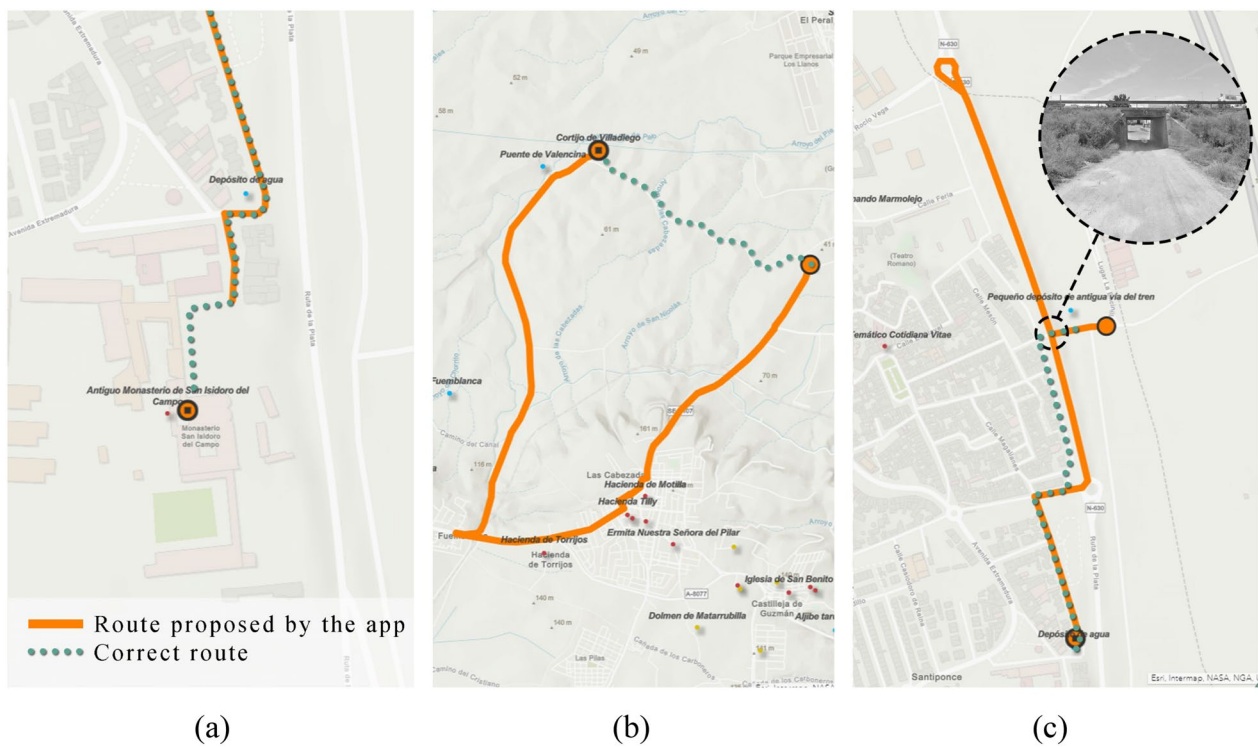


Fig. 12 Examples of errors detected in route calculation. **a** End of the itinerary not leading to the access of the asset accurately. **b** Existing road not considered in the calculation. **c** Intersection between different types of road not detected

heritage, its scope is limited. More general objectives, such as reactivating the most vulnerable territories or counteracting the strong polarisation between urban and rural areas, require coordinated strategies and consensus between actors as diverse as the Administration, technical experts, economic actors, social actors and citizens. In this sense, the promotion and development of applications such as VIDA-HTL can be part of these coordinated strategies, highlighting the impartial role of university institutions to assume the leadership of these initiatives. Moreover, in this first version, no weighting coefficients are applied to the routes. This reduces the possibilities to influence social behaviour and to orientate the use of the application towards more ambitious goals.

We concluded that a first point of improvement could be the prioritisation of routes in the territory by applying route weighting coefficients. This formula could be employed to encourage, for example, a greater use of those roads or paths which have historically articulated the territory. In this respect, it is assumed that visual accessibility to the landscape and, ultimately, the reactivation of the processes of territorial construction depends on the usage of these roads and paths.

An essential improvement of the application would also come from the continued enrichment of the developed 'VIDA-HTL Hub', since it would allow the inclusion of

new multimedia content associated with the heritage registers and the routes themselves (such as videos, images, and sounds). Such a substantial quantity of information on heritage assets included in a variety of formats would result in greater accessibility that would benefit end users (inhabitants and tourists), who would be able to select the most appropriate type of content according to their interests.

Lastly, potential lines of future research have been identified. The first line corresponds to the implementation of a protocol for the screening of cultural assets that are not collected in the repositories and databases by means of artificial intelligence. To do so, applications of deep learning for computer vision such as object detection or image segmentation can be suitable. This would give visibility to those assets that, despite their heritage value, have yet to be included in specialised repositories and databases. The second line corresponds to the inclusion in the web application of 3D models of the cultural assets and their surroundings, as part of the ULA-3 defined in this contribution. For this purpose, well-established 3D GIS modelling procedures based on the use of geographic data of different natures can be used. This would enable a deeper knowledge of the cultural assets from a more detailed perspective.

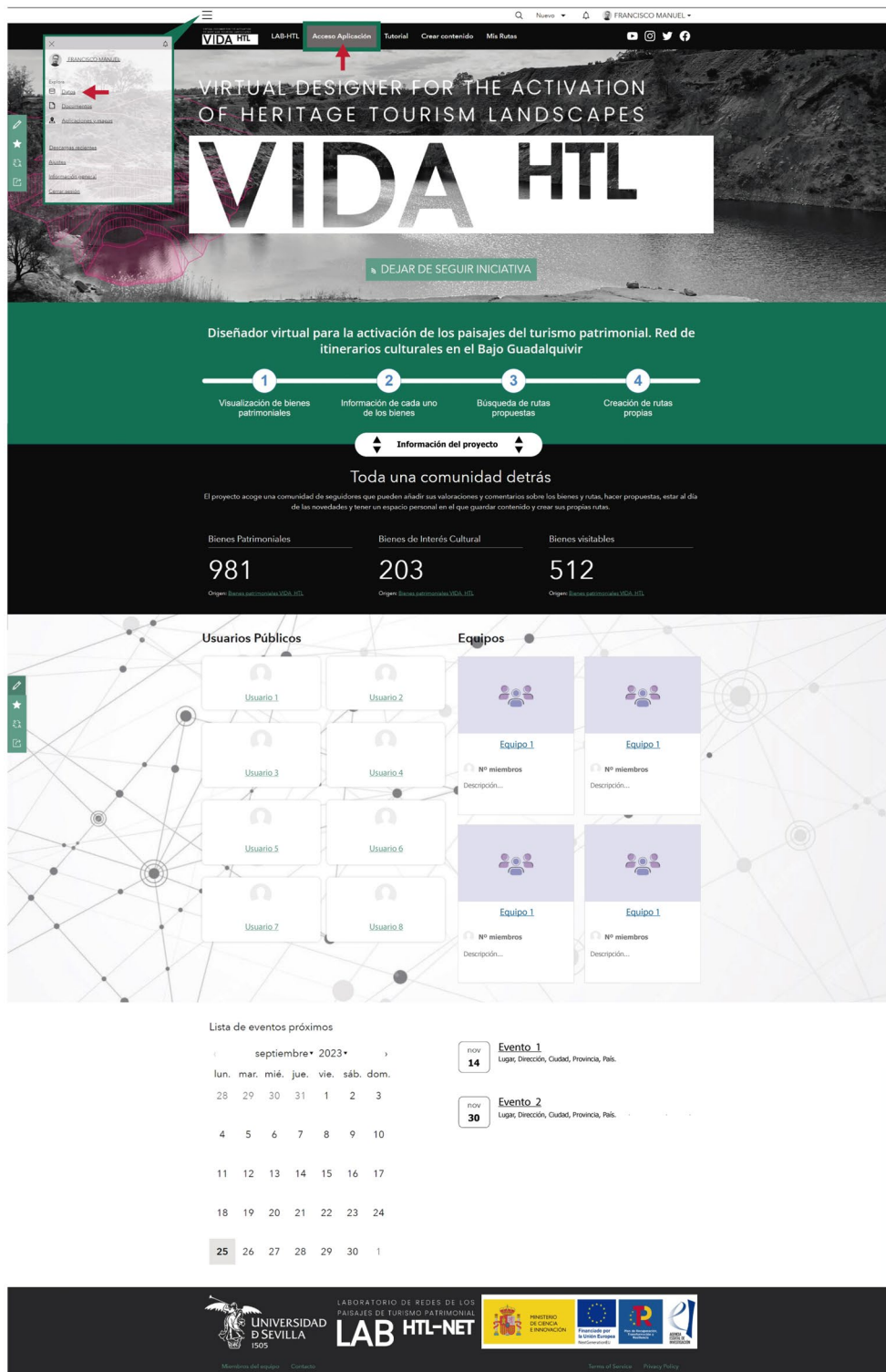


Fig. 13 VIDA-HTL Hub Homepage. Access to the web application and download of data outlined in the header

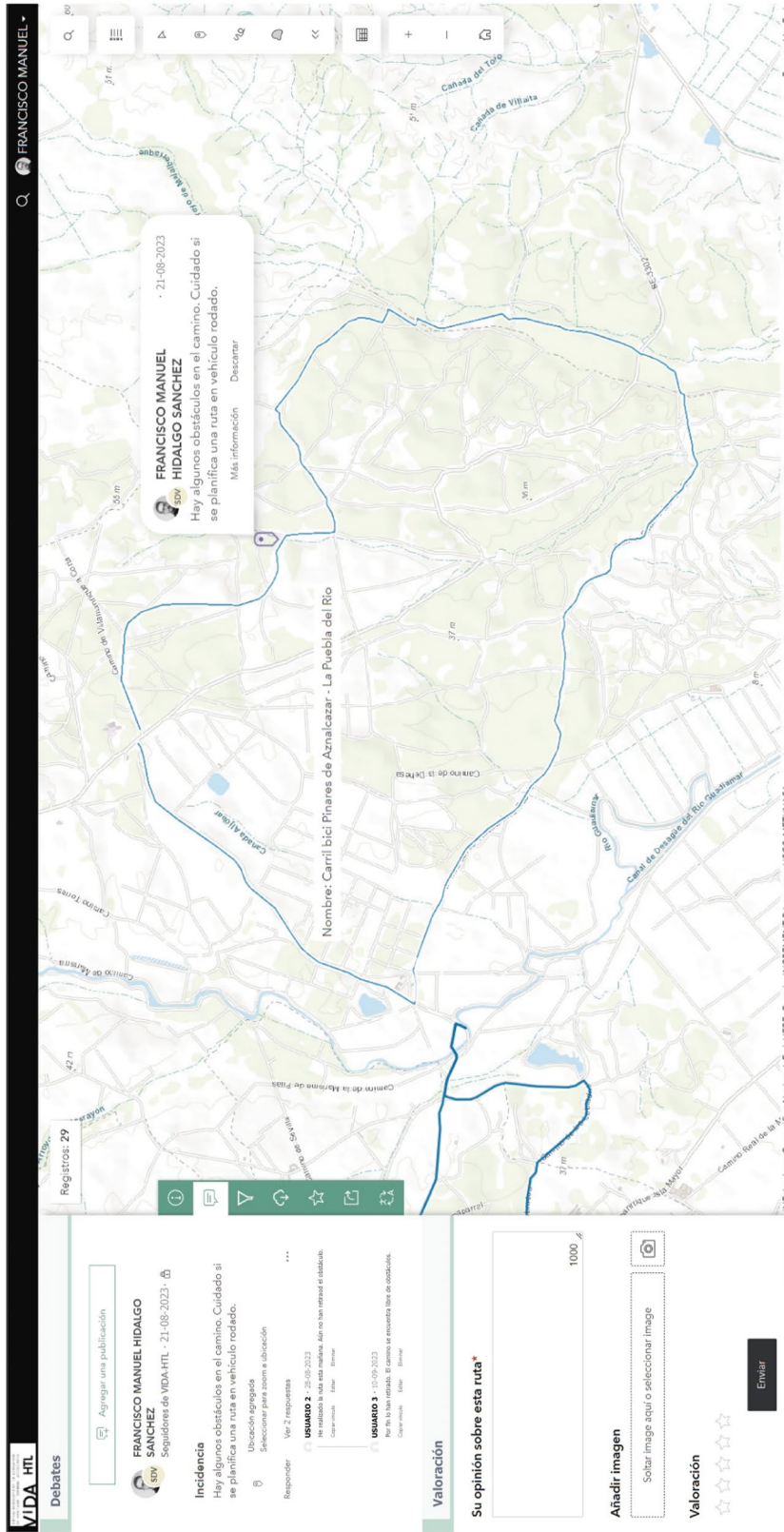


Fig. 14 Communication between users and assessment of spatial data in the VIDA-HTL Hub

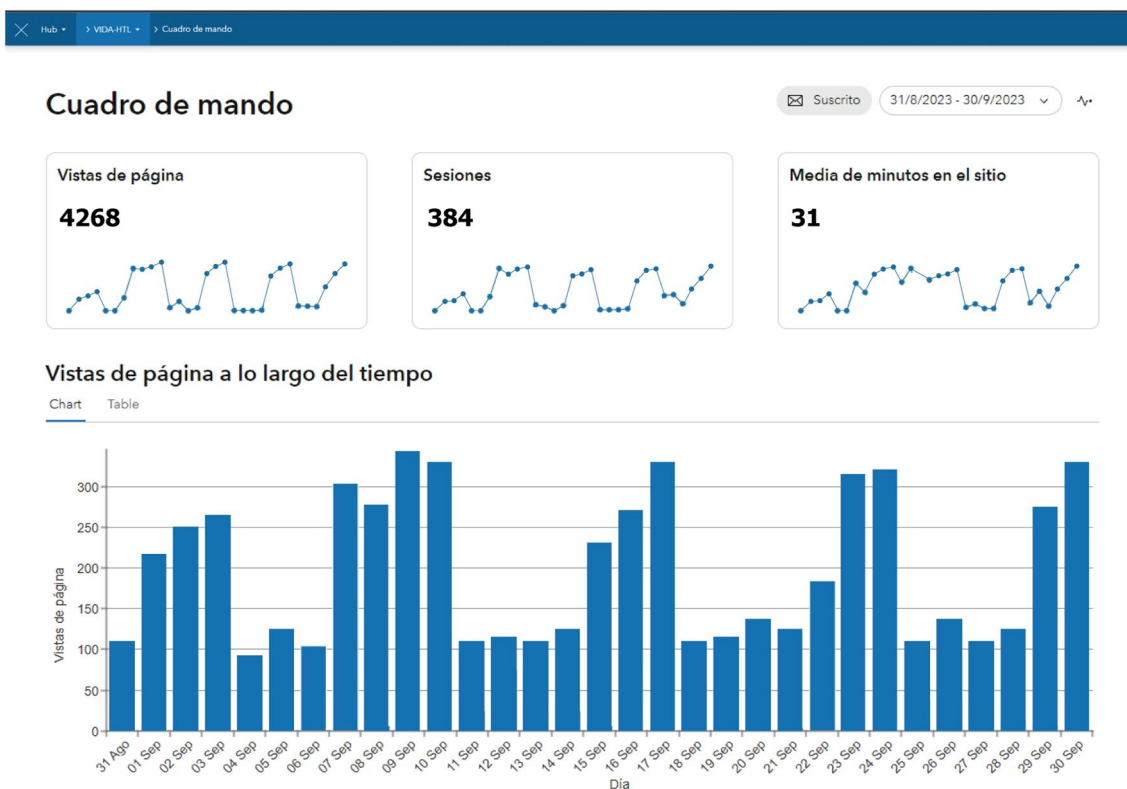


Fig. 15 Dashboard showing the evolution of user activity during a whole month

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s40494-024-01173-w>.

Additional file 1: Table S1. Environmental and Tourist Services included in the VIDA-HTL web application.

Additional file 2: Table S2. Widgets implemented in the VIDA-HTL web application.

Acknowledgements

This publication is part of the R&D project Multi-Scale Protocol for the Activation of the Heritage Tourism Landscapes PID2020-119437RB-I00 funded by MCIN/AEI/10.13039/501100011033. This publication is part of the R&D project Virtual Designer for the Activation of the Heritage Tourism Landscapes PDC2021-121563-I00 funded by MCIN/AEI/10.13039/501100011033 and by the "European Union NextGenerationEU/PRTR". The authors also gratefully acknowledge the financial support of the University of Seville via a pre-doctoral contract granted to Francisco M. Hidalgo-Sánchez (VIPIT-2020-IV-3). The authors also thank the Andalusian Historical Heritage Institute (IAPH) for providing the requested spatial data.

Author contributions

All the authors of this publication have collectively contributed to the development of the published version of this manuscript.

Funding

Grant PID2020-119437RB-I00 was funded by MCIN/AEI/10.13039/501100011033. Grant PDC2021-121563-I00 was funded by MCIN/AEI/10.13039/501100011033 and by the "European Union NextGenerationEU/PRTR". Grant VIPIT-2020-IV.3 was funded by the University of Seville.

Availability of data and materials

The datasets supporting the research conducted herein are included within the article. The access link to the VIDA-HTL Hub is: <https://vidahl-unisevilla.hub.arcgis.com/>.

Declarations

Competing interests

The authors declare there to be no potential conflict of interest.

Author details

¹Departamento de Construcciones Arquitectónicas II, Escuela Técnica Superior de Ingeniería de la Edificación, Universidad de Sevilla, Avenida Reina Mercedes, 4A, 41012 Seville, Spain. ²Departamento de Teoría de la Arquitectura y Proyectos Arquitectónicos, Escuela Técnica Superior de Arquitectura, Universidad de Valladolid, Avenida Salamanca, 18, 47014 Valladolid, Spain. ³Departamento de Estructuras de Edificación e Ingeniería del Terreno, Escuela Técnica Superior de Arquitectura, Universidad de Sevilla, Avenida Reina Mercedes, 2, 41012 Seville, Spain. ⁴Departamento de Expresión Gráfica Arquitectónica, Escuela Técnica Superior de Arquitectura, Universidad de Sevilla, Avenida Reina Mercedes, 2, 41012 Seville, Spain. ⁵Departamento de Proyectos Arquitectónicos, Escuela Técnica Superior de Arquitectura, Universidad de Sevilla, Avenida Reina Mercedes, 2, 41012 Seville, Spain. ⁶Instituto Universitario de Arquitectura y Ciencias de la Construcción (IUACC), Universidad de Sevilla, Avenida Reina Mercedes, 2, 41012 Seville, Spain.

Received: 9 October 2023 Accepted: 7 February 2024

Published online: 16 February 2024

References

- Ray C. Culture economies: a perspective on local development in Europe. Newcastle: Centre for Rural Economy; 2001.
- Pieraccini M, Guidi G, Atzeni C. 3D digitizing of cultural heritage. *J Cult Herit*. 2001;2(1):63–70. [https://doi.org/10.1016/S1296-2074\(01\)01108-6](https://doi.org/10.1016/S1296-2074(01)01108-6).
- Perrin L, Beauvais N, Puppo M. Procedural landscape modeling with geographic information: the IMAGIS approach. *Landsc Urban Plan*. 2001;54(1–4):33–47. [https://doi.org/10.1016/S0169-2046\(01\)00124-4](https://doi.org/10.1016/S0169-2046(01)00124-4).
- Pavlidis G, Koutsoudis A, Arnaoutoglou F, Tsioukas V, Chamzas C. Methods for 3D digitization of cultural heritage. *J Cult Herit*. 2007;8(1):93–8. <https://doi.org/10.1016/j.culher.2006.10.007>.
- Wheatley D, Gillings M. Spatial technology and archaeology: the archaeological applications of GIS. London: CRC Press; 2002.
- Chapman H. Landscape archaeology and GIS. Stroud: Tempus; 2006.
- Hidalgo-Sánchez FM, Carrascal-Pérez MF, Rey-Pérez J, Plaza C, Mascort-Albea EJ. Cultural heritage, sustainability, conservation, and social welfare. A management plan for the historic municipal buildings of Seville (Andalusia, Spain). *Hist Environ Policy Pract*. 2022;13(4):426–58. <https://doi.org/10.1080/17567505.2022.2146332>.
- Campanaro DM, Landeschi G, Dell'Unto N, Leander Touati AM. 3D GIS for cultural heritage restoration: a 'white box' workflow. *J Cult Herit*. 2016;18:321–32. <https://doi.org/10.1016/j.culher.2015.09.006>.
- Ferreira A, Liberato P, Liberato D, Rocha Á. Information and communication technologies in creative and sustainable tourism. In: Advances in intelligent systems and computing. Cham: Springer; 2019. p. 91–100.
- Xiang Z, Fuchs M, Gretzel U, Höpken W. Handbook of e-tourism. Cham: Springer; 2020.
- Pepe M, Costantino D, Alfio VS, Restuccia AG, Papalino NM. Scan to BIM for the digital management and representation in 3D GIS environment of cultural heritage site. *J Cult Herit*. 2021;50:115–25. <https://doi.org/10.1016/j.culher.2021.05.006>.
- Hidalgo-Sánchez FM, Mascort-Albea EJ, Kada M, Romero-Hernández R, Canivell J, López-Larrinaga F. 3D GIS semi-automatized modelling procedure for the conservation of the PHiM: heritage municipal buildings of Seville (Spain). A new dimension for urban cultural data management. *J Comput Cult Herit*. 2022;15(1):1–25. <https://doi.org/10.1145/3467976>.
- Ferreira-Lopes P. Achieving the state of research pertaining to GIS applications for cultural heritage by a systematic literature review. *Int Arch Photogramm Remote Sens Spat Inf Sci*. 2018;XLII-4(4):169–75. <https://doi.org/10.5194/isprs-archives-XLII-4-169-2018>.
- Szepesi J, Ésik Z, Soós I, Németh B, Sütő L, Novák TJ, et al. Identification of geoheritage elements in a cultural landscape: a case study from Tokaj Mts, Hungary. *Geoheritage*. 2020;12(4):89. <https://doi.org/10.1007/s12371-020-00516-w>.
- Spanò A, Sammartano G, Calcagno Tunin F, Cerise S, Possi G. GIS-based detection of terraced landscape heritage: comparative tests using regional DEMs and UAV data. *Appl Geomat*. 2018;10(2):77–97. <https://doi.org/10.1007/S12518-018-0205-7/FIGURES/26>.
- Zhang J, Sun H, Xu S, Aoki N. Analysis of the spatial and temporal distribution and reuse of urban industrial heritage: the case of Tianjin, China. *Land*. 2022;11(12):2273. <https://doi.org/10.3390/land11122273>.
- Amici V, Maccherini S, Santi E, Torri D, Vergari F, Del Monte M. Long-term patterns of change in a vanishing cultural landscape: a GIS-based assessment. *Eco Inform*. 2017;37:38–51. <https://doi.org/10.1016/j.ecoinf.2016.11.008>.
- Zhu L, Li Z, Su H, Wang X. Temporal and spatial distribution of ancient sites in Shaanxi Province using geographic information systems (GIS). *Herit Sci*. 2021;9(1):121. <https://doi.org/10.1186/s40494-021-00598-x>.
- López Sánchez M, Linares Gómez Del Pulgar M, Tejedor Cabrera A. Historic construction of diffuse cultural landscapes: towards a GIS-based method for mapping the interlinkages of heritage. *Landsc Res*. 2021;46(7):916–31. <https://doi.org/10.1080/01426397.2021.1921717>.
- Cuca B, Agapiou A. Impact of land-use change and soil erosion on cultural landscapes: the case of cultural paths and sites in Paphos district. *Cyprus Appl Geomat*. 2018;10(4):515–27. <https://doi.org/10.1007/S12518-018-0237-Z/FIGURES/11>.
- Krejci L, Kolejka J, Vozenilek V, Machar I. Application of GIS to empirical windthrow risk model in mountain forested landscapes. *Forests*. 2018;9(2):96. <https://doi.org/10.3390/f9020096>.
- Rey-Pérez J, Domínguez-Ruiz V. Multidisciplinarity, citizen participation and geographic information system, cross-cutting strategies for sustainable development in rural heritage. The case study of Valverde de Burguillos (Spain). *Sustainability*. 2020;12(22):9628. <https://doi.org/10.3390/su12229628>.
- Álvarez Larrain A, McCall MK. Participatory mapping and participatory GIS for historical and archaeological landscape studies: a critical review. *J Archaeol Method Theory*. 2019;26(2):643–78. <https://doi.org/10.1007/S10816-018-9385-Z/FIGURES/8>.
- Dayoub B, Yang P, Dayoub A, Omran S, Li H. The role of cultural routes in sustainable tourism development: a case study of Syria's spiritual route. *Int J Sustain Dev Plan*. 2020;15(6):865–74. <https://doi.org/10.18280/ijstdp.150610>.
- Fistola R, La Rocca RA. Slow mobility and cultural tourism. Walking on historical paths. In: Green energy and technology. Sharjah: Bentham Science Publishers; 2018. p. 301–22. https://doi.org/10.1007/978-3-319-77682-8_18/COVER.
- Quattrone M, Tomaselli G, Riguccio L, Russo P. Assessment of the territorial suitability for the creation of the greenways networks: methodological application in the Sicilian landscape context. *J Agric Eng*. 2017;48(4):209–22. <https://doi.org/10.4081/jae.2017.696>.
- Scandiffio A. Parametric definition of slow tourism itineraries for experiencing seasonal landscapes. Application of Sentinel-2 imagery to the rural paddy-rice landscape in northern Italy. *Sustainability*. 2021;13(23):13155. <https://doi.org/10.3390/su132313155>.
- Rolando A, Scandiffio A. Multimodal access to minor places in heritage-rich landscapes: GIS mapping to define slow-tourism routes from the stations in the railway networks in-between Turin and Milan. *Sustainability*. 2022;14(23):15723. <https://doi.org/10.3390/su142315723>.
- Quattrone M, Tomaselli G, D'Emilio A, Russo P. Analysis and evaluation of abandoned railways aimed at greenway conversion: a methodological application in the Sicilian landscape using multi-criteria analysis and geographical information system. *J Agric Eng*. 2018;49(3):151–63. <https://doi.org/10.4081/jae.2018.744>.
- Scandiffio A. Mapping spatial quality of slow routes with a GIS-based method a comparative assessment of alternative routes. *Int Arch Photogramm Remote Sens Spat Inf Sci*. 2019;XLII-2/W15(2/W15):1071–6. <https://doi.org/10.5194/isprs-archives-XLII-2-W15-1071-2019>.
- Pareja-Pareja G, Martínez-Ibarra E. Revisión bibliográfica internacional sobre el patrimonio geológico [International bibliographic review on geological heritage]. *Investigaciones Geográficas*. 2023;2023(79):67. <https://doi.org/10.14198/INGEO.22558>. (in Spanish).
- Ballesteros D, Caldevilla P, Vila R, Barros XC, Rodríguez-Rodríguez L, García-Ávila M, et al. A GIS-supported multidisciplinary database for the management of UNESCO global Geoparks: the Courel Mountains Geopark (Spain). *Geoheritage*. 2022;14(2):41. <https://doi.org/10.1007/s12371-022-00654-3>.
- Sieng KT, Eboy OV, Pugh-Kitingan J, Bee BBB, Bagul AHBP, Baco Z. Megalithic stone heritage trail mapping using GIS as tourism product for cultural sustainability in Tambunan. *Sustainability*. 2023;15(4):3714. <https://doi.org/10.3390/su15043714>.
- Karadeniz E, Er S, Boyraz Z, Coşkun S. Evaluation of potential geotourism of Levent Valley and its surroundings using GIS route analysis. *Geoheritage*. 2022;14(2):77. <https://doi.org/10.1007/s12371-022-00710-y>.
- Ruiz-Jaramillo J, García-Pulido LJ, Montiel-Vega L, Muñoz-González CM, Joyanes-Díaz MD. The potential of defensive architectural heritage as a resource for proposing cultural itineraries. *J Cult Herit Manag Sustain Dev*. 2023;13(2):288–316. <https://doi.org/10.1108/JCHMSD-01-2021-0007>.
- Ottomano Palmisano G, Govindan K, Loisi RV, Dal Sasso P, Roma R. Greenways for rural sustainable development: an integration between geographic information systems and group analytic hierarchy process. *Land Use Policy*. 2016;50:429–40. <https://doi.org/10.1016/j.landusepol.2015.10.016>.
- Rovelli R, Senes G, Fumagalli N, Sacco J, De Montis A. From railways to greenways: a complex index for supporting policymaking and planning. A case study in Piedmont (Italy). *Land Use Policy*. 2020;99: 104835. <https://doi.org/10.1016/j.landusepol.2020.104835>.
- Sang K, Fontana GL, Piovan SE. Assessing railway landscape by AHP process with GIS: a study of the Yunnan-Vietnam railway. *Remote Sens*. 2022;14(3):603. <https://doi.org/10.3390/rs14030603>.
- Costantino D, Angelini MG, Alfio VS, Claveri M, Settembrini F. Implementation of a system WebGIS open-source for the protection and sustainable

- management of rural heritage. *Appl Geomat.* 2020;12(1):41–54. <https://doi.org/10.1007/s12518-019-00275-6>.
40. Ruiz R, Moyano A, García-Duque MR, Hernández-Lamas P. Strategies for the correct contextualisation and management of drove roads in urban historic landscapes. *Landsc Res.* 2020;45(7):854–72. <https://doi.org/10.1080/01426397.2020.1778660>.
 41. Panagiotidis VV, Malaperdas G, Palamara E, Valantou V, Zacharias N. Information technology, smart devices and augmented reality applications for cultural heritage enhancement: The Kalamata 1821 project. In: *Communications in computer and information science*. Berlin: Springer; 2019. p. 222–31. https://doi.org/10.1007/978-3-030-12957-6_15.
 42. Cillis G, Statuto D. Landscape protection and tourist valorisation of the cultural and natural heritage of the unesco site of Matera (Italy). In: *Public recreation and landscape protection—with nature hand in hand? Conference proceeding 2018*. Mendel University in Brno; 2018. p. 226–31.
 43. Cai Z, Fang C, Zhang Q, Chen F. Joint development of cultural heritage protection and tourism: the case of Mount Lushan cultural landscape heritage site. *Herit Sci.* 2021;9(1):86. <https://doi.org/10.1186/s40494-021-00558-5>.
 44. Pietroni E. Virtual museums for landscape valorization and communication. *Int Arch Photogramm Remote Sens Spat Inf Sci.* 2017;XLIII-2/W5(2W5):575–82. <https://doi.org/10.5194/isprs-archives-XLIII-2-W5-575-2017>.
 45. Loren-Méndez M, Mata-Olmo R, Ruiz R, Pinzón-Ayala D. An interdisciplinary methodology for the characterization and visualization of the heritage of roadway corridors. *Geogr Rev.* 2016;106(4):489–515. <https://doi.org/10.1111/j.1931-0846.2016.12203.x>.
 46. Merino Del Río R. Criteria for designing cultural itineraries as a strategy for restoring the dynamics of cultural landscape formation. Some research notes about the case study of Itálica. *Ri-Vista.* 2020;18(1):238–63. <https://doi.org/10.13128/RV-8093>.
 47. Merino del Río R. *Proyectar el paisaje desde el patrimonio territorial: criterios para un diseño de itinerarios culturales y aplicación al área de influencia de Itálica* [Projecting the landscape from the territorial heritage: criteria for the design of cultural itineraries and application to the area of influence of Itálica]. Universidad de Sevilla, Università degli Studi di Firenze; 2021. **(in Spanish)**.
 48. Merino del Río R. Connecting the archaeological site of Itálica (Spain) to its landscape: a three-step method to unveil and enhance landscape values through the design of cultural routes. *Landscapes.* 2021;22(2):123–46. <https://doi.org/10.1080/14662035.2021.1969792>.
 49. López Sánchez M, Linares Gómez del Pulgar M, Tejedor Cabrera A. Acknowledging heritage through the landscape: towards a networked interpretation of the historical context of the territory. *Disegnarecon.* 2021;14(26):10.1-10.17. <https://doi.org/10.20365/disegnarecon.26.2021.10>.
 50. Tejedor Cabrera A, Linares Gómez del Pulgar M, López Sánchez M, Merino del Río R, (coord.). *Innovación para la gestión integrada del patrimonio, el paisaje y el turismo* [Innovation for the comprehensive management of heritage, landscape and tourism]. Editorial Universidad de Sevilla (EUS) y Ediciones Universidad de Valladolid (EUVA), editor. Sevilla, Valladolid; 2020. p. 428. **(in Spanish)**.
 51. Merino del Río R, Linares Gómez del Pulgar M, Tejedor Cabrera A. Analysis of the territorialisation processes in the lower Guadalquivir through historical cartography. *EGA Revista de Expresión Gráfica Arquitectónica.* 2021;26(41):102. <https://doi.org/10.4995/ega.2021.14255>.
 52. Geertz C. *Mondo globale, mondi locali* [Global world, local worlds]. Bologna: Il Mulino; 1999. p. 136 **(in Italian)**.
 53. Giddens A. *Europe in the global age*. Cambridge: Polity Press; 2007. p. 246.
 54. Górgolas Martín P. Seville in the face of the metropolitan challenge: from institutional failure to territorial commodification. In: *Reciprociudad design diplomacy in Seville*. *Recolectores Urbanos* Editorial; 2021. p. 203–34.
 55. Sanchez Fuentes D, Mascort-Albea EJ, Del Espino Hidalgo B, Hidalgo-Sánchez FM, Gutiérrez MA. Spatial data for the design of critical cartographies in the metropolitan area of Seville (Spain). In: *Reciprociudad: design diplomacy in Seville*. Sevilla: *Recolectores Urbanos*; 2021. p. 251–64.
 56. Poli D. The representation process of local heritage for territorial projects. In: *Bioregional planning and design, vol. II*. Cham: Springer International Publishing; 2020. p. 51–79. https://doi.org/10.1007/978-3-030-46083-9_4.
 57. Sanchez Fuentes D, Mascort-Albea EJ. Metropolitan metabolism: the ecological footprint. In: *Contin A, Giordano P, Nacke M, editors. Training for education, learning and leadership towards a new metropolitan discipline* Inaugural book. Buenos Aires: CIPPEC; 2021. p. 41–6.
 58. Fernández Cacho S, Sáenz de la Cuesta H. Landscape laboratory of the Andalusian institute of historical heritage: actions and achievements for the implementation of the European landscape convention. In: *Strasbourg: Council of Europe, editor. National conference for the implementation of the European Landscape convention of the council of Europe*; 2018. p. 35–44.
 59. Fernández Cacho S, Carrera Díaz G, Ortiz LL. Open information on Andalusian cultural heritage. In: *Villa D, editor. Open data for cultural heritage: place based digital humanities between representation, design and innovation*. Roma-Milano: Planum Publisher; 2017. p. 31–40.
 60. Junta de Andalucía. *Balance del año turístico en Andalucía. Año 2021* [Assessment of the tourism year in Andalusia. Year 2021]. Sevilla; 2021. **(in Spanish)**.
 61. Héder M. From NASA to EU: the evolution of the TRL scale in public sector innovation. *Innov J.* 2017;22(2):1–23.
 62. Huang TW, Lin DL, Lin Y, Lin CX. Taskflow: a general-purpose parallel and heterogeneous task programming system. *IEEE Trans Comput Aided Des Integr Circuits Syst.* 2022;41(5):1448–52. <https://doi.org/10.1109/TCAD.2021.3082507>.
 63. Huang TW, Lin DL, Lin CX, Lin Y. Taskflow: a lightweight parallel and heterogeneous task graph computing system. *IEEE Trans Parallel Distrib Syst.* 2022;33(6):1303–20. <https://doi.org/10.1109/TPDS.2021.3104255>.
 64. Sundaramoorthy S. *UML diagramming: a case study approach*. Boca Raton: CRC Press; 2022.
 65. Scott B. *Designing web interfaces: principles and patterns for rich interactions*. Sebastopol: O'Reilly Media; 2009.
 66. Sharp H. *Interaction design: beyond human-computer interaction*. Indianapolis: Wiley; 2019.
 67. Tidwell J, Brewer C, Valencia A. *Designing interfaces: patterns for effective interaction design*. Sebastopol: O'Reilly Media; 2020.
 68. *Guía de Arquitectura Contemporánea* [Contemporary architecture guide]. <https://c.guide/>. Accessed 5 Sept 2023. **(in Spanish)**.
 69. *Camino de Hierro - un lugar para el disfrute* [The iron path—a place for enjoyment]. <https://www.caminodehierro.es/>. Accessed 5 Sept 2023. **(in Spanish)**.
 70. *Buscador de espacios naturales y equipamientos - ventana del visitante* [Search engine for natural areas and facilities—visitor's portal]. <https://www.juntadeandalucia.es/medioambiente/portal/web/ventanadelvisitante/buscador-de-espacios-naturales-y-equipamientos?categoryVal=>. Accessed 5 Sept 2023. **(in Spanish)**.
 71. Fundación Docomomo Ibérico. *Mapas e itinerarios* [Docomomo Iberico Foundation. Maps and itineraries]. <https://docomomoiberico.com/mapas/>. Accessed 5 Sept 2023. **(in Spanish)**.
 72. Junta de Andalucía. *Guía Digital del Patrimonio Cultural de Andalucía* [Digital guide of the cultural heritage of Andalusia]. 2012. <https://guiaidigital.iaph.es/inicio>. Accessed 18 Sept 2023. **(in Spanish)**.
 73. *Arquitectura Catalana* [Catalan architecture]. <https://www.arquitecturacatalana.cat/es>. Accessed 5 Sept 2023. **(in Spanish)**.
 74. *Caminos vivos de Sevilla* [Living paths of Sevilla]. <http://www.caminosvivos.com/>. Accessed 5 Sept 2023. **(in Spanish)**.
 75. Wikiloc | *Rutas del Mundo* [World routes]. <https://es.wikiloc.com/>. Accessed 5 Sept 2023. **(in Spanish)**.
 76. Fundación de los Ferrocarriles Españoles. *Gerencia de Vías Verdes y Medio Ambiente. Itinerarios de las Vías Verdes de España* [Itineraries of the greenways of Spain]. <https://www.viasverdes.com/itinerarios/principal.asp>. Accessed 5 Sept 2023. **(in Spanish)**.
 77. *Secretariato Regionale per L'Emilia-Romagna. Tourer.it* [Tourer]. <https://www.tourer.it/>. Accessed 5 Sept 2023. **(in Italian)**.
 78. Potsiou C, Ioannidis C, Soile S, Maria BA, Chliverou R, Apostolopoulos K, et al. Geospatial tool development for the management of historical hiking trails—the case of the holy site of Meteora. *Land.* 2023;12(8):1530. <https://doi.org/10.3390/land12081530>.
 79. Hidalgo-Sánchez FM, Torres-González M, Mascort-Albea EJ, Canivell J, Romero-Hernández R, Martín-del-Río JJ. NDT spatial data integration for monumental buildings: technical information management for the Royal Alcazar of Seville. *Build Res Inf.* 2023;51(6):625–47. <https://doi.org/10.1080/09613218.2022.2162476>.

80. Bartha G, Kocsis S. Standardization of geographic data: the European inspire directive. *Eur J Geogr.* 2011;2(2):79–89.
81. Junta de Andalucía. Tesouro de Patrimonio Histórico Andaluz [Thesaurus of the Andalusian Historical Heritage]. Sevilla: Instituto Andaluz del Patrimonio Histórico; 1998. (Colección Digital de Bellas Artes). **(in Spanish)**.
82. The art & architecture thesaurus online (AAT). Los Angeles: Getty Research Institute; 2017. (Colección Digital de Bellas Artes).
83. Consejería de Medio Ambiente. Junta de Andalucía. Mapa de Paisajes de Andalucía [Map of Andalusian landscapes]. 2004. https://www.junta.deandalucia.es/medioambiente/portal/landing-page-mapa/-/asset_publisher/wO880PprC6q7/content/mapa-de-paisajes-de-andaluc-c3-ada-1/20151. Accessed 10 Sept 2023. **(in Spanish)**.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.