

Article

A sustainable approach to tourist signage on (historical) trails

Firstname Lastname^{1,t,‡}, Firstname Lastname^{2,‡} and Firstname Lastname^{2,*}

¹ Affiliation 1; e-mail@e-mail.com

² Affiliation 2; e-mail@e-mail.com

* Correspondence: e-mail@e-mail.com; Tel.: (optional; include country code; if there are multiple corresponding authors, add author initials) +xxx-xxxx-xxx-xxxx (F.L.)

† Current address: Affiliation 3.

‡ These authors contributed equally to this work.

Abstract: Guiding the visitor to appreciate all the attractions of a region is paramount for building a memorable experience. In the literature, we find many articles exploring the use of sophisticated technologies towards such a goal. The case of wilderness resources exhibits a peculiar aspect, since the presence of human artifacts and the signage may damage the experience, and introduce pollutants as well. In this paper, we consider the case of a natural trail targeted to niche tourism to understand the available options for signage aiming to provide directions, guide the exploration, and warn about dangers. The footprints of the various options are evaluated, and we describe the outcomes of an experimental setup implemented to verify the applicability of our approach.

Keywords: keyword 1; keyword 2; keyword 3 (List three to ten pertinent keywords specific to the article; yet reasonably common within the subject discipline.)

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1. Introduction

Although an official decision is still pending, there is a widely agreed proposal for the naming of the time that we are living as the Anthropocene. Behind this proposal is the

recognition that humans have the potential to significantly alter the environment in which they live on a global scale.

The problem with the above fact is that we humans are not able to understand long-term consequences of deploying such a potential, nor even to keep it under control. Even worse, such capacities are often used with the aim of short-term local effects, ignoring long-term global ones, with the risk of long-term global deterioration. This attitude pervades all activities, starting with the most basic ones such as the supply of food and homes, and is often influenced by economic profit.

Leisure activities play an important role in bringing profit to niche businesses. This creates a reinforcing effect that follows the negative dynamics seen above: a leisure activity that is neutral in itself (e.g., skydiving) can have a significant impact due to induced effects (lifts) that strengthen the success of the activity (easier to practice) bringing more investment and impact. Unlike the beneficial effects, which are usually well localized, the negative impact has a very broad spectrum that includes environmental, social, and economic sectors, as discussed by Patthey in [1].

To manage this situation, international agencies promote the keyword "sustainability" as a guideline for the conservation of our habitat. Jeffry Ramsey et al. [2] consider the concept behind this word as "vague and disputed but not meaningless" and that cannot be used without a concrete framework, especially in a normative context. To solve the problem of measuring sustainability, Tom Kuhlman et al. [3] point out an inherent tension in the term between growth and stability. This tension has been attenuated by a change in the meaning of the word, which has gone from focusing on preservation for an indefinite future to a concept that includes three "pillars", society, economy, and environment, as determinants that need to be protected in the present to promote sustainable development in the future. The authors relate artificial and environmental goods, discriminating the two cases where a loss in the latter can or cannot be compensated by an increase in the former, introducing the terms of *weak* and *strong* sustainability.

The promotion of human cultural heritage is situated in such a complex scenario. As noted by Jorge Otero in [4], local communities benefit from the promotion of heritage: conservation activity generates social growth, while tourism provides an extra income that can be reinvested in promotion. However, just as in the case of ski resorts, there is a risk of compromising the resource itself. This interaction raises a question of sustainability also for cultural conservation initiatives, two issues that are usually considered in synergy. As in the document "World Heritage and Sustainable Development" of UNESCO, which calls for actions that "harness the potential of World Heritage properties and heritage in general, to contribute to sustainable development".

This research stems from such a painful contradiction in trying to answer the question: is there a way to unlock the potential of a cultural resource while at the same time limiting the damage to a social, economic, and environmental equilibrium?

The question arises in the course of a project funded by the Italian Ministry of Research aimed at applying cutting-edge technologies to the investigation of karst caves that may have been inhabited in the past, from prehistory to today. Among the expected results of the project is the definition of a strategy to disseminate the results of the research and allow non-specialists to visit and enjoy the results, thus contributing to the economy of rural areas that are severely exposed to de-population. A sustainable strategy is even more crucial as the geological environment of interest is particularly fragile, as noted by Aleksander Antic et al. in [5].

This document provides a conceptual solution for a specific aspect. The solution is conceptual in that it tries to follow a guideline that takes into account as much detail as possible in a way that can be used in other environments but is very practical in its application. Given the closely interlinked nature of the situation, we observe how a very specific aspect, tourist signage, exhibits effects on society, the economy, and the environment.



(a) CAI mark on a tree



(b) A direction sign

Figure 1. Signs frequently found on trails in Italy

2. Unlocking site potentials through signage

The signage used to guide and inform the visitor is of paramount importance and must be carefully designed to accomplish its functions while following the guidelines of a sustainable approach.

The functions of signage are twofold

- an effective signage must guide the tourist across the resort. A map represents a starting point to this end, but not all visitors feel comfortable reading a map. The ideal signage should include visible reference points and explicit actions, like "turn right after crossing the stream". A good example of such signage is the one used by the Italian Alpine Club (CAI), consisting of colored stripes marked on tree bark (see figure 1a). The marks are placed in such a way that standing near one of them, the hiker can spot the successive on the trail
- a sign should explain the reasons for interest in a site. This includes featuring the site where the sign is installed, but also other nearby points of interest that invite the visitor to continue the visit (see figure 1b). In this sense, the CAI signal above is not useful. A simple board with a site name may be sufficient only when the site is sufficiently popular. Otherwise, a more structured message should be used to explain the reasons why the feature is regarded as relevant.

In our study, we consider a range of solutions that help towards sustainable support to sustainable tourism, specifically to the dynamic provision of information during a visit along a natural trail, not covered by Internet connectivity (a *dead zone* using the term used by Pearce and Gretzel [6]). We consider the presence of two stakeholders for the signage itself [7]: the hosting organization (the *host* for short) which implements a signing installation, and the visitor (or *user*) which extracts useful and enjoyable information from signing devices.

The purpose of such an installation is guiding the *user* on a tour that includes urban streets, buildings, natural trails, and caves (this latter being the topic of the project giving financial support to our research). The task of the *host* organization is to provide the *user* with all sorts of information that may guide him across the visit, making it as profitable and enjoyable as possible. A traditional approach makes use of physical information boards with graphical or textual content, as in figure 1.

Our study starts by pointing out the issues related to such a solution:

- dimensions: the board must be sufficiently large to contain the desired content, taking into account its readability from a distance
- installation logistics: depending on the location, the transportation and placement of a plaque may require a basement or other sorts of supports

- environmental impact: to be effective, the plaque has to be prominent, and this may negatively affect the quality of the site 121
- accessibility for the visually impaired: the plaque is not useful for visually impaired persons 122
- accessibility for stranger visitors: to limit the size of the plaque, the number of translations must be limited as well 123
- update limits: to update the content, the plaque must be replaced 124
- removal logistics: when the board degrades it must be either removed or replaced, which entails waste disposal together with other issues similar to those found during the installation 125

Such considerations motivate an interest in an alternative way of communication. 131

2.1. Technology to minimize intrusion 132

We characterize the problem as an instance of *weak sustainability*: we do not preclude intervention in the environment, but the impact of such intervention must be better than that related to traditional signs. To this end, we include in our solution tools that are not part of the site but remain with the user. 133

During the last decades, we witnessed the diffusion of smartphone devices, and we have no reason to expect a change in such a trend. Smartphones empower individual communication capabilities, allowing them to receive sound, visual, and tactile interactions. The relevance of such capabilities for the improvement of a tourist experience has been widely investigated, either in urban environments [8] or in a rural milieu [9] to find ways to exploit such tools. Again, we start from the limits of such technology, especially in the case of outdoor activities. 137

One is that smartphones although widely available, are not equally familiar to everybody. This is related to *usability*, with a term borrowed from P. Wan in [7]. The second is that several functions depend on the provision of enabling services: for instance, their networking capability is useless if the device cannot reach the Internet. So the *applicability limits* of a solution need to be defined. 144

Starting from the two aspects above we envision the guidelines for a successful smartphone-based strategy, keeping in mind its sustainability. 149

Regarding *usability*, the basic recommendation is to keep the operation as simple as possible, within the experience of the majority of users, without requiring the need to familiarize themselves with new applications. 151

The definition of its *applicability limits* is more complex, especially for outdoor activities. In such cases, the provision of a networking infrastructure incurs a severe environmental impact. Consider the installation of antennas to cover a wide area and the power supply for the radios. 154

2.2. Related works 158

The research literature marginally covers the utilization of smartphones for tourist signage purposes. 159

An exhaustive solution is described by P. Liu in [8], which details an infrastructure that guides the visitors inside an urban milieu. In that case, the presence of pervasive networking facilities is a cornerstone for the whole architecture, which deeply depends on Internet connectivity. 161

Wan [7] evaluates the quality of signage, without referring to a specific technology, but with many examples showing physical boards, using as a formal reference the Universal Design Principles [10]. 165

The number of research papers explodes when we extend the range to articles investigating smartphones' impact on tourism. The *smart tourism* topic is very popular, and covered by several review papers that provide a framework to the vast literature. 168

A popular research direction covers the social aspects related to the use of the smartphone. W. Tan [11] covers all aspects of a touristic experience related to the smartphone, 171

from the definition of travel destination to assistance during the visit. Much attention is dedicated to the network of connections that is established thanks to the smartphone, which, again, is considered on the Internet. Such an assumption is in contrast with the title, which indicates a nature-based destination, where notably the Internet is not always reachable.

On the other hand, roaming in places not reached by the Internet, or *dead zones* using the words of Pearce and Gretzel in [6], may evoke contrasting feelings, from rewarding to threatening.

More recently, the smartphone has been considered not strictly related to communication. In 2021 A. Slavec et al. investigated the use of cameras [12] while on travel in locations with a relevant cultural heritage to sustain its preservation and engage the tourists using location-based games, similar to Pokemon Go or geo-caching.

In 2023 V. Rodrigues et al. published a systematic review of papers considering the interrelationships between tourism and portable digital devices [13]. Although the title evokes a one-way contribution, i.e., the impact of digitalization is assumed to be positive on the quality and the sustainability of touristic offers, in the conclusions the authors reveal the awareness for the need to address "*the preservation of tourism attractions/sites*" and call for a "*a holistic approach ... to support a concept that still lacks conceptual and empirical clarification*".

In that direction, we meet the phenomenon of *overtourism*, covered by significant literature reviewed by Dodds and Butler [14], which focuses on urban tourism and its social consequences. The impact of *overtourism* on resorts that trade on their natural resources is investigated in the case of the Hawaii Islands [15] or Costa Rica [16] stressing the impact on the social fabric.

The present paper wants to fill the gap highlighted by Rodriguez, providing a conceptual yet pragmatic approach to a well-defined aspect of tourism support, taking into account "by design" its sustainability. Once a range of relevant solutions has been identified, we proceed to the empirical part: a *proof of concept* implementation that verifies the feasibility of a specific solution.

We stress that this article does not aim now at quantifying user satisfaction or the economic revenue associated with the specific solution. Such a target is outside the scope of our research, and indeed the figures that would measure the success of a strategy deserve further investigation. We aim at isolating an issue, proposing a sustainable strategy for its solution, and implementing a proof of concept for it.

2.3. A simple, low-impact solution

We aim to design sustainable and effective smartphone-based signage.

A straightforward approach concentrates on the wireless capabilities of such a device. Given the premise that the Internet is not reachable, the *host* stakeholder might provide a local network of low-power radios covering the region of interest. Small servers connected to the network would provide specific Web services. The approach requires a modest investment and a marginal environmental impact: for instance, a small device based on the ESP8266 single-chip computer (SCC) has a coverage of tens of meters, and a volume in the order of the cm^3 . They can provide WiFi Access Points as well as Web content. The ESP8266 has a capacity of 32KB, which is sufficient for explanatory text and a low-resolution image. Other SCCs, like the ESP32, are more powerful but exhibit a higher power consumption.

Power supply dependency is a serious limitation for such kind of solution. A radio transmitter is a rather power-consuming device, in the range of Watts. Even if intermittent, the operation of a battery-operated networking device cannot be guaranteed for long periods and the host organization should consider power harvesting, which negatively contributes to the economic cost and environmental footprint of the device.

For this reason, we do not consider a solution based on the deployment of a networking facility as a valid competitor against traditional board-based design. As explained, the reasons are related to poor sustainability.



Figure 2. An NFC coin, a QR tag used in the prototype, and a 1 Euro coin by comparison on a paper with a square of 1cm

An alternative consists of the utilization of passive devices, like Near Field Communication (NFC) transmitters. The transmitting device is flat, the size of a coin, and costs less than one dollar per piece. To receive the content the smartphone must be very close to the NFC tag. The power needed to operate the radio is drained from the smartphone so that the transmitter does not depend on batteries. The NFC device capacity is in the range of KBytes, nearly a page on this journal. Storing content in an NFC tag requires a smartphone with a specific app.

The NFC technology is currently very diffused, and reading an NFC tag as text requires the installation of an appropriate application. Once the application is running the operation simply consists in approaching the smartphone to the tag: the tag content is transferred to the user's device as a chink of text which can be treated as such. The smartphone can read it aloud, to compensate user's inabilities, or translated, to cope with linguistic issues. Such capabilities do not need an Internet connection.

Another solution in the family of passive devices is the QR tag (QR stands for Quick-Response). Such a technology does not require radio communication but uses the smartphone camera to acquire a graphical code that is translated into text. The capacity of a QR tag depends on the number of dots in the image, which in turn depends on the size of the code and the smartphone camera characteristics. We may consider that the capacity of a QR tag roughly equals that of an NFC tag. A QR tag is larger than an NFC tag of comparable capacity, and manufacturing requires a printer.

A preliminary check verifies compliance with the Universal Design Principles [10]:

- *Equitable use* is closely related to the smartphone technology, which is itself considered a vehicle for equitability,
- *Flexibility in use* is enabled by the device capabilities, which allow listening instead of reading, translating the information in a different language, or storing it for later use,
- *Simple and intuitive use* holds since the operation requires a single application, possibly already installed since useful in many circumstances, and tag reading requires a single finger touch on the smartphone

- *Perceptible information* is a critical requirement, which contrasts to keep low environmental intrusion. This point will be further discussed in the section devoted to the implementation 253
254
255
- *Tolerance for error*: there are no margins to use the device in a way that compromises user safety. The deliberate or accidental release of the passive device into the environment determines a minor pollution 256
257
258
- *Low physical effort* holds, although the user needs to carry the smartphone 259
- *Size and Space for approach and use* need to be carefully considered. In the case of the NFC tag the smartphone needs to be nearly in touch with the passive device, while the QR code must be in the line of sight and frameable without effort 260
261
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Such minimal solutions (see figure 2) compare well with other more complex ones that make use of the user's smartphone. There is a trade-off concerning capacity, but in many circumstances, a capacity of 2-300 words is sufficient to convey the description of the site or provide directions for the visit. If capacity limits are not an issue, a solution based on NFC or QR tags exhibits several advantages:

- does not require any power supply, 268
- has a limited impact on the landscape, 269
- does not entice theft, 270
- has a negligible cost, 271
- is durable, 272
- produces a limited quantity of waste when disposed of, 273
- content can be stored for later usage; for instance, to visit a URL once the user reaches a zone covered by the Internet. 274
275

The two passive technologies of choice exhibit the following features, that may make one of them preferable for a specific application:

- an NFC tag is smaller than a QR tag; 278
- writing an NFC tag requires a smartphone, while the QR tag needs a printer; 279
- reading an NFC tag works near-to-contact, while QR tags can be read from a distance; 280

For a signage application, a QR tag is preferable because a noticeable size is needed. In addition, keeping the tag out of reach prevents vandalism and misuse.

In conclusion, we have reasons to select a QR-tag-based solution as a good candidate for smartphone-based signage. We now consider how it copes with the limits of a traditional board-based approach (as listed in table 2):

- dimensions: a 2-300 characters QR-code has a dimension in the order of 100 cm² 286
- logistics: QR-code board can be installed on any sort of pre-existent or natural support 287
- impact: the board has minimal interference with the landscape and may easily go unnoticed 288
- accessibility for the visually impaired: the text can be read aloud 289
- international: the text can be translated automatically 290
- update: the board can be easily replaced when the content becomes obsolete 291
- disposal: the card releases a limited quantity of pollutants related to ink support (paper or plastic) 292
293
294

There are two relevant trade-offs that the host needs to resolve. One is related to the visibility of the tag. The trade-off is between visual impact and visibility. The other is related to monitoring tag utilization. This may be useful for all sorts of planning activities and is discussed in section 4.

3. Materials and Methods

As anticipated in the introduction, our study wants to provide a proof of concept for a sustainable solution in a concrete setup. To comply with such a holistic approach, we need to start with the definition of the operation framework.

This section is devoted to the description of an economic and social context, as well as the historical background representing the heritage resource we want to promote. Next, we will discuss the technical details of the solution.

The geographical area of interest is the surroundings of *Casoli*, a small village in a mountainous region in the north of Tuscany, in Italy. The area falls within the municipality of *Bagni di Lucca*, in the province of *Lucca*. In 2021, the archaeological team of our project realized an archaeological map assessing the reasons of interest for the heritage and the geomorphological features of the area.

3.1. The natural and cultural resources of Casoli and its vicinity

Bagni di Lucca is located on the north-eastern boundary of the Province of *Lucca*, in *Val di Lima*, and is part of the *Media Valle del Serchio* district. With its mountains it marks the historical border with the Modena and Pistoia area, it is very rich in potential for its naturalistic, archaeological, and historical heritage, both expressed and as yet unexpressed. Thanks to the archaeological map the main sites of interest from prehistoric to contemporary times in this municipality are catalogued, photographed, and georeferenced.

From a historical-geographical point of view, this area is identified with the *Lima* stream and its tributaries, which impress to the area a particular geomorphology, very impervious despite the modest hilly elevations.

The *Lima* stream has characterized the history of *Bagni di Lucca* since ever: some of the oldest evidence of human presence in the valley has been found along its ancient river terraces, such as caves and rock shelters frequented since the Palaeolithic age; the manufacturing industry (paper mill, flour mills and, in recent times, energy production) have exploited since the Middle Age until the 1980s [17–19].

On the naturalistic side, the region of *Bagni di Lucca* encompasses an incredible concentration of biodiversity, counting no less than three sites of the Natura 2000 Network [?] European Economic Community (EEC) initiative.

There are three SCIs-SACs (Sites of Community Interest and Special Areas of Conservation) located in the area north of the *Lima* stream, corresponding to the Apennine portion, covering 23% of the municipal surface:

- the limestone areas of *Val di Lima* and *Balzo Nero*;
- *Monte Prato Fiorito-Monte Coronato-Valle dello Scesta*;
- *Orrido di Botri*.

The latter is also a SPA (Special Protection Area) and the *Orrido di Botri* State Reserve is located within it [?]. It is therefore a natural heritage with a fragile balance that needs to be preserved.

In recent years, the main tourist attractions have concentrated on the *Lima* stream, with some associations and private entities promoting outdoor experiences, particularly fluvial sports, such as canyoning, rafting, and sup. Other important tourist attractions are trekking and hiking, supported by a network of paths tracked by local CAI (*Club Alpino Italiano*).

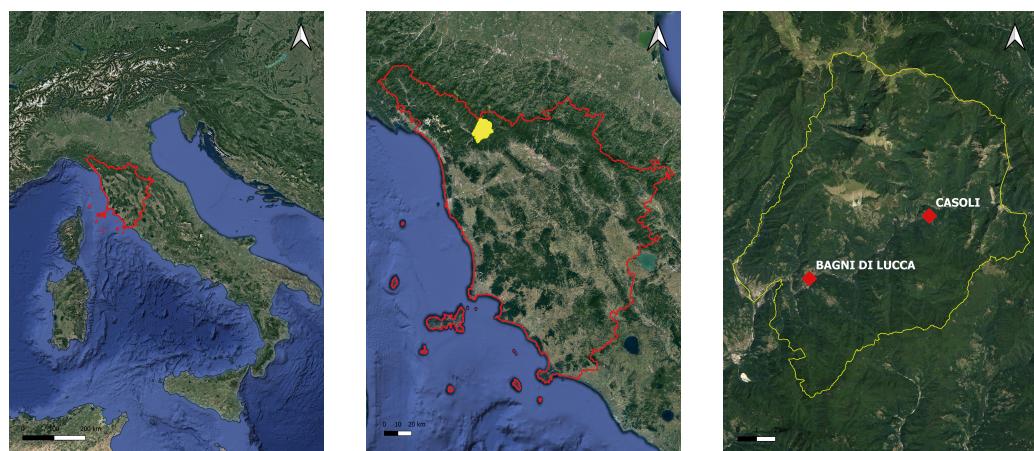
In the last few years the community opened two entirely new trails:

- the *Alta Via dei Pastori* (2019), a ring around *Monte Prato Fiorito* that takes up the ancient grazing route, and
- the *Sentiero degli Avi* (2020), a ring that from *Montefegatesi* reaches *Monte Coronato* [20]

Another recently developed project (2019) is the expansion of the Saint Bartholomew's Path, which runs through the territory of *Pistoia*, with a variant that from *Popiglio* continues in five stages in the municipality of *Bagni di Lucca* to *Pieve di Controne*, acting as the '*Lucca gateway*' to the Path [?].

Such initiatives led to a considerable revival of interest among Italian and international hikers in the area, especially for the Apennine side of the valley.

The way to improve the valorization and enjoyment of this area applies to a slow tourism approach. This approach can involve the community, especially in the southern



(a) Italy and Tuscany, bordered in red
(b) Tuscany and the municipality of *Bagni di Lucca* (in yellow)
(c) Location of the *Casoli* village in the *Bagni di Lucca* municipality, bordered in yellow. The small town of *Bagni di Lucca* is visible located a few kilometers west of *Casoli*

Figure 3. The region of *Casoli*

part of the municipality, which is still less frequented, more hilly, and therefore less traveled by the network of trails. We propose the creation of geo-itineraries characterized by the rediscovery of the historical roads, partly well-preserved, which connected the villages with the valley bottom and between them, including those sites of interest that encapsulate the history of this area, starting with the caves.

3.1.1. An historical perspective of an Italian mountain site

The village of *Casoli* is located south of the *Lima* stream on a hill named "*Tanette*". In the local small lair, the name reveals the presence of karstic cavities, some inhabited between the Paleolithic and the Iron Age and used also as stations on the trans-Apennine routes [17,21–24].

Ceramic fragments dated between the 3rd century B.C. and the 1st-2nd century A.D. prove that Ligurian populations occupied the region scattered and in small nuclei. The dedication of the Latin colony of *Lucca* in 180 B.C. marked a decisive turning point in the Romanisation of the area and, shortly after, the definitive subjugation of the Ligurian populations, accompanied by a rapid acculturation [21,25].

We have little evidence of Roman settlements in the mountainous hinterland, and the scarce archaeological traces are concentrated in the cave of *Buca La Piella*, investigated in 1975 by the Centre for Archaeological Studies of *Lucca*; it has two entrances joined by a walkable tunnel and rooms of discrete dimensions that overlook the outside. In addition to numerous faunal remains and fragments of locally produced common pottery, twenty bronze coins belonging to the 3rd century AD, bronze and lead objects were found [21,26,27].

In Longobard and Carolingian times, *Lucca's Val di Lima* was one of the three administrative districts into which the mountains were divided and was called "fines Contronenses" [28–30]. The only find from this period is the *Grotta di Arzale*, a rock shelter that opens up northwest of *Casoli* [21].

The first attestation of the settlements of *Casoli* and *Lacu* (Lake) dates back to the 10th century [21]. Most documents of this period show the fractioning and alienation of ecclesiastical heritage in favor of the city aristocracy, securing an accumulation of funds and power that was to form the basis of the subsequent domains [21,28,31,32].

Written sources mention a castle in *Casoli* from 1180, but its foundation must be earlier. Between the 13th and 15th centuries, the fortification was at the center, along with the other castles of the *Val di Lima*, of clashes between *Lucca*, *Pisa* and *Florence*, with alternating fortunes, as it was a strategic border area for the power of *Lucca*. Today, very little is preserved and the area has been partly inhabited [21,31,33].

The same document from 1180 mentions the church of *San Donato*, located in the main square of the village of *Casoli*. The current structure dates back to the 12th-13th centuries, with subsequent renovations. Initially dedicated only to *San Donato*, it acquired a double dedication after the abandonment of the church of *Sant'Andrea de Lacu*. The latter is located on a plateau to the east of Lake *Casoli* and is attested from 1260 [21,34,35], but already in the 15th century, we learn of its state of abandonment [21,36]. This was probably due to the depopulation of the lake area and the simultaneous strengthening of the town of *Casoli*, which was fortified and better protected during this unstable phase.

Today, the Romanesque church of *Sant'Andrea de Lacu* is in a state of decay, with a rectangular plan, ending on the east side with a semi-circular apse. Inside, there is a reused element of the previous building, testifying to an older origin, probably contemporary with the ancient settlement of *Lacu* (Lake) mentioned in sources from the 10th century and no longer visible today.

In the early modern age, villages of the area experienced a progressive architectural renewal, which still largely characterizes the settlements today. Within *Casoli*, a series of residential buildings with imposing dated portals are preserved, some with courtyards, and mansions that denote a discrete deployment of resources by wealthy social classes. Also dating from the modern era is the *Madonna di Castello* Oratory, characterized by an entrance enclosure and located along the cobbled road that traces the ancient route between the village and the summit area of the medieval castle [21].

Along the road that led toward *Lucchio* crossing the area of *Casoli* Lake, there is the chapel of *Madonna di Col di Piano* and two "metati", buildings destined for chestnuts drying, referable to the contemporary age. Referred to as the "bread tree," chestnut fruits and the flour derived from them were a staple of the mountain diet until the mid-1900s [37,38].

3.2. An integrated view of tourism in the *Casoli* region

Within the paper's aim framework and from a touristic point of view, the relevance of the touristic context of the territory is crucial in understanding the socio-cultural system of potential tourist destinations. In light of this and for a holistic study approach to social features of tourism, the host and traveler relationship is directly related to local development and local government systems [39].

In this study, the holistic perception of local stakeholders and community empowerment (with its increasing potential) in tourism at the local level acquires a particular value. For this specific purpose, this paragraph is well related to the tourism dynamics of the Municipality of *Bagni di Lucca*, the administrative land hosting *Casoli*.

3.2.1. The tourism context of / The tourist dynamics in *Bagni di Lucca*, the *Val di Lima* and *Casoli*

In Italy, a municipality is the smallest geographical-administrative unit offering accessible data about tourism, which are the fundamentals of our research. The municipality of *Bagni di Lucca* boasts historical popularity for its landscapes told by famous poets (such as Giosuè Carducci, Giovanni Pascoli, Eugenio Montale, George Gordon Byron, Percy Bysshe Shelley) and celebrities like Paolina Bonaparte. The typical Liberty style architecture characterizes the villas like the *Real Casinò* featuring elegant gardens representing the power of the Republic of *Lucca* in the early XIX century and the *Belle Epoque*. Such historical prominence made the town a well-known destination abroad, thanks to the massive emigration and the presence of the Thermal Bath structure ¹, nearby must-see attractions of the time.

¹ Terme di *Bagni di Lucca*: <https://www.termebagnidilucca.it/>

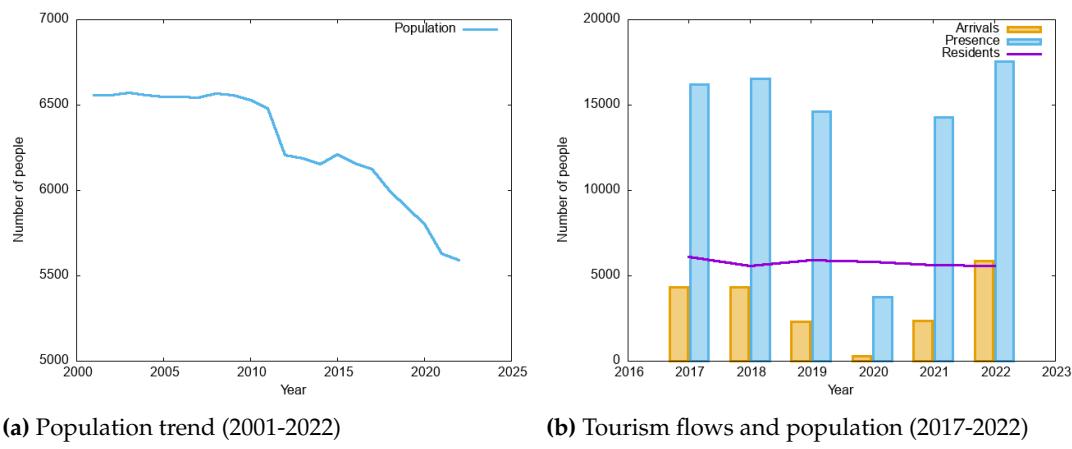


Figure 4. Demography and tourist flows in the municipality of *Bagni di Lucca*

Bagni di Lucca owes part of its charm to the river *Lima*, which runs along the city before flowing into the *Serchio* River. The *Lima Valley* (*Val di Lima* in the local idiom) is a touristic basin set in the *Serchio Valley*, dotted with medieval and Roman villages with historical remains such as underground caves. The *Val di Lima* area is well-known for its environmental beauties including rupestrian and lake ecosystems, and offers a wide range of tourist attractions related to sports, from water sports, such as canyoning and rafting, to trekking in water and land, climbing, mountain biking, and horseback riding. Overall, the *Val di Lima* has the capabilities to promote a very identifying destination brand straddling the town of Lucca and the mountain area of the *Garfagnana*.

The strategic position of *Bagni di Lucca* is one of the strengths of its tourism context, together with the presence of such attractive elements like the *Orrido di Botri* with the *Canyon Park*², and other service companies and associations for experiential tourism.

The demographic trend enlightens a relevant aspect of *Bagni di Lucca* society, and the employment statistics of the population mirror the social, cultural, and economic aspects of its touristic ecosystem.

Bagni di Lucca stretches on 164.70 km² area with a population density³ of 3395 inhabitants per square kilometer and a job occupancy rate of 33.53%. Regarding human growth at the territorial level, it is relevant to consider the *Bagni di Lucca* population trend during the 2001-2022 period. The curve shown by figure 4a registers a constant and slight decrease of one thousand people in a twenty-year time frame (2001: 6556 people; 2022: 5593 people).

During the latest decades, numerous touristic operators have started their touristic activities by taking advantage of the climatic and morphological characteristics of the territory. From a quantitative perspective, it is relevant to understand the tourist flows during a 5-year time frame; the chart in figure 4b highlights a decreasing trend from 2017 to 2021 by considering the pandemic breakdown impacts on tourism.

The Tourism Density Index⁴ is 106.41 tourists per km² in 2022. The arrivals exhibit a drop from 2019 (from 4339 in 2017 to 2363 in 2021), and touristic presences have suffered a slight decrease during the same period, as shown in figure 4b, while a further increase has been registered in 2022 (5.876 arrivals).

The touristic area of *Val di Lima* features a tourist area belonging to *Bagni di Lucca* Municipality, the second touristic area after *Barga*, in the *Media Valle del Serchio Area*.

² <https://www.canyonpark.it/>

³ Index referring to the number of people living in a territory per square kilometer. It is the rate between the annual number of residents and the surface area. In our case and for 2022, the density is 5593 people over 164.70 km².

⁴ The Tourism Density Index shows the tourism concentration in the higher touristic season. It is the rate between the number of tourists and the surface area.

Region	Bagni di Lucca	Lucca
Resident density (residents/km ²)	33.95	215.71
Touristic density (visitors/km ²)	106.41	1866.96
Average stay (days)	2.98	3.36
Accommodation density (accommodations/km ²)	10.14	19.30
Coexistence Index (100 × Foreign/Italian)	103.74%	69.87%

Table 1. Tourist numbers in *Bagni di Lucca* in 2022⁵

Table 1 provides statistical data concerning tourist flows and accommodation in *Bagni di Lucca*. Notably, the tourist density of 106.41 tourists per km² is higher than the population density (33.95 inhabitants per km²).⁴⁶⁶⁴⁶⁷⁴⁶⁸

The number of nights per tourist amounts to an average of 2,98 nights per tourist during a year and it is also significant since it shows, on one hand, *Bagni di Lucca* context appeal for tourists choosing to stay a number of nights more than a weekend and less than a week. On the other hands, this data means that people like staying in this touristic comprehensory and they may have founded attractions, services and activities they need. Consequently, a well-organized turistic system attracts potentially touristic presences widespread on the municipality territory.⁴⁶⁹⁴⁷⁰⁴⁷¹⁴⁷²⁴⁷³⁴⁷⁴⁴⁷⁵

The coexistence index describes the distribution of tourist nationalities: 103.74 foreign tourists per 100 Italians in *Bagni di Lucca* indicates a significant share of foreign tourists.⁴⁷⁶⁴⁷⁷

For a benchmarking point of view, the provincial touristic context of *Lucca* is mentioned in this study with the purpose to highlight the percentage weight of *Bagni di Lucca* tourism flows within the whole tourism dynamics of the Province of *Lucca*. As concerns tourist indexes shown in Chart 3, the touristic density counts 1866, 96 people per square kilometer (1773 kmq), with an average stay of 3,36 nights per tourist, showing a medium-length permanence in the provincial territory; this data is in line with *Bagni di Lucca* average stay (2,98 nights). The provincial area of *Lucca* shows an accommodation density of 19,30 on 10, 14 of *Bagni di Lucca*, while the coexistence index of *Lucca* (with 69,87 foreign tourists on 100 Italian tourists) is lower than *Bagni di Lucca*'s coexistence index (with 103,74 foreign tourists in 100 Italian tourists). Definitely, it can be claimed that *Bagni di Lucca* is well positioned in the whole touristic context of *Lucca* since it represents one of the less populated municipalities in the territory with interesting tourist indexes. In fact, *Bagni di Lucca* boasts its historical thermal tourism tradition together with a well-equipped environment for sport and adventure tourism, on a surface of 164,70 kmq, that is one of the biggest municipality areas in the province of *Lucca*.⁴⁷⁸⁴⁷⁹⁴⁸⁰⁴⁸¹⁴⁸²⁴⁸³⁴⁸⁴⁴⁸⁵⁴⁸⁶⁴⁸⁷⁴⁸⁸⁴⁸⁹⁴⁹⁰⁴⁹¹⁴⁹²

Summing up, the quantitative data give evidence of a vibrant and attractive tourist reality constantly attracting tourists during the last decade. Thanks to such tourist flows *Bagni di Lucca* is considered one of the main tourist areas of the *Val di Lima* and the Serchio Valley. Several promotional websites advertise *Bagni di Lucca* attractions⁶: the sitography closing this paper contains a long but incomplete list that confirms such a statement, and Table 2 exposes the promotional touristic system offering varied experiences in the *Val di Lima* area. The variety of outdoor touristic services dates back to the '90s when some associations began organizing mainly trekking excursions and rafting experiences.⁴⁹³⁴⁹⁴⁴⁹⁵⁴⁹⁶⁴⁹⁷⁴⁹⁸⁴⁹⁹⁵⁰⁰

From the point of view of our research, the context of the *Bagni di Lucca* helps to understand the complexity and variety of mixed tourism clusters (a sort of "touristic ecosystems" with common identity elements such as: anthropic, socio-cultural, and historical features, as well touristic services).⁵⁰¹⁵⁰²⁵⁰³⁵⁰⁴

⁵ Each index gives a different type of touristic information about *Bagni di Lucca* Municipality: the touristic density represents the number of tourists per km²; the Average stay index is the average number of nights spent in town by tourists; the Accommodation Density Index is related to the number of touristic presences on the number of beds occupied by tourists all over the year; the coexistence index shows the relevance of foreign tourists per 100 Italian tourists.

⁶ Among local websites, these two destination websites are: www.turismobagnidilucca.com and www.valdilima.org.

Touristic promotion	Kind of service
Aguarajà River Experience https://aguaraia.it/	Soft rafting, Rafting, Canyoning, aqua-trekking, kayak
Rafting H2O https://www.raftingh2o.com/	Soft rafting, Rafting, Canyoning, aqua-trekking, kayak
RocKonda https://www.rockonda.it/	Soft rafting, Rafting, Canyoning, aqua-trekking, kayak
A.S.D. Garfagnana Rafting https://www.garfagnanrafting.com/	Soft rafting, Rafting, Canyoning, aqua-trekking, kayak
Val di Lima Off-Road https://www.valdilimaoffroad.com	Quad, enduro
Canyon Park https://www.canyonpark.it/canyon-sup	Canyoning, aqua-trekking, stand-up padding, mental care and yoga, eco laboratory
Pro Loco Bagni di Lucca https://www.turismobagnidilucca.com/ https://www.valdilima.org/	Sportfishing, mental care, trekking, survival, paragliding, horse riding, diving
eBike Adventure Tour http://www.ebikeadventuretour.it/	Ebike, Mountain bike
Val di Lima eBike https://valdilimaebike.it/	Mountain e-bike, Quad, Enduro, Paintball
Terme Bagni di Lucca https://www.termebagnidilucca.it/	Spa, beauty and wellness experience

Table 2. Tourism experiences' offer in *Val di Lima* area ⁷

After a detailed analysis of the touristic and social context of *Bagni di Lucca*, it can be claimed that the area boasts a good tourist appeal towards Italian and foreign tourists searching for various kinds of experiences, such as thermal, environmental, outdoor, sport and cultural activities [40].

The Municipality of *Bagni di Lucca* and the tourist area of the *Val di Lima* are the context for the small village of *Casoli*, which is one of the 31 villages belonging to the Municipality. It is 7,22 km far from *Bagni di Lucca*, at an altitude of 500 meters of altitude.

Casoli is a fascinating village settled on the green and rolling hill landscapes crossed by the river *Lima*, in the *Media Valle del Serchio*. Its territory features multiple kinds of touristic sights: from soft and hard outdoor experiential attractions (specifically the Canyon park activities like canyoning, rafting, and trekking experiences) to Romanesque churches' remains and huts. Qualitative studies oriented to tourist attractions, and widely, to the complexity of the semi-structured tourism show that *Casoli* exhibits unique features despite its tourism variety.

There aren't touristic information at the administrative level of *Casoli*, so that the tourism context analysis concerns the Municipality area of *Bagni di Lucca*, as the first territorial context providing tourist data registered by ISTAT.

Given the context and the local vocation, we conclude that *Casoli* is a small destination for tourists practicing heterogeneous touristic circuits in individual and combined ways. According to qualitative and quantitative analysis [40] on the touristic and social context of *Bagni di Lucca*, as the municipal area encompassing *Casoli* village, the mentioned area boasts a good touristic appeal towards Italian and foreign tourists searching for various kinds of experiences, such as thermal, environmental, outdoor, sport and cultural activities. Local stakeholders operating in the tourism system offer a variety of services all year round. Whenever possible the offer is enriched with original touristic approaches paying attention

⁷ The list might not include all private stakeholders of the territory, since some touristic operators might have an Internet presence and others might operate as public-private players. The companies and associations in the list have been individually contacted but some did not respond to our survey on touristic information.

to sustainability. As part of the *Bagni di Lucca*'s ecosystem with its touristic vocation, *Casoli* is defined as a well-known destination. Given that *Casoli* is a target of semi-structured tourism, and to preserve its peculiar social fabric, sustainability of development actions is of paramount importance. The latter aspect suggests paying attention to environmental conservation, cultural heritage conservation, intergenerational continuity, and economic equity [41].

3.2.2. Guidelines for a sustainable development

In [42] Dianne Dredge describes the role of private and public entities in making tourism sustainable, which we summarize in the following actions:

- Public actions:
 - to foster an inclusive stakeholder approach for the tourism ecosystem
 - to promote a community-involved tourism vision
 - to monitor and analyze tourism flows
 - to plan a *slow tourism* development strategy to achieve environmental, cultural, and socioeconomic sustainability objectives
 - to develop digitization tools and strategies for culture and tourism fruition
- Professional actions:
 - to renovate experiential tourism with a sustainable approach
 - to develop potential touristic areas with unexpressed tourism appeal
 - to diversify tourism offer based on tourist provenance and service preferences
 - to monitor tourism flows and tourist behaviors
 - to foster a public-private collaboration approach to use public funds for tourism and cultural projects toward sustainable objectives

The above-mentioned tourism and culture measures should be included in a wider and holistic planning vision for *Bagni di Lucca* as a heterogeneous cultural and sustainable destination. The combination of private and public interest as a long-term strategy for a comprehensive tourism approach needs a bottom-up vision involving residents and local operators in tourism and tourism-related sectors [43,44].

In this way, community-involved tourism can be a promising solution for sparsely populated areas with significant tourist attractions, such as the village of *Casoli*. This type of tourism involves active participation and entrepreneurship from the local community to promote self-employment, community management, and stakeholder decision-making processes [45].

In order to create a successful strategic plan, it is crucial to have a thorough understanding of the destination's morphology, environment, history, culture, society, and economy, with sustainability being the key value. Policymakers should recognize such needs and act in this way, both politically and socially as described by Beatrix et al. in [46]. As concerns the empiric case of *Casoli* village, within the wider context of *Bagni di Lucca*, tourism is a key driver for re-population and re-qualification strategies, mainly where historical and archaeological sight can be promoted with natural attractions.

In such a context digitalization plays a primary role in innovation actions, allowing effective monitoring of tourism dynamics, improving the touristic experience with geo-localization tools, and providing the tools to design and operate tourism initiatives [44].

3.2.3. Our activity

We include three stakeholder communities in the evaluation of the response to the initiative. We do not speak about *success* since the initiative is deliberately soft, and an outcome is expected in years, and the definition of the evaluation criteria rises new questions. So we are content to see if the stakeholders regarded the initiative as an intrusion, as helpful, or simply neutral.

We considered four stakeholder communities:

- *the residents* the local community that currently inhabits the site

- *entrepreneurs* who currently have a business on the site 581
- *administrators* that are in charge of managing the site resources and that, at due time, 582 will respond to the two stakeholders above, and finally 583
- *the users*, those that come to *Casoli* to visit the Cave of La Piella and that we find the 584 QR-codes on their way 585

The category of the users escapes an evaluation since the QR tag does not record 586 reading operations. We added to the text message in the QR-tag an external link, that 587 we monitor for the number of hits on pages dedicated to the specific tag: however, this 588 feedback largely underestimates the number of times the tag is read. 589

Considering that each stakeholder category has specific concerns that need to be 590 addressed, our focus has been on understanding the unique characteristics of each category, 591 including their needs and expectations for tourism and environment development. 592

As concerns residents, we had the opportunity to meet only two people living in 593 *Casoli* and providing us a few information which was not useful for our study aims; local 594 entrepreneurs we met informed us about the trekking tourism flows passing through *Casoli* 595 and the Piella Cave path, which usually starts from the Canyon Park experience. 596

The administrators of *Bagni di Lucca* Municipality were highly involved in addressing 597 the study's concerns and provided valuable information regarding archaeological and 598 cultural aspects that align with our study goals, namely to enhance *Casoli* area as a sustainable 599 area for hi-tech oriented tourists. 600

In light of the above assumptions, a reflection on community-involved tourism 601 perspective is needed. As shown by this empirical study, a small village like *Casoli* can require 602 a valorization strategy taking advantage of the wider local tourism context. 603

According to a holistic development vision, when a tourist destination meets its 604 community issues it means that local stakeholders must balance a tourist industry vision 605 with sustainability goals at a comprehensive perspective on environment, socio-cultural 606 and economic long-term benefits, as described by George B. Et Alii, () 607

Indeed, a multi-stakeholder approach could represent a valuable tool for "minor 608 tourism" and well-established tourist destinations. 609

Literature on this scientific focus, as described by Richards G and Derek H. () gives 610 evidence on local stakeholders' role as 'designers' of their living territory. This is particularly 611 important in inland and marginal tourist areas that require a sustainable approach to 612 development, rather than relying on mass tourism. 613

A systemic vision is necessary to manage these areas effectively. With these concerns, 614 inner area governance needs a sustainable-led community and policy approach considering 615 socio-cultural local aims for tourism system implementation and environment development. 616 In these terms, local awareness is fundamental for private and public stakeholders enabling 617 sustainable decision-making processes. 618

On the pragmatic hand, the scientific aim of our territorial exploration is to promote 619 cultural and tourist points of interest with high tourist value. In this regard, we have 620 analyzed the potentiality of involving local administrations and professional tourism 621 operators to create new tourist itineraries by valorizing existing hiking trails. Firstly, the 622 Municipal Structural Plan should include an archaeological survey; secondly, local tourism 623 stakeholders will benefit from a destination management action to promote environmental 624 and socio-cultural sustainability. 625

Definitely, community-involved tourism may represent the balanced intersection between 626 community and development through policymakers' actions and decision makings 627 (Jamal T. and Dredge, 2014). In this view, the socio-political framework of tourism, 628 involving governance measures, has to include environmental requalifying and destination 629 planning (Sharabani et alii, 2020; Richards and Hall, 2003). 630

Policy measures for sustainable and resilient tourism should focus on culture-led 631 and community empowerment activities, such as preserving the history and memory 632 of the place, promoting slow tourism and cultural innovation, as well as implementing 633 digitalization activities. 634

3.2.4. Sites and trail's state of art

As explained in the previous section, the area around *Casoli* is a good candidate for our case study because of its long history, which is witnessed by architectural and geological features. In the following, we define the relevant features and report on their accessibility.

The cave named *Buca La Piella* is the foremost site from an archeological point of view. It is located in a fascinating environment outside conventional circuits, which is why it is less frequented and consequently less compromised. It is reachable leaving a marked path to follow the bed of a tributary of the *Lima* stream. The trail is dotted with minor karst caves, and the *Buca La Piella* is reachable by climbing up on a steep slope in the wood on the left of the watercourse.

Not far from the *Buca La Piella* on the same side of the river is another karst cave named *Antro dell'Ugola*. It is reachable following a faint and intermittent track that departs from a marked path. It is characterized by a suspended geological formation reminding an uvula, hence the name.

Both caves are going to be analyzed in the course of the Underlandscape project [?], and findings can further enhance the interest in both sites.

Along the dirt road from the village in the direction of Lake *Casoli* are some of the most interesting sites. The medieval remains of the *Church of Sant'Andrea de Lacu*, now in a state of serious disrepair, without its roof and with static problems, but characterized by its Romanesque forms and 10th-century decorations.

The *metati* (structures for drying chestnuts), together with the hundred-year-old chestnut trees, testify to the exploitation of forest resources since the Middle Ages.

A little further along the CAI path is the *Oratory of the Madonna di Col di Piano*. Recently renovated, with its canopy it has been a shelter for wayfarers since modern times.

Inside the town of *Casoli*, narrow streets branch off to the main square, where the medieval *Church of Saints Donato e Andrea* with its bell tower can be admired. From here, an ancient street climbs to the top of the hill. On the way up there is a small oratory called *Madonna di Castello*, still consecrated but in poor conditions.

On the summit are the remains of the *Medieval Castle* with its walls. In need of consolidation of the walls, it cannot be visited at the moment as it is on private property; it is only possible to observe part of its structures from the path.

Two other sites that are particularly curious but cannot be visited because located on private properties are the so-called *Celtic Calendar*, an artificially excavated rock interpreted as a kind of sundial, and an epigraph reused in a house interpreted as Lombard.

3.3. Implementing a QR-based signage

The concept behind the implementation was that of guiding the visitor through a self-organized experience using a signage technique that improves the traditional boards, as explained in section 2.1. To verify on the field the practical aspects and the implementation process we realized several QR tags that were later secured to an existing support. See the list in Table 3.

The proposed signage cannot replace CAI signage (see figure 1a), which is recognized throughout the country and is very effective. However, the new signage can effectively complement it to provide more detailed information at multiple levels, from short text to in-depth information on the project site. In addition, being able to read the written directions along the path can be of great help to inexperienced hikers, particularly on unclear and not-quite-visible trails such as the one we suggested to reach *Buca La Piella*.

Tags are printed on Synaps™, a non-biodegradable polyester synthetic film by Agfa-Gevaert NV. Agfa documents the production process giving guarantees of sustainability [?]. According to Agfa, Synaps is more sustainable than laminated paper. From previous experiences, it is also more durable.

The tags are tied to pre-existing structures, like trees or poles, to keep the environmental footprint as lightweight as possible. The tag is tied with a thin biodegradable string.

A QR tag is designed to implement three levels of reading (LoR), with an increasing level of technology involved:

- visual: the information is printed on the tag. The user does not need any technology to read the content;
- QR tag text: this is the text encoded in the tag. The user needs a smartphone-like device and an appropriate app to read, possibly aloud, the content;
- URL: these are Web URLs encoded in the tag text. The user needs an Internet connection to visit the URL.

We placed QR tags both along the trail and at sites of interest; the former are placed at detours and, at more complex points, at close range so that from one you can see the next, as per the CAI standard [47]. They can therefore have the function of a simple signpost to visually indicate the continuity of the trail. The second LoR gives access to the written indications recorded within it, which are more accurate and precise than those printed on the tag. The third LoR provides further capabilities, as detailed below, but is accessible only whenever the location is covered by the Internet.

There are many ways to distribute the content among the three LoRs, dictated by tag purpose and location. For our experiment, we used the same organization for all tags, which privileges the second LoR, namely the text encoded in the tag (see figure 5a):

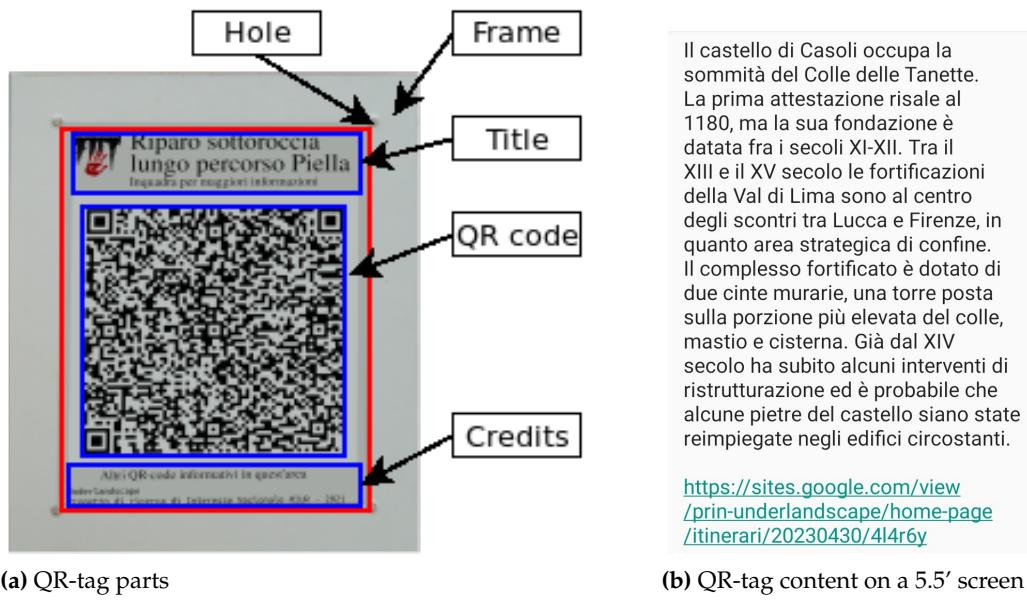
- visual LoR (see figure 5a): the tag is approximately the size of a game card, 80 cm^2 . 40% of the frame (32 cm^2) provides mechanic resistance to the holes needed to secure the tag. 60% of the remaining (48 cm^2) contains the QR-code, 20% for a heading containing the name of the location, one line instruction for use, and the project logo, and a footer (12%) for further instructions and project credits;
- QR text LoR (see figure 5b): it describes the site or gives directions to reach the destination of the trail. The text includes historical, archaeological, and naturalistic information, together with the URL for the next LoR. In our prototype, the maximum length of the text amounts to 700 characters. A Huawei FIG-LX1 (2017) decodes the tag from a distance of more than 50cm using an Android application available on the Play Store. The same phone can read aloud the content (in Italian) without Internet connectivity;
- URL LoR: such information is useful only in a few locations since the area is not uniformly covered by broadband networks: for instance, during a recon to the *Piella* cave, none of the smartphones of the participants received sufficient broadband network signal to visit the linked page. However, the application records the URL so that the user might visit it when entering a covered area. Each page contains site-specific information, an interactive map with the location of all the QR tags (see figure 6a), and a form for user feedback (see figure 6b). The map is hosted by the UMap Web service (<https://umap.openstreetmap.fr/it/>) [?], and displays the location and content of all QR-tags (as shown in figure 5b). The server hosting the site is configured to collect aggregated statistics about visitors' activity.

The production process of a series of tags has also been investigated to streamline the task and use only basic Information Technology skills.

The master document is a *GeoJSON* file describing the area and the tagged features: a GPS tracking application can be used to record an initial version of it during a recon.

The finalized master document contains a single *GeoJSON FeatureCollection* object containing one *Feature* object for each tag. Each *Feature* contains a *Geometry* object of type *Point*, and a *properties* object with fields containing information needed to create the tag: the *uid*, a random string of six lowercase letters used to produce the associated URL, the *title* printed on the tag, and the text encoded in the QR code (see table ??) where part of the *description* field is omitted. The *properties* are also shown on the UMap map.

Editing the basic map to fill-in the QR-code content and the other fields does not require technical skills since the tools integrated into the UMap user interface already fit

**Figure 5.** QR tag parts and content

La collocazione di questo QR-code rientra nel progetto di ricerca [Underandscape](#).

Su questa mappa trovi altri QR-code esplicativi nei dintorni. Buona passeggiata!

(a) Linked page: the map

(b) Linked page: survey form

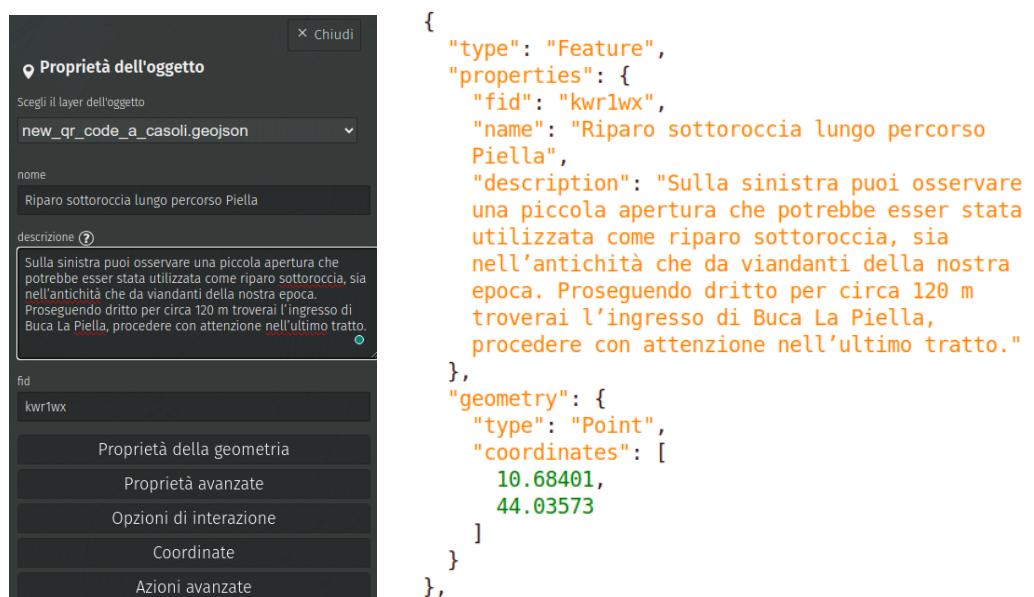
The survey form (b) contains the following questions:

- La presenza del QR code è stata utile. *
1 2 3 4 5
Anche no... Certo!
- Preferisci trovare un cartello informativo invece di dover usare il telefono
1 2 3 4 5
Anche no... Certo!
- Ho consultato altri QR code del progetto. Indica il numero *
La tua risposta
- Ho intenzione di tornare sul territorio per visitare i siti d'interesse non ancora visitati.
1 2 3 4 5
Anche no... Certo!
- Sono soddisfatto dell'esperienza di visita. *
1 2 3 4 5
Anche no... Certo!

Figure 6. Content of the Web page linked to the URL in a QR tag

Name	Long	Lat	URL Key	Length
Buca La Piella	10.68361	44.03667	t5ysrm	476
Calendario celtico	10.66985	44.03986	my0kp8	484
Castello	10.67062	44.04004	4l4r6y	597
Chiesa dei SS. Donato e Andrea	10.66947	44.03928	lwtyx6	632
Iscrizione longobarda	10.67244	44.03906	60m75s	369
Lago di Casoli	10.67761	44.03468	xqjpbk	369
Madonna di Castello	10.66994	44.03960	qlci89	395
Madonna di Col di Piano	10.67760	44.03173	3w44wr	414
Metato	10.67764	44.03591	sbgnl0	660
Sant'Andrea de Lacu	10.67592	44.03530	fxq83v	657
Antro dell'Ugola	10.68296	44.03871	mprs0w	226
Deviazione per Antro dell'Ugola	10.68343	44.03971	e4n2js	88
Deviazione per Buca La Piella	10.68427	44.03573	hve4pj	139
Deviazione per Sant'Andrea de Lacu	10.67663	44.03507	13uav3	200
Ingresso Buca La Piella	10.68358	44.03592	5ahvp8	190
Riparo sottoroccia lungo percorso Piella	10.68401	44.03573	kwr1wx	286

Table 3. The QR-tags placed around *Casoli*. The URL key is a random code that appears on the web page linked to the QR code. The Length refers to the description in the QR tag and is in characters.



(a) Editing a feature associated with (b) GeoJSON Object representing the same the feature a QR-tag in UMap

Figure 7. Editing the GeoJSON with uMap editor. The resulting file is automatically converted into printable QR-tags

the purpose (see figure 7a). The resulting geojson object for a tagged feature is shown in figure 7b.

The master document is rendered by UMap on the page linked to the tags (as in figure 6a).

A *Bash* script running on a Linux system makes straightforward the conversion of the GeoJSON file into a printable array of QR tags. The code, a total of 90 source lines written in *Bash* and *Python* taking advantage of the *ogr2ogr* and *qrencode* commands, is on GitHub [?].

4. Results and discussion

Our point is to illustrate a methodology to improve the touristic offer of a site that is not specific to a use case, but applicable to a broad range of frameworks. The methodology must be sustainable in the broader sense: social, environmental, and financial.

We applied the methodology to a small-scale example: a signage system addressing the guidance of visitors in a rural area with a cultural heritage to be protected and valorized at the same time.

Firstly we evaluated the aspects of interest of the site, and we found natural formations and human artifacts tracing back to the Paleolithic Era. Other relevant aspects are that the site is not included in mass tourism circuits but is not far from them. The area is exposed to depopulation due to the shortage of productive activities.

To preserve the native social and financial framework we do not aim at mass tourism. Instead, we target a motivated, non-casual visitor, and devise potential reasons for its visit. We found many of them: a not easily accessible cave inhabited since pre-history, a village with historical buildings, and nearby architecture dating back to the Middle Ages.

We investigated the task of guiding the visitor and telling the history of the place with inexpensive and non-intrusive techniques. The proposed solution consists of a dozen QR tags placed at key locations. The total cost of the tags amounts to a few Euros for the printing service, although finding a shop with an appropriate printing device may be difficult. The impact on the environment is extremely limited, as shown in figure 8.



(a) A tag secured to a tree near a shelter **(b)** Google Earth view of the surroundings of the tag. The map is north-oriented, and shows the village of *Casoli* in the left-high corner

Figure 8. Tag placement at different scales

The preparation of the signage requires a solid knowledge of the site. This demanded consulting historical documents, assessing the touristic vocation of the area, and two on-site surveys.

On the technical side, the proposed signage provides a benchmark difficult to improve in terms of environmental impact and cost, but its *performance* is difficult to evaluate.

One performance index might be the number of times a given tag is scanned. Indeed, we recorded several hits to the URLs in the QR tags, but their number and the way they are collected are not appropriate to form a statistic of their utilization. One reason is the fact that the use of the tag is not always associated with a hit, and vice-versa.

The reactions we collected by interviewing local stakeholders are positive, which gives us the impression that the initiative is respectful and consistent with the social and economic framework. The measurement of the efficacy in financial terms is beyond the scope of this paper, but it has to be said that the aim of this work is to provide assistance and improve the experience of actual visitors, not to multiply their number.

Although we are satisfied that the solution complies with the sustainability principles that inspired this work, we identified two issues that indicate directions for future research:

- The balance between visual impact and effectiveness is critical. The current dimension of the tag is such that the visual impact is limited, but this negatively affects its efficacy; it is easy to miss a tag containing possibly relevant information;
- Monitoring visitor's activity, like the frequency of visits of a given tag, or the sequencing of visited tags, which may be of interest for managing the site, depends on user motivation.

Trading off cost and simplicity for effectiveness and measurability there are solutions, based, for instance, on Bluetooth communication or dedicated applications, that may improve such aspects.

5. Conclusions

Like any other productive activity, tourism is exposed to being unsustainable, damaging the very resources that allow it. To avoid heavy drawbacks the design of the activity has to consider the complex framework where it will operate, and the word used to indicate this is *holistic*, and it is extremely difficult to put into practice. A methodology made of examples and guidelines simplifies the task.

This paper is a step in this direction. We address a common problem, that of providing the visitor with directions in an area not reached by mass tourism, with the aim of acquiring the financial resources for its survival while preserving its distinguishing traits.

We show how a balanced use of technology may help in the task, with a process that is necessarily multidisciplinary, joining skills coming from the diverse domains: sociology, economics, humanities and technical. The paper demonstrates how their interplay brings ad-hoc results targeting sustainability and efficacy.

The resulting implementation is original in the literature, and minimalistic in its deployment. The detailed description enables its reuse as a starting point in future initiatives.

The discussion regarding the deployed experiment indicates directions for future investigation on the technical side. For instance, the availability of non-intrusive long-range devices that send a message whenever sensing a presence might improve signals discoverability. The Bluetooth Low Energy technology goes in that direction, but hidden tags with BLE and energy harvesting would have broken the economy constraints.

From a different point of view, the lack of discoverability suggests a recreational scenario inspired by Geocaching® and Pokemon-GO®.

In conclusion, more sustainable solutions to old problems exist and are reachable melting technology and humanities. Policy-makers are crucial in the development and monitoring of sustainable measures. This is especially important in the tourism industry where sustainability is a multifaceted topic that includes resident ecosystem resilience and regeneration efforts by both policy-makers and private tour operators.

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Sample Availability: Samples of the compounds ... are available from the authors.

Abbreviations

The following abbreviations are used in this manuscript:

MDPI	Multidisciplinary Digital Publishing Institute
DOAJ	Directory of open access journals
TLA	Three letter acronym
LD	Linear dichroism

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