

Research for Development

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Cinzia Talamo · Rajendra Singh Adhikari ·  
Corinna Rossi *Editors*

# Innovative Models for Sustainable Development in Emerging African Countries

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# Research for Development

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# Preface

This book belongs to a series, which aims at emphasizing the impact of the multidisciplinary approach practised by ABC Department scientists to face timely challenges in the industry of the built environment. Following the concept that innovation happens as different researches stimulate each other, skills and integrated disciplines are brought together within the department, generating a diversity of theoretical and applied studies.

Therefore, the books present a structured vision of the many possible approaches—within the field of architecture and civil engineering—to the development of researches dealing with the processes of planning, design, construction, management and transformation of the built environment. Each book contains a selection of essays reporting researches and projects, developed during the last six years within the ABC Department (Architecture, Built environment and Construction engineering) of Politecnico di Milano, concerning a cutting-edge field in the international scenario of the construction sector.

Undoubtedly, the African continent will see the most interesting trends in the near future for the construction sector, as well as the most serious risks in terms of sustainability of the development models. These countries face two parallel challenges: fighting the lack of resources and channelling their development along a sustainable path. In both cases, innovative methods and technologies can offer a significant contribution: affordable housing set within the social context should develop in parallel with a wise exploitation of the energetic resources; the sustainability of the entire system partly depends on how waste is handled and how to set up a virtuous recycling system; emergency situations must be addressed rapidly and efficiently, and the introduction of low-cost technologies may allow to turn study and preservation of the cultural heritage into an opportunity for development, without subtracting resources from humanitarian assistance. In general, connecting past and present will help to shape the future of countries, where carefully chosen innovative instruments can really make the difference and can allow giant leaps towards a sustainable social, cultural and environmental balance.

The book presents a selection of innovative projects carried out in African countries, aiming at tackling two main areas: offering practical solutions to specific necessities and experimenting cost-effective methods and technologies, which could be easily applied in order to achieve high-quality results. The papers have been chosen on the basis of their capability to describe the outputs and the potentialities of carried-out researches, giving a report on experiences rooted in the reality and at the same time introducing the perspectives for the future.

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# Introduction to Volume

Estimating population, urban and economic growth for Asian and African countries (United Nations 2014) highlights the need to draw up new design approaches that promote the development of original architectural languages appropriate to the local identity and to the new development models. These models support the consolidation and growth of local cultures and economies and at the same time aim at reducing energy consumption, minimizing environmental pollution, increasing the use of renewable sources and effectively responding to water demand.

Therefore, a change of paradigm is required, together with a novel approach to urban (and peri-urban and rural) planning and usage of territories. In this perspective, a holistic view should influence the entire built environment, i.e. the configuration of goods, the structure and use of land and the way in which basic services—such as energy, water, food and waste treatment—are handled. It is about working to move away from the current model of linear urban metabolism—based on the ‘take-make-dispose’ approach—to a circular one, where the consumption of resources and the waste production are minimized.

Combining these changes into practice requires working in two main directions. It means, first of all, focusing on the relationship between the architectural, urban and physical aspects of new developments, climate and energy demand. Secondly, it requires identifying and integrating the necessary strategies and infrastructures to close off the energy–water–food–waste circle, searching for a high level of efficiency and self-sufficiency.

The present book revolves around these issues and describes the contribution of the ABC Department of Politecnico di Milano regarding the multidisciplinary research and development (R&D) activities, carried (and being carried) out on these multifaceted issues. It presents a selection of innovative projects carried out in African countries, aiming at tackling two main areas: offering practical solutions to specific necessities and experimenting cost-effective methods and technologies that can be easily applied in order to achieve high-quality results.

Emerging countries face two parallel challenges: channelling their development along a sustainable path and fighting the lack of resources. In both cases, innovative methods and technologies can offer significant contributions, presented in this book:



affordable housing set within the social context should develop in parallel with a sustainable exploitation of the energetic resources (Part I); the sustainability of the entire system partly depends on how waste is handled and how to install a virtuous recycling system (Part III); emergency situations must be addressed rapidly and efficiently, and the introduction of low-cost technologies may allow to carry out study and preservation of the cultural heritage without subtracting resources from humanitarian assistance (Parts II and IV). In general, connecting past and present (Part V) will help to shape the future of countries where carefully chosen innovative instruments can really make the difference and can allow significant leaps towards a sustainable social and environmental balance.

Cinzia Talamo  
Niccolò Aste  
Corinna Rossi  
Rajendra Singh Adhikari

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# Digital Workflow to Support Archaeological Excavation: From the 3D Survey to the Websharing of Data



Corinna Rossi, Cristiana Achille, Francesco Fassi, Francesca Lori, Fabrizio Rechichi and Fausta Fiorillo

**Abstract** Archaeology has recently seen a rise in the use of digital tools and new technologies. However, in many cases, innovative tools are used to perform old operations, and their potential is not fully exploited to achieve equally innovative results. Moreover, in the practice of archaeological excavations, the collection of digital data proceeds alongside the collection of classic paper archives, thus prompting the necessity to find a way to combine different sets of data. The research team engaged in the ERC project LIFE (CoGrant 681673) is working on the identification of the most effective survey methods in relation to specific logistic and environmental conditions, as well as on the possibility to efficiently combine digital and paper archives, and is testing the results on two archaeological excavations in Egypt.

**Keywords** WEB-BIM · BIM3DSG · 3D models · Reality-based modelling · Sharing · Big data · Informative system · Archaeology

## 1 Introduction

In the last ten years, new technologies have been gaining momentum in archaeology; however, their use and distribution are still rather uneven. Both the acquisition (thanks to the various available options such as laser scanners, UAV and photogrammetry) and the classification of data in an electronic format are becoming increasingly commonplace, but the interaction between the various sets of data is often patchy. This is due to a combination of issues, including the understandable need to avoid substantial disruptions to the consolidated archaeological workflow, as well as a number of technical difficulties relating to the interaction between digital and paper archives. The use of pen and paper on an archaeological excavation can be supported but cannot be entirely replaced by digital means; the issue here is not the presence of different sets of data, but the fact that these sets of data do not communicate in an effective or efficient way. Therefore, the challenge is to identify the most efficient

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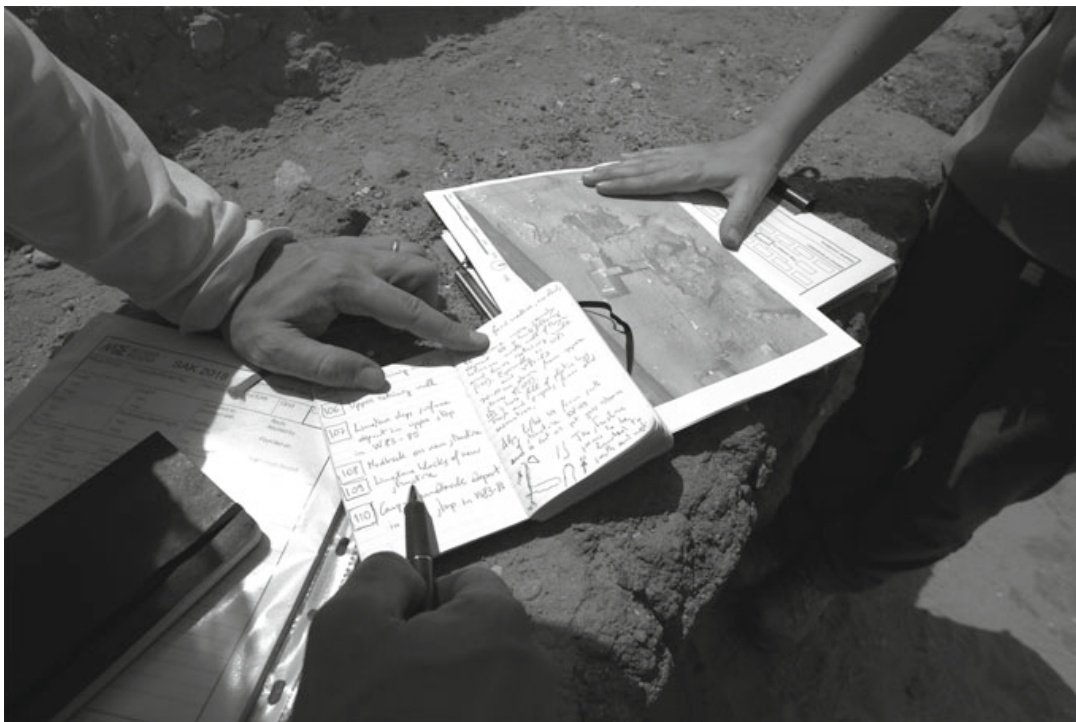
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survey methods both in terms of implementation on the field and of post-processing and eventually set up a comprehensive informative system which would be able to combine different types of data.

## 2 Fieldwork and Digital Tools

On the field, pencil and paper still play a fundamental role and will continue to do so. The vast majority of archaeological missions still produce a large amount of data on paper, from which, at a later stage, all the relevant information will be collected in order to reconstruct the stratigraphy and the evolution of the site. The study of specific finds, sometimes, takes place years after their retrieval; in general, the post-fieldwork processing can take a long time, and sometimes never reaches an end, thus producing a variable amount of so-called grey literature, that is, data that is collected but never published (Fig. 1).

Digital tools are gaining space in the archaeological practice, but they are often confined to specific areas, their potential not fully exploited. For instance, 3D models



**Fig. 1** Data may be acquired in a digital manner; however, on the field, pen and paper represent the most useful and convenient tools to take notes and check cross-references. In Egypt, sand, wind and strong sunlight make the use of tablets on the field rather uncomfortable. The issue is not necessarily whether or not the technology is available, but whether or not it is really useful in that specific circumstance. Archaeologists comparing written notes with one another, during the 2018 Dutch-Italian excavation at Saqqara of the Museo Egizio, Turin and the Rijksmuseum van Oudheden, Leiden

of items are used just as ‘better’ (more attractive and efficient) images in comparison with photographs, but they are rarely exploited to really enhance specific characteristics of the object which would otherwise be invisible or undetectable (e.g. Rossi and Fiorillo 2018).

One aspect that is gaining importance is the use of photogrammetry to obtain orthoimages of excavated areas (e.g. Verhoeven et al. 2012; Fregonese et al. 2016). Seemingly, electronic databases are now widespread; even if they all respond to some basic requirements, they are generally run independently by each archaeological mission and tailored to their specific needs. Another issue is represented by the fact that some obviously expected results imply rather complex technical solutions: for instance, achieving the connection between items and space (so easily noted on paper) means merging 3D, GIS and databases into an informative system (a complex operation).

The overall impression is that there is ample room to find a more productive and proactive role of digital imaging within archaeological practice, but some basic conditions must be respected.

Archaeological excavations rely on long-established practices, drawing from a common corpus of rules and conventions, interspersed with specific variations depending on the habits of the specialists involved in the excavation and the post-excavation phases. Especially in the case of long-running projects, the introduction of new methods and tools is certainly welcome, but can be problematic if they disrupt the consolidated workflow.

Any major change would be a matter of modifying not only personal habits, but also the methodologies with which data is collected, classified and studied thus far. Therefore, the introduction of any new tool must be carefully evaluated in terms of impact on consolidated practice, as to avoid that the costs of its adoption surpass the benefits.

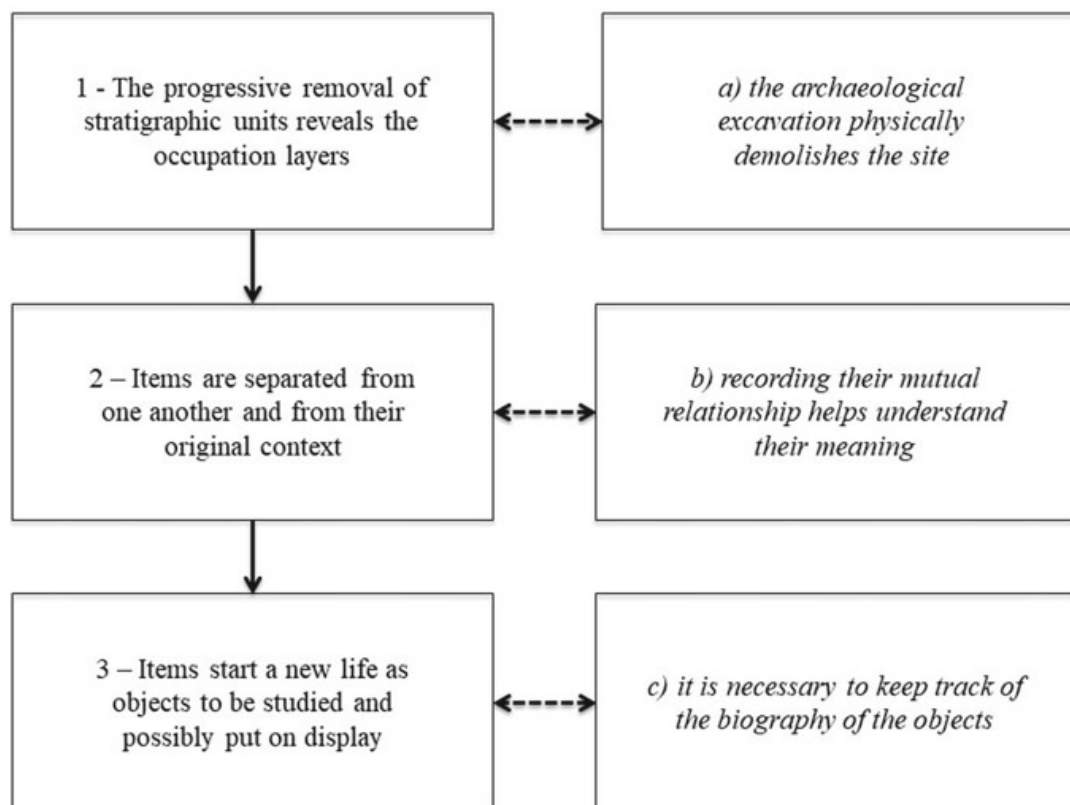
### **3 Establishing Connections**

The most interesting and productive aspect of a closer interaction between archaeology and digital imaging is the possibility to virtually construct or reconstruct lost contexts and severed ties.

An archaeological excavation is a destructive activity: progressively, archaeologists physically remove the layers that accumulated over the centuries and separate forever the items that are found during the excavation from their original context. When the components of the stratigraphy are divided, some items start a new life, becoming objects to be studied and possibly put on display (Fig. 2).

This process of destruction and separation is irreversible. The only surviving link to the original context is the information recorded during the excavation phase; when this is not available (either because an object was found during illicit digging activities, or because the excavation reports remain unpublished), the process of





**Fig. 2** Archaeology as a destructive process: actions, consequences and countermeasures

detachment of the object from its original setting, and therefore its original identity, reaches its maximum extent (Del Vesco 2018).

Digital imaging, in itself, represents a way to document in an efficient and effective way a number of aspects of both the excavation process and the items that are retrieved. Potentially, it may provide an efficient basis on which to create connections among the various types of data, in order to reconstruct the lost context and re-trace the complete biography of the objects (Betrò 2011; Greco 2018).

Digital records offer the additional benefit of being able to share information easily; this means reducing the danger of generating grey literature, as well as offering the possibility to create or re-create virtual connections that would be impossible to achieve in the real world.

In conclusion, connectivity is the keyword around which to construct a successful dialogue between archaeological practice and new technologies, aiming at responding to the needs of archaeologists and, at the same time, exploiting the potential of digital imaging and records.

## 4 Surveying in 3D an Archaeological Excavation

Archaeological fieldwork is traditionally recorded on context sheets, one for each context retrieved during the excavation process, which is filled by hand with all the relevant information (identification code, retrieval date, location, dimensions, material, etc.). The relative position of each context in relation to the adjacent contexts is carefully noted; all of this information is later conflated into the so-called Harris Matrix, a scheme that summarizes the mutual relationships of all contexts that have been retrieved.

Although, in a way, this passage represents the three-dimensionalization of the excavation data, it leads to the construction of a vertical section of the stratigraphy, a two-dimensional representation. The traditional archaeological method, therefore, skirts the third dimensions, but never really deals with it as it moves mainly on paper. The possibility to produce 3D surveys and models of the excavated remains, thus, offers fresh possibilities of investigation and practical applications that are likely to produce interesting results in near future.

While the 3D survey of standing remains offers the same advantages that are already known from the more general field of digital techniques applied to the cultural heritage, the potential of surveying in 3D the stratigraphy of an excavation is still being explored. The research team of the ERC project LIFE is working on this subject in collaboration with the Museo Egizio, Turin, at the excavation of the New Kingdom tombs of Saqqara (Egypt), led by Rijksmuseum van Oudheden, Leiden and the Museo Egizio, Turin.

The concession of the Dutch-Italian mission includes a number of large tombs built for themselves by high-ranking officials who lived in the period during the Eighteenth and the Nineteenth Dynasties of the New Kingdom (Martin 1991). Among them, there was Maya, Treasurer of Tutankhamun, and Horemheb, who built a tomb for himself there when he was a powerful general of the Egyptian army; he later became pharaoh and was eventually buried in the Valley of the Kings, on Luxor's West Bank.

The upper levels of the area currently under excavation, located to the north of the Tomb of Maya, contain evidence of later occupation, including some small Rameside chapels built alongside re-used funerary shafts, and the later, feeble remains of domestic occupation dating back to the Coptic Period (Del Vesco et al. 2019). All these remains are being surveyed in 3D by photogrammetry, thus offering archaeologists the chance to construct something of a virtual digging diary, to which they can go back to check the appearance of the excavation in any given day. The use of photogrammetry means that the ensuing 3D models have a realistic appearance which, if matched with a very high resolution, allows for the visualization of a wealth of small details, some of which might have been overlooked on the spot. This is proving an extremely useful tool during the post-fieldwork processing of the data, which takes place, by definition, after the fieldwork and away from the site.

## 5 Handling the Data

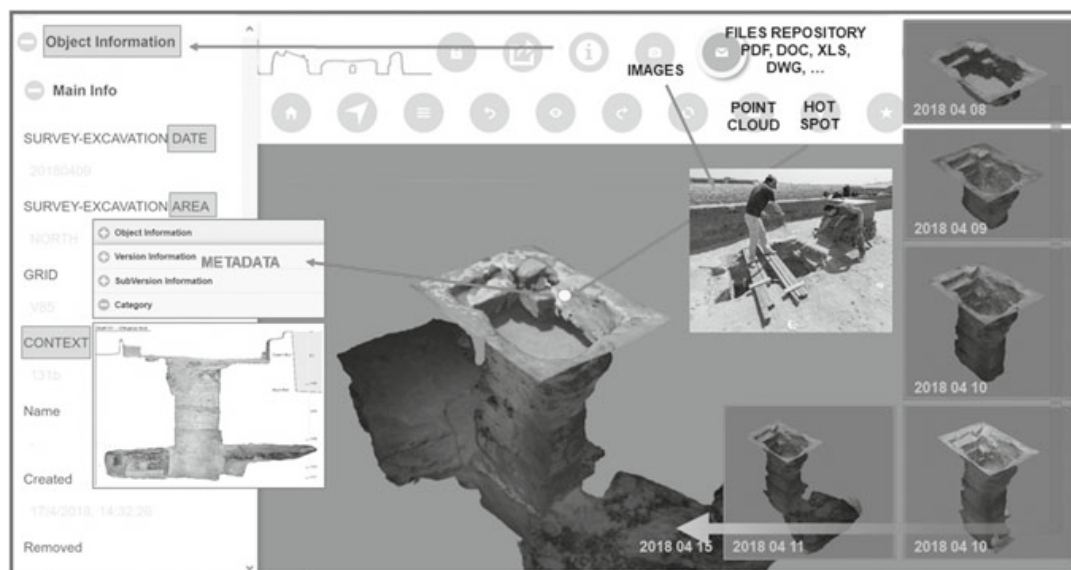
Once the 3D data has been collected and processed, the problem is how to let it interact with other types of data (texts, images, etc.) containing other information. This is a more general problem, if course, that is not specific to the archaeological realm.

Starting in 2010, the 3D survey group of the Politecnico di Milano developed a prototype of an HBIM (Building Information Model for Cultural Heritage) system for the maintenance of the Veneranda Fabbrica del Duomo di Milano (Fassi et al. 2011). This experiment worked as a pilot project to develop a more general information system (BIM3DSG), to be proposed as a standard fruition and valorization procedure in the world of cultural heritage, using 3D as the basis of informative systems (Rechichi et al. 2016). The expected result was to provide a tool that could enhance the potential of using a virtual digital model in the cultural heritage sector, particularly for the restoration, extraordinary and ordinary maintenance of a historical and artistic monumental complex. Later, the system was also applied to the Basilica di San Marco in Venice (Fassi et al. 2017; Adami et al. 2018), for the conservation practices of Pietà Rondanini (Mandelli et al. 2017) and over the last few months for the conservation of large architectonic environmental UNESCO heritage sites such as the Sacri Monti of Piedmont and Lombardy (Tommasi et al. 2019).

BIM3DSG is created for the advanced management and 3D visualization of heterogeneous models characterized by a high geometrical complexity, as is common in the field of cultural heritage (Fassi et al. 2014). The system is divided in two parts. The first is conceived to be mainly used by professionals and 3D specialists, and it is developed into the modelling software and aims to add or modify 3D models (point cloud, nurbs and mesh with or without texture). The second part is conceived for all other users and allows for the use of the system via the web. It requires only a web browser and is specifically designed to also be used on mobile devices such as laptops, tablets and smartphones, even those characterized by low hardware resources. Both sections allow the user to access the interesting parts, zones, sectors, areas, in addition to the whole model; the selection of desired objects can be achieved through a variety of search functions or can be obtained automatically through spatial relationships (Fassi and Parri 2012).

A sample of possible operations that can be carried out within the system are (i) to manually compute distance measurements and automatically measure surface area, volume and coordinates of every object; (ii) to add/edit/view user information; (iii) to attach external files, such as photos, videos, documents and dwg files associated with one or more objects or models and (iv) to add/edit/view maintenance, restoration and building site activities with all related information. All these operations can be carried out via a web browser.

The core of the system is a dynamic database that contains all the data and automatically manages the use of the system via web, both in reading and in writing



**Fig. 3** The online system is expressly designed for the management, sharing and use of high-resolution 3D models and information following the excavation phases. The system allows measurement operations to be performed, along with the possibility to visualize very high-resolution orthophotos, place hotspots, linked documents and images

mode. The database is created to offer the possibility to add extra information systems created ad hoc for every single study case. This is the key aspect of the system that can be therefore easily adapted to completely different study cases.

In 2015, BIM3DSG became a component of the ERC project LIFE, for the management and visualization of the data collected during the archaeological expeditions to Umm al-Dabadib, in Egypt's Western Desert (Fassi et al. 2015). The initial work performed on these archaeological remains proved extremely useful and interesting, and prompted the development of a new branch of research, focusing on the construction of a version of the core system which would be specifically designed to respond to the needs of archaeological excavations (Fig. 3).

The main issue relating to the creation of a version of the system specifically designed for archaeology is the need to link time, space, objects and information, in order to visualize the past situation and allow for a comparison with the current situation or with the different phases of modification. An archaeological excavation is an ongoing process, during which items of various types are found and removed: the informative system accompanying the excavation must therefore be able to record in real time the physical transformation of the area under excavation and geo-reference both in space and time the findings that are progressively retrieved. Recording in 3D the excavation and its findings has a number of advantages but may always be feasible, due a combination of logistic, environmental and financial reasons. Whether or not 3D models of items and contexts are adopted, it is certainly necessary to attach to the finds different types of information, ranging from images to written notes. The ideal solution is to be able to do so from the smallest context to the landscape scale,

thus connecting any findings to the wider framework of the site, as well as to the bigger picture.

Finally, considering that most of the specialized analysis on the findings is carried out at a later stage, and by researchers often scattered across various countries, the informative system is designed to offer a collaborative work environment, so that the data is available to the research team independently from their physical location.

## 6 Conclusions and Directions of Future Research

The spread of 3D models and the advantages of digitally recording data and information has an inevitable impact on archaeology, overlapping, missing out certain aspects and in some cases clashing with the traditional archaeological practice. The work carried out by the research team of the ERC project LIFE at the ABC Department focuses on solving these issues at various levels: by testing the most effective survey strategies, as well as by developing an informative system based on connectivity among data, information, places and people. The core of the system is being constantly updated and upgraded by the creation of new components and the fine-tuning of others, in strict collaboration with the archaeologists, who will be the final users of this product.

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