

# Integrated GIS Monitoring Systems for Sustainable Spatial Management in Historical Built Areas

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Publication date:	July 2018
Title:	Integrated GIS Monitoring Systems for Sustainable Spatial Management
Digital or print:	Digital
Publisher:	<p>IOP Science</p> <p>IOPscience is an online service for journal content published by IOP Publishing. IOPscience embraces innovative technologies to make it easier for researchers to access scientific, technical and medical content.</p>
Available at:	<a href="https://iopscience.iop.org/article/10.1088/1757-899X/471/9/092059/meta">https://iopscience.iop.org/article/10.1088/1757-899X/471/9/092059/meta</a>

**Keywords:** HBA; sustainable management; GIS

## **Abstract**

The article is focused on the definition of crucial elements and their interactions for the definition of a concept of effective integrated GIS monitoring system as supporting tool for sustainable spatial management. The article is dealing with monitoring system requirements and describes steps of the monitoring process in concrete details that include proposals for an efficient and effective monitoring system. It describes why monitoring is needed, what is possible to monitor, who is active in the monitoring process and briefly described possibilities for monitoring. Applicability of the concept is confirmed by practical implementation of GIS monitoring system focused on energy efficiency spatial aspects in the city of Poprad. The article particularly summarizes preliminary outputs of international project Bhenefit supported by Interreg Central Europe programme. The project is focused on improving sustainable management approaches of historic built areas and looking for novel solutions improving decision-making and managing processes efficiency, through monitoring and assessing, risk prevention, environmental sustainability, conservation and re-use

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To cite this article: Vladimir Ondrejicka *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **471** 092059

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# Integrated GIS Monitoring Systems for Sustainable Spatial Management in Historical Built Areas

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**Abstract.** The article is focused on the definition of crucial elements and their interactions for the definition of a concept of effective integrated GIS monitoring system as supporting tool for sustainable spatial management. The article is dealing with monitoring system requirements and describes steps of the monitoring process in concrete details that include proposals for an efficient and effective monitoring system. It describes why monitoring is needed, what is possible to monitor, who is active in the monitoring process and briefly described possibilities for monitoring. Applicability of the concept is confirmed by practical implementation of GIS monitoring system focused on energy efficiency spatial aspects in the city of Poprad. The article particularly summarizes preliminary outputs of international project Bhenefit supported by Interreg Central Europe programme. The project is focused on improving sustainable management approaches of historic built areas and looking for novel solutions improving decision-making and managing processes efficiency, through monitoring and assessing, risk prevention, environmental sustainability, conservation and re-use.

## 1. Introduction

Monitoring processes represented a component of management. According to the UNESCO Recommendations, monitoring is assumed as a necessary and sufficient condition for programming, obtaining through direct observations, useful information to predict, and then to decide in advance. The term "monitoring" has its origin in the industrial field, indicating the continuous control over a machine in operation, using special instruments that measure the characteristic parameters like speed, consumption, production, etc. [1-2].

In a context where 'development' and 'urban heritage conservation' are seen as conflicting rather than cooperative processes, there is a need for an updated, integrated approach to urban management especially when we are talking about areas with high potential of heritage values cumulated in smaller area defines as Historic Built Areas (HBA). As it is defined in the project of Bhenefit, a HBA is a Historic built environment, both limited to a portion of an urban area or extended to a not-natural, designed landscape (shaped by complex human forces acting on the natural environment), which is made up of innumerable unique. It's also interlinked human-built elements (buildings, infrastructures, streets, canals, factories etc.) which tell the particular story and identity of the place. A HBA is typically the result of a centuries-long process of evolution, which is dictated in part by changes in natural conditions but much more immediately and obviously by human effort, by adding, adapting and replacing, and it is, therefore, a powerful expression of culture and history [3].

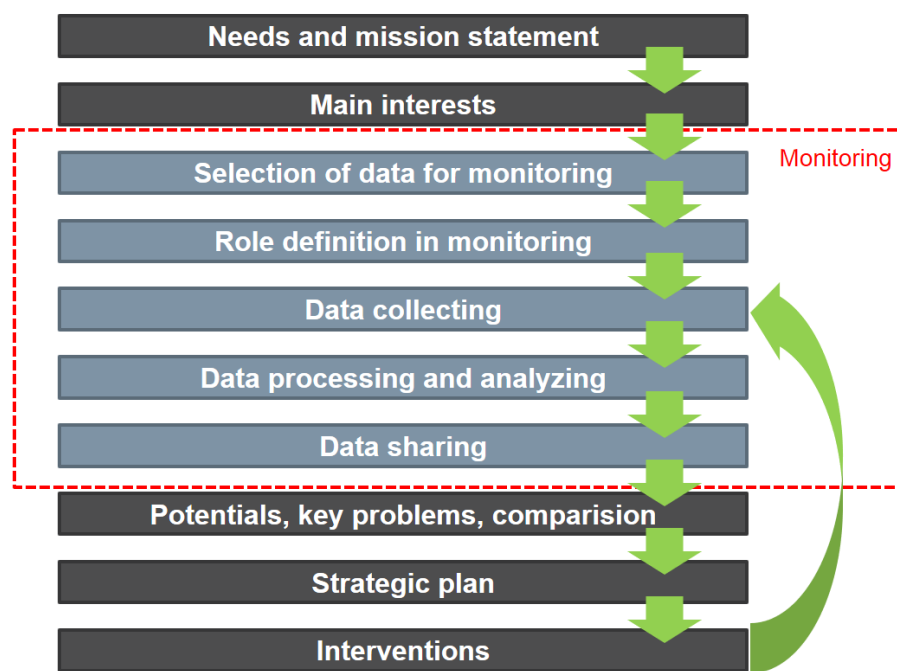


According to the previous, the monitoring in HBA can be explained as the continuous controlling process over selected historic structures in transformation, aimed at structural and functional indicators using ICT tools. The following parts describe why monitoring based on GIS in HBA is needed, what is possible to monitor, who is active in the monitoring process and briefly described possibilities for monitoring.

## 2. A methodological approach to monitoring in HBA

Monitoring involves assessing the condition of the historic area and may lead to recommendations that outline the requirements for conservation and to management activity that results in work carried out. Monitoring is essential to understanding a problem before any remedial action is attempted [4]. This work can be an investment in the future management of the historic urban area. Decisions must be based on detailed knowledge about the relevant area.

A crucial aspect of monitoring is proper position in the structure and logic steps of whole planning process ensuring efficient inputs and outputs for other relevant planning processes. The position of monitoring in the planning process is illustrated in the figure 1 below.



**Figure 1.** Monitoring in the planning process

A monitoring system in HBA depends on specific conditions due to reasons for monitoring. It is important to follow defined main interests and objectives (strategic approach). The goal is to get data that will be evaluated contextually and show potentials, key problems, and differential comparison.

The following questions are important for setting up the monitoring system:

- What are the main interests in monitoring?
- Which data is needed to collect and are they already available in the area of interest (geometrical survey, shapefiles, GIS database, etc.)?
- What are possibilities for data collecting/management?
- Who is responsible for data collecting/management/monitoring?

### 2.1. How to answer crucial questions

If objectives for monitoring are known, it is possible to proceed with the selection of data, which will be monitored. Every data must have a purpose. It helps to avoid unnecessary data. A selection has to note the relevant interests for certain HBA. The focus must be on indicators that can change their value. Monitoring data can be divided into three groups: basic data, building condition data and sustainability components (set of data relevant to a defined interest). The possible components and relevant data according to the Bbenefit approach [3] are summarized in the table 1.

**Table 1.** The possible sustainability components and relevant data according to the Bbenefit approach [3]

Group	Components/area of interest	Examples of data, which can be monitored
environment	<b>Energy efficiency</b>	insolation, used materials, energy consumption (total, per m <sup>3</sup> ), thermovision measurements ...
	<b>UHI</b>	insolation, urban greenery (a type of vegetation, greenery index in the block), temperature, thermovision measurements, ...
	<b>Waste and water</b>	flood risk, groundwater,
	<b>Pollution</b>	air pollution, noise intensity, ...
	<b>Mobility</b>	transport accessibility, traffic intensity, ...
social	<b>Services and facilities</b>	description of the use of objects, ...
	<b>Cultural life and leisure facilities</b>	description of the use of objects, ...
	<b>Identity perception [5]</b>	mental maps, landmarks, ...
	<b>Gentrification vs. mixite</b>	accessibility of services, ...
	<b>Accessibility</b>	accessibility for the disabled, ...
	<b>Urban Safety [6]</b>	the occurrence of natural disasters/man-made risks, type of risks, accessibility for emergency services...
economy	<b>Tourism impact</b>	importance of interesting points, number of visits, events, ...
	<b>Maintenance costs</b>	energy kW/m <sup>2</sup> , kW/m <sup>3</sup> ...
	<b>Transformation costs</b>	a number of transformed objects, ...

A wide range of stakeholders influences changes in HBA, and conversely these changes influences them. This leads to increased interest in tracking changes. There is a need for monitoring support and for cooperation in the management process.

- **Municipalities** as local authorities are main actors in HBAs, which involve and cooperate with other stakeholders. In the monitoring process, their role is to coordinate monitoring activities.
- **Heritage-based and interested organizations** must be involved in monitoring, especially as providers of some data about the area.
- **Owners, inhabitants, visitors and other similar stakeholders** in the area can be involved in monitoring ad hoc.
- **Another public** is in the role of the viewer.

If we know reasons, interests, and objectives of monitoring, the next step is to define monitoring process as a set of procedures. This process could be divided into main parts: a. data collecting, b. data processing and analysing and c. data sharing. The completeness and incisiveness of monitoring activities are related to:

- sources of knowledge taken into account;
- the frequency of data acquisition and analysis;
- parties involved in the various monitoring activities;
- to find tolerance ranges and the threshold level. [1]

### **Data collecting and periodicity**

Data collecting as the first step in monitoring may use these methods:

- data survey including desk research, collecting existing data and historical records (archaeological records, historic plans, ...)
- creating and completing forms or standard checklists based on site visit, familiar information, recorded observations, photographs, ...
- acquiring new necessary data through measurements, sensors, remote sensing, ...
- crowdsourcing (to involve stakeholders)

Generic statistical or indicative analysis of the urban area is not sufficient. Detailed analysis of the area is time-consuming and requires professional expertise to identify specific elements that contribute to the sustainability of the historic urban environment [7]. Monitoring methods should be applied at a specific scale. According to Department of Conservation from New Zealand different levels of survey and monitoring in historic areas may be recognized:

- Small-scale plan. Monitoring confined to the acquisition of a range of data at a fairly superficial level and with very limited potential for measuring gradual medium or long-term change.
- Medium-scale plan of a place and all components, but without detailed plans of each component. Good potential for monitoring medium-term change across the site but limited usefulness for recording changes to individual structures.
- Large scale plan including details of place and all components (scale of site plan normally better than 1: 500.) Good potential for monitoring medium and long-term change across the site and individual components [4]

For built structures, there is again a range of levels of documentation. There is no single best way to record a standing structure, but ground, floor, and roof plans together with elevations and sections are usually required to adequately record condition.

All sites require some degree of condition monitoring in order to determine the rate and causes of any deterioration, to establish if any negative visitor or management impacts are occurring, and indicate where intervention may be necessary. The more accurate information on existing objects may lead to an optimal design of monument restoration [4].

The periodicity of monitoring is a next aspect that must be taken into account. It is not generally possible to determine how often every HBA should be monitored. The frequency depends on the nature of monitored data and on the organization, which is responsible for monitoring. However, rules for periodicity must be specified. These rules can be divided into:

- Strict periodicity – short-term or long-term fixed cycles (it can be linked to local strategy or development program).
- Ad hoc – based on needs (e.g. new planned activity in the area) or milestones (e.g. before and after intervention).

### **Data processing and analyzing**

An important component of any monitoring algorithm is to provide analysis and reporting of the information as well. Some collected data may be used in aggregate to report on the overall state of historic structures.

Therefore, new analytical tools and concepts are needed. These tools would enrich and expand the traditional methods and achieve sustainability of cultural heritage in any urban context. Currently, modern digital technologies that can provide clear information on the condition of the historic urban area, or identify vulnerabilities and can be used to measure and register change and to process comparative analyses [7]. In spatial management are used tools such as Geographical Information Systems (GIS) and Building Information Modelling (BIM) is used. This is due to the ability to link spatial and non-spatial data of physical features, which can contribute substantially in documenting different urban features and in modelling processes in the monitored area [8].

A geographic information system (GIS) is a computer-based tool for mapping and analysing things that exist and events that happen on earth. GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps [9].

BIM (Building Information Modelling) is an intelligent 3D model-based process that gives architecture, engineering, and construction (AEC) professionals the insight and tools to more efficiently plan, design, construct and manage buildings and infrastructure [10].

These technologies require relevant input data about monitored area or building including a great range of geometric and descriptive information (attributes). Great range of geometric and descriptive information can be used for the interpretation, monitoring, visualization and evaluation of urban heritage areas. Detailed analysis of HBA leads to evaluation, which should be represented visually on maps and models that illustrate current situation, as well as the need for action.

### **Data sharing**

In today's society, access to data and information is an important element. Access to information is important for stakeholders in the area and can lead to better understanding of needs and to adopt the development strategy as a common interest.

Tools like GIS and BIM allow presenting information in an advanced digital form. Interactive maps and models can provide more information and in a faster and more attractive way than long texts or traditional raster formats. Spatial data processed in GIS can be visualized on the web via WebGIS technology. WebGIS is a web mapping application that allows publishing, viewing and browsing spatial data. Proper data processing is crucial for the quality of WebGIS. The aim is to provide comprehensive information that is easily accessible and simplifies the process for obtaining the required information. An important advantage is the ability to add data from different sources.

Next opportunity for spatial data sharing is to publish it in the way of open data. As open data can be published data in shapefile format (.shp), in geodatabase (usually. gdb), in format for Google maps (.kml or .kmz) or in format based on the JavaScript Object Notation (GeoJSON). This data should respect Directive 2007/2/EC, an EU initiative to establish an infrastructure for spatial information in Europe (INSPIRE) that is geared to help to make spatial or geographical information more accessible and interoperable for a wide range of purposes supporting sustainable development.

Data processed by BIM technology can be published on the web via BIM portal. The BIM portal is a collaborative working tool for multiple stakeholder engagements on a BIM project. For example, software called The BIM portal is an open source software under MIT license shared through GitHub as free. Common directive for BIM data sharing does not exist. The most used formats for BIM projects are. rvt or .dxf.

However, the common aim for data sharing is to deliver information, not raw data.



### 3. Conclusion and recommendations

The methodological approach to monitoring based on GIS and georeferenced data as is present in the Bhenefit project and in short form summarized in the article is not strictly defined only for HBAs but can be used for wide range of urban sustainable development topics. Based on know-how derived from the Bhenefit project and implementation (all phases) of monitoring systems in pilot areas (Poprad, Mantova, Karlovac) we can define main principles for efficient monitoring system:

- **Preparation for collaboration:** well prepared institutional framework and stakeholder-based approach according to the topic/interest of the monitoring system.
- **Sustainability of data sources:** to allow a development of databases for a wide range of users and data providers in the future. Open-access approach.
- **Periodicity** – proper setup of data collection, evaluation and interpretation according to the topic/ interest of the monitoring system.
- **Long-term view (ex-ante)**
- **Valuation**

The output of monitoring should provide clarity for all users and explain why some actions are needed. The key is information that demonstrates the role of conservation in helping local governments to meet their sustainability agendas and targets in the urban sustainable development of historical built areas.

### Acknowledgement

This contribution is the result of the implementation of the INTERREG project Bhenefit CE 1202 “Build heritage, energy and environmental-friendly integrated tools for the sustainable management of historic urban areas”.

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