

## GIS-BIM Interoperability for Regeneration of Transurban Areas

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### 1 ABSTRACT

In order to manage analysis and project processes at a territorial, urban and architectural scale, linking information to metric data is an increasingly important topic.

At a geographic and cartographic stage, the function of storing, managing and viewing data and information is performed by GIS (Geographic Information Systems), where vector features as points, lines, polygons are gathered in layers connected to an attribute table.

In a similar way, when scale factor increases, for buildings and other engineering works there is a growing necessity to preserve data or attributes together with the features where they belong. For this purpose, a major role is played by BIM (Building Information Modeling), a modelling process in which the parts of a building are hierarchically organized and every feature is connected to an information table containing all data useful for the ongoing working process or for managing the life cycle of the modelled building or infrastructure.

While the two systems are similar in concept, at the moment they suffer lack of mutual communication, especially in conveying informations from a platform to another.

Studying relationships and possible connections between different data storage environments like GIS and BIM is one of the research topics of DATA – Developing Abandoned Transurban Areas, a research project now in progress at University of Padova, involving Departments of Civil, Architectural and Environmental Engineering and Industrial Engineering.

The main goal of the project is to design pilot regeneration scenarios for wasted or underused places, focusing on a part of the western peri-urban area of Padova marked by the overlapping of partially abandoned industrial or commercial buildings, transport infrastructures like a ring road and a railway, residential fabric and green or agricultural land.

Among DATA key features there is a multi-scale approach: in a framework where urban peripheries are considered a relation system between a city and the surrounding territory, the project aims to combine the methods of urban and territorial analysis with a design concept in which industrial landmarks or empty spaces become the core of possible urban transformations.

Therefore, starting from data mining and management related to the areas of interest, procedures for GIS to BIM data transfer are surveyed and implemented; then, the buildings, facilities and building complex involved in scenarios design will be modelled in detail, and relevant building-scale information will be added.

At the moment, within the project, a pipeline to convert a GIS map of the buildings in our area of interest into a BIM 3D model provided with all the information of the GIS layer has been developed. Then, when the BIM model is modified, its updated attributes can be taken back to the GIS level.

The aim of this paper is to describe the workflow for GIS-BIM interoperability in DATA project, results achieved at the moment and future goals and applications.

Keywords: urban regeneration, GIS, BIM, interoperability, urban projects

## 2 GIS, BIM AND INTEROPERABILITY FOR URBAN PROJECTS

### 2.1 Overview

The development and widespread diffusion of digital modelling tools for building and infrastructures is creating new architectural and engineering project management standards, which are now being recognized in a growing number of countries and administrations. One of its key features is interoperability between

different project scopes – like architecture, structures and plants – and between different operation fields. In recent years, the framework of Smart City in its strongest forms has been facing criticism because it appears not to be able to provide effective solutions to a number of urban critical issues, often involving social and economical conflicts.<sup>1</sup> Nevertheless, the use and integration of digital technologies in urban planning and design, whether considered a supporting tool and not a solution itself, may offer good chances to simplify processes and operations and to enhance the capabilities of decision makers and urban actors.

Research and practices for GIS-BIM data transmission fit into this conceptual layout.

In Building Information Modeling, the virtual database connected to any model, together with communication power of 3D viewing, makes the data interpretation easier and more user-friendly. The main purpose of a 3D model at a urban scale is to share, manage and analyse, in a smart way and on a common platform, information coming from various sources and useful for the governance of buildings, infrastructures and other engineering works laying on the territory. Monitoring transformation processes from the general to the particular and back would allow a look at territorial planning strategies, their site-specific feasibility and then again at their urban impact. Within these processes, the digital city becomes a high-performance test model. While GIS models are meant to acquire, manage and view georeferenced data, generating data aggregations which can be represented as 2D thematic maps, BIM allows to link information to 3D geometric features of buildings and to export them in specific software for different scopes and time phases.<sup>2</sup> Despite the kind and quantity of data available for each one of these systems is unlimited, it is still complicated to convey information from a digital environment to another.

## 2.2 Exchange formats and processes

Since for most of their history GIS and BIM software have been developed separately and for different purposes, at the moment there is no tool able to automatically convert features and attributes from one level to another. There are instead several procedures, usually based on the definition and conversion of open exchange formats.<sup>3</sup> An accurate review of researches on the state of the art of integration can be found in Liu et al., 2017. Essentially, one can say that in this field there are two main exchange formats: CityGML, developed By Open Geospatial Consortium, and Industry Foundation Classes or IFC, by buildingSmart. CityGML is more GIS-related, and allows to represent 3D city models provided with semantic features. It is structured into Levels Of Detail (LOD), from 0 to 4 with the higher levels corresponding to higher modelling complexity. On the other side, IFC format is the main interoperability tool within BIM. In an IFC model entities are divided in categories and can belong to different Levels of Development (LODt), from 100 to 400. This concept is in some ways similar to those of Level of Detail, but refers to the phases of design process for a building or an artefact.

A common way to connect GIS and BIM levels is to operate conversions, translations or extensions in the existing standards. This brought to a great number of experiments using plug-ins or even developing new intermediate formats to bridge the distance. One of the most popular semi-automatic conversion methods is so-called Extract, Transform, Load (ETL), which is performed by platforms like Feature Manipulation Engine and also by companies like Esri and Oracle.

Another data integration system is the one based on Semantic Web Technologies. Here, the output is no actual visual model but instead a shared set of reference ontologies containing common information, and available both for CityGML and IFC conversion.

Every method has its pros and cons and fits different needs and requests. At this stage of research there is still no killer app to reduce the complexity of the processes providing accurate results.

It may be worthwhile, finally, to mention recently explored and still less standardised fields such as Landscape Information Modeling (LIM) or Infrastructure Information Modeling (IIM).

<sup>1</sup> For example see Buck, While, 2017; Glasmeier, Christopherson, 2015

<sup>2</sup> De Marchi et al, 2016

<sup>3</sup> For thorough reviews on GIS-BIM integration, see Liu et al, 2017; Song et al, 2017

### 3 THE DATA PROJECT

#### 3.1 Research context

“DATA – Developing Abandoned Transurban Areas” is a project involving Department of Civil, Environmental and Architectural Engineering and Department of Industrial Engineering of University of Padova. It is a research project funded by Veneto Region through European Social Funds, and lasts one year. It started in June of 2017, so it will conclude in June of 2018.

The aim of the project is to design pilot transformation scenarios for transurban areas awaiting regeneration. The last decades in evolution of Western cities, especially in Italy, have been marked by growth, sometimes poorly planned, of urban territories. Along the city borders that led to incorporation of suburbs and proliferation of junk spaces and infrastructures, while relocation or closing of industrial, commercial or public service activities produced a large number of decommissioned or underused sites.

Such phenomena also have environmental costs in terms of soil consumption and sealing: soil is now considered a hardly renewable resource, and so future urban development should lean on transformations of existing spaces rather than further expansion. This raises issues about reuse of neglected buildings or places to reactivate functions and social activities.

These processes can be regarded as systemic in contemporary dynamics of city fringes. In order to understand their inner working and how to change them, it is possible to locate sample areas which feature the described spatial settings. There, context-based procedures to collect and select and analyse data can be tested, and pilot design scenarios connecting urban and architectural scale can be developed.

#### 3.2 Area of interest

The case study for DATA is located in West Padova, one of the municipalities with the highest level of soil consumption in Italy. Here, beyond a railway and a near ring road, lays a sparse urban fabric, structured along two penetration axes. A canal marks the western physical border and municipality boundary. This city part features a mix of buildings and crops and some big architectural complexes: the former cattle market area, the main cemetery, two barracks, one of which is decommissioned and a former mental hospital, now a health complex.

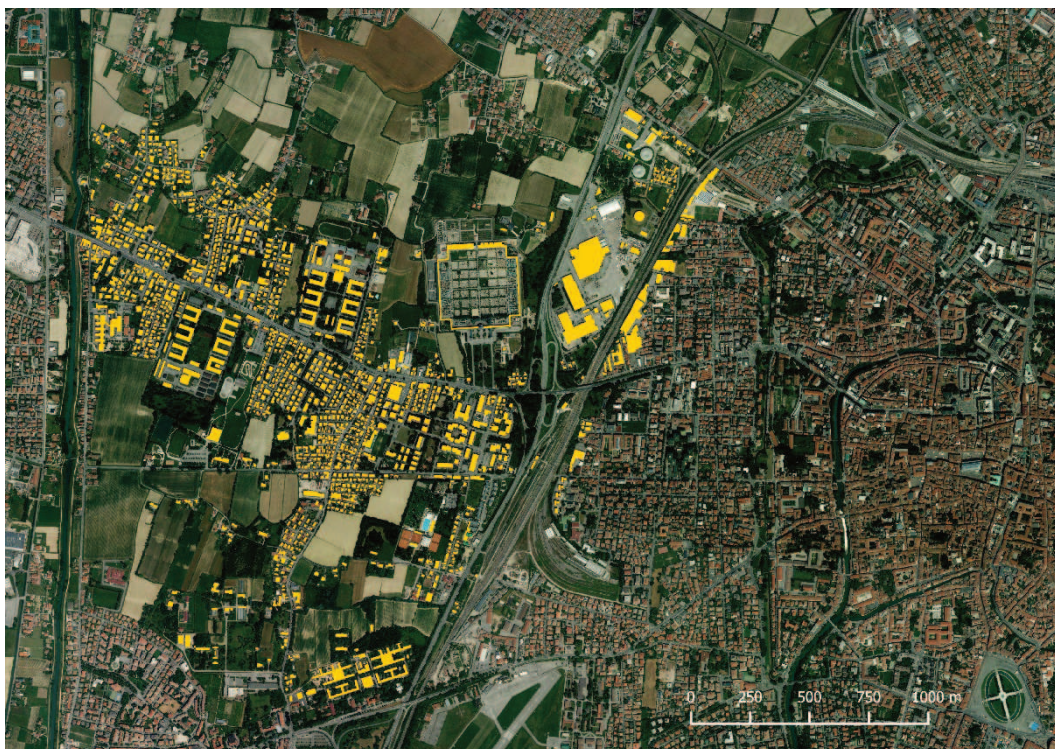


Fig. 1: Map of the area of interest in relation to the centre of Padova.

The urban landscape is marked by industrial landmarks and infrastructures that stand out in the surrounding residential fabric. This zone serves as a good example for issues and potential of peri-urban environments, as



the presence of transport infrastructures produces a disconnection from the city center but could also breed connection nodes. Besides, sites now underused and agricultural softscape could be the core of sustainable urban development.

### 3.3 Planned interventions

DATA project aims to combine and mash up different skills. It is indeed organized in six topics, managed by research fellows and their supervisors:

- WebGIS and data mining;
- Building and Land Information Modeling;
- Design scenarios;
- Urban planning and feasibility studies;
- Urban mining;
- Data management and ICT.

The first phase of the project, still ongoing, has been dedicated to define targets in detail, to find and discuss analysis methods and to set interactions between involved research fields.

A masterplan has been realized, showing transformation concepts for the study area:

- Opening to the city the big architectural systems;
- Connecting areas now fragmented by infrastructures;
- Bringing the green to the foreground.

The concept of pilot scenarios means that analysis developed and actions planned for the chosen peri-urban environment may be replicated in other urban regions, in Padova or elsewhere, which show similar features.

## 4 PROCEDURES AND RESULTS

### 4.1 GIS data collection and fusion

To check the feasibility of the process of data transmission from GIS environment to BIM, a test has been performed on a sample area, corresponding to the core intervention zone of DATA project, in the western periphery of Padova. The selected base data were an excerpt of the Regional Technical Map, with information about the function of buildings, and a portion of the municipality map of volumetric units, that is architectural volumes with their heights as an attribute. These data were provided by public administrations, and in particular Veneto Region Geoportal for the Technical Map and Padova Municipality for the volumetric building map. Therefore, they are highly reliable for analysis and planning processes.

Since useful information were on different layers, a data fusion was necessary. It has been performed on QGIS software, chosen as the main GIS work platform for its versatility, usability by researchers and free availability.

Therefore, attributes of volumetric map and Regional Technical Map were integrated through a spatial join. The new obtained layer was then cleaned deleting unnecessary attributes and indexed, that is every polygon in the layer has been provided with a progressive ID number to make it recognizable.

The selected attributes for GIS-BIM conversion, for each polygon representing a building, are:

- ID code
- Function code
- Function description
- Bottom elevation above sea level
- Top elevation above sea level
- Height

Finally, geometrical entities underwent topology check and correction, to avoid reading errors by the BIM software: in this case the chosen one was Autodesk Revit, probably the most common authoring software in

this field and one of the most suitable on the interoperability side. The GIS layer was now ready to be exported.

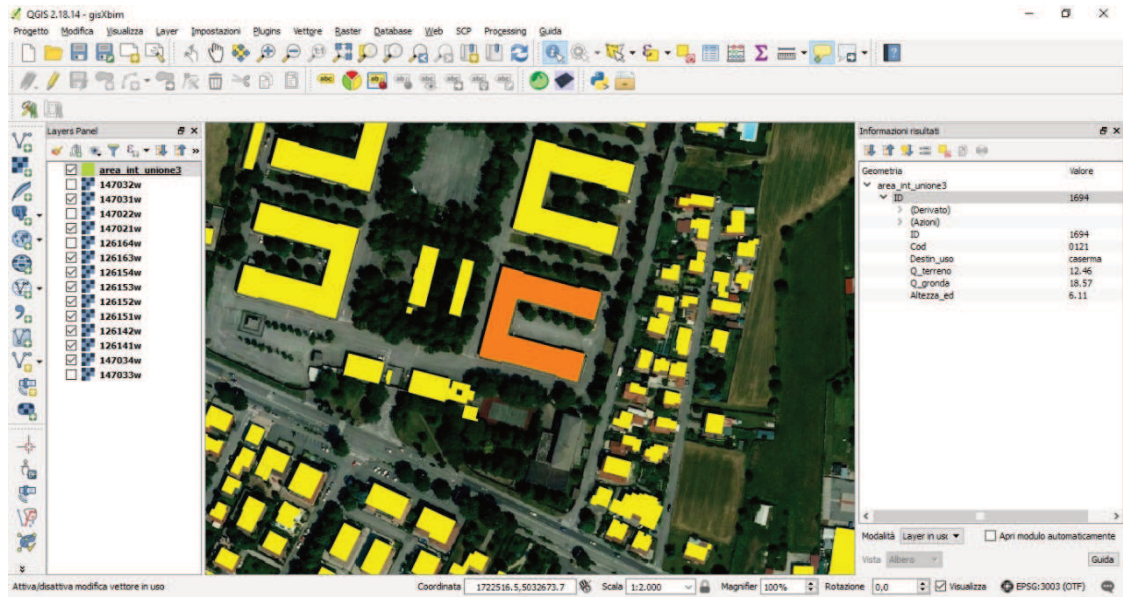


Fig. 2: A selected building in QGIS, showing the values of his attribute table fields.

#### 4.2 Creation of BIM model

The process of data transfer and generation of a BIM 3D model based on 2D vectors has been carried on by Dynamo. It is an open source software available as a Revit plug-in and centered on visual programming, or algorithmic management of workflows through editing of objects and diagrams instead of code scripting.

Although sometimes it may clash with the complexity of sequences and procedures to follow to achieve the requested output, if properly used visual programming can be a very effective tool to simplify such sequences. In this case, in fact, the script implemented in Dynamo was able to import the shapefile exported from QGIS and read its features and attributes. Starting from building height values, extrusion solids were generated by converting polylines into volumes. The script automatically associated to these solids all the other parameters coming from the GIS layer, with corresponding values.

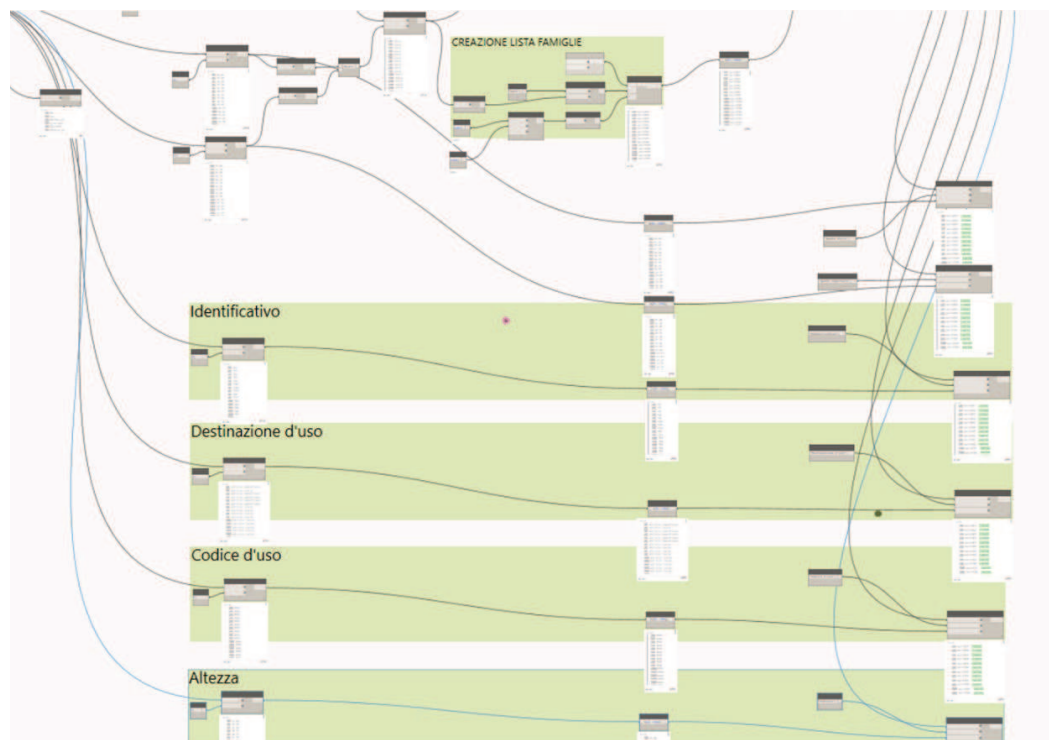


Fig. 3: A sample from the Dynamo GIS-BIM data conversion process.

More in detail, the first step was importing and reading the shapefile from QGIS; then, polylines in the GIS file were detected, obtaining building geometries. Information related to ground elevation and height of each building were used to displace and extrude every geometry. Solid geometries were finally imported in Revit as masses, associating instance properties coming from the GIS attribute table to every BIM family created.

The output is a 3D model of a portion of Padova, where every building is by itself a simplified three-dimensional model provided with all the information also loaded in GIS environment: a dynamic graphical and tabular database which can be enquired to obtain specific information.

Besides its capabilities as a data repository, the model is also a good visual tool to depict 3D spatial features of the investigated area and can serve as a background for renderings, videos and other visual communication activities for the DATA project. As a simple use case with the sample attributes used, different colors can be assigned to buildings according to their functions, thus producing an easy-to-read model displaying as-is situation and, editing some parameters, possible design scenarios.

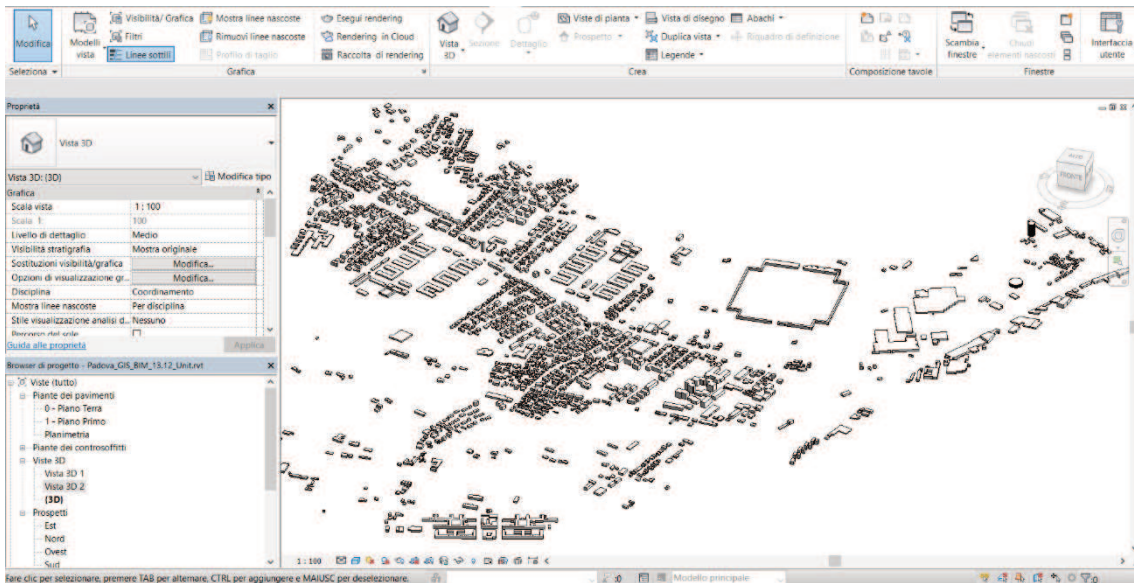


Fig. 4: The Revit BIM model obtained from the original shapefile.

When enquired, the same features in BIM and GIS show of course the same values. It is possible to further enhance the accuracy of the BIM model by moving buildings to their real elevation above sea level, since this data is available. Anyway, this is an operation more suitable for areas with relevant differences in height, rather than almost plain areas like the sample one.

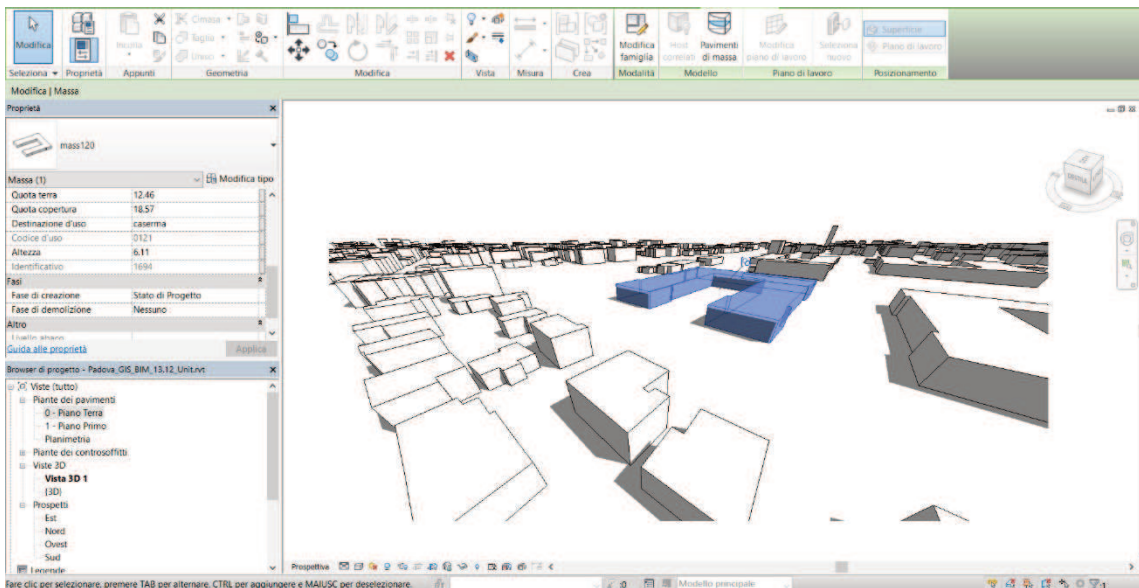


Fig. 5: The building selected in QGIS now viewed in Revit, showing the same attribute values.



### 4.3 Possibility of reverse process

Once realized a 3D as-is model, it can of course be modified: projected volumes can be included, parameter values can be updated and other ones coming from field survey can be added. For full interoperability all these new information should be carried back on the original GIS layers.

There are at least two different ways to do it, one related to geometry and the other to associated information. On the drawing side, as-built volumes added or edited in Revit can be brought back to QGIS by exporting a plan view of the model to a CAD format, for example DXF, appointing the proper reference system if necessary and then importing new or modified entities in QGIS, where they can be integrated to an existing layer.

Regarding information, from the Revit model it is possible to extract a CSV attribute table; on QGIS, a tabular join can be performed on it, if there is a common field between the two tables to integrate. In this way, additional parameters or new values for existing ones can be conveyed to the GIS level.

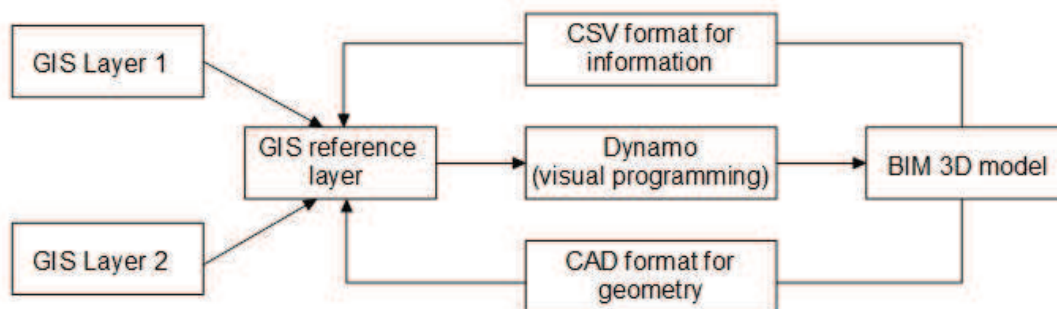


Fig. 6: A layout of the proposed workflow.

## 5 CONCLUSION

The procedure described above puts a direct connection between two major software, respectively QGIS and Revit. It is more oriented to data transmission from GIS to BIM than to the construction of a detailed BIM model, but limited to its purposes it is very accurate and perfectly replicable. In the coming months, within DATA project, further tests will be made to improve some passages and possibly to add new data related to the development of design scenarios and the creation of a communication platform.

The performed workflow is just a sample of what is possible to do to manage more efficiently multi-scale AEC operations<sup>4</sup>. Its range of applications is wide: it could be a support for implementing and updating a 3D digital building cadastre by public administrations, thus reducing data storage fragmentation; but it could also be used in a great number of urban transformation processes, each one of them would require specific and detailed data. For example, considering our area of interest, to enhance energy sustainability data about energy performance category of buildings may be collected, together with building orientation and climate data; for real estate management projects, a series of detailed social and economic data surveyed on field could be combined with a building-scale map of empty dwellings.

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