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A BIM/GIS DIGITALIZATION PROCESS TO EXPLORE THE POTENTIAL OF DISUSED RAILWAYS IN ITALY

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ABSTRACT:

Digitization processes, i.e., the practice of converting physical assets into digital assets, are gradually transforming the Architecture, Engineering, Construction and Owner Operators (AECOO) industry, and it concerns new and existing buildings and infrastructures. This study is about the management of disused railways and aims to present a BIM (Building Information Modelling) / GIS (Geographic Information Systems) workflow to identify and model disused railways buildings. The workflow was tested on the '*Potenza Inferiore Scalo*' – '*Laurenzara*' disused railway located in the South of Italy. The objective is the creation of a comprehensive digital database to help decision-makers give new utility to these existing infrastructures and buildings. And this is because the railway heritage can represent an essential factor in sustainable development processes and landscape regeneration.

1. INTRODUCTION

Secondary and complementary railways were developed in Europe from the second half of 19th Century to connect the inland small towns to the main railway lines. Moderate traffic volume and limited resources pushed the adoption of narrow-gauge railways, which had an estimated construction cost of 30% less than standard-gauge railways. The advantage of narrow-gauge (up to 1 m gauge) is the reduction of the minimum curvature radius and then a major flexibility for adapting the track to the natural terrain topography. This allows to limit the ground modification and the number and importance of infrastructures such as tunnels and bridges, with a general reduction of the construction cost (Rongone, 1998). Moreover, the narrowed track gauge occupies a smaller quantity of ground, which means decreased expropriation costs. On the other hand, winding paths and high slopes caused a lower speed of vehicles. At that time, speed limits were tolerated because there was no other option to speed up the transport of people and goods. Today, it is totally different (Guida et al., 2000).

In Italy, railway lines became the vector of national unity, making the connection between people in different places possible (Maggi, 2017). After the destruction and, sometimes, reconstruction due to both World Wars, in 1952 the National Law No. 1221 (Italian Parliament, 1952) entirely revised the situation of granted railways, deciding between modernization and replacement with road transport. This was the beginning of the expression '*deadwood*', which referred to railways in severe economic difficulties and instability. Nowadays, a total of 8,080 km of disused railways are distributed throughout the territory (Marcarini and Rovelli, 2018).

The railway heritage can represent an essential factor in sustainable development processes and landscape regeneration (Llano-Castresana et al., 2013). The need to cut harmful emissions and the growing awareness about environmental issues have led to the improvement of green infrastructure (Ferretti and Degioanni, 2017). In this context, converting disused railways into non-motorized transport infrastructure dedicated to soft mobility (greenways) can represent a great opportunity to reassess these existing infrastructures and improve people's health (Eizaguirre-Iribar et al., 2016).

This study aims to develop a digital database using the potentialities of Building Information Modelling (BIM) and Geographic Information Systems (GIS) to highlight the value of these assets inside the territory (Rovelli et al., 2020). The proposed workflow was tested on a disused railway in the Basilicata Region of Italy.

2. CASE STUDY

In order to test the potentiality of BIM/GIS integration for the digitization of disused railways, the case study of '*Potenza Inferiore Scalo*' – '*Laurenzana*' was analysed (see Figure 1).

2.1 Case study history and data

'*Potenza Inferiore Scalo*' – '*Laurenzana*' disused railway was a narrow-gauged line (950 mm), single-track and not-electrified railway track in the Basilicata Region of Italy. The track has a total length of about 42,50 km, and it connects Potenza, the capital city of the Basilicata Region, with the rural territory crossing extremely rough terrain (Zisa and Altavilla, 2020). The railway remained active from 1919 to 1980 when it was definitively closed because of the Irpinia Earthquake. In particular:

1. '*Potenza Inferiore Scalo*' – '*Pignola*' line was activated in 1919 (later than expected because of the First World War) and closed in 1980; and
2. '*Pignola*' – '*Laurenzana*' line was opened in 1931 (due to financial problems) and closed in 1969.

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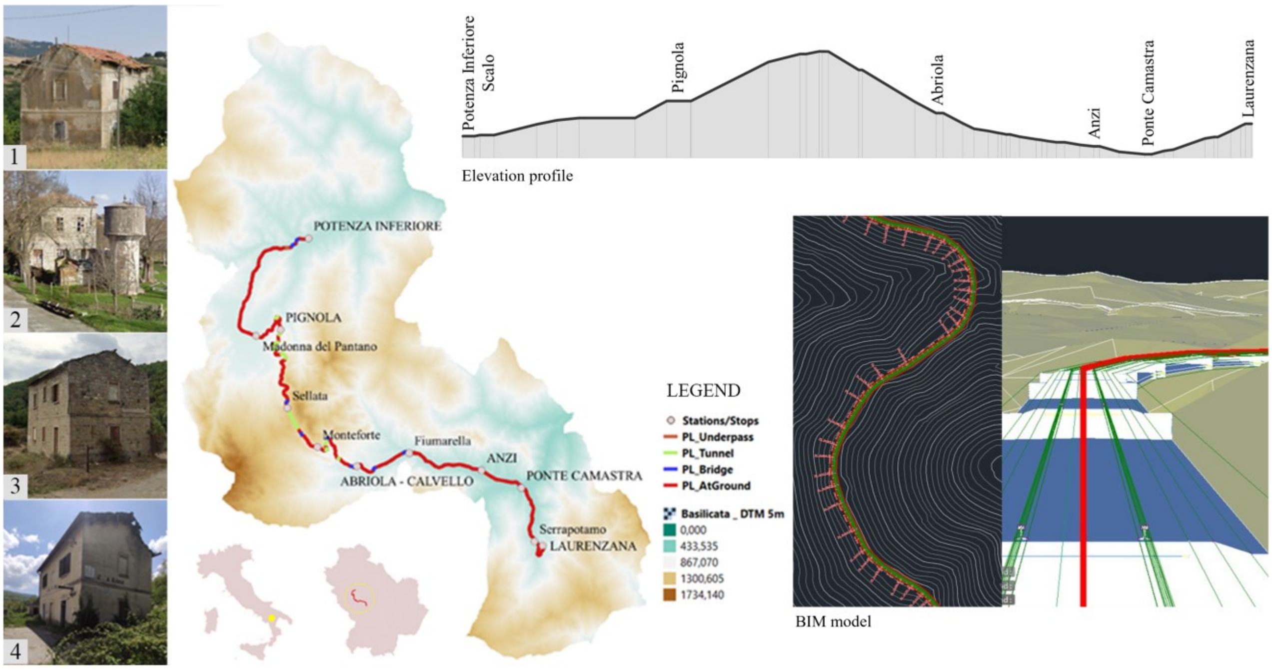

Figure 1. ‘*Potenza Inferiore Scalo*’ – ‘*Laurenzana*’ railway line. (Reference system: WGS 84 UTM 33N - EPSG 32633). The figure reports: 1) ‘*Tora*’ stop ; 2) ‘*Abriola-Calvello*’ station; 3) ‘*Fiumarella* stop; and 4) ‘*Serrapotamo*’ stop.

Throughout its working life, the railway was administered by ‘Società Mediterranea per le Ferrovie Calabro Lucane’ (MCL) until 1964 and by ‘Ferrovie Calabro Lucane’ (FCL) until 1980. As usual for narrow-gauged railways, the line followed as much as possible the topography, reaching a maximum slope of 60‰ in the first ascent along the Lucan Apennines. The descent begins steep (slope of 60‰) and gradually becomes less inclined (15-20‰). The last ascent toward the terminal station runs along a hairpin for a change in the direction of 180 degrees (slope 35-50‰). After the closure, the condition of railway elements can be outlined as follow:

1. Rails have been removed and the vegetation has invaded the railway route. Just a small part of it has been converted into a cycle-pedestrian route (Ferrovie Abbandonate, 2007);
2. Bridges/viaducts and underpasses are still in place and do not present visible structural weaknesses; and
3. Stations, roadhouses and tolls are almost all in disrepair.

The first part of this research (survey activities and digitization of the railway centreline) has previously been discussed in Garramone et al. (2022). Briefly, after the photographic survey and, the archive and web research, a GIS railway centreline was created. Once all the elements (bridges/viaducts, tunnels, underpasses, and at-ground elements) were checked and, if necessary, modified, the BIM alignment was created. A single-track narrow-gauged general section (950 mm) was used to build the rail corridor. Finally, to test the interoperability and the use of open standards for infrastructure asset management, the rail alignment was exported using *IFCAlignment* (the entity developed by buildingSMART to store alignment information and data) from IFC (Industry Foundation Classes, the BIM open standard), version 4.1 (Garramone and Scaioni, 2022). Although information was stored in a single IFC file, horizontal and vertical profiles were separately exported, highlighting the need for IFC improvement in the infrastructure field. To do this, buildingSMART has launched different working groups (IFC Rail, IFC Road, and IFC Bridge) in order to implement IFC standards for infrastructure (buildingSMART, 2017). The IFC Rail project started in 2017 and has been developing the IFC standard for rail. Phase 1, the definition of a candidate standard, ended in March 2020, while Phase 2, the implementation and validation of the candidate standard, ended in January 2022. This innovation, introduced as a change into IFC 4.3 (buildingSMART, 2022), will become an integral part of the future IFC 4.4.

The purpose of this research is to complete the digital database by adding railway buildings models. A total of 32 buildings (6 stations, 5 stops, 18 roadhouses and 3 tolls) are located along the line, approximately one every 1.3 km. Table 1 lists all the buildings and the progressive distance on the line.

2.2 *Pignola* Station

This paper presents the case of *Pignola* Station (Figure 2). It comprises a passenger building (ticketing, waiting room and offices on the ground floor and apartments on the top floor) and a goods warehouse. The water supply and the toilet building (collapsed) complete the complex. Unlike isolated units (roadhouses), the bakery was not built. The station was dismantled in 1980 and a FAL (*Ferrovie Appulo Lucane*) employee inhabited it until a fire broke out, causing the roof collapse. Currently, the station is abandoned and showing signs of extreme deterioration.

Figure 2. *Pignola* Station: photo from the on-site survey.

BUILDINGS	
NAME	PROGR. DISTANCE
POTENZA Station	km 00+000.00
Roadhouse	km 00+552.03
Roadhouse	km 02+866.72
Roadhouse	km 04+883.31
Roadhouse	km 07+006.79
Madonna del Pantano Stop	km 09+159.03
Roadhouse	km 10+858.69
Tolls (S.P. N5)	km 11+507.69
PIGNOLA Station	km 12+130.82
Roadhouse	km 13+112.90
Roadhouse	km 14+997.37
Roadhouse	km 17+343.24
Sellata Stop	km 18+362.14
Roadhouse	km 19+891.96
Monteforte Stop	km 21+497.03
Roadhouse	km 22+212.93
Roadhouse	km 24+002.41
Tolls (S.P. N16)	km 25+290.59
ABRIOLA-CALVELLO Station	km 25+693.38
Roadhouse	km 27+002.66
Roadhouse	km 28+530.03
Fiumarella Stop	km 29+484.71
Roadhouse	km 31+163.19
Roadhouse	km 33+282.32
ANZI Station	km 34+291.70
Roadhouse	km 35+417.65
PONTE CAMASTRA Station	km 37+067.97
Tolls (S.P. N92)	km 37+398.21
Roadhouse	km 38+750.57
Serrapotamo Stop	km 40+765.96
Roadhouse	km 42+027.77
LAURENZANA Station	km 42+501.01

Table 1. List of all the buildings (stations, stops, roadhouses and tolls) and their position.

To create the digital model, two main data sources were used: photos from the on-site survey and technical drawings of original projects. The model was carried out in the building information modelling software *Autodesk Revit*®, version 2022 (Autodesk, 2021). Before starting, some preliminary operations were done: the project location was set correctly, using the geographic location, the project base point and the survey point, and rotating the real north in the proper position. Then, through the dimensions shown in the technical drawings, a group of grid lines (plan view) and levels (elevation view) were added as references to create the model. At this point, the passenger building was first modelled from exterior walls, then interior walls, floors, and roof. At the end, specific doors and windows families were created and imported into the model. The same process was followed to model the goods warehouse. Figure 3 shows the ground floor and its rooms, the first floor with the division of the apartments, and the roof.

The model was then exported as IFC, version 4 to share it through different software packages and applications. The IFC file was edited, adding other properties and information to the model. Five new property sets were created:

1. *PSet_Building_GeneralInformation* contains information about position (altitude, city, latitude, longitude, progressive distance and region), operators and year of activation and dismantling;
2. *PSet_Building_GISdata* to make the match between GIS feature and BIM model unique. For this purpose, '*FeatureID*' and '*classref*' (GIS properties taken from the "building layer" of the Basilicata DBGT) were added to the model;
3. *PSet_BuildingElements_Station* describes passengers building elements characteristics and actual status (external openings, internal openings external plaster, internal plaster, ground floor pavement, first floor pavement, roof, slab, structure, vertical connection);
4. *PSet_BuildingElements_Warehouse* describes warehouse elements' characteristics and actual status (external openings, pavements, roof, and structure); and
5. *PSet_Cadastre* contains cadastre information (sheet, particle and cadastral code).

Of course, it is possible to modify them and create new property sets as needed.

Once the IFC model was enriched with properties and information, the integration with GIS was carried out. In this case, the link referencing paradigm was used to integrate the BIM Station model into the GIS environment. GIS software QGIS, version 3.16 (QGIS Association, 2021), was used to manage this case study. This paradigm uses links in the primary schema to components of the secondary schema. Links are specified as URI (Uniform Research Identifier) and, through web services, are used to merge BIM and GIS data (Pauwels et al., 2017). This is one of the more accessible ways of viewing the model and its properties. First, the information model was uploaded to an online IFC viewer. Two different tools were tested. The first tool is *Viewer*, the free online file viewer from Autodesk (Autodesk, 2018). IFC is only one of the about 80 file formats that can be uploaded. Uploaded files remain available only for 30 days, after which they will be deleted. It is totally free, and there are no paid versions. Models can be explored, revised, and shared with anyone through the link. The second tool is *BIMData Platform* (BIMData, 2020), an open-source solution for the online data exchange and collaboration for BIM projects (Diara, 2022).

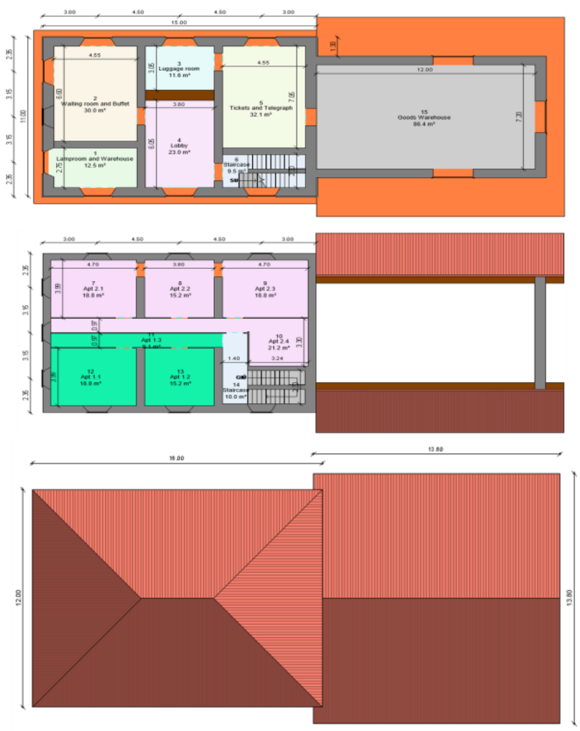

Figure 3. *Pignola* Station BIM model: ground floor, first floor and roof.

The source code is accessible to users and two formats are available (free and professional). The main differences between them are the storage space (300MB free and 10GB professional) and the addition of some functions in the professional version. BIM Collaboration Format (BCF) plugin allows revisions on IFC model and this is a fundamental aspect for multidisciplinary approaches. Finally, models can be easily shared with collaborators.

BIMData Platform was chosen due to its open-source nature and the absence of a deadline for the uploaded files. Once the model was uploaded, the shared link was added to the GIS feature properties, both as a link and as a QR code. At this point, the IFC model can be accessed easily through the link or the QR code. In this way, it is possible to see at the same time both GIS and BIM information. Another benefit is that the model is accessible regardless of the geographic system and can be viewed by ‘non-experts’ who want to explore and investigate the model (Figure 4).

2.3 Other buildings

In the same way, other buildings were modelled and integrated into the GIS environment. In particular:

1. The water supply (capacity 25 mc) located in *Anzi* Station (Figure 5). This is one of the four water supplies along the line. The others are located at the first roadhouse (capacity of 50 mc), *Pignola* and *Abriola-Calvello* Stations (capacity of 25 mc). Initially, this was a typical facility for steam locomotive supply that had a limited autonomy. Later, the use of Diesel traction and, especially, electric traction led to abandon these structures; and
2. The toilet building in *Fiumarella* stop (Figure 6). This is a small building with single-layer masonry walls (thickness of 26 cm) and a hipped roof covered with *Marsigliese* tiles.

In this way, it is possible to create a unique GIS layer containing all the railway buildings (stations, warehouses, roadhouses, tolls, water supplies bakeries and toilets) linked to their respective IFC models. These models are easy to access (direct link or QR code) and to query (according to the property sets defined).

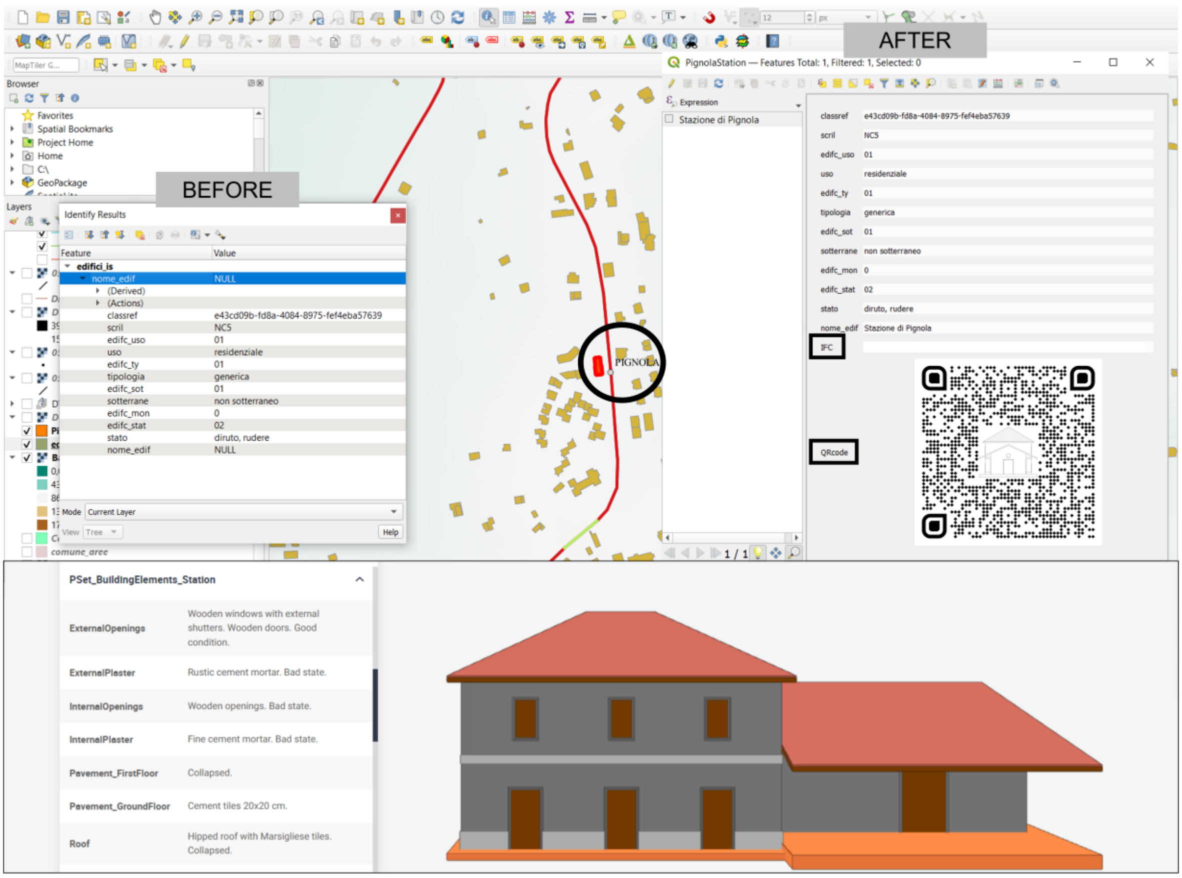

Figure 4. Adding IFC link and QR code into the GIS building properties (QGIS 3.16). On the top, the figure highlights the difference between before and after the editing. The web model viewer (BIMData Platform) with the model properties is shown on the bottom. (Note: to access the model, it is necessary a BIMData free account).

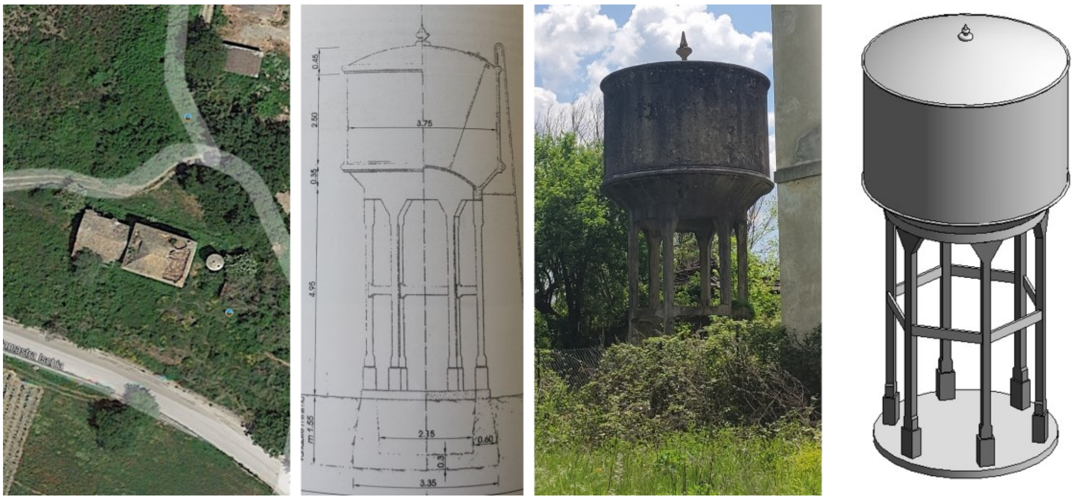

Figure 5. *Anzi* Station water supply. From the left: Google Earth image, technical drawing, photo from the survey and BIM model.

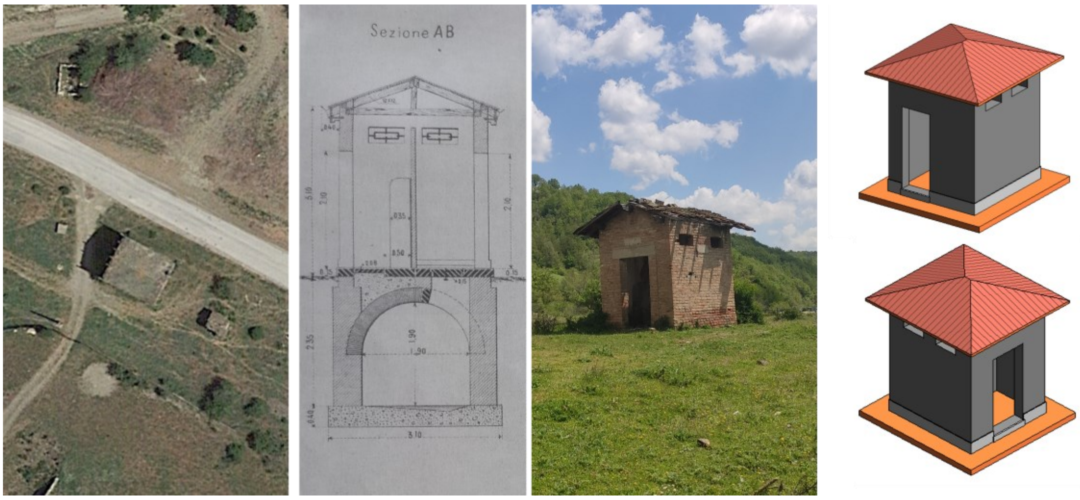

Figure 6. *Fiumarella* stop toilet building. From the left: Google Earth image, technical drawing, photo from the survey and BIM model.

3. CONCLUSION

This research aimed to present the BIM/GIS database enrichment of the '*Potenza Inferiore Scalo*' – '*Laurenzana*' disused railway. In the last decades, several kilometres of railways were closed due to the growth of road infrastructure and the negative ratio between management costs and the number of passengers of local and inner railways. Most of the time, these lines are unique paths crossing territories, landscapes, and small towns, and giving them back to the community with a different function could be valuable. The digital transformation of the built environment can help this process, and, in particular, this paper presents a BIM/GIS workflow in order to identify and digitize railways buildings. Starting from the on-site survey and the archive and on-line research, BIM models of some railways building examples were created and integrated into a GIS environment. In this way, all the information (geographic, geometric and non-geometric) are stored in a single database and can be easily accessed. A comprehensive digital database of disused railways can support decision-makers in highlighting the value of these paths inside the territory in order to transform them into something useful once again for the community.

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