Digitization process for disused railways. A case study in Basilicata (Italy)

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Abstract. The digital transformation is gradually changing the Architecture, Engineering, Construction and Owner Operators (AECOO) industry, and it applies to new and existing constructions. In particular, this study is about the management of disused railways, which usually represent unique paths inside territories and cities. Leveraging the potential of BIM and GIS, the aim is to realize a digital database of the disused railways to help decision-makers give a new value to these existing infrastructures. '*Potenza Inferiore Scalo*' – '*Laurenzana*' disused railway was used as a case study.

Key Words: BIM GIS Integration, Digitisation, Disused railway

1 Introduction

The digital transformation is gradually changing the Architecture, Engineering, Construction and Owner Operators (AECOO) industry, and it applies to new and existing constructions. Buildings and infrastructures are involved in this process but in different ways [1]. In particular, this study is about the management of disused railways, which usually represent unique paths inside territories and cities. The railway heritage can represent, all over the world, a key element in landscape regeneration and sustainable development processes [2]. '*Rail-trails*' [3] defines the conversion of a disused railway into a greenway, non-motorized transport infrastructure dedicated to soft mobility (cyclists, pedestrians, horse riders, etc.) [4]. The growing demand and the social need for green infrastructure often collide with public funds and priorities [5], so each project needs to be deeply evaluated before its adoption.
This ongoing research aims to realize a digital database of the disused railways to help decision-makers give a new value to these existing infrastructures [6]. In particular, the focus is to test the potential of Building Information Modelling (BIM) and Geographic Information Systems (GIS) integrated approach to handle the problem of these existing infrastructures [7]. The proposed methodology is applied to an abandoned railway line in the Basilicata Region of Italy. The objective is to output a digital model that represents the railway. The main contributions of this research are:

- rail information extraction from GIS raster data;

- the development of a digital model based on the BIM/GIS interoperability.

The structure of this paper continues as follows: Section 2 briefly describes disused railways in Italy and focuses on narrow-gauged type, Section 3 presents the case study data, and Section 4 outlines conclusions and future developments.

2 Disused railways in Italy

Starting from 1839, for almost 180 years, railway lines have deeply changed Italian territory's perception [8]. The train, an icon of the industrial revolution, has made the connection between people in different places possible. It became the vector of national unity. After 1950, the increasing of road transport reduced the importance of railways and since the 1960s, a great number of them have been closed. A total of 8080 km of disused railways (railways closed to traffic, deviation of the line, and incomplete railways) are currently distributed through the territory. Fig. 1 analyses places, operators, gauge types, number of tracks and uses of disused Italian railways, to date [9].

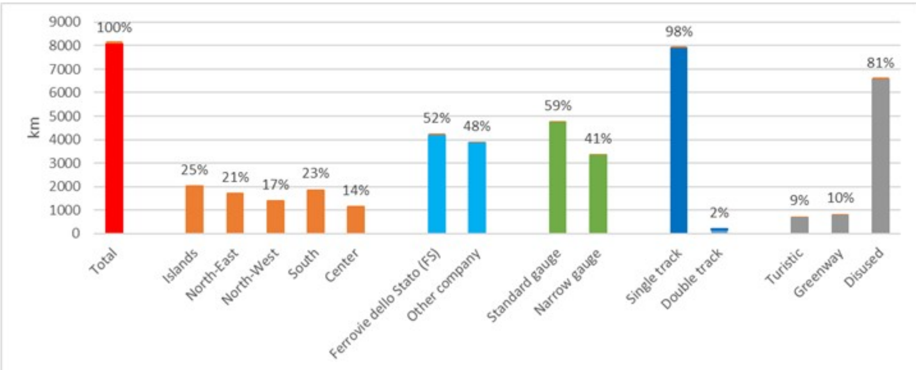

Fig. 1. Disused railways: total (red), places (orange), operators (light blue), gauge types (green), number of tracks (violet), and uses (grey).

Data shows that the problem is distributed on the whole national territory, and almost all the closed railways are single track. Most of them are inland railways with a narrow-gauged section. The story of these railways can be divided in two main periods: the improvement from 1880 to the start of World War II and the degrowth until nowadays. Once the main railways were realized, it was necessary to create the secondary ones to reach isolated places. The choice of narrow gauge depended on the lower investment needed, about 30% less than the standard gauge. This is because a smaller gauge allows to develop lines that follow the terrain slope, and then fewer interventions (land works, tunnels, bridges) are required [10]. Winding paths and high slopes mean low-speed trains. At the beginning, this was not considered a problem because they were the only way to reach the destination in most cases. However, after the war, the increasing investment in road transport led to leave the train for people and freight transport. For this reason, there are so many disused railways to date.

3 Case Study

A disused railway case study, '*Potenza Inferiore Scalo*' – '*Laurenzana*', was considered in order to create a digital database. The analysis of the '*Potenza Scalo Inferiore*' – '*Laurenzana*' railway was carried out as follows:

1. walking along the line. The photographic survey of the different elements (stations, roadhouses, water suppliers, bridges, viaducts, galleries, etc.) allowed to verify the actual status of the line;
2. researching information at the local authorities in Potenza, that are the National Library and the Provincial and Municipal Historical Archives;
3. '*on line*' bibliographic and references research.

3.1 Railway history

At the end of the 19th century, an economic rail network to connect the inner small towns in the South of Italy was increasingly needed. The '*Società Mediterranea per le Ferrovie Calabro Lucane*' (MCL) in 1915 started to build about 1200 km of narrow-gauge railways in Basilicata, Apulia, and Calabria Regions. A total length of 42.50 km of railways was created to connect Potenza, the capital city of the Basilicata region, with the rural territory traversing extremely rough terrain [11]. Delayed by World War I, the construction of the first part of the line, '*Potenza Inferiore Scalo*' – '*Pignola*', ended in 1919 while the second part, '*Pignola*' – '*Laurenzana*', was completed in 1931 [12]. In order to handle the ever-increasing traffic volume from 3,700,000 in 1938 to 7,000,000 in 1951 (on the whole line) a modernization plan was launched for maintenance and renovation of rolling stock and rail fixed installations. In particular, the replacement of almost all the tracks allowed to rectify parabolic curves up to a minimum radius of 310 m. Works carried out on the railway line improved speed and reduced travel times. Moreover, electric and water systems were installed in stations and roadhouses to make workers' day life more comfortable.

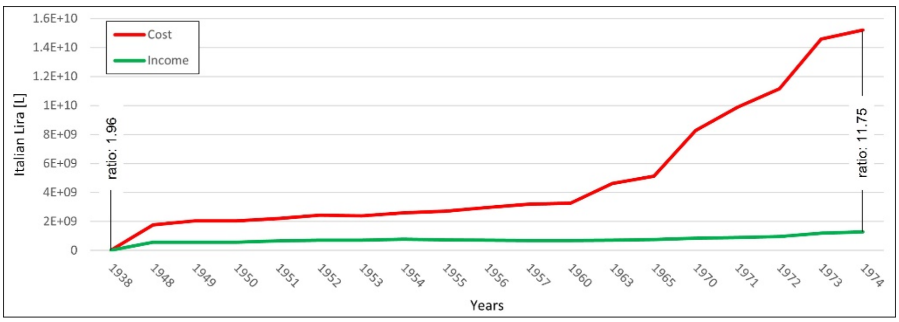

Fig. 2. FCL cost/income ratio from 1938 to 1974.

In 1961, the line suffered a serious accident that resulted in the loss of MCL concession and the creation of the *Governamental Commissarial Management of Ferrovie Calabro-Lucane* (FCL). In the following years, due to the decrease in rail passengers and freight traffic and the more and more negative cost/income ratio (see Fig. 2), different railway lines were suspended and replaced with road transport [13]. The line '*Pignola*' – '*Laurenzana*' was definitively closed in 1974, while '*Potenza Inferiore Scalo*' – '*Pignola*' in 1980, after the Irpinia earthquake. In 1990, the *Governamental Commissarial Management of Ferrovie Calabro-Lucane* was divided in *Ferrovie Appulo-Lucane* (FAL) for railways of Puglia and Basilicata and *Ferrovie della Calabria* (FC) for railways of Calabria.

3.2 Railway description and field survey

The 42.50 km of narrow-gauged (950 mm) railway comprises:

i) 6 stations ('*Potenza Inferiore*', '*Pignola*', '*Abriola-Calvello*', '*Anzi*', '*Ponte Camastra*' and '*Laurenzana*');

ii) 5 stops ('*Madonna del Pantano*', '*Sellata*', '*Monteforte*', '*Fiumarella*' and '*Serrapotamo*');

iii) 21 buildings (roadhouses and tolls) approximately every 1.3 km.

Table 1 synthesises railway description and railway elements divided by category.

Table 1. Railway description and elements classification.

Length	≈ 42.5 km
Opening date	1919-1931
Closing date	1974-1980
Operators	MCL (1919-1964) FCL (1964-1980)
Electrification	No
Gauge	Narrow - 950 mm
Max slope	60‰

	km	%
At ground	39.53	93.01
Tunnel	2.33	5.48
Bridge/Viaduct (principals)	0.61	1.44
Underpass	0.03	0.07
Retaining structures	9.33	21.95
Horizontal development	9.16	21.55

The starting point of the survey was '*Potenza Inferiore Scalo*' station (674 m asl), that is still active on the '*Altamura*' – '*Avigliano*' – '*Potenza*' railway line. The passenger building was newly rebuilt after the Irpinia heartquake in 1980. Leaving the city, the line can be divided and analysed into three main parts (see Fig. 3):

1) the first ascent along the Lucan Apennines leads to reach, crossing '*Pignola*' station (863 m asl), the highest altitude (1128 m asl), with a maximum slope of 60‰. To arrive at this point, different interventions have been realized: land containment works (retaining and counter-bank walls), tunnels (the longest is '*Sellata*' gallery, 1146 m), and viaducts;

2) the descent begins steep (slope of 60‰), reaching '*Abriola*' station. Then, the slope becomes gradually less (15-20‰) until it arrives to '*Ponte Camastra*' station, the lowest point (577 m asl);

3) the second ascent toward the terminal station, '*Laurenzana*' (741 m asl), runs along a hairpin for a change in the direction of 180 degrees (slope 35-50‰).

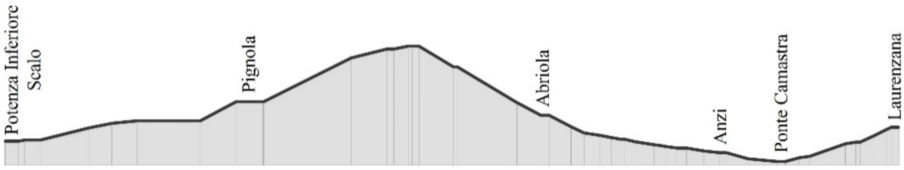

Fig. 3. Elevation profile and stations.

Since the closure, the rails have been removed. Most of the line is abandoned. The vegetation has taken possession of the railway route; just a small part of it has been converted into a cycleway [14]. Bridges, viaducts, and galleries are still in existence and do not present visible structural weaknesses. A completely different situation concerns stations, roadhouses, and tolls that are almost all in disrepair.

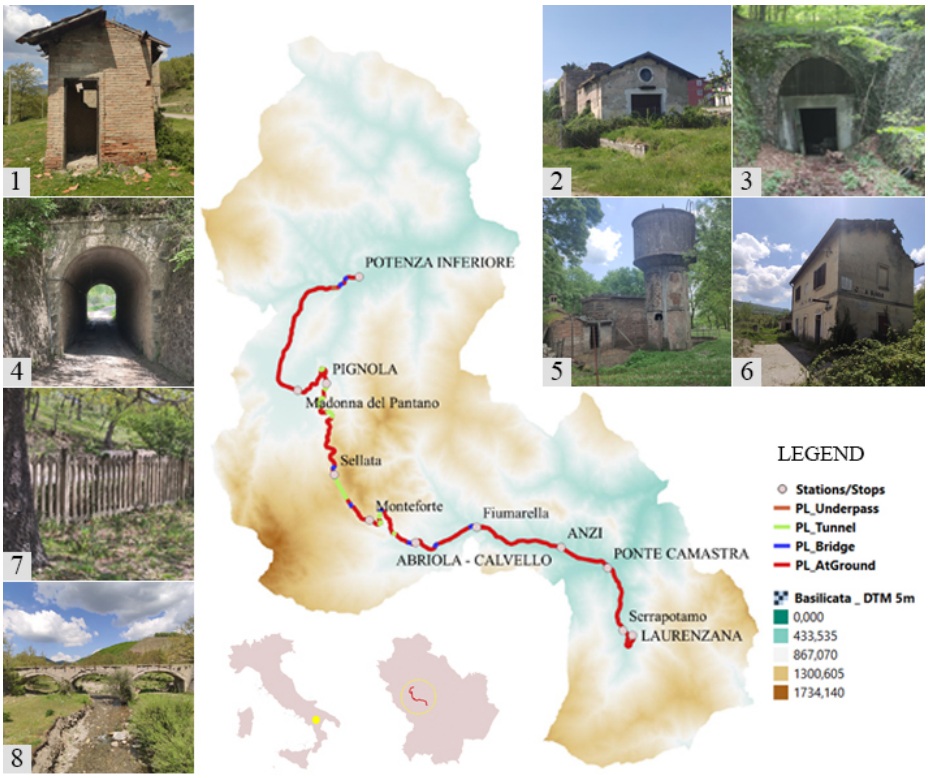

Fig. 4. '*Potenza Inferiore Scalo*' – '*Laurenzana*' railway line. (Reference system: EPSG 32633 WGS 84 UTM 33N). Photos: 1) '*Fiumarella*' stop: passengers' bathroom; 2) '*Pignola*' station; 3) '*Sellata*' gallery; 4) '*Anzi*' station: viaduct; 5) '*Abriola-Calvello*' station: water supply; 6) '*Serrapotamo*' stop; 7) '*Fiumarella*' stop: fence; 8) '*Fiumarella*' stop: three-arched bridge.

3.3 Digital model

The purpose of this study is to create a digital database of this disused railway implementing the potentialities of BIM and GIS to underline the value of this track inside the territory.

The input data used to develop the model are the digital terrain model (DTM, 5 meters resolution) from Basilicata Geoportal [15], railway line (raster data) from National Geoportal [16], administrative boundaries (shapefile data) from ISTAT [17] and, the analysis of some original plan drawing [18]. Data were visualised and analysed using the GIS software QGIS [19], version 3.16, and the civil infrastructure software Autodesk Civil 3D® [20].

A railway network can be divided into two different types of elements [21]: *linear* and *punctual*. Stations and stops are punctual elements, and their connections are linear elements [22]. The latter can be further divided into *section* of homogeneous categories (bridge/viaduct, tunnel, and underpass) [23]. After importing railway line raster data into Autodesk Civil 3D®, a 2D (*x*-*y* plane) polyline was drawn in order to create a vector element of the line. To identify different rail locations (at ground level, tunnel, bridge/viaduct, and underpass), four different layers were defined. Then, the vector polyline was loaded into QGIS and saved as shapefile format. Using the DTM as a reference, the vector was *draped* on it in order to set the *z* coordinate of each point of the polyline to a value extracted from the raster DTM. Dot elements (*x, y, z* coordinates) were placed to indicate stations/stops. The terrain model, railway line, and stations/stops were later analysed in Civil 3D, especially to check the accuracy of *z* values.

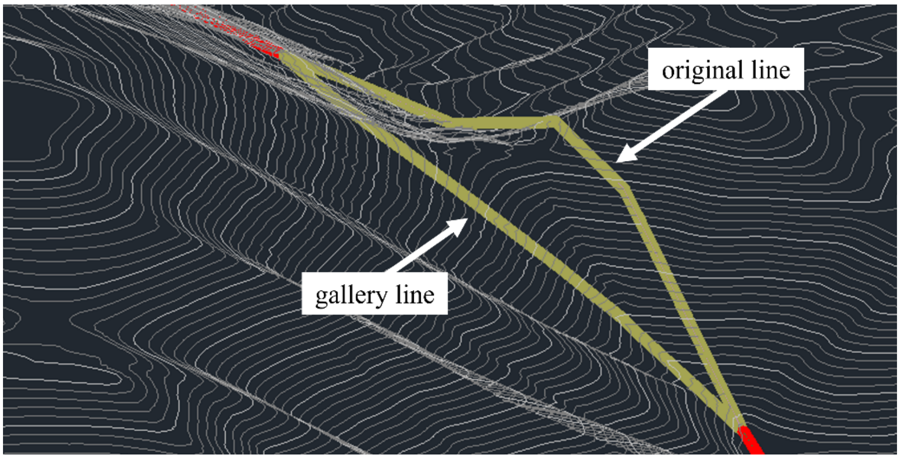

Fig. 5. '*Sellata*' gallery (length: 1146 m; altitude: about 1120 m). The 'original line' follows DTM elevation, while 'gallery line' is the correct position.

This step is necessary because the draping process does not consider the existence of tunnels, bridges/viaducts, and underpasses, and all the line is considered at ground level. Fig. 5 shows '*Sellata*' gallery: the original line follows DTM elevation points,

while the real gallery line is under the terrain. The line was modified considering the gallery's start and endpoint *z* values.
Once all the elements were checked and, if necessary, modified, the alignment was created. A single-track narrow-gauged general section (950 mm) was used to build the rail corridor (see Fig. 6).

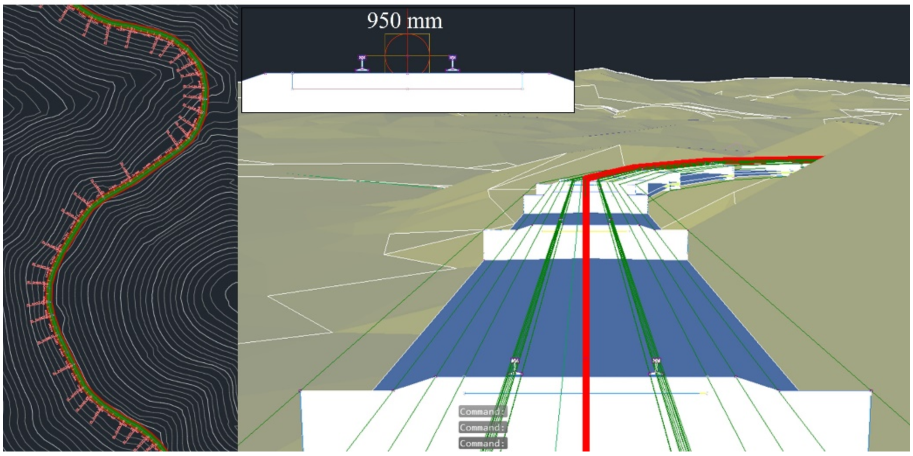

Fig. 6. Narrow-gauged section and railway model.

The final model can be used both to visualize the line inside the territory and to store and extract all the required information.

4 Conclusions

The growth of road infrastructures and the resulting gradual abandonment of rail transport led to close several kilometres of railway. These lines represent a unique path inside the territory, and it could be useful to return them to the community. In this paper, a methodology to create a BIM/GIS digital model was tested on a case study: the '*Potenza Inferiore Scalo*' – '*Laurenzana*' disused railway. Data collection and on-site survey were the starting point; then, the raster to vector transformation was carried out; and finally, the creation of the digital model. A digital database of the disused railways can help decision-makers to give a new value to these existing infrastructures in order to transform dead lines, symbol of the failure, in something new for the community. This model is the first step and it needs to be enriched. Further work will concern the creation of detailed BIM elements (bridges/viaducts, tunnels, underpasses, and buildings) with the addition of historical information.

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