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Building Information Modeling (BIM) application for an existing road infrastructure

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Abstract

New technologies are changing the sector of infrastructures design and construction. One of the most important is the I-BIM (Infrastructure Building Information Modeling), that is a management information system of digital processes for infrastructures.

In this study the I-BIM approach has been used for the upgrade of a section of the SS 245 road, in the north of Italy, in order to show its benefits applied on existing road infrastructure.

The project involved the design of a new road segment and its connection with the existing road network and with a railway line. These last were respectively solved by a roundabout and by a jacked tunnel under the railroad with wing walls at each exit side of the structure.

The steps carried out in this study were modelling the 3D digital terrain model from point cloud; creating the horizontal alignment, vertical profiles and editing cross-sections; modelling the jacked tunnel; creating the roundabout; generating the 3D parametric model of the complete road and visualizing the infrastructure in the real-world context. The real innovation consists in the creation of a plugin that allows extrapolating directly from the design program to the compute one, all the features need to be calculated.

The BIM tools used were "Autodesk AutoCAD Civil 3D" and "Revit Structure", used respectively for road geometrical design and for tunnel structural project.

The obtained results have been showed that the I-BIM approach represents not only a powerful tool to optimize and validate the road project according to norms before its construction, but also to see how the infrastructure works with the 3D real environmental context.

Keywords

Building information modelling (BIM), Infrastructures Building Information Modelling (I-BIM), Road, Tunnel, Roundabout, Bicycle lane, Plugin.

1. Introduction

The Building Information Modeling (BIM) is a relatively new design method for the construction industry, developed in the last years in many countries.

The term BIM was coined by Professor Charles M. Eastman in the 1970 and literally means the computerized modelling of a generic building construction. It is based on a process which organize all the information about the accomplishments (Logothetis, Delinasiou & Stylianidis, 2015). It is a method of design for data, charts and technical documents relating to construction, in a more advanced system than in the past (Latiffi, Mohd, Kasim & Fathi, 2013). It is not only a three-dimensional representation, but also a shared model that stands as the first step in the development of the AECOO (Architecture, Engineering, Construction and Owner Operators) industry in the world. For this, the BIM concept is being expanded into areas of expertise where it was not originally conceived (Dave, Boddy & Koskela, 2013; Ehrbar, 2016).

Its success is mostly due to a new design approach that allows to follow the entire life cycle of the project including additional information, very useful to see in depth every single aspect as the time schedule, the financial management, the calculations and the simulations (Obergriesser & Borrmann, 2012).

This new approach concerns not only a new design vision, but also a sustainability analysis (Azhar, Carlton, Olsen & Ahmad, 2011).

All these features can significantly reduce the design time by providing real-time control, involving the reduction of costs by making more effective representation of the model (Strafaci, 2008).

Every single element is connected with the materials, suppliers and design features according to costs and organizational management (Bryde, Broquetas & Volm, 2013). In this way is possible to work remotely on the same file, from different positions, resolving the important problem of the exchange of data and information between the various figures who approach the project.

To obtain these conditions, the issuing of standards and guidelines is very important. Shared procedures and methods, as well as standardized documents, are the basis for creating a common language and modalities of approach among stakeholders. In this context, interoperability becomes a fundamental requirement. This element is important between different BIM software and disciplines, to standardize the workflow. For this reason it was necessary to establish an international interchange format, called IFC (Industry Foundation Classes), with the intention of collecting the information contained in all project views (Obergriesser & Borrmann, 2012). It is an open and neutral information model, not linked to any specific software manufacturer, designed to support interoperability between individual applications. The IFC sets itself as a format specifically designed to reproduce aspects ranging from feasibility studies, design, construction and finally maintenance (Bradley, Li, Lark & Dunn, 2016). It is an open data model schema, for the definition of components' geometry and other physical properties to allow the transfer of data between CAD applications. This feature allows to exchange the data contained in the initial design model, between different software and application platforms. It enables to intervene from the design, to maintenance until the eventual disposal of the structure, obtaining an easy dialogue between the various professional figures (Volk, Stengel & Schultmann, 2014).
Compared to 3D design CAD, the BIM is not only the representation in three-dimensional space but also a model in which every entity has a precise role and information in the project. A BIM model prepared by an architect can be relatively easily and quickly converted to the analytical model, that constructor can use in the structural analysis. In a few simple steps structural engineer can obtain the stresses or deflections and proceed with detailed checking of code requirements (Abbondati et al., 2020; Czmoch et al., 2014).
In the UNI 11337-4 (2017) every element of the project is connected with a specific LOD. This acronym refers to two concepts: “Levels Of Development” and “Levels Of Detail”. The first one shall mean the degree of geometric elements and the information related to them, while the second one means the level of detail of the BIM model. The process stands on three levels of classification: the first, made up of 2D CAD models; the second which consists of 3D format models; the third linked to the BIM concept (Ghaffarianhoseini et al., 2017).

Another function in the drafting of a project is the Autodesk Revit software archives that can be used to create families of system. The Family Editor enables to edit them graphically, establishing parametric relationships between their geometries. It also allows the user to create “loadable” or “local” families. Is not possible, instead, create a “system” families, because they are not useful in order to be more rigid and they have predefined parameters to operate only through special dialogs (Farr, Piroozfar & Robinson, 2014).

Since the BIM benefits have been established and several BIM-capable tools available on the market, the diffusion of BIM within the Italian AEC industry is in continuous development. At European level, European Directive 2014/24/EU requires public administrations to use digital systems in their processes. In Italy, the Ministry of Infrastructure has introduced an initial plan for making BIM mandatory from 2019, but only for projects above 100 million. This marks the first of a series of a several deadlines, ending with full implementation by 2022, when BIM will become mandatory for all public procurement projects.

In Italy BIM is mainly used by design studies and engineering companies and its main use is for architectural and structural design (Dell’Acqua, 2018; Abbondati et al., 2020). Instead, projects of infrastructural networks have found very little BIM application both in literature and construction (Leone et al., 2017).
But, considering the innovative advantages of this new design vision, it becomes very important to launch this new approach to infrastructure projects.

2. BIM for road infrastructure

Although the BIM is born for the buildings, now it is extending also at the infrastructure scale that includes the following domains (Cheng, Lu & Deng, 2016):

- transportation infrastructures: roads, railways, bridges, tunnels and mass transit hubs (airports, ports and harbours);
- energy infrastructures: power generation plants (nuclear, wind, tidal), oil and gas (storage/distribution terminals, refineries, wells) and mining;
- utility infrastructures: networks/pipelines for the delivery and removal of electricity, gas, water and sewage;
- environmental infrastructure: structures for managing flood and coastal defence such as dams, levees, weirs or embankments.

At the infrastructure scale the BIM is also called I-BIM (Infrastructures Building Information Modelling).

The infrastructure design is more complex than the building design. The main difference is related to the infrastructure extension because it often develops for many kilometres and it presents many interferences with the surrounding environment. Consequently, an accurate geo-reference is very important. It can be achieved by alignment of Geographical Information Systems (GIS) with BIM, obtaining a database linked to a graphical representation of geometric entities for GIS (dots, lines and polygons) and parametric objects for BIM (walls, windows, doors) (Fanning, Clevenger, Ozbek & Mahmoud, 2015; Bradley, Li, Lark & Dunn, 2016; Barazzetti & Banfi, 2017).

One of the areas in which BIM can have a great development is the domain of road infrastructures, because it allows to revolutionize the traditionally CAD design approach offering more interoperability capabilities. Increasing sharing, collaboration and exchange of information between the different areas of design and different software applications, it allows to reduce the risks and unforeseen on-site events verifying interference between architectural, structural and engineering objects. Since information is stored as a database in BIM, any data changes required during the design process can be logically undertaken and managed throughout the project life cycle (Miettinen & Paavola, 2014; Minagawa & Kusayanagi, 2015).

In the BIM project of a road infrastructure this database is characterized by a topographic nature, because there is a point clouds linked to laser scanners for the acquisition of refitting data and mesh with precise geo-referencing. The data are reworked for the generation of the digital soil model (DTM), consisting of a succession of surfaces as elevation models generated by triangulation. From this it is possible to achieve the digital reconstruction of the three-dimensional axis of the road (Kang & Hong, 2015; Kim, Kim, Ok & Yang, 2016). In this way, the BIM platform allows to generate the 3D model of the road infrastructure based on alignment and cross-section, introducing specific elements as the road pavement stratigraphy, drainage networks of platform waters, complementary works and sub-services. This model is characterized by the definition of objects classes, to subdivide the road into a defined number of components with an informative content. In this way is possible to extract from the model road map, longitudinal profile and cross-sections at any time, and the elaboration can be dynamically updated (for example for upgrading and/or extraordinary maintenance of the road) (Bradley, Li, Lark & Dunn, 2016; Chong et al., 2016).

The use of BIM in road infrastructure projects can be a useful tool in three main phases: preconstruction, construction and management (Lee, Bae & Cho, 2012; Chong et al., 2016). The preconstruction stage comprises road planning, design and site preparation, study of the site layout and logistics, project scheduling, materials management and engineering analysis, because BIM is able to provide a platform to simulate the loads required in the building to ensure structural safety and serviceability. The construction stage, instead, involves the construction team's scheduled activities that can benefit significantly from the use of BIM. It involves construction inspections, human resource management and progress tracking, quality assurance and costs control. The management phase explains the activities after construction, whereby the project has already been handed over to the client. Some BIM related activities during this stage could be considered planned maintenance, system analysis, asset management, emergency plan and transportation management.

In Italy, initially, the use of BIM in road infrastructure projects was used exclusively in academic circles or international programs for the migration from traditional methods to BIM, that required several years of application. Nowadays there are different main engineering companies that have adopted BIM for pilot projects about road infrastructures, with the aim to involve their Specialised Engineering Units to quickly acquire the capacity of developing a complete BIM-based project.

In this paper the BIM approach has been adopted for the requalification and the upgrade of an existing road section to highlight the main potential of this innovative process. The project has involved the functional and geometrical design of: the road stretch; its connection to the existing road network, which has been resolved by a roundabout; a rail crossing, solved by a new road underpass; a bicycle lane.
The project has held different areas of civil engineering i.e. road, structural, hydraulic and geotechnical works. A specific coordination between the software products relating to linear works and the ones concerning spot structure work has been required, to obtain the various software products interconnected in the general assembled model. The BIM tools used in this case study were "Autodesk AutoCAD Civil 3D" and "Revit Structure", used respectively for road geometrical design and for tunnel structural project. Each element has been studied through parametric families and has been associated with specific properties that defined the identity data for cost analysis and the computational management of the work. For this reason, a new plugin that creates .IFC files readable by the "STR Vision CPM" software, for the project cost estimation, has been created.

3. Description of case study

The project object of study involves the requalification and the upgrade of a section of the SS 245 road, in the north of Italy, in order to eliminate the railroad crossing of the Castelfranco – Bassano railway line (figure 1). This last, in fact, caused long vehicles queues on the SS 245 road, with great problems of air and noise pollution for the habitants of the Castello di Godego town.

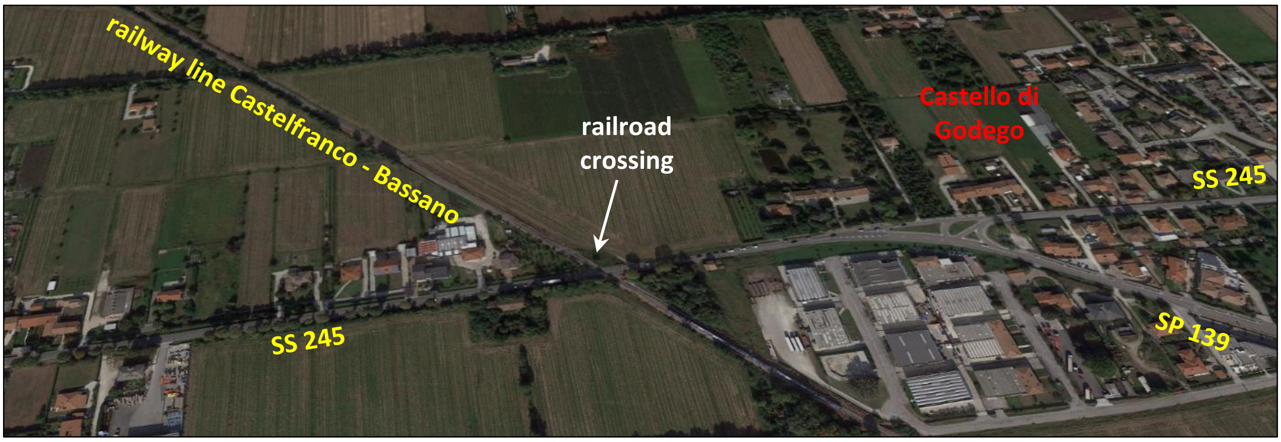

Figure 1: existing urban context

The project involves the design of a new section of the SS 245 road, about 1 km long, with its connection to the SP 139 existing road that has been resolved by a roundabout (figure 2). The intersection between the SS 245 and the railway line, instead, has been solved by a jacked tunnel under the railroad, with wing walls at each exit side of the structure. In this way the increasing of the road safety and the decreasing of the air pollution, for local residents and other users of the road, have been reached. Since the new road section is inside the Castello di Godego town, on its one side a bicycle lane has been designed.

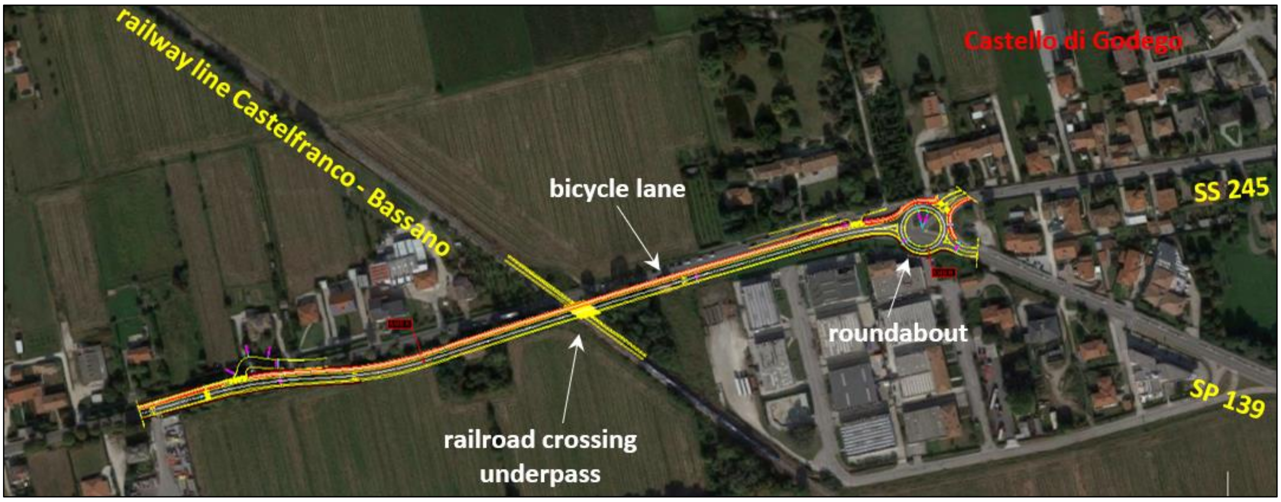

Figure 2: upgrade of existing road

The new route section is a single carriageway-two lanes road that is located in the Castello di Godego town, in the province of Treviso in the Veneto region. It has a rather homogeneous width of about 9.50 m (two 3.50 m wide lanes and one 1.25 m wide sidewalk) and the posted speed limit is 50 km/h. In accordance with the Italian regulations (Ministry of Infrastructures and Transports, 2001) the limit values of design speed are 60 and 100 km/h. It develops on the side of the existing road that is used as an access road to private property. The bicycle lane has a rather homogeneous width of about 2.50 m.

4. The BIM project

BIM was adopted by the project team from the beginning of the project. Each major stakeholder had participated and contributed to the development of the BIM model.
The BIM tools used in this case study were "Autodesk AutoCAD Civil 3D" and "Revit Structure", used respectively for road geometrical design and for structural project of the jacked tunnel under the railroad with wing walls at each exit side. Each element of the structures has been studied through parametric families and it has been associated with specific properties that defined the identity data for cost analysis and the

computational management of the work. For this reason, a new plugin that creates .IFC files readable by the "STR Vision CPM" software, for the project cost estimation, has been created.

This project has been developed and elaborated in the following steps:

- the design of the road section with the bicycle lane: it has been developed according to DM 05/11/2001, starting from the observed traffic volume. The Digital Terrain Model (DTM) has been obtained from the available cartographic maps and using "Autodesk AutoCAD Civil 3D" the TIN surfaces have been created. Then the horizontal alignment and vertical profile have been implemented with the cross section in BIM and the associated cross-section template has been edited;
- the design of the road underpass: the type sections of the jacked tunnel have been developed in parametric form and after the creation of parametric sections, the 3D model of the road solid has been generated;
- the design of the roundabout: to connect the designed road section with the existing road network, a two-lanes roundabout has been studied and its 3D model has been generated;
- the calculation of volumes, quantities and materials used: since using the "Autodesk AutoCAD Civil 3D" tool is not possible to export file in .IFC format and use the BIM approach for costs estimation, in order to solve this problem, an alternative methodology, that allows to create automatically an exportable file in IFC. format with all the information necessary for cost calculation, has been studied. A new plugin that creates .IFC files readable by the "STR Vision CPM" software has been created.

4.1 The road design

The first step of the study was to create a Digital Terrain Model (DTM) from the available cartographic maps, composed by nodes with an associated elevation. A triangulated irregular network (TIN), which is a representation of a continuous surface consisting entirely of triangular facets, used mainly as Grin primary elevation modelling, has been created (Figure 3).

Using "Autodesk AutoCAD Civil 3D" the TIN surfaces have been visualized through the 3D viewer, in order to evaluate the correctness of the inserted data and to appreciate the perfect legibility of the existing model (Figure 4). Before starting, a preliminary operation of data reprocessing and cleaning has been performed.

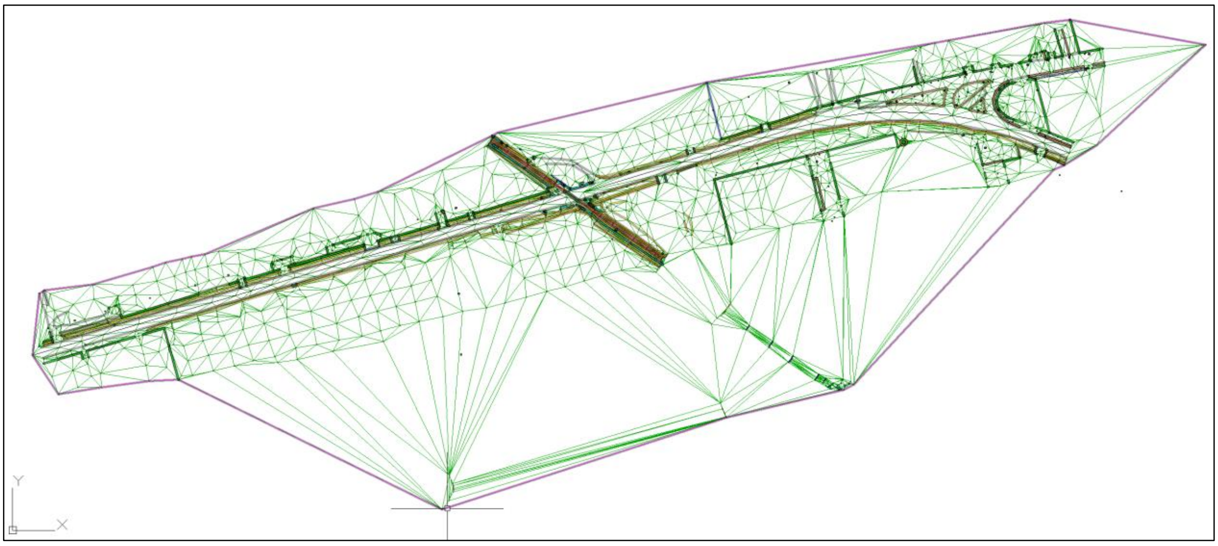

Figure 3: Triangulated Irregular Network

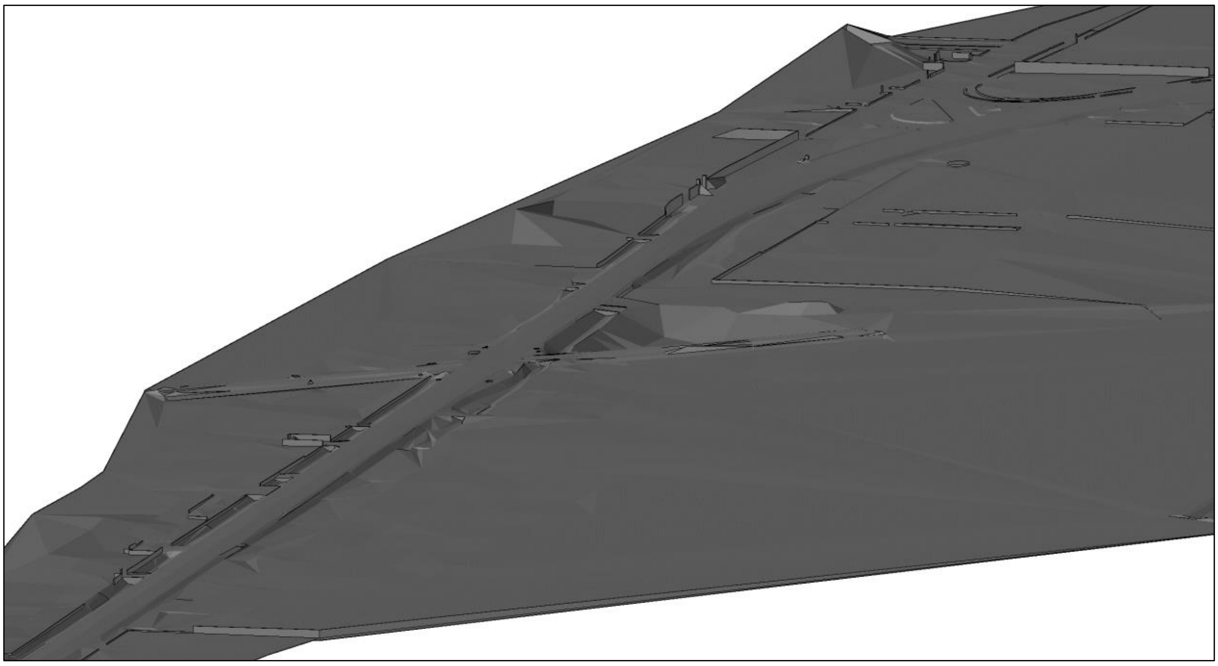

Figure 4: TIN surfaces in 3D viewer

The horizontal alignment and vertical profile have been implemented with the cross section in BIM, to realize the 3D parametric model of the road infrastructure according to DM 05/11/2001 (Ministry of Infrastructures and Transports, 2001). The software, in fact, contains a tool called “Country Kit” for the dynamic check of the road design consistency according to current legislation, directly within the working environment.

The horizontal alignment of the road section is composed by 4 straights and circular curves connected by clothoids (Table 1). According to DM 05/11/2001, the radius of the curve has been defined, longer than the straight length. For the clothoids the limitation of the pendency, the correct perception of the horizontal alignment and a limitation of a reaction due to acceleration (the parameters “A” is a scale factor of the clothoids connected with the flatness) have been verified.

Table 1: Horizontal alignment of the road section

Element’s number	Straight line	Clothoid			Circular curve	
	Length [m]	Length [m]	Radius [m]	A	Length [m]	Radius [m]
1	27.06					
2		39.11	350	117		
3					43.65	350
4		39.11	350	117		
5	1.13					
6		33.33	300	100		
7					44.71	300
8		33.33	300	100		
9	6.82					
10					236.76	7300
11	81.32					
12		33.33	300	100		
13					46.23	300

The associated cross-section template has been edited. The road section has a camber with the high point on its centreline, a width of about 9.50 m (two 3.50 m wide lanes and two 1.25 m wide shoulder) and a transversal slope of 2.5%. The bike lane has a 2.50 wide lane and a transversal slope of 2.5%. A concrete curb has been inserted between the bicycle lane and the road (Figure 5).

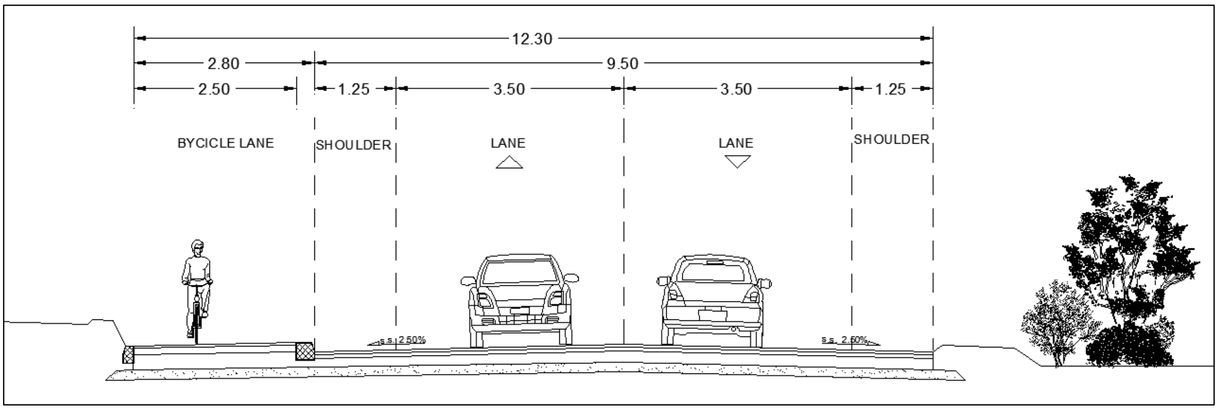

Figure 5: cross-section of the project

The determination of the elevation profile and the insertion of gradients and vertical curves have been carried up maintaining an adequate vertical distance between the railway and the road tunnel. The design of the vertical curves was based on the project of road speed.

The jacked tunnel has been designed with the same width of the road section (9.50 m) and with the length adequate for the future doubling of the railway line (30 m), envisaged on the west side of the existing line. The vertical distance between railway subgrade and carriageway has been set for 5 m and a ramp on each side of the tunnel with a gradient of 4.5% have been inserted. The vertical curves were 1460 m in radius.

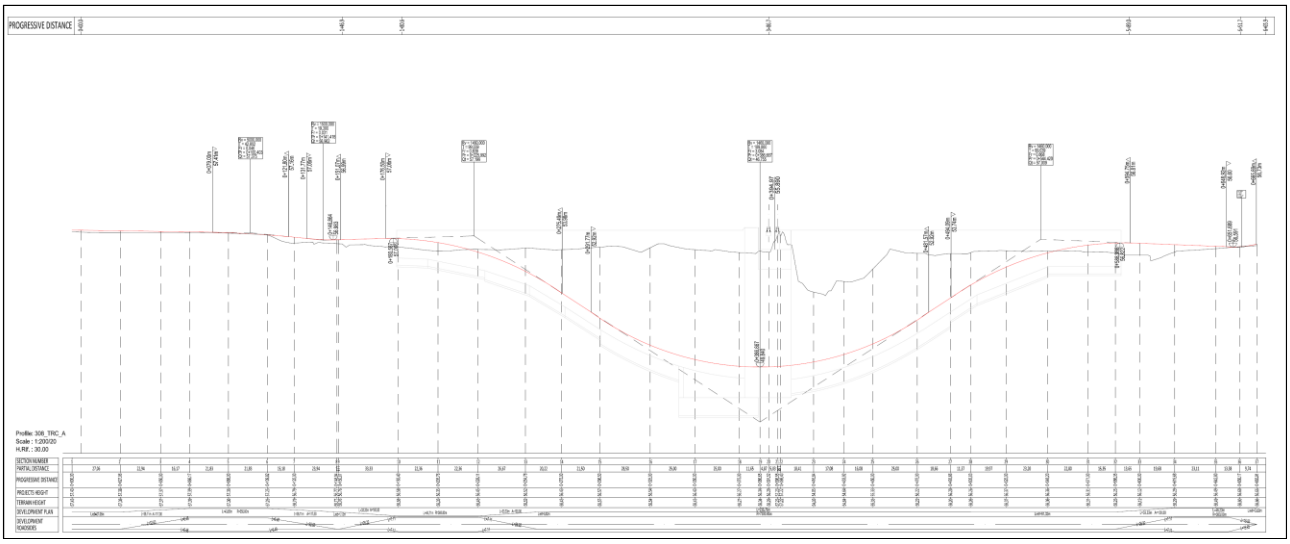

Figure 6: Elevation profile

Through “Country Kit” application the planimetric and altimetric check, according to the regulations in force, has been carried out. The points that did not respect the regulations, have been corrected.

After this check the type sections have been developed in parametric form, by defining rules and functions that modify the geometry of the same according to the terrain and the route’s course. The construction of the type section is obtained by assembling individual elementary components, so as to be able to define (Italferr, 2019):

- the geometry of the structure;
- the characteristics of the various materials;
- the information necessary to describe the work, the structure of the WBS, the references to the materials, etc.;
- the quantities of the different processes from which one starts to define the costs of the work.

In Figure 7 the example of the section used for modelling has been shown. As can be seen, all the main elements that make up a road section have been modelled, along with all the accompanying elements such as the carriageway, the water collection channel, the grassing of the escarpments and the elements constituting the road platform. The road pavement is composed by 5 cm of surface course in Splitt Mastix Asphalt, 6 cm of binder course and 17 cm of base course in Warm Bituminous Mixture, 15 cm of granular foundation. The bicycle lane pavement is composed by 3 cm of surface course in Splitt Mastix Asphalt, 10 cm of binder course and 23 cm of base course in Warm Bituminous Mixture, 15 cm of granular foundation. To obtain high resistance to plastic deformation and high surface texture, Splitt Mastix Asphalt has been used (Sangiorgi et al., 2008).

Each of the modelled elements is independently recognizable and in such a way that, once the cross-sections of the road have been developed, it is able to supply the quantity of earthworks for each element present (i.e. for the body of the embankment, for grassing, for the bituminous mixture, etc.).

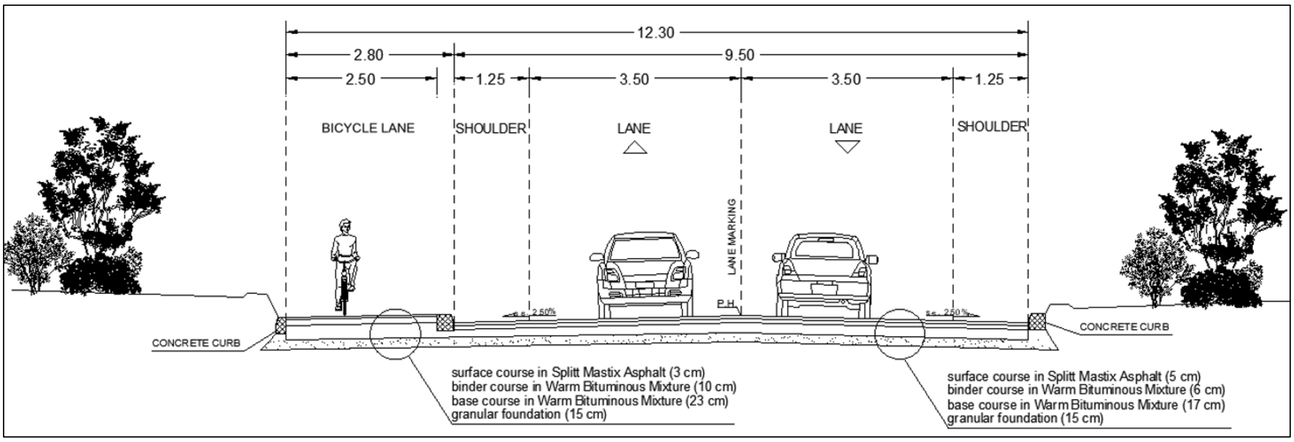

Figure 7: Type section

After the creation of parametric sections, the 3D model of the road solid has been generated, which allowed to manage separately all data created and inserted so far in the model (planimetric layout, longitudinal profile and parametric sections) (Figure 8). In this way the calculation of volumes, quantities and materials used has been performed.

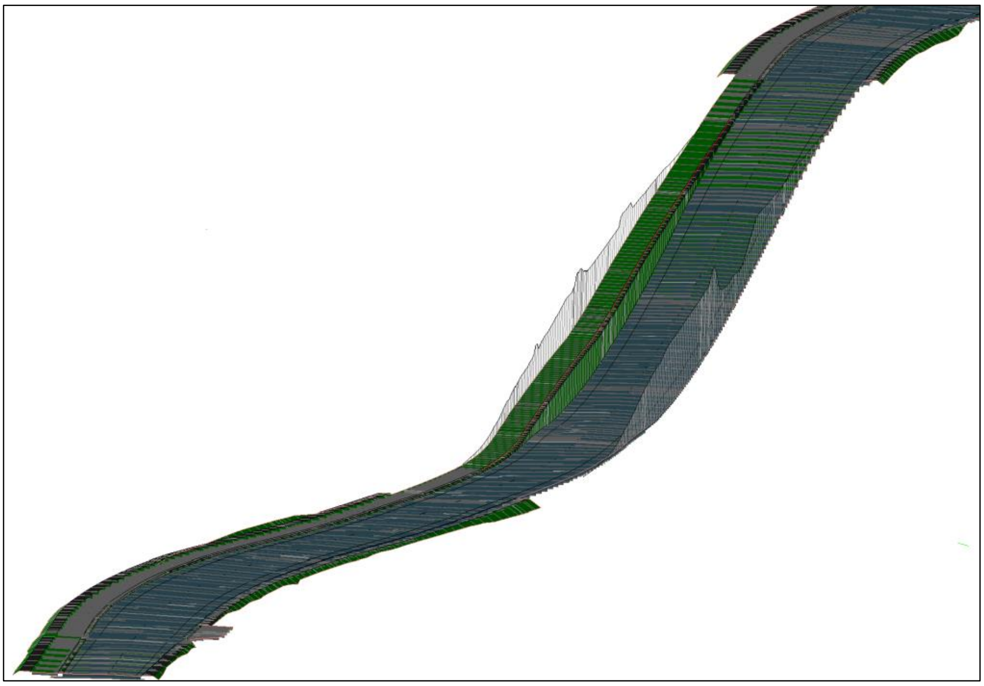

Figure 8: 3D model of the road

To connect the designed road section with the existing road network (SP 139), a two-lanes roundabout has been studied. It was characterized by a central island 31 m wide and a circulatory roadway with a diameter of 45 m. The entry and exit lanes were respectively 4.5 and 5.5 m wide. The transversal slope of the circulatory roadway is about 2% and the longitudinal slope is null.
Through “Country Kit” application the planimetric and altimetric check, according to the regulations in force, has been carried out. The points that did not respect the regulations, have been corrected.

For circulatory roadway and for entry and exit lanes, the horizontal alignment and vertical profile have been implemented. After the creation of parametric section, the 3D model of the roundabout has been generated. In this way the plan and the 3D model of the complete designed road has been obtained (Figures 9 and 10).

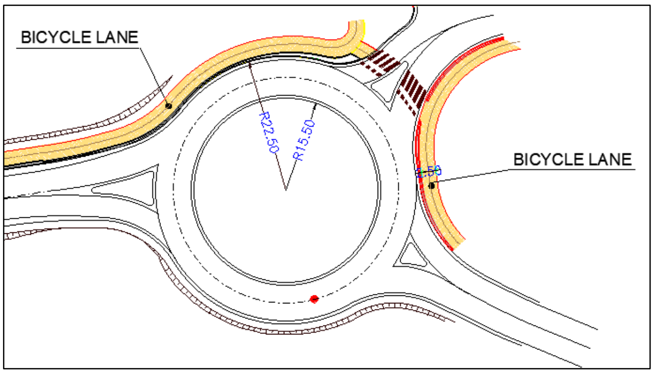

Figure 9: Plan of the roundabout

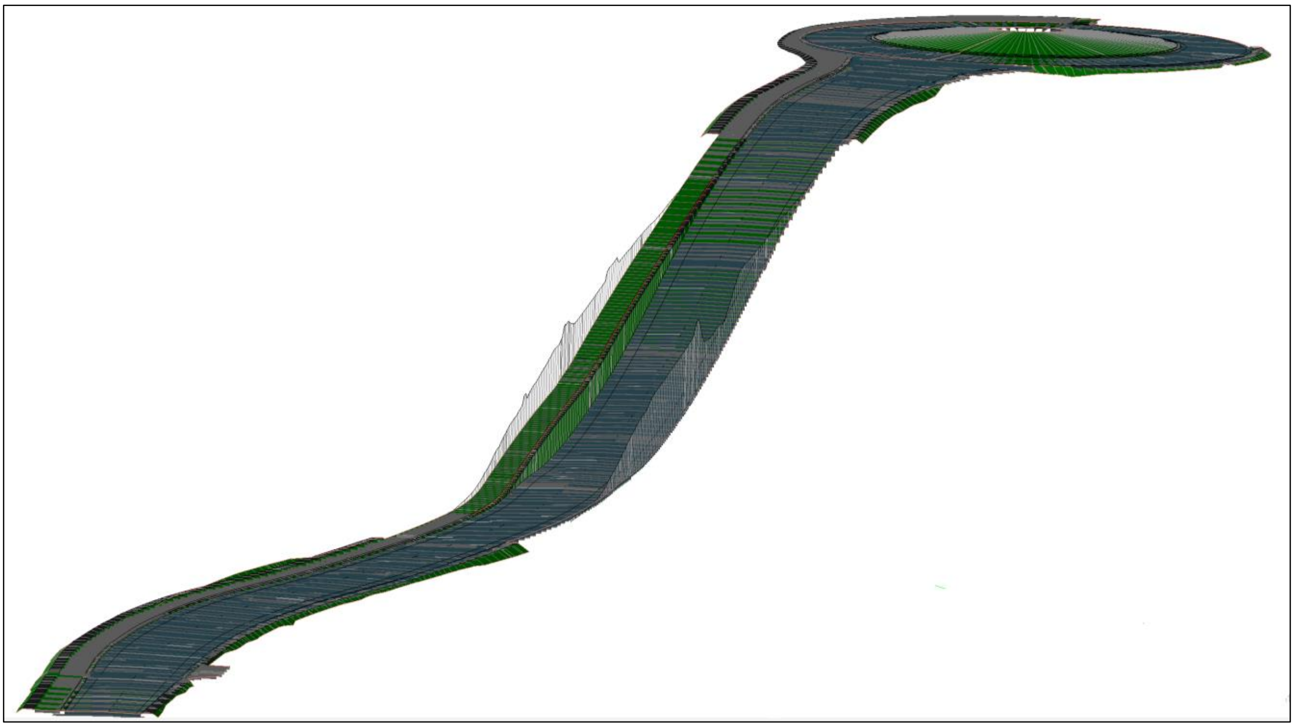

Figure 10: 3D model of the road and of the roundabout

4.2 The tunnel design

The structure design needed a preliminary horizontal placement and the choice of the reference height and the longitudinal slope. The vertical distance between railway subgrade and carriageway has been set for 5 m.

To create the underground space at shallow depth beneath the existing railway infrastructure, the jacked box tunnelling technique has been used, because in the available environmental conditions it was impractical and inconvenient to undertake construction from the surface. The monolithic reinforced concrete box has been casted on a jacking base and a shield has been built on to the leading end of the box, with thrust jacks provided at the rear end reacting against the jacking base.

The resolution of this interference has involved a succession of the jacked box tunnel and approach ramps at each side of the structure. The ramps, made with a succession of "U-shaped" and “T-shaped” walls, have been planned upstream and downstream of the tunnel, in order to accommodate the nature of the land on site and the height of the road surface compared to ground level.

A jacked box tunnelling consisting of two lateral walls, thickened 0.80 m, and an upper slab and a foundation, thickened 1.00 m, has been chosen. The length was 29.70 m and the total inside width was 12.50 m (two 3.50 m wide lanes, two 1.25 m wide shoulders, one 2.50 m wide bicycle lane) (figures 11 and 12). The upper slab and the foundation were characterized by different dimensions because the first has been oriented parallel to the railway track, while the second was orthogonal to the direction of thrust jacks to obtain a non-oblique push (figure 15).

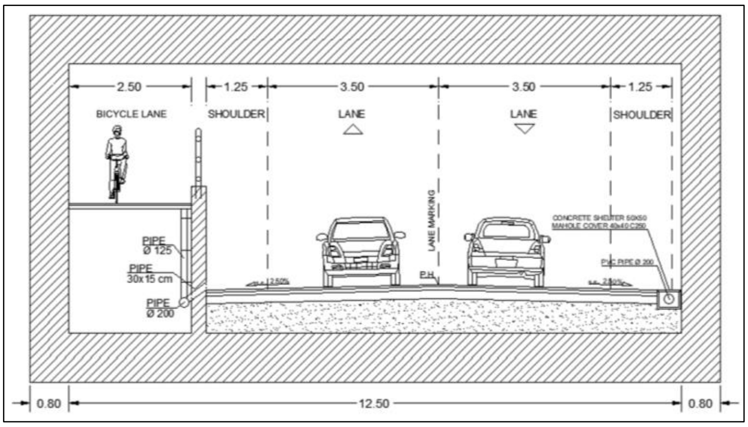

Figure 11: Cross section of the jacked box tunnelling

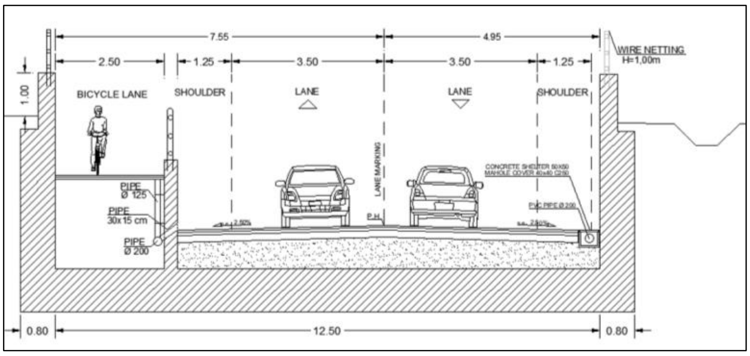

Figure 12: Cross section of the "U-shaped" walls

The BIM tools used in this case study was “Revit Structure”. The “Revit family” concept has been used to build the elements of the model. Each element has been studied through parametric families and has been associated with specific properties that defined the identity data for cost analysis and the computational management of the work.
Different own family types have been created and they were assembled into the system (Figure 13).

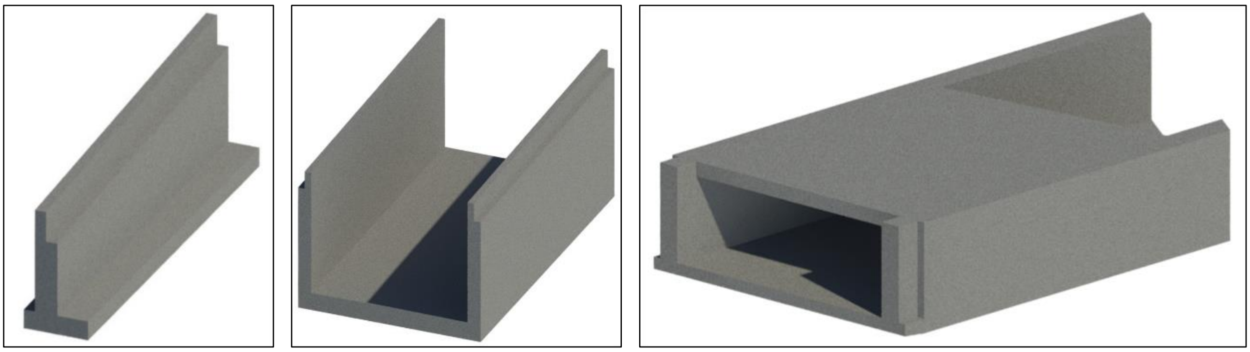

Figure 13 Revit families for “T-shaped” wall, "U-shaped" wall and jacked box tunnel with the jacking base

After the creation of the Revit families of structural elements, they have been loaded into a construction project in order to manage the project timing. Two time- steps have been considered (Figure 14):

- the construction of the monolithic reinforced concrete box on the jacking base and its fully installation under the railway line;
- the demolition of tunnel shields and the construction of internal finishing and roadway.

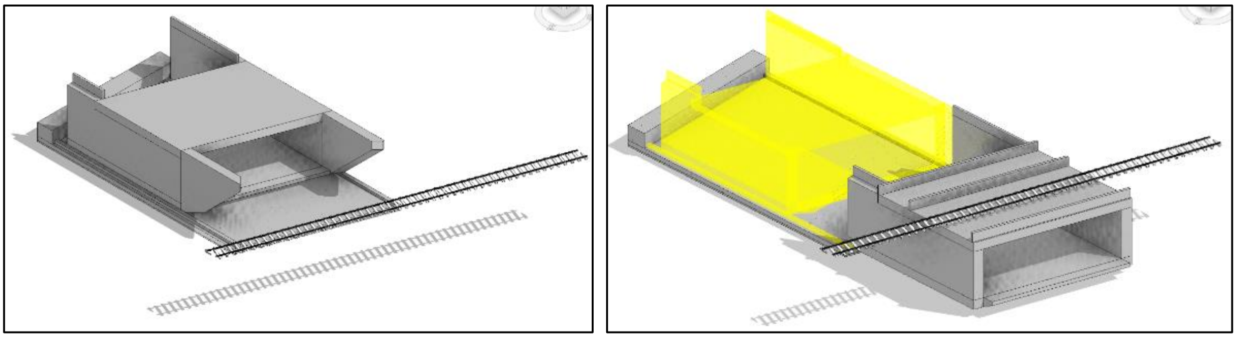

Figure 14: Construction project of the system

The modelling of the road underpass has followed the same operating procedure used for other objects. This has meant definition of tunnel horizontal layout first and vertical profile after, followed by cross section design. Figure 15 represents the complete underpass model placed in the road project.

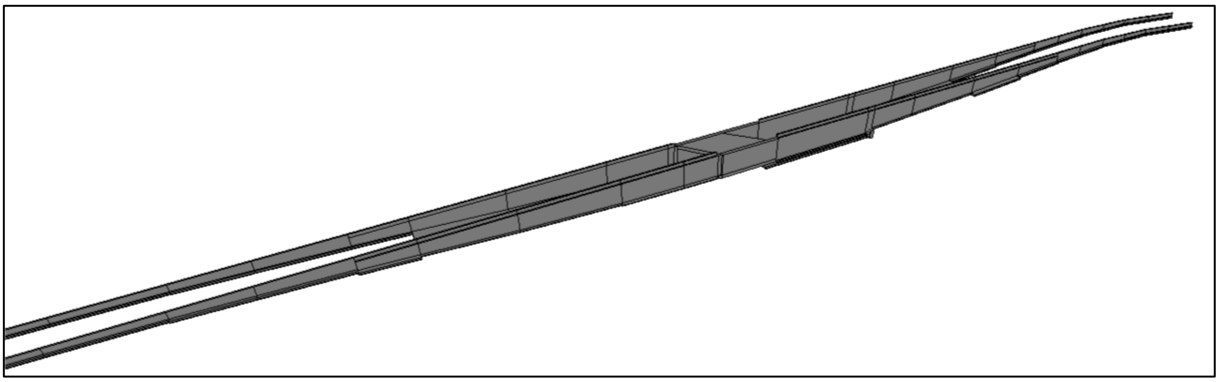

Figure 15: 3D model of the underpass

4.3 The project costs estimation

In the study the "STR Vision CPM" (Construction Project Management) software has been used. It is a tool to evaluate costs, plan and schedule works and support the works site management in a BIM process. The software is integrated with functions of metric computation, in order to obtain the dimensions for the economic estimation of each element directly from the 3D models.

Each structural element has been studied through parametric families and has been associated with specific properties, that defined the identity data for cost analysis and the computational management of the work. Using the "Revit Structure" tool for structural elements, is possible to export file in .IFC format useful for its cost estimation.
Using the "Autodesk AutoCAD Civil 3D" tool for road elements, is not possible to export file in .IFC format and use the BIM approach for costs estimation. In order to solve this problem, an alternative methodology, that allows to create automatically an exportable file in IFC. format with all the information necessary for cost calculation, has been studied. A new plugin that creates .IFC files readable by the "STR Vision CPM" software has been created.
It has been composed of two sections: the first, that defines tables containing data on material movements starting from the encodings of the project elements for each cross section; the second, that evaluates costs and produces the final file in .IFC format. In this way the project costs estimation has been conducted in a BIM approach, with consequent time savings.

For each project cross-sections, the plugin evaluates the ground's movements and extrapolates the compute's quantity interpreting the simple polylines as length, area or projection (Figure 16). Then it allows extrapolating the final file (IFC format). This macro individuates the tables with the data of every single elaboration and generates a series of "elements of transport", in which it memorizes all parameters of computation. The real advantage of this plugin is the compilation of the tables of the ground's movements which is put into an excel file. After which it allows updating the entities directly in computation software.

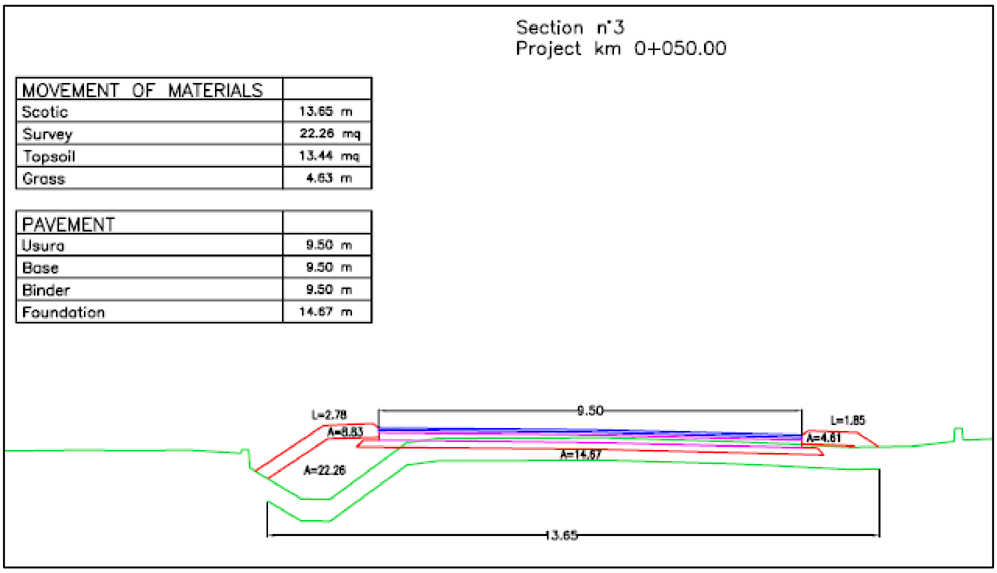

Figure 16: The output of the plugin

The cost estimations have been conducted considering separately road and bicycle lane, roundabout and jacked tunnel. These last were respectively the 14%, 18% and 68% of the total cost of the works.

5. Conclusions

I-BIM is not yet well developed in Europe compared with other country as Asia and America. Practical applications include the use of I-BIM models for energy infrastructures and little use for transportation ones. In this paper the upgrade of a section of the SS 245 road has analysed in I-BIM, in order to show the benefits of I-BIM applied on existing road infrastructure.

The project involves the design of a new segment of the SS 245 road and of its connection with the existing road network, resolved by a roundabout, and with a railway line, solved by a jacked tunnel under the railroad with wing walls at each exit side of the structure.

The steps carried out in this study were as follows: a) modelling the 3D digital terrain model from point cloud; b) creating the horizontal alignment, vertical profiles and editing cross-sections; c) modelling the jacked tunnel; d) creating the roundabout; e) generating the 3D parametric model of the road; f) visualizing the infrastructure in the real-world context.

The methodology described represented not only a powerful tool to optimize and validate the project according to norms before its construction, but also to see how the infrastructure works with the 3D real environmental context.
The main difference between I-BIM technology and conventional 3D CAD is that the latter describes a building by independent 3D views such as plans, sections and elevations. Editing one of these views requires that all other views must be checked and updated. Data in these 3D drawings are graphical entities only, such as lines, arcs and circles, in contrast to the intelligent contextual semantic of I-BIM models, where objects are defined in terms of features and parameters. The technological component of I-BIM helps project stakeholders to visualize what there is to be built in a simulated environment to identify any potential design, construction or operational issues.

Some problems have been found in the use of interchange formats. For the project costs evaluation, in fact, a plugin, that allowed to perform the computation in I-BIM logic, has been created. Thanks to the use of the plugin, it could be possible to directly extrapolate the compute from Civil-3D to STR Vision CPM, without realize a manual compute.

References

Abbondati, F., Biancardo, S.A., Palazzo, S., Capaldo, F.S., & Viscione, N. (2020). I-BIM for existing airport infrastructures. Transportation Research Procedia, 45, pp. 596-603. https://doi.org/10.1016/j.trpro.2020.03.052

Azhar, S., Carlton, W. A., Olsen, D., and Ahmad, I. (2011). Building information modeling for sustainable design and LEED rating analysis. Automation in Construction, 20(2), pp. 217–224. https://doi.org/10.1016/j.autcon.2010.09.019

Barazzetti, L., & Banfi, F. (2017). BIM and GIS: when parametric modeling meets geospatial data. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 4, pp. 1–8. http://hdl.handle.net/11311/1040807

Bradley, A., Li, H., Lark, R., & Dunn, S. (2016). BIM for infrastructure: An overall review and constructor perspective. Automation in Construction, 71, pp. 139–152. https://doi.org/10.1016/j.autcon.2016.08.019

Bryde, D., Broquetas, M., & Volm, J. M. (2013). The project benefits of building information modelling (BIM). International Journal of Project Management, 31(7), pp. 971–980. https://doi.org/10.1016/j.ijproman.2012.12.001

Cheng, J.C.P., Lu, Q., Deng, Y., (2016). Analytical review and evaluation of civil information modeling. Automation in Construction, 67, pp. 31–47. https://doi.org/10.1016/j.autcon.2016.02.006

Chong, H.Y., Lopez, R., Wang, J., Wang, X., Zhao, Z. (2016). Comparative analysis on the adoption and use of BIM in road infrastructure projects. Journal of Management in Engineering, 32 (6). https://ascelibrary.org/doi/abs/10.1061/(ASCE)ME.1943-5479.0000460

Czmoch, I., Pekala, A. (2014). Traditional Design versus BIM Based Design. Procedia Engineering 91, pp. 210 – 215. https://doi.org/10.1016/j.proeng.2014.12.048

Dave, B., Boddy, S., & Koskela, L. (2013). Challenges and opportunities in implementing lean and BIM on an infrastructure project. 21st Annual Conference of the International Group for Lean Construction 2013 (IGLC 2013), pp. 60–69. ISBN: 978-163266018-3

Dell'Acqua, G. (2018). BIM per infrastrutture - Il Building Information Modeling per le grandi opere lineari. In EPC (Ed.), Rome. ISBN: 978-88-6310-880-4

Ehrbar, H. (2016). Building Information Modelling – A new tool for the successful implementation of major projects of German railways. Geomechanik und Tunnelbau, 9 (6), pp. 659-673. https://doi.org/10.1002/geot.201600053

European Commission (2004). Directive 2004/18/EC of the European Parliament and of the Council of 31 March 2004 on the coordination of procedures for the award of public works contracts, public supply contracts and public service contracts. http://data.europa.eu/eli/dir/2004/18/oj

European Commission (2014). Directive 2014/24/EU of the European Parliament and of the Council of 26 February 2014 on public procurement and repealing Directive 2004/18/E. http://data.europa.eu/eli/dir/2014/24/oj

Fanning, B., Clevenger, C.M., Ozbek, M.E., Mahmoud, H. (2015) Implementing BIM on infrastructure: Comparison of two bridge construction projects. Practice Periodical on Structural Design and Construction, 20 (4). https://ascelibrary.org/doi/abs/10.1061/%28ASCE%29SC.1943-5576.0000239

Farr, E. R. P., Piroozfar, P. A. E., & Robinson, D. (2014). BIM as a generic configurator for facilitation of customization in the AEC industry. Automation in Construction, 45, pp. 119–125. https://doi.org/10.1016/j.autcon.2014.05.012

Ghaffarianhoseini, A., Tookey, J., Ghaffarianhoseini, A., Naismith, N., Azhar, S., Efimova, O., & Raahemifar, K. (2017). Building Information Modelling (BIM) uptake: clear benefits, understanding its implementation, risks and challenges. Renewable and Sustainable Energy Reviews, 75, pp. 1046–1053. https://doi.org/10.1016/j.rser.2016.11.083

Italferr (2019). Innovating to design the future - white paper on Building Information Modeling. http://www.italferr.it/content/dam/italferr/expertise/innovazione/Innovare%20per%20progettare%20il%20futuro.pdf

Kang, T. W., & Hong, C. H. (2015). A study on software architecture for effective BIM/GIS-based facility management data integration. Automation in Construction. 54, pp. 25–38. https://doi.org/10.1016/j.autcon.2015.03.019

Kim, J. U., Kim, Y. J., Ok, H., & Yang, S. H. (2016). A study on the status of infrastructure BIM and BIM library development. Proceedings of the International Conference on Computational Science and Computational Intelligence, pp. 857–858. DOI: 10.1109/CSCI.2015.52

Latiffi, A. A., Mohd, S., Kasim, N., & Fathi, M. S. (2013). Building Information Modeling (BIM) application in Malaysian Construction Industry. International Journal of Construction Engineering and Management, 2, pp. 1-6. DOI: 10.5923/s.ijcem.201309.01

Lee, S. I., Bae, J. S., & Cho, Y. S. (2012). Efficiency analysis of Set based Design with structural building information modeling (S-BIM) on high-rise building structures. Automation in Construction, 23, pp. 20–32. https://doi.org/10.1016/j.autcon.2011.12.008

Leone, M., D'Andrea, A., Loprencipe, G., Malavasi, G., & Bernardini, L. (2017). Building Information Modeling (BIM): Prospects for the development of railway infrastructure industry. Proceedings of AIIT International Congress TIS Rome 2017, April 10-12, Rome. ISBN 9781138030091

Logothetis, S., Delinasiou, A., & Stylianidis, E. (2015). Building information modelling for cultural heritage: a review. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 2, pp. 177–183. DOI: 10.5194/isprsannals-II-5-W3-177-2015

Miettinen, R., Paavola, S. (2014). Beyond the BIM utopia: approaches to the development and implementation of building information modeling. Automation in Construction, 43, pp. 84–91. https://doi.org/10.1016/j.autcon.2014.03.009

Minagawa, M., & Kusayanagi, S. (2015). Study on BIM utilization for design improvement of infrastructure project. Procedia Engineering, 125, pp. 431–437. https://doi.org/10.1016/j.proeng.2015.11.113

Ministry of Infrastructures and Transports (2001). Decreto Ministeriale n. 6792 del 5/11/2001 Norme funzionali e geometriche per la costruzione delle strade. Rome (in Italian). https://www.mit.gov.it/normativa/Decreto_Ministeriale_numero_6792_05-11-2001

Obergriesser, M., Borrmann, A. (2012). Infrastructural BIM Standards - Development of an Information Delivery Manual for the geotechnical infrastructural design and analysis process. In: Gudnason, G., & Scherer, R. (2012). eWork and eBusiness in Architecture, Engineering and Construction. CRC Press. , ISBN 978-0-415-

62128-1

Sangiorgi, C., Tataranni, P., Simone, A., Vignali, V., Lantieri, C., Dondi, G. (2018). Stone Mastic Asphalt (SMA) with crumb rubber according to a new dry-hybrid technology: a laboratory and trial field evaluation. Construction and Building Materials, 182, pp. 200–209. https://doi.org/10.1016/j.conbuildmat.2018.06.128

Strafaci, A. (2008). What does BIM mean for civil engineers? CE News, 20(9), pp. 62-65. ISBN: 1-800-466-6275

Volk, R., Stengel, J., & Schultmann, F. (2014). Building Information Modeling (BIM) for existing buildings: literature review and future needs. Automation in Construction. 38, pp. 109–127. https://doi.org/10.1016/j.autcon.2013.10.023