

# Extended Abstract

## BIM implementation to railway infrastructures

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### Abstract

The Building Information Modeling (BIM) is a growing industry methodology in the Architecture, Engineering and Construction (AEC). BIM appears as a new method of work between designers of various specialties, more collaborative and based on a three-dimensional model, centralizer of different type of information of geometric, physical and economic character. The main objective of this work is to analyse the application of the BIM methodology to the rail transport infrastructure sector, namely, to the design of the railway.

The creation of the railway line model was carried out, using two softwares which can be applied to BIM methodology, where the limitations were identified and the procedures adequate to obtain the 3D / BIM model were presented. It was also generated the 4D / BIM model regarding the constructive planning with another BIM base tool, allowing to obtain the visual simulation of the different work tasks to be performed. Subsequently, it was performed the extraction of information of the BIM model, to get tables of materials quantities of ballast, sub-ballast, foundation, geosynthetic and also earthworks, as well as the representation of the drawings from the project according to the two modeling softwares.

It was concluded that the BIM methodology and the tools used can be applied with advantage in the project, despite the difficulties. As a constantly evolving methodology, it is expected that, in the future, it will be able to fully utilize it and lead to significant improvements in the sector.

**Keywords:** BIM methodology, railway infrastructure, 3D and 4D modelling, information achievement

### 1. Introduction

The global railway industry market is showing a solid growing, despite a slight delay, is expected to increase by 2,3% per year by 2020 (Suchocki, 2017). The railway efficiency depends, essentially, from the railway infrastructure quality and performance. Therefore, it's essential to develop a good project, in a way to guaranty the best circulation conditions of the trains.

Nowadays, the construction industry has been directed towards the implementation of the BIM methodology in several sectors. BIM is a concept of collaborative work, strongly supported in technological advances in computation. BIM tools enable the development of buildings projects, including the design, construction, maintenance, management and demolition phases. However, it is hardly used in the transport infrastructure sector (road, railways, bridges, tunnels, airports and ports) (Campestrini *et al.*, 2015). It is important to develop the software related to BIM in the field of transport infrastructures and encourage the owners to implement this methodology in their companies.

This study has as main objective, the analyses of application of BIM methodology to a case of study of a renovation work on a railway infrastructure. This dissertation explains the tridimensional (3D) modeling process of the project in two different software, and generate, with other software, the 4D / BIM model regarding the constructive planning. Finally, this study has the objective to present the advantages of this methodology in this sector.

## **2. BIM**

### **2.1. IFC - Railway**

The Industry Foundation Classes (IFC) is a standard created to allow the sharing of complete and accurate models among various stakeholders, regardless of the applications they use, to ensure an efficient exchange of information throughout the process.

In the specific case of the railway, the chinese railways have developed an IFC Railway model for the high-speed lines with the hierarchy indicated in Figure 1. The IFC Railway presents a clear separation between the semantic model and the geometric model: the semantic model intends to develop new entities related to the various rail elements (platform, track, sub-base, tunnels or viaducts). The geometric model characterizes new geometric forms of railway entities, based on some existing IFC entities. In addition, it is possible to interconnect with the IFC Road structure, as there are several identical structural elements, as well as geometric modeling (Sécio, 2018).

As railway infrastructures are usually linear systems, they may change their layout. A mechanism introduced in the IFC Railway makes it possible to know the relative position of the elements and to maintain the positioning of signals, rails, catenary posts, etc., whenever there are changes in the path.

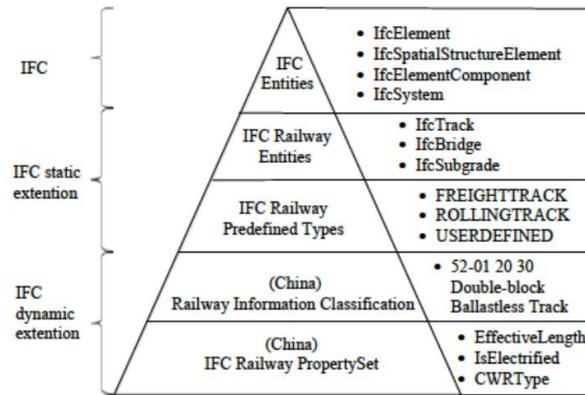


Figure 1 - Structure of IFC Railway defined by China Railways (Sécio, 2018)

## 2.2. Applications in road and railway infrastructures

There are few reports on case studies, however, there is some interest in the applicability of BIM in the infrastructure sector. Two cases of road projects were consulted, one in Australia and the other in Shanghai. These cases describe: the development of the road project and the simulation planned with some use of BIM tools; the elaboration of a network-based interface for the BIM model; the integration of BIM with GIS; the tracking and updating of the development of the BIM model construction; the integration of BIM and a laser scanning device and the printing of the 3D model (Chong *et al.*, 2016).

The integration of BIM into rail projects has gained some importance in the infrastructure sector. According to (Bensalah and Mharzi, 2018) the advantages and benefits are considerable, for example: cost control; support for decision making; reduces the volume of additional jobs due to design errors; analysis detection of interface problems; improves visual perception; supports prefabrication; support for maintenance planning and infrastructure management. However, interoperability remains a major problem in horizontal infrastructures due to the lack of standardized data. BuildingSMART has already begun work on creating data models for roads, railways, bridges and tunnels, which can improve interoperability and integration based on different objects, alignment and GIS models (Russell *et al.*, 2016).

In the present work were used the Autocad Civil 3D and Infraworks software related to the part of 3D modeling, while exploring Revit for the creation of families and also in the modeling of the project. Finally, Navisworks was used to obtain the constructive process and plan the project. The use of all this software's was also a way to test the interoperability between them.

## 3. 3D/4D Modeling

### 3.1. Civil 3D

This sub-chapter describes the three-dimensional (3D) modeling of railway infrastructure geometry, using the software Autocad Civil 3D (version of 2019) developed by Autodesk. All this

modeling work was based on a learning process conducted through tutorials and online courses available on the Autodesk website and on the internet.

The modeling began by obtaining the area of study, through geolocation and other software entitled Infracore. The corresponding coordinate system was introduced and imported from Infracore topography components, such as contour lines. Then, the horizontal alignment was created, followed by the longitudinal profile of the terrain and the vertical alignment. To point out, the vertical alignment was generated, considering, the balance between landfill and excavation, and maximum gradients. The next step was to create the cross sections, through the parameterized object library of the software. Different components of the project were used, to complete the cross sections. In the case of the study, it was only necessary to create two cross sections. One referring to the track section and another to the hydraulic passage present in that sub-section of the case study.

Finally, was used a tool, entitled Corridor. Corridor is a tool that links every object, mention previously, such as vertical and horizontal alignments, longitudinal profile and cross sections. Therefore, any change in them, will affect the entire project. The final appearance of the geometric model it's illustrated in Figure 2.

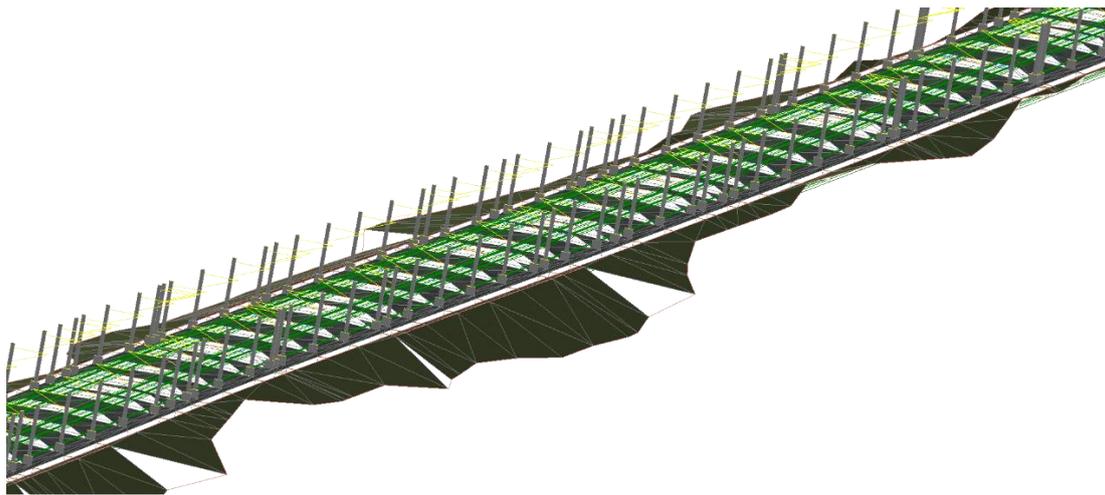


Figure 2 - 3D Model Perspective of the Infrastructure Created

### 3.2. Revit

Finished the geometric model in Civil 3D, it was tried to export it, to Revit and to Navisworks, to test the interoperability between the different software's. In the case of transposing the infrastructure model for Navisworks, the model is unique, in other words, there are objects that are all interconnected, such as, the formation of the railway (ballast, rails, sleepers, etc.), and it is not possible to recreate the phases of the construction process. Therefore, it was necessary to model the project in Revit, through the creation of families. In a research carried out were found two families, referring to the sleepers and fastenings and to the rails (Figure 3). These families were used together with the creation of the remaining components. The components, such as the ballast, sub-ballast, geosynthetics and foundation layer were generated with the slab layer, belonging to the Structure component of Revit.

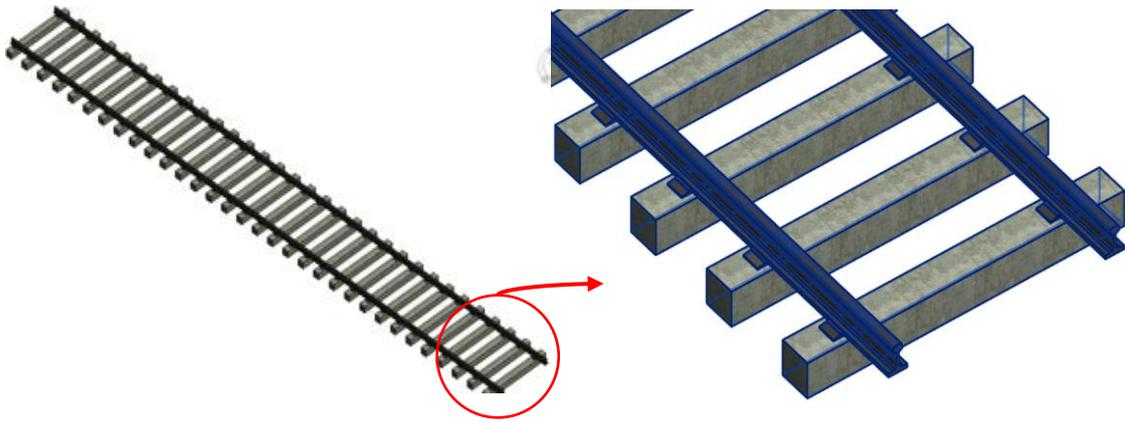


Figure 3 - 3D model of the railway

The last component modeled was the drainage, elaborated through the pipe's commands of the Revit systems component. Finally, the surface of the terrain, where the railway infrastructure was built, was integrated in Revit. This surface was imported from Civil 3D to Revit, and the geometric model was placed in the correct deployment location with the help of the contours and satellite photography of Civil 3D.

### 3.3. Navisworks

Finished the geometric modeling in Revit, the 4D model was generated, which in the BIM concept consists in the inclusion of the time parameter, and was applied in the construction phase simulation. The phase definition process involves the creation of sets. Selection sets are static groups of items, and are useful for saving a group of objects that you want to regularly perform some action on, such as hiding them, changing transparency and so on.

Seven sets were created to illustrate the different constructive phases. These have been attached to different tasks that were part of constructive process. These tasks are: track replacement, ballast dismantling, geotextile and geogrid application and ballast placement and filling attacks. All this process integrates the variable time, inserted to each task a beginning and an end. The duration of the tasks was inserted through an estimate because the data provided doesn't only contemplate the section studied. The different phases are illustrated in Figure 4.

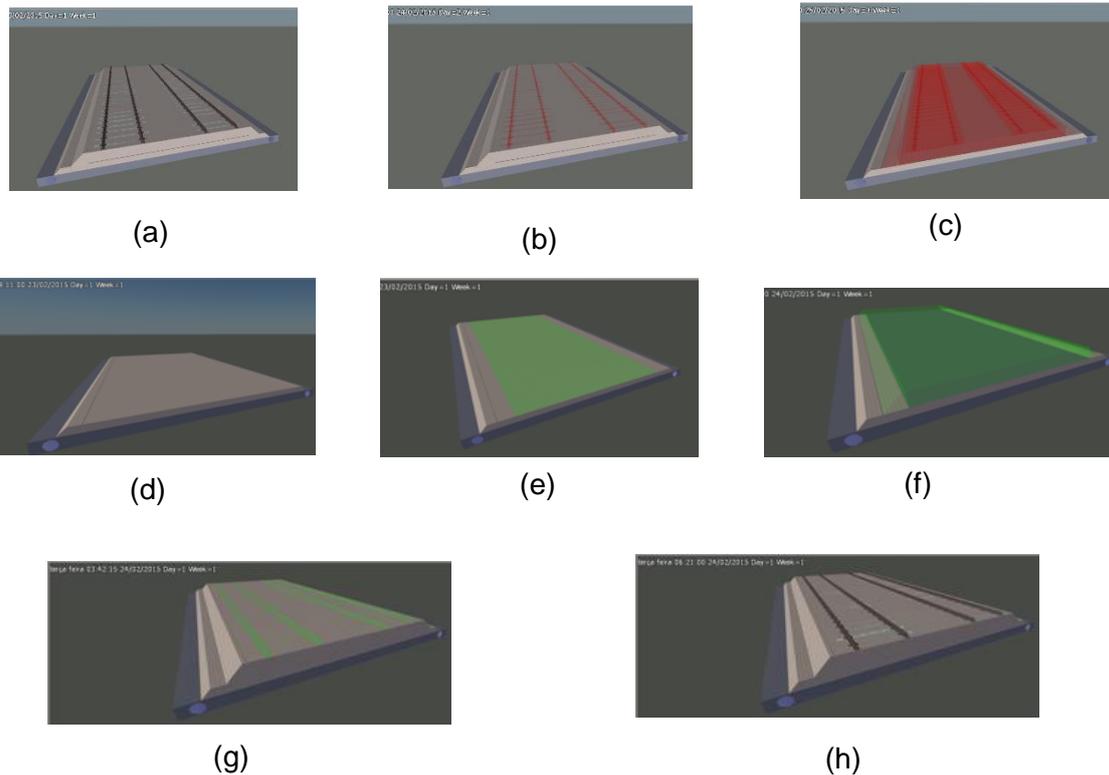


Figure 4 - Tasks simulation

## 4. Use of information

### 4.1. Tables of materials quantities (Revit and Civil 3D)

Regarding the case study, tables of material quantities are obtained, particularly, ballast and sub-ballast volumes and geosynthetic area. With the Revit, it is possible the generation of dynamic tables, in other words, any changes made to the model have immediate effects on the tables, but does not yet allow an adequate edition, regarding the presentation of results.

For the table relating to ballast, sub-ballast and geotextile the following fields were defined: Family and Type, structural material, volume and area. The results are represented in the Tables 1 and 2.

Table 1 – Infrastructure volume and area

Family and Type	Material	Volume (m <sup>3</sup> )	Area (m <sup>2</sup> )
M_Footing-Rectangular: Balastro	Ballast	7555,72	-
M_Footing-Rectangular: Sub-Balastro	Ballast	4998,6	-
M_Footing-Rectangular: Fundação	Sand	9649,8	-
M_Footing-Rectangular: Geotextil e geogrelha	Polypropylene	-	14296
	<b>Ballast total</b>	12554,32	-
	<b>Total</b>	22204,12	<b>14296</b>

Table 2 – Ballast volume

Family and Type	Material	Volume (m <sup>3</sup> )
M_Sloped Corbel: Balastro	Ballast	420,16
M_Sloped Corbel: Balastro	Ballast	420,16
M_Sloped Corbel: Sub-Balastro	Ballast	294,71
M_Sloped Corbel: Sub-Balastro	Ballast	294,17
<b>Total</b>		1429,2

$$\text{Ballast total volume} = 12554,32 + 1429,2 = \mathbf{13983,52 \text{ m}^3}$$

The same was realized in Civil 3D, but in this software the tables had to be transferred to Excel manually, because the Civil 3D system does not allow exportation. In this software was also calculated the volume related to drainage. The value obtained for the ballast total volume were 14462.94 m<sup>3</sup>. Comparing this to values, the difference between the two is 3.6 %, in other words, the result was slight representative. Therefore, it was concluded that both calculation methods are reliable.

#### 4.2. Track geometric quality

In an infrastructure project, to ensure good track behavior, it is important to check the quality of all its elements since construction, and to monitor their behavior throughout the useful life. Track geometric inspections are intended to measure and monitor possible structural degradation and track condition. Therefore, in an inspection, the main parameters to be evaluated are the geometric parameters of the track, framed in the standard (EN 13848-1, 2008). The 5 main track geometric quality parameters are the following:

- Longitudinal levelling;
- Transversal levelling;
- Alignment;
- Gauge;
- Twist.

In Civil 3D was only possible to control two parameters, the gauge and transversal levelling. This functionality it's important for modeling complexes railway projects.

#### 4.3. Sketched components

In this sub-chapter, it was described the way in which technical design drawings were created through two software's, Civil 3D and Revit.

In Civil 3D, first it was created boxes, over the all drawing, to fill the information of the alignment and longitudinal profile on each sheet. To represent the all project, it was need 4 sheets. All the cross sections were fill in another two sheets, along with a materials volume table next to each cross section.

In Revit, it was necessary to create a sheet first, selecting the size and type of legend. Until this stage, no scale has been reported. Modeling only requires the indication of the work unit, the internal scale, which corresponds to modeling units. However, in Revit there is always a scale associated with the modeling process, namely, at each view (layout). In Figure 5 is illustrated a sample of a drawing removed from Revit.

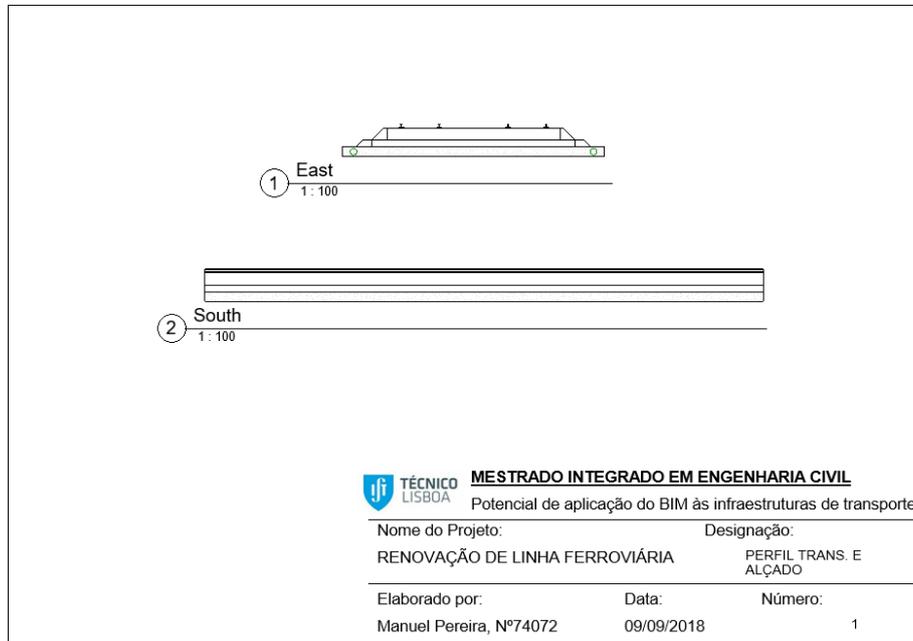


Figure 5 - Sample of a design drawing from Revit

## 5. Conclusions and future work

The BIM methodology is currently present in the architectural community and in some engineering companies, in areas, such as, structures and construction. However, there is a greater difficulty to implement the methodology in the transport infrastructures.

It is in this context that this dissertation is encompassed, since there are no geometric modeling works that encompass transport infrastructure projects. The work was intended to promulgate its applicability. Despite the limitations, the use of BIM tools has advantages in the design of transportation infrastructure projects. The main objective of the dissertation was to analyse the application of the BIM methodology to the rail transport infrastructure sector, supported by the development of three phases:

- 1st. Creation of the project model;
- 2nd. Planning of the constructive process;
- 3rd. Use of model information to obtain tables of quantities and design drawings.

The project that served as a case study corresponds to the renovation of a national railway line. To stress, that the software learning was performed without any initial training and with support in tutorials.

Concerning the objectives of the 3 phases, these were fulfilled, but at the same time were felt some difficulties, mainly in the geometric modeling. In a later phase of the modeling, it was

verified that the software was not suitable for the BIM methodology. Although Civil 3D allows the creation of three-dimensional representations quite correctly, the generated models are still made up of edges and surfaces, as in traditional CAD.

It was concluded, thus, that although there are difficulties and some delay in this area of transport infrastructures in relation to other areas of application of the BIM methodology, its adoption is positive and should be implemented gradually and its use encouraged in engineering and infrastructures projects. A great advantage to be drawn from this methodology is the reduction of costs, of projects such as these of high size and cost. In this sense, it is recommended that the BIM methodology be included in the training of new engineers and within the scope of the academic program, since it is believed that in the future this methodology will be present in any civil engineering company.

For future work, in the scope of BIM with application to transport infrastructures:

- It would be interesting to analyze the behavior of BIM tools in longer sections and with the existence of curved alignments;
- The development of families, especially in Revit, associated with transport infrastructures so that infrastructures projects can be modeled more easily and be complete and more realistic;
- Introduce an adequate maintenance and track inspection system with all the geometrical parameters usually required, so that maintenance planning associated with quality control inspection tests could be integrated.

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