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I-BIM for existing airport infrastructures

Francesco Abbondati[a]*, Salvatore Antonio Biancardo[b], Sabrina Palazzo[b], Francesco Saverio Capaldo[b], Nunzio Viscione[b]

[a]University of Naples Parthenope, Department of Engineering, Centro Direzionale Isola C4, I-80143 Naples, Italy
[b]University of Naples Federico II, Department of Civil,Construction and Environmental Engineering, Via Claudio 21, I-80125 Naples, Italy

Abstract

New methods and technologies are changing the sectors of engineering and constructions. International researchers introduce the acronym I-BIM (Infrastructure Building Information Modeling) to point out a management information system of digital processes for infrastructures. In this study is shown the 3D parametric solid model of Lamezia Terme International Civil Airport's runway located in Southern Italy. The 3D parametric model, including horizontal/vertical profiles and cross sections, was carried out using Autodesk Civil 3D, while the territorial context was recreated in Autodesk Infraworks360. Grip numbers data, collected during surveys from 2004 to 2015, were implemented in the mentioned 3D model. This intelligent 3D model-based process can be used in optimal Airport Pavement Management System (APMS) for planning maintenance operations (BIM seventh dimension) in according to Civil Aviation regulation.

Keywords: I-BIM; runway; airport pavement management system (APMS).

1. Introduction

Infrastructure Building Information Modeling (I-BIM) is an intelligent 3D model-based process that gives architecture, engineering, and construction (AEC) professionals the insight and tools to more efficiently plan, design, construct, and manage infrastructure. Since it's a recent definition, sometimes words like "Heavy-BIM" e "Horizontal-BIM" are used to make a difference with "Vertical-BIM" that refers to vertical building projects (Construction, McGraw-Hill 2012).

* Corresponding author. Tel.: +39-081-768-3945; fax: +39-081-768-3946.
E-mail address: francesco.abbondati@uniparthenope.it

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The new Public Procurement, Legislative Decree n. 50 of 18 April 2016 (Presidente della Repubblica 2016), requires the use of methods and electronic tools for the design and the realization of new projects. On December 1, 2017, the MIT Minister Decree (Ministero delle Infrastrutture e dei Trasporti 2018) was published, introducing a series of requirements: starting from this year the use of BIM is a mandatory for all the new projects with an overall cost more than 100 million of euro, and from January 1, 2025, this methodology will become a mandatory for all new projects regardless of its cost. For this reason, the use of I-BIM is actually a reality in Italy with companies such as ANAS and Italferr that have already implemented it in the management of their activities in according also to the UNI 11337-4:2017 (Ente Italiano di Normazione 2017).

The introduction of BIM for infrastructure generates some changes of instrumental nature especially in the process. The innovation applies to contractors, designers, companies, manufacturers of components and software, managers, universities, public and private research centers. Every step of the life cycle of the infrastructure is involved from the strategic planning to the operational phase.

Interoperability is one of the most important aspects in the digitization of constructions: it means the possibility to exchange data by means of non-proprietary file extensions. Today IFC (Industry Foundation Classes) is the available open format. It is developed by the Building Smart International organization that in 2015 defined the standard IFC-alignment for the codification of road layouts (Building Smart 2016).

All design phases must be thought in BIM method and all specialists involved in the project must know and manage BIM technology in order to achieve the best benefits (Ingletti et al. 2017).

Lee et al. (2014) reported that there is a lack of BIM skilled personnel and insufficient BIM education and training. Due to these facts, not all participants are able to utilize BIM in the construction process.

Leone et al. (2017) reported that by using BIM software it was possible to assign the main properties for each material composing the railway section for the quadruple-track railway project belonging to the Milano Rogoredo – Pavia network. This method enables the complete control of costs and timing during the construction stages workflow.

In recent years the infrastructure sector boasts numerous valuable experiences in the implementation of projects of major structures and infrastructures in I-BIM system (Dell'Acqua 2018, Dell'Acqua et al. 2018). Also, in bridges' projects in Egypt, BIM was used to overcome the problems arising from applying the traditional engineering and delivery methods and processes. Marzouk et al. (2010) describe how to implement successfully Building Information Modeling on bridges' projects by forming Building Information Modeling execution plan which requires four steps: identifying high value BIM uses during project planning, design, construction and operational phases; designing the BIM execution process by creating process maps; defining the BIM deliverables in a form of information exchanges; developing the infrastructure needed to support the implementation.

The main difference between BIM technology and conventional 3D CAD (Computer-Aided Design) 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, an error-prone process that is one of the major causes of poor documentation. In addition, data in these 3D drawings are graphical entities only, such as lines, arcs and circles, in contrast to the intelligent contextual semantic of BIM models, where objects are defined in terms of features and parameters. The technological component of 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 (Azhar et al. 2012).

In 2030, air traffic will be doubled compared to the observed data in 2011; for this reason, Europe must have airport infrastructures able to manage to the predicted demand. Airport's operational capacity is related also to environmental impacts of their activities. That's why BIM is essential to develop intelligent models for designing, constructing, planning and managing the infrastructures.

In this paper is presented the 3D parametric solid model of Lamezia Terme International Civil Airport runway. The airport was inaugurated in 1976 and, according to Ente Nazionale per l'Aviazione Civile (ENAC), it's the main airport in Calabria with 2.5 million passengers recorded in 2017. I-BIM modeling permits to realize an intelligent runway, because it is possible to add information about materials, certifications, structural and functional parameters. This paper also aims to highlights that the use of BIM for a reverse engineering case study, allow to create a smart runway 3D model that can be also used for planning maintenance operations implementing the BIM seventh dimension.

2. Case study

The reverse engineering case study presented here is the 3D parametric solid model of Lamezia Terme International Civil Airport runway located in Southern Italy (Fig. 1). Lamezia Terme is one of the main airports of the Southern Italy, well connected with the strategic railway station of the “Tirrenica Meridionale”, the A2 freeway overpass and Gioia Tauro harbor.

Fig. 1. Lamezia Terme International Civil Airport

LICA is the assigned International Civil Aviation Organization (ICAO) Code, the runway is 2400m long and 60m wide and belongs to 4D class. This case study was carried out using Autodesk Civil 3D software in the following steps: a) creating the digital elevation model; b) creating the horizontal alignment; c) creating the vertical alignment; d) modeling the 3D corridor using the edited assembly template; e) importing grip number (GN) data measurement in the 3D model; f) creating 3D real-world context.

2.1. Creating the digital elevation model

The first step of the study was to create a Digital Terrain Model (DTM) from the available cartographic maps, composed by “points” with an associated elevation. For this purpose, 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, was created as shown in Fig. 2.

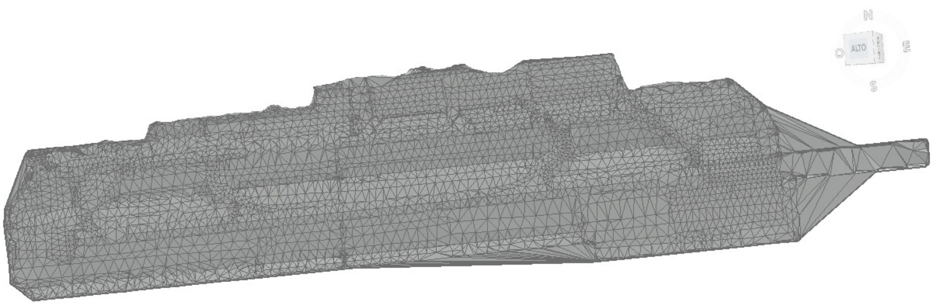

Fig. 2. TIN ground surface of the runway

2.2. Modeling horizontal alignment and vertical profiles.

The horizontal alignment of the runway is composed by one tangent element long 2400m and is located in a flat area. The associated design profile, composed practically by one straight grade equal to 0.25%, is shown in Figure 3, where the red line refers to the ground longitudinal profile and the blue one to the runway design profile.

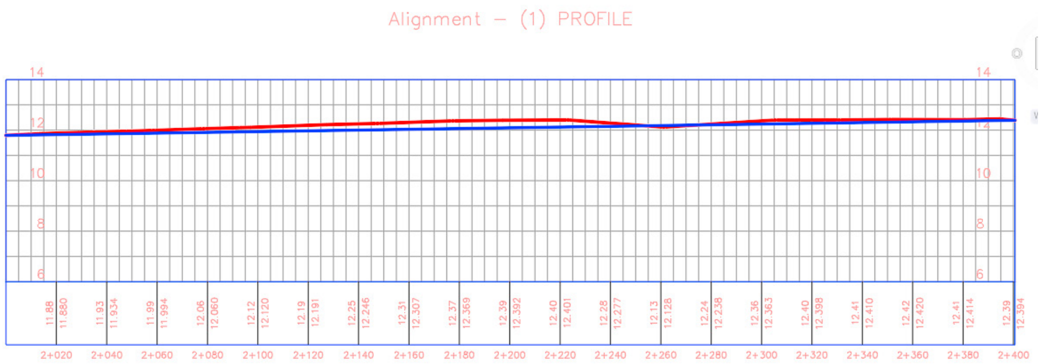

Fig. 3. Design profile of the runway

The alignment and the altimetric profile were implemented with the cross section in BIM to realize the 3D parametric model of the infrastructure.

2.3. Editing the cross-sections.

Before moving to the corridor modeling phase, the associated cross-section template was edited. Analyzing the results collected with a ground-penetrating radar shown in Fig. 4, it was possible to identify the associated layer information on the runway pavements

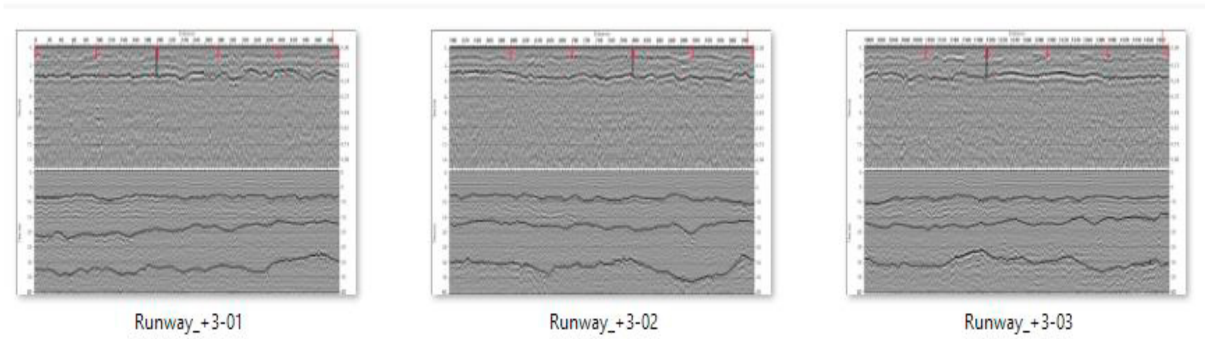

Fig. 4. Data from ground-penetrating radar

The runway pavement is composed by 20 cm of surface course in bituminous conglomerate, 26 cm of base course, 49 cm of subbase course and 74 cm of subgrade. In 2005, on the runway were made surface reconstruction treatments including scarification and refilling joints, adding a new surface and binder layers. The cross-section templates were edited as shown in Fig. 5. All the components not included in the standard library of Civil 3D software, were created and edited by using the tool Subassembly Composer. In this way, it was also possible to assign to each layer the geometric feature properties, but also the non-geometric features such as documents (i.e.: certifications) and details on the materials parameter, creating an intelligent object.

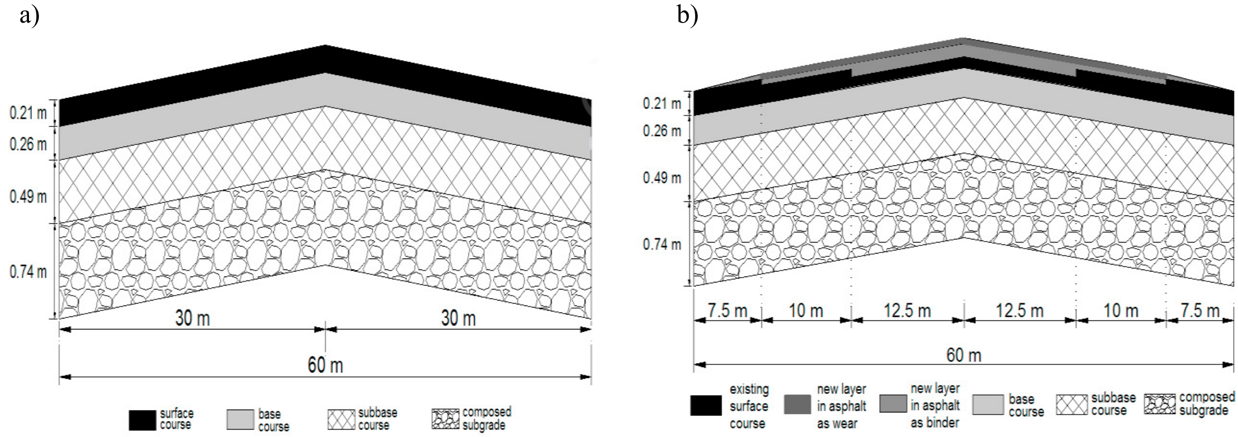

Fig. 5. a) cross-section before treatments; b) cross-section after treatments

2.4. Modeling the corridor

The corridor model builds on and uses various Autodesk Civil 3D objects and data, including surfaces, alignments, profiles, cross-sections. The 3D corridor was generated from the baseline horizontal alignment by placing 2D section (shown in Fig. 5) at incremental locations, and by creating matching slopes that reach a surface model at each incremental location. The output is shown in Fig. 6.

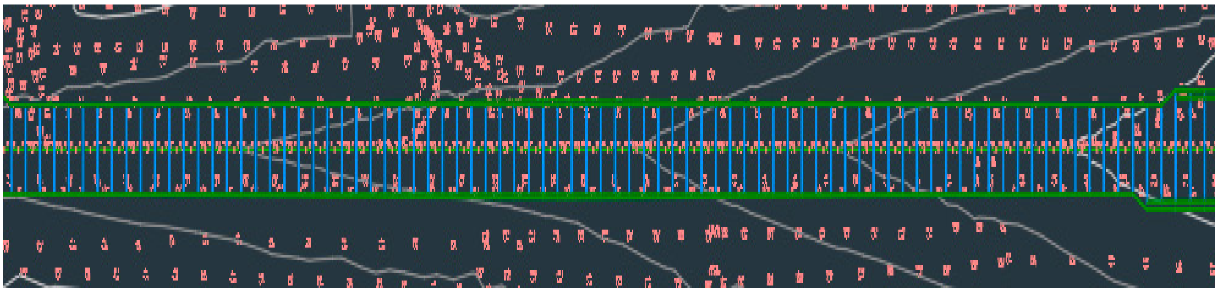

Fig. 6. 3D parametric solid model

2.5. Importing data in 3D model for the APMS.

The role of an APMS is to assist decision makers for planning evaluable strategies to maintain the pavements in a serviceable condition over a given period. One of the main benefits in using an APMS is that it can provide a more efficient way to monitor the condition of the runway pavement system and it can be used to examine deterioration trends in different runway pavement sections within the system (Thighe and Covalt 2008).

Data acquisition and processing are essential components of an APMS. The database is the core management system, including the values of several variables and factors that influence the pavements performance (Russo et al. 2018, Veropalumbo et al. 2018) as well as information on the network operation: maintenance, operation, accident and social costs (Čokorilo 2008, Čokorilo et al. 2013, Moretti et al. 2018).

In this study grip number (GN) data, collected from 2005 to 2015, were imported in the 3D model (Fig. 7). In the survey, made with a Grip Tester Trailer, GN data for the entire runway on the alignments ±3m and+6m respect to the centerline were collected, in according to the circular ENAC APT 10A (ENAC, 2014).

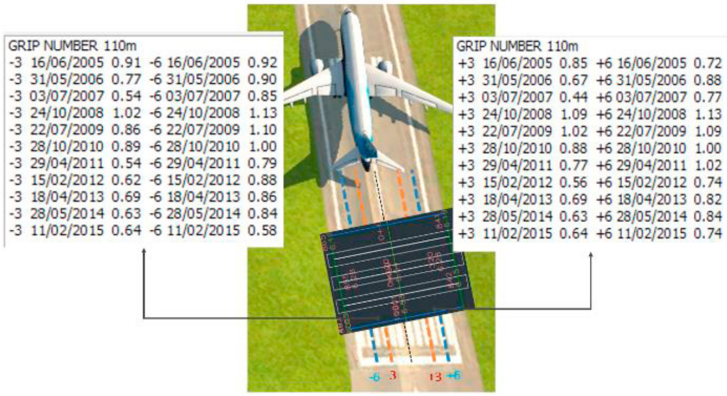

Fig. 7. Importing data in 3D parametric solid model

These data can be used in APMS to control the deposits of vulcanized rubber of aircraft tires on the runway. This happens mainly in the touch-down areas during landing operations, and the loss of grip compromises the safety of both take-off and landing operations (De Luca et al. 2016a, De Luca et al. 2016b, De Luca and Dell'Acqua 2018).

De Luca et al. (2014) proposed a procedure to estimate the decay curve characteristics of the surface of the runway. The procedure is based on empiric models by which it is possible to correlate the Grip Number (GN) and the cumulative load (LC_t). Using the suggested procedure, the decay curves of the runway were plotted.

2.6. Creating 3D real-world context

Infraworks360 allows visualizing the design project, sharing cloud-based models with project stakeholders for real-time feedback, and transforming designs into compelling presentations. Using the tool "Model Builder" it was possible to select the case study area and extract the terrain base model. The main difference between Autodesk Civil 3D and Infraworks360 is that the first one works within the ".dwg" environment, while the second one is a database-backed application. The 3D model was enhanced with static objects such as street features, vegetation and transport components (see Fig. 8).

Fig. 8. 3D real-world context

Contextualizing the model is essential for the study phase of expansion projects. In facts, several treatments have been carried out in Lamezia Terme International Civil Airport since 2015 (Società Aeroportuale Calabrese (SAC), 2015), providing a solid basis for the air traffic increasement in the next 20 years. The first was the stretching of the threshold 28 from 2400 meters to 3000 meters, and the link between the taxiway and the new threshold (Fig. 9).

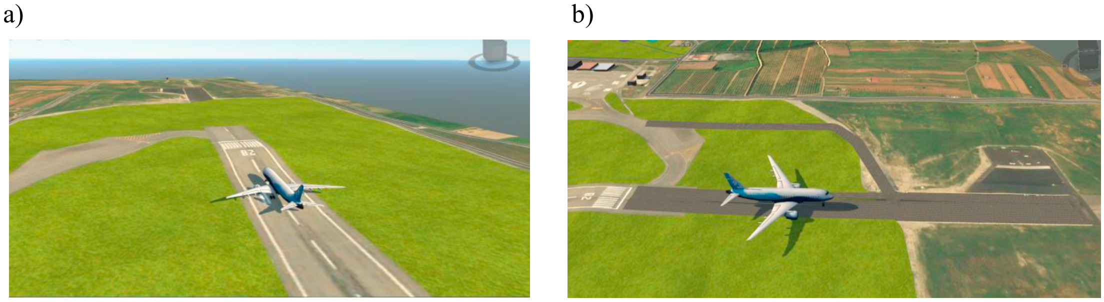

Fig. 9. (a) Runway before improvements, (b) Runway after improvements

According to SAC (2015), new installations such as edges, approaching bright path, were implemented on the runway. After these renovation treatments, the new declared distances of the runway 10-28 of the Lamezia Terme International Civil Airport are shown in Table 1.

Table 1. Runway 10-28 distances

	TORA		TODA		ASDA		LDA	
	Before	After	Before	After	Before	After	Before	After
Runway 10	2414	3016	2624	3076	2414	3016	2308	3012
Runway 28	2414	3016	2474	3076	2414	3016	2307	2652

Note: TORA is the Take Off Run Available; TODA is the Take Off Distance Available; ASDA is the Accelerate and Stop Distance Available; LDA is the Landing Distance Available.

3. Conclusions

I-BIM is not yet well developed in Europe compared with other country as Asia and America. Practical applications include the massive use of I-BIM models for energy and little use for tunnel infrastructures, airports and ports (Dell'Acqua et al. 2018). Lamezia Terme International Civil Airport is one of the few existent airport infrastructures have been started to be analyzed in I-BIM. The aim was to show the benefits of I-BIM applied on existing airport infrastructures. The methodology described represents not only a powerful tool to optimize and validate the project before it becomes reality (Abbondati et al. 2016), but also to see how the infrastructure works with the 3D real-world context (Biancardo et al. 2018, Russo et al. 2017, Dell'Acqua 2015, Russo et al. 2015). The steps carried out in this study are as follows: a) modeling the 3D digital terrain model from point cloud; b) creating the horizontal alignment, vertical profiles and editing cross-sections; c) modeling the 3D parametric model of the runway; d) importing GN data in the 3D model; e) visualizing the infrastructure in the real-world context. The growing volume of information in a pavement network leads to a need to have an efficient data processing system and quick query speeding the making decision process. When a pavement management system is implemented, it gives an objective and effective guidance to the various activities involved in maintenance, furthermore it is possible to monitor and promote planning, manage the documentation required for each of the tasks scheduled making them formal and to help the feedback process between them. In this case study the use of BIM permits to create a dynamic database of the runway friction measurements. With a simple click on a generic section of the runway, is possible to visualize both historical and current values of the measurement. This can be extended to every features of the runway. BIM technology provides a comprehensive and integrated quality information repository, and makes the sharing of visual, integrated, quality information possible for the existing assets. BIM permits to realize not only an intelligent 3d model of the runway, but also schedule and evaluate maintenance treatments, according to Norms (ENAC, 2014).

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