Airport Pavement Management Systems: An Open BIM Approach

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Abstract. Building Information Modelling (BIM) offers the possibility to access and oversee information about the asset, throughout its lifecycle. One of the phases where BIM can provide key benefits is the Operation phase, e.g. facility management/maintenance, decommissioning and major re-programming, supported by the Information Management Process (IMP), which may include a Computer-Managed Maintenance System (CMMS). When discussing roads, highways or runways the maintenance phase is largely concentrated on the pavement, and a robust Pavement Management System (PMS) should be integral part of the IMP, focusing mainly on the evaluation of the pavement's present condition and prediction of its future condition. In the airport domain, the importance of an Airport Pavement Management System (APMS), falls both in a cost effectiveness and aviation safety viewpoint, providing consistent, objective and systematic procedures for determining priorities, schedules and resources' assignment. Introducing the case study of the Lamezia Terme International Airport, this paper presents possible improvements in the interoperability of maintenance data of the airport's runway with reference to the IFC Reference Processes, being that Maintenance Management is one of the defined projects within the Facilities Management (FM) domain inside BuildingSMART International.

Keywords: Airport Pavement Management System (APMS) · Building Information Modelling (BIM) · Industry Foundation Classes (IFC)

1 Introduction

In the Ministerial Decree 560 of 2017, Italy set the timeline for the mandatory but gradual introduction of the use of digital modelling methods and tools for the Construction Sector based on the asset's tender value. Starting from the first of January 2019, public works with a tender value equal or greater than 100 million euros will be obliged to apply innovative approach that includes Building Information Modelling (BIM), in 2025 all public works should fully integrate BIM.

Infrastructure projects should nowadays be supported by Building Information Modelling (BIM) processes and benefit from their numerous advantages, namely at the

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design (visualization, automatic low-level corrections when the design changes, consistency of the design intent verification), collaborative (project team is given at an early stage a better understanding of the project) and Operation and Management levels (Sacks et al. 2018).

Originally developed for the architectural field, the BIM application to transportation infrastructure projects still demands some research, particularly on fully interoperable specific standards, however the rewards of its application throughout the whole lifecycle of the asset(s) justifies the effort of the academic and industrial communities. Figure 1 presents a summary of the infrastructure domains and the phases of the assets' lifecycle where BIM can be applied.

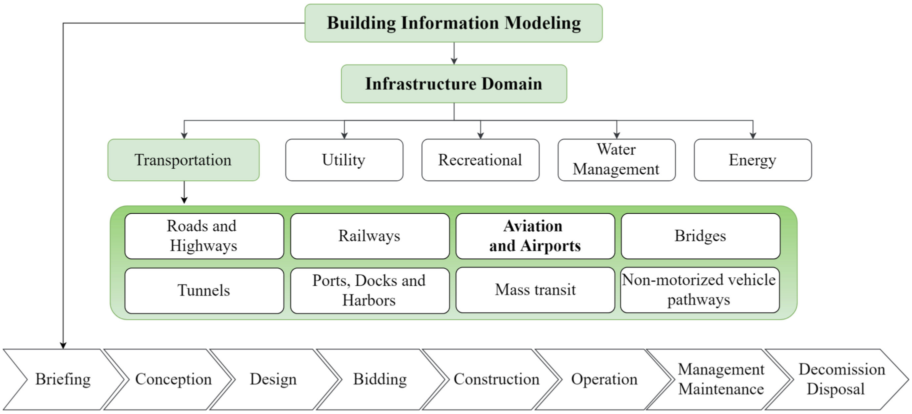

Fig. 1. BIM infrastructure domain and asset lifecycle phases.

BIM can be of crucial importance when applied in the Operation and facility management/maintenance phases. In the complex Airport domain, the importance of these stages cannot be overlooked, as it is both in terms of security and strategic importance to keep these infrastructures in optimal operating conditions.

Even in the case of airports where the BIM model has already been established concerning all the infrastructure (including the airside detailed pavement areas model), the integration of an eventual existing APMS is not absent of challenges. As highlighted in the Airport Room Roadmap Report (BuildingSMART 2015), a complete asset management plan still evidences problems that present challenges, namely in terms of inefficient and uncomplete handover information exchange, big data filtering, long-term planning needs and software application interoperability.

The importance of a well-established complete APMS as integrant part of the Airport BIM model is paramount, and this paper aims to provide guidelines as to better obtain its integration in an open BIM context.

BuildingSMART International (2019) establishes that Open BIM has as main goal the improvement of the process of exchanging non-proprietary BIM models and other data based on open standards and workflows.

2 BIM and the Information Management Process

An Information Management Process (IMP) is the method an organization uses to acquire/retrieve, organize and maintain information concerning an asset.

Figure 2 illustrates the integration of eventual already in-place enterprise systems, as an APMS, with the BIM process.

After validation procedures from the responsible team of the enterprise system, the information provided by such systems can go to the publish area of the Common Data Environment, as indicated in the Publicly Available Specifications, PAS 1192-2:2013 and PAS 1192-3:2014.

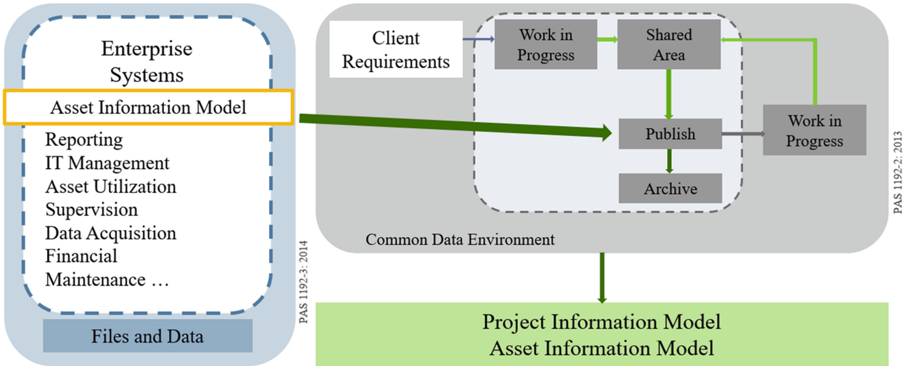

Fig. 2. Integration of an APMS system in the BIM process (Adapted from PAS 1192-2:2013 and PAS 1192-3:2014).

The process is therefore highly dependent of the quality and relevance of the contained information, the Computer-Managed Maintenance Systems (CMMS) provide a tool for all the data organization and can serve to reduce maintenance-related related costs and increase productivity of the management team.

The maintenance activities require an effective organization and an accurate, comprehensive and accessible database of relevant information. Recognizing that an airport air-side is submitted to rigorous and frequent inspections, and that any problem detected must be timely addressed, its clear that this type of infrastructure benefits significantly from well-structured models and robust management systems.

3 Airport Pavement Management Systems

Airports are divided in two main areas, landside and airside. The airfield pavements include the runway(s), taxiways, taxi lanes and aprons on the airside area.

Operation and Maintenance procedures of the pavement areas of the airport airside benefit and are binded to be sustained by the data contained in the APMS. Figure 3 illustrates that the pavement management can be applied at the network level, where the overall condition of the network and future state condition are evaluated and predicted, and the needs for intervention are prioritized for specific sections (either preventive maintenance, rehabilitation or reconstructive interventions), in sum, planning, budgeting and policy decisions. At the project level occurs the selection of project-specific pavement preservation treatments, (materials and procedures). The construction and monitoring of the treatment performance are also contained in this level (Hajek et al. 2011).

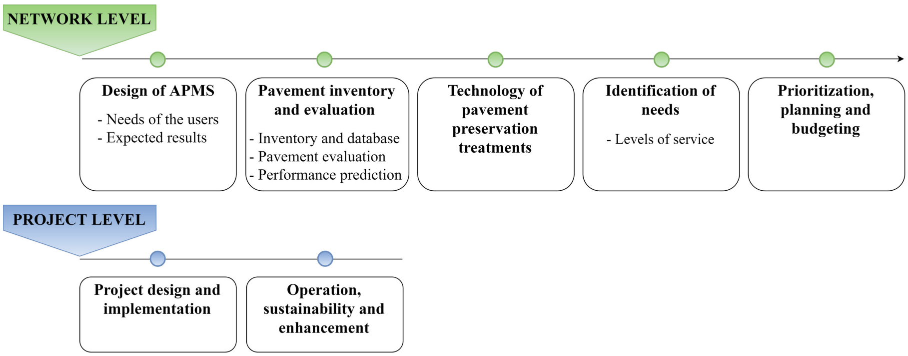

Fig. 3. Airport pavement management levels (Adapted from Hajek et al. 2011).

In Italy, the Italian Civil Aviation Authority, ENAC, carries out activities of regulation and control of the air sector, based on international (conventions, protocols, regulations and directives), national (laws and decrees) and internal regulations and circulars. Of particular interest to the present paper are the guidelines specific for the application of APMS (ENAC 2015). In this document the benefits of the implementation of these systems are listed; the development of a computerized database promoting the organization and storage of pavement related data, the regular and objective monitoring of the pavement condition, the establishment of deterioration rates and the planning and optimization of the treatments according to the available budget.

For a correct allocation and reference of all the information contained in the database, the pavement inventory divides the airport pavement network in branches (e.g. runways, taxiways), sections (with uniform pavement structure) and sample units as recommended in the ASTM standard D5340-12 (ASTM International 2018). A summary of the relevant data that should be contained on the database and connected to the division previously described is shown in Fig. 4.

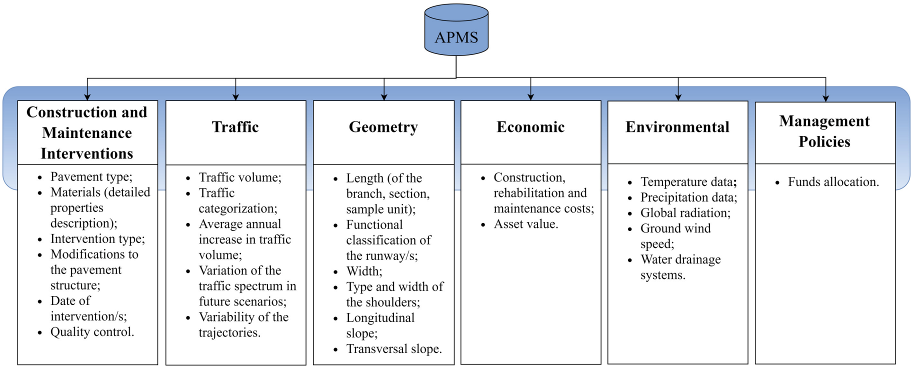

Fig. 4. APMS database information (Adapted from ENAC 2015).

4 Lamezia Terme International Airport

The Lamezia Terme International Airport is the main airport in the Calabria Region, Italy, with the identifier codes, International Air Transport Association: SUF and International Civil Aviation Organization: LICA. The airport opened in 1976, and has since then been subject to improvements, namely in 1982 and in 2007, the latter where a structural requalification of the air-side pavements took place. The airport airside is composed of one runway, one taxiway, four taxi lanes and aprons, distributed as can be seen on Fig. 5.

Fig. 5. Lamezia Terme International Airport.

The Airside pavement description and main characteristics are described as follows: The runway, is designated Rwy 10/28, according to its magnetic azimuth orientation. The runway has a flexible pavement type, with a loading-carrying capacity, pavement classification number PCN 58/F/B/W/T, where F: flexible pavement; B: subgrade strength (CBR between 8–13%); W: tire pressure supported unlimited and T: PCN estimated by technical evaluation (De Luca and Dell'Acqua 2018).

It presents a length of 3000 m, width of 45 m; shoulder width: 14 m, and variable longitudinal slope (ranging from 0.13% to 0.38%). The transversal slope presents values of 1.25% or 1.40% according to the section.

The taxiway, designated "Sierra", presents a flexible pavement type. The taxiway has a length of 1750 m, width of 30 m, shoulder width: 10 m, longitudinal slope: variable ranging from 0.09% to 0.49%, transversal slope: variable: 1.30%, 1.50%.

The airside contains four taxiway exits also with flexible pavement type structure and variable geometric characteristics, highly dependent of on the constraints imposed by the connection of the the runway to the taxiway (namely in terms of longitudinal and transversal slope). Generally, the sections of the exits present a width of 25 m and 10 m shoulder width.

5 Runway BIM Model

5.1 Geometry

The initial part of the Lamezia Terme airside case study, and main part of the present paper focuses on the construction of the runway 10/28 digital twin, i.e. a model that mirrors the asset (data-rich 3D model), and represents, reacts and can cause changes in the actual runway, when connected to the APMS. First and foremost, it is important to highlight that the runway model was produced with a tool dedicated to road design, from the Bentley Systems company, and for that motive, all the digital runway components had to be customized and detailed for the airport case, namely the transversal sections of the runway. The overall view of the airside model can be seen in Fig. 6, the model also includes the alignments for future incorporation of the taxiway and taxiway exits model.

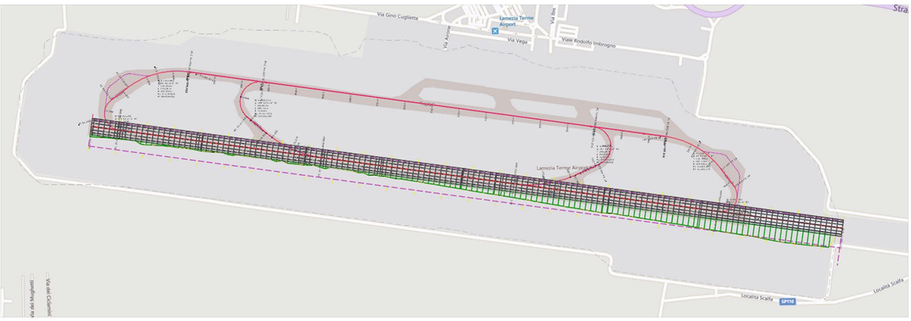

Fig. 6. Overall view of the airside model.

The corridor of the runway 10/28 was created based on a custom parametric cross-section that incorporates the designation of the pavement layers and specific identification point designations, as can be seen in Fig. 7. The main constraints imposed for the construction of the cross-section were of the horizontal, vertical and slope nature and the connection to the terrain was established defining an end-condition component for both the cut and the fill cases. It is important to mention that in the general model, at this stage, the connection to the terrain from the left side of the runway (West-East direction) was purposely excluded from the model, for future study of the intersections between runway and taxiway exits.

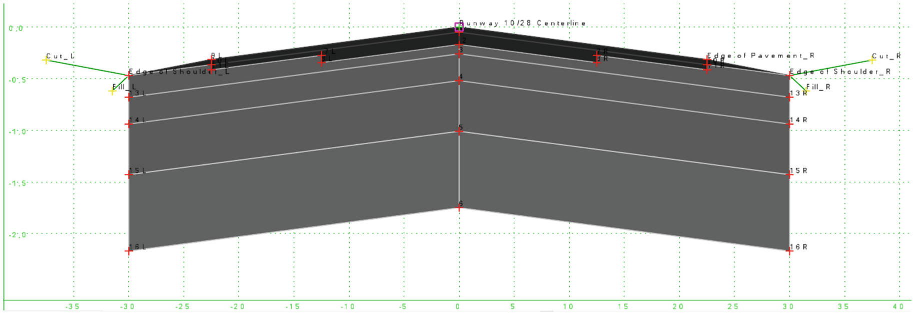

Fig. 7. Runway 10/28 custom cross-section.

5.2 Semantic Data

One of the main advantages of developing the BIM-model is the capacity of integrating non-graphical information. Even though the UNI 11337- 4 (U. Committee 2017), does not illustrate in detail the runway case application, the description of a Level of Development G, provides guidelines as to the information that a model built for operation and maintenance purposes should include. Although inspired by the USA scale (LOD 100, 200, …, 500), and integrating aspects of the UK LOD convention, the Italian scale is affected by national requirements not present in both systems. The national Italian LOD scale is represented by capital letters in alphabetic order from A to G. In the LOD G the model elements should express the updated virtualization of the status of the asset, including information about every management, maintenance and/or repair and replacement intervention carried out over time, as well as the current level of degradation.

Quantitative and qualitative characteristics, namely performance indicators, dimensions, form, location, cost, etc., should be updated with respect to the life cycle phase.

Figures 8 illustrates the integration of information to the runway model, connected at the branch and sample unit levels, in this case data related to a radargram test performed.

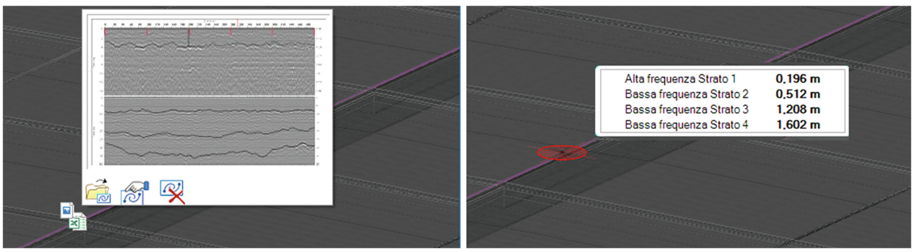

Fig. 8. Radargram field test data.

All data related to the pavement reported distresses should also be included, e.g. eventual alligator or fatigue cracking, bleeding, corrugation, depression, raveling, weathering. Indicators related to the pavement deterioration and characterization as the Pavement Condition Index (PCI) and the integrity of the top surface of the runway, are other important features that should be part of the records. The surface condition is evaluated by regular inspections, dependent on the environmental conditions, the wear and tear and on the accumulation of rubber deposits. The integrity of the runway can be evaluated through the study of its surface friction levels.

6 Interoperability Between a BIM Model and the APMS

In linear infrastructure projects, such as is the case of the runway, interoperability still poses some challenges. To this purpose, Common Data Standards, such as the Industry Foundation Classes (IFC), are currently in development, not yet including data schemas for infrastructure works (Tibaut et al. 2015).

However, some of the already published and validated IFC's can be applied to this specific case improving the connection between the APMS database and the model. This paper suggests the application of the ifcPropertySets mechanism to demonstrate how can the information can be connected in an open standardized way.

Although some properties can be defined directly within the schema of the IFC model, others can be added freely to the instance model. Being that, as referred, the schemas for linear infrastructures are not available yet, it is only normal that specific characteristics of these assets are not detailed in the most common properties of the defined IFC's. The already defined IfcCivilElement is a generalization of all elements within the civil engineering works and can be applied to occurrences of typical linear construction works as pavements.

So, using the already defined IfcCivilElement, connected to the wearing course of the runway, the possibility of integrating data to be used in the APMS becomes optimized. The already available Property Sets for the IfcCivilElement are: Pset_Condition, Pset_EnvironmentalImpactIndicators, Pset_EnvironmentalImpactValues, Pset_ManufacturerOccurrence, Pset_ManufacturerTypeInformation, Pset_PackingInstructions, Pset_ServiceLife and Pset_Warranty. The proposed amplification (Fig. 9), concerns data referent to the friction levels of the runway's surface, obtained through the Griptester, and the connection is made through a defined IfcPropertySet, named "WearingCourseConditionHistory". The left side of Fig. 9 shows the newly IfcPropertySet specific for the connection of the previous history records, such as the latest GripTester results, and the right side shows a standardized PropertySet, in the case "Pset_Condition", with examples of the correspondent information included.

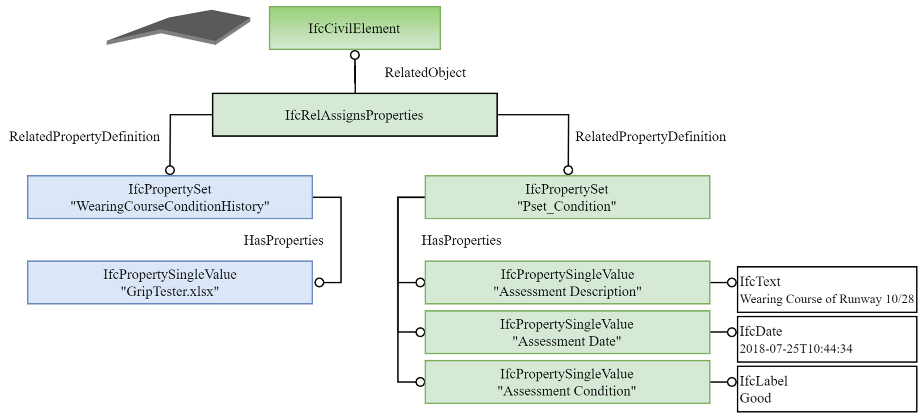

Fig. 9. Use of properties, integration of the IfcPropertySet "WearingCourseConditionHistory".

By using this mechanism when the IFC project file is shared between stakeholders the access to all this data is displayed, as well and integrated in the APMS. The connection to "GripTester.xlsx" assures that all previously friction field tests results are connected to the wearing course of the runway, organized by date, including information about the sample unit, distance from the runway centerline and corresponding grip-number obtained.

This mechanism can be further extended to include other data, serving the PropertySet "WearingCourseConditionHistory" as an example. The PropertySet allows the introduction of further properties.

7 Conclusions and Future Developments

The present paper presents a mechanism to further enhance the interoperability between the BIM model aggregated information and the APMS database. The detailed mechanism is based on the IFC use of properties and their connection to specific objects of the model, the example presented is the Runway 10/28 wearing course and the connection to friction related historic data. While the finished schemas are not available for the infrastructure field it is important to study options within the already published ones as they will certainly be applicable in the future. Given the importance of maintaining the airside pavement in optimal conditions, the connection of relevant information and its interoperability is crucial for an optimized management of the asset.

Future developments of the project presented in this paper will include the completion of the Airport's air-side pavement areas modelation, the further enrichment with non-geometric data, the study and implementation of semantic web technologies which can further improve the integration of relevant data to the model and the expansion of the IfcPropertySets mechanism for Airport pavement management purposes.

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