

Building Information Modelling Concept Applied in Maintenance of Buildings

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ABSTRACT: *Building maintenance is the responsibility of its owner which must use, whenever appropriate, a technician to perform the inspection. A good maintenance depends on the analysis of the anomalies detected during the inspection of the site. Building Information Models (BIM) have revealed themselves as a good tool when it comes to supporting maintenance actions, due to their ability to store enough information in one digital model. The aim of the proposed work was to implement the benefits provided by BIM on a software tool used as support to maintenance of buildings. During an inspection activity for maintenance purposes, the implemented application, containing a rigorous database, allows the user to identify each anomaly present in building components, directly onto the BIM model, automatically associating them with probable causes, repair methods and a photograph of the anomaly uploaded at the site. Therefore, gains in productivity and a decrease in the error probability can be achieved. The inspection data is stored in the BIM model, making it suitable for consultation when planning maintenance. Additionally, it was case study the interoperability between BIM modelling and visualizing software, regarding the preservation of information, especially in the standard format Industry Foundation Classes (IFC). This work contributed to demonstrate, not only that there are still problems concerning the interoperability between BIM software, but also the advantages of employing BIM for building maintenance purposes.*

Keywords: Maintenance, Inspection, Building Information Modelling, Standard IFC

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1. Introduction

Building Information Modelling (BIM) is the digital representation of all the physical and functional characteristics of a facility, being used as an information repertoire, which can be shared and updated throughout the facility's life-cycle [1]. The parametric creation process of the BIM model provides a chance of performing an automatic detection of conflicts, of promoting a link between the model and the schedule planning stage (the creation of the 4D model), of interconnecting the model with budgeting data (5D model definition) [2] and of relating the modelling with different processes regarding the facility management and maintenance throughout its life span (referred as the 6D model) [3]. The aggregation of several types of information on a single platform provides tremendous value to the model, functioning as a resource that can be accessed directly by countless people, avoiding the expense of time and money in work duplications and allowing the constant update of information.

There is currently a growing concern about the maintenance and upkeep of buildings, not only due to regulatory standards set out in the project, but also the requirement of the users in terms of safety, health and building comfort [4]. BIM models have revealed themselves to be an excellent tool not only during the stage of planning and construction, but also in the maintenance phase, mainly because of its large capacity for storing information associated with the three dimensional (3D) representation [5]. The fact that it is possible to access all the information of the building, through a single platform, combined with the automatic update of the model whenever changes are made, makes the BIM model very advantageous and promising during the exploration stage of a building, for this way, more reliable and accurate maintenance operations can be achieved [6].

If on one hand, getting an accurate and omission free update of the models using the Industry Foundation Classes (IFC) standard, is one of the main difficulties encountered when using BIM models during the exploration stage of a building [5], then on the other, maintenance of buildings has proved to be a rather complex task to accomplish, because the identification and analysis of all kinds of failure in construction requires a considerable effort of the agents responsible for maintaining the facility [4]. As such, in this work we have developed an innovative software tool, aimed to support the inspection operations of buildings, making them more efficient and error-free, due to its rigorous database, allowing the user to identify anomalies in the construction components directly on the BIM model, and associate them with the probable cause, recommended solution, repair method and a photograph. Additionally, it was case study the interoperability between BIM modelling and visualizing software, regarding the preservation of information, especially in the IFC standard.

This work [7] contributed to demonstrate, not only that there are still problems concerning the interoperability between BIM software, but also the advantages of employing BIM for building maintenance purposes.

II. BIM Model

The architectural BIM model was created, using the Revit Architecture software. In order to illustrate how to carry out the modelling of a building using a BIM based software, a small fraction of real estate development in Cascais, near Lisbon, Portugal, was chosen as case study. The building consists of three floors; the ground floor consists of two dwellings and the remaining floors, four duplex dwellings. Each dwelling consists of bedrooms, toilets, kitchen, living room, hall and balcony.

In the model, all elements represented as walls, floors, ceilings, roof, doors, windows, and handrails, were created by adapting existing 3D parametric objects in the Revit library. The components of decorative character and equipment, such as sofas, chairs, toilets, tables were used directly, merely taking into account the scale factor during their inclusion in the model. The following list presents the orderly steps in the creation of architectural BIM model.

Order Procedure

- **1st step:** Defining sill elevations of the flooring.
- **2nd step:** Importing dwg files
- **3rd step:** Defining the construction platform
- **4th step:** Modifying the contour lines
- **5th step:** Creating, editing and inserting the walls
- **6th step:** Creating, editing and inserting the doors and windows
- **7th step:** Creating, editing and inserting the pavements and the false ceilings
- **8th step:** Creating, editing and inserting the roof
- **9th step:** Creating, editing and inserting the staircases
- **10th step:** Creating, editing and inserting the guardrails
- **11th step:** Inserting the components

Some drawings and projections can be obtained from the established model. Figure 1 shows a plan and a cut and Figure 2 illustrates the main facade, a general perspective of the model, and one view shot of the interior. Figure 1. Ground floor plan and vertical cut.

3. Program to Support Maintenance

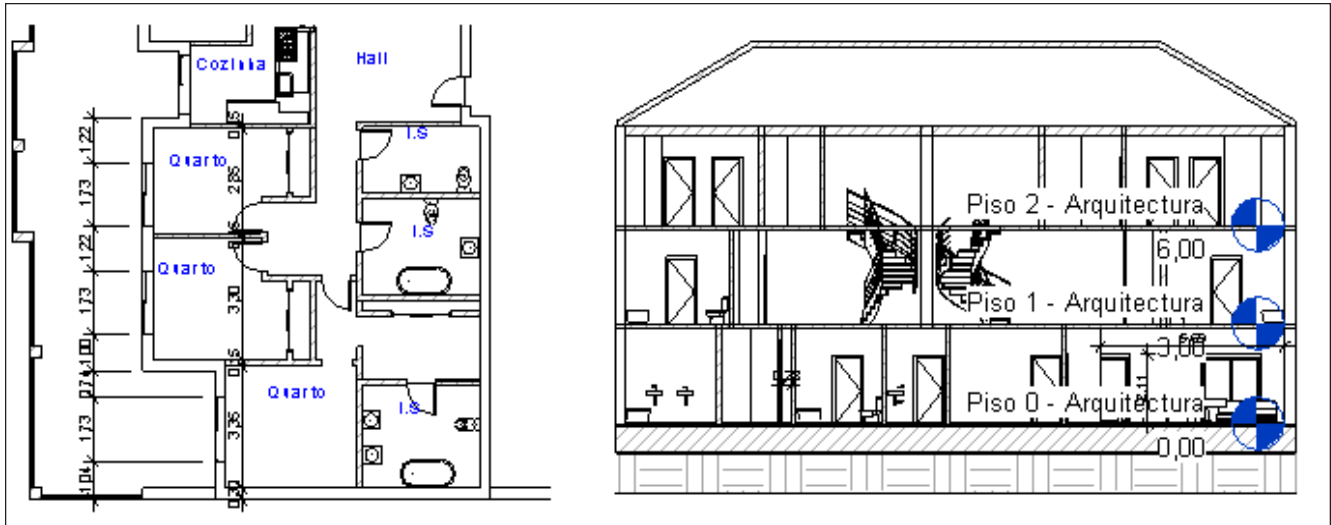


Figure 1. Ground floor plan and vertical cut

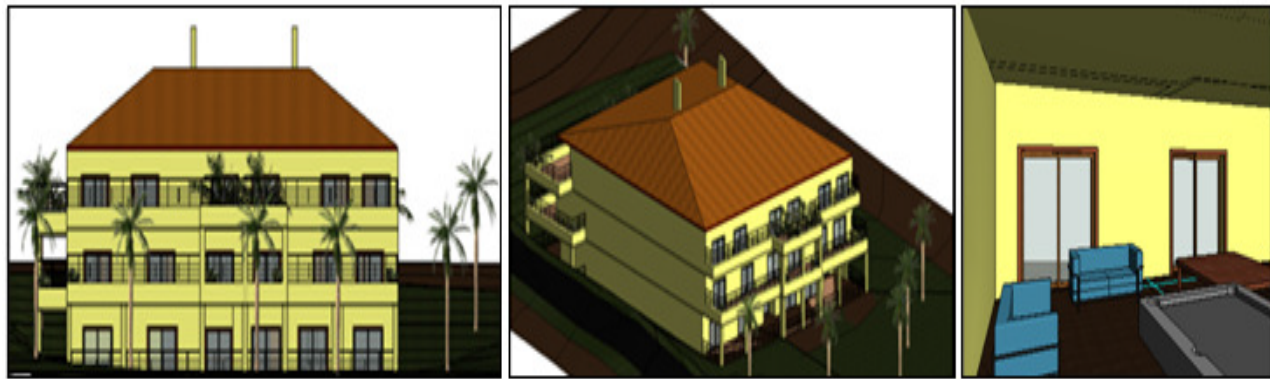


Figure 2. Main façade, general and interior perspective of the 3D model

The interactive inspection operations sheet, created using the Visual Basic software, has as main objective to support the implementation of an inspection. In its development the database that was used consisted in the compilation of information from other dissertations also developed for maintenance purposes. The information provided in this work relates to anomalies, causes, solutions and repair methodology concerning constructive components: exterior walls [8]; interior walls [9]; pitched roofs [10]. Therefore, during an inspection, the maintenance technician, when observing an anomaly, can consult the database support to fill out the inspection sheets and select the identified anomaly on the site.

Subsequently, the completed inspection sheet is then converted to the *pdf* format and inserted into the BIM model. This model should be constantly updated, in order to accurately support the facility with repair and maintenance plans. The developed computer application has its interface illustrated in Figure 3. An inspection sheet must include some initial information such as identification of the technician, the date of the inspection and the identity and characteristics of the building (address, city, number of floors, year of construction, etc...). A sheet of the inspection must include some initial information such as identification of the technician, the date of the inspection and the identity and characteristics of the building (address, city, number of floors, year of construction, etc...). Most of this information is selected from *ComboBox* elements, so your registration is carried in a fast way. A *ComboBox* element is defined with a combination of a text box and a list box, allowing the filling of the text box with one of the options provided in the list that appears as a descending menu.

In addition, a *ComboBox* element allows the user to group relations of dependence between them, providing different lists depending on types of elements, that is, the box lists differ according to the option selected in advance. In the developed software tool, this feature is observed between the elements and sub-elements (Figure 4), among the verified sub-elements and anomalies (Figure 5) and between anomalies and possible causes, solutions and repair sequences (Figure 6).

Figure 3. Interface of the inspection sheet

Figure 4. Sub-elements available when choosing the element

Figure 5. Lists of available anomalies according to the chosen element and sub-element

The application also allows you to include a photograph of the anomaly taken at the site and convert the information presented in the sheet of inspection to a document in pdf format. Such possibilities are essential for an inspection sheet, because the addition of a photograph allows the user to recognize the anomaly, its severity and location, and conversion to pdf format enables the user to save the inspection form in an universal format. The result of filling the form and its presentation in pdf, are illustrated in Figure 7.

Roof

Elemento: Cofre
 Anomalia: Desc

Sub-elemento: Pontos angulares

Causas possíveis:

- Proteção do remate com matizes inadequados, usados de forma incorrecta ou recobrimento demasiado pequeno
- Falta de verificação do executado, não garantindo qualidade
- Deficiente execução devido a mão-de-obra não qualificada

Solução:

- Reparação de remates e pontos angulares

Sequência de reparações:

- 1º Efectuar a remoção das peças acessórias e do remate
- 2º Aplicar ou substituir o núcleo metálico entre o paramento e o revestimento, fiando-o ao suporte com argamassa e com pregos ou parafusos ao tijolo
- 3º Colocar um capamento metálico na parede emergente cobrindo-a até ao tecto
- 4º Aplicação do revestimento deve ser efectuado um corte longitudinal uniforme para permitir a separação das águas
- 5º Efectuar uma limpeza geral para remover todas as detritas geradas

Wall

Elemento: Revestimento em pintura
 Anomalia: Empolamento

Causas possíveis:

- A presença de humidade em excesso na base de aplicação ou no ambiente
- O desrespeito do intervalo de tempo de repitura
- A incompatibilidade química do produto de pintura com a base de aplicação

Solução:

- Repitura

Sequência de reparações:

- 1º Escovagem ou à remoção total ou parcial do revestimento por pintura
- 2º Verificar se a base apresenta degradação (com fissuração ou fendas, frênil ou apodrecida) e, nessa situação, proceder à sua reparação

Figure 6. Causes, solution and repair sequence automatically filled

RELATÓRIO DE INSPECÇÃO, DIAGNÓSTICO E PROPOSTA DE REABILITAÇÃO

IDENTIFICAÇÃO DO EDIFÍCIO

Morada: Urbanização de Amoreiras, lote 218
 Código Postal: 1900 Cidade: Cascaes
 Freguesia: Cascaes Distrito: Lisboa

CHARACTERÍSTICAS DO EDIFÍCIO

Nº de pisos: 1 Nº de fogos: 1 Ano de construção: 2008
 Utilização do Edifício: Habitação colectiva e residencial (Apartos, habitação)
 Possui cobertura em terrço? Não
 Outras observações: Não a avaliar

ANOMALIA, SOLUÇÃO E METODOLOGIA DE REPARAÇÃO

Elemento: Paredeis interiores Sub-elemento: Revestimento em pintura
 Anomalia: Empolamento

Causas possíveis:

- A presença de humidade em excesso na base de aplicação ou no ambiente
- O desrespeito do intervalo de tempo de repitura
- A incompatibilidade química do produto de pintura com a base de aplicação

Solução:

- Repitura

Sequência de reparações:

- 1º Escovagem ou à remoção total ou parcial do revestimento por pintura
- 2º Verificar se a base apresenta degradação (com fissuração ou fendas, frênil ou apodrecida) e, nessa situação, proceder à sua reparação
- 3º Preparação adequada da superfície e posterior pintura ou repitura com produtos compatíveis aplicados nas condições especificadas

Outras observações:

Referência para degradação do desempenho do edifício: Baixo Urgência de reparação: Baixo
 Necessidade de desocupação do fopo/fogos? Não Meio de acesso ao local: Escadaria interiores

Consequências possíveis: Favela estruturalmente em mau estado

Técnico: Duque Simões Data: 29-09-2013

Equipamentos e materiais necessários à reparação:

- Escova
- Tintas compatíveis com o suporte e respetivo material de proteção

Registo Fotográfico: (clique no espaço abaixo para carregar foto)



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 Anomalia: Empolamento

Causas possíveis:

- A presença de humidade em excesso na base de aplicação ou no ambiente
- O desrespeito do intervalo de tempo de repitura
- A incompatibilidade química do produto de pintura com a base de aplicação

Solução:

- Repitura

Sequência de reparações:

- 1º Escovagem ou à remoção total ou parcial do revestimento por pintura
- 2º Verificar se a base apresenta degradação (com fissuração ou fendas, frênil ou apodrecida) e, nessa situação, proceder à sua reparação
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Técnicas de diagnóstico/ensaios utilizados: Análise visual
 Análise de presença de água em empolamentos
 Tubo de Kertan para avaliar a absorção de água e água presa

Equipamentos e materiais necessários à reparação:

- Escova
- Tintas compatíveis com o suporte e respetivo material de proteção

Registo Fotográfico: (clique no espaço abaixo para carregar foto)



Técnico: Duque Simões Data: 29-09-2013

Figure 7. Interface of the filled out inspection form and Inspection sheet in pdf format

4. Interconnection Between The Bim Model And The Program

A BIM visualizer is an application that enables access to all information created in the BIM model. Unlike the modelling software, navigation and interaction with the model is performed quickly and lighter, and can also be accessed from mobile devices such as smartphones or tablets. This type of application also allows integrating the diverse information from architectural designs, structures, building installations and budgeting, and also allows the analysis of conflict detection. This item covers how to combine the BIM model of the building, the information from the inspection form, using a BIM visualizer. This study requires the analysis of interoperability between the BIM modeller and the BIM visualizer (*Navisworks*), regarding in particular data and information transfer in the IFC format. Furthermore, an inspection form is filled in and, afterwards, saved and included in the model, so that it can be used as a basis for consultation when planning maintenance operations.

The data transfer between the BIM modeller and visualizer, in IFC standard, resulted in complete preservation of information and error free. The only limitations observed were the clutter of information and a lack of storage capacity of the previously predefined colours, which led to the total deprivation of colour of the model, as illustrated in Fig. 8. The interconnection between the inspection program and *Navisworks*, is implemented through a link, created and added separately by type of building element. In this work, the name of the link is “Program”. After adding the link to all building elements suitable for inspection, the application is ready to be used in an inspection activity.

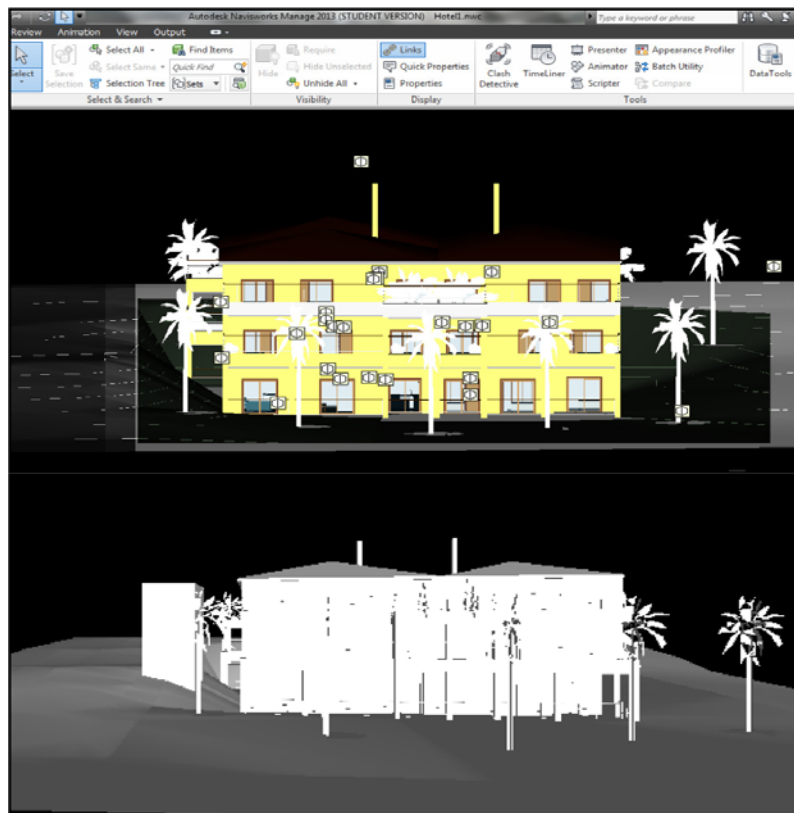


Figure 8. Navisworks interface showing the color deprivation in the IFC format

In an inspection activity the maintenance technician, using the developed application, selects the element where an anomaly was observed, in this case an interior wall (shown in blue in Figure 9). Through the BIM model, the service technician can identify the constituent materials of the interior wall (Figure 9) and has the possibility to run the inspection program, by selecting the link “*Program*”, fill out the inspection form and store it in the BIM model, through the creation of a new link. Let us assume for example, that the inspection sheet was recorded under the name “Inspection 29 Oct. 2013- Anomaly paint blistering”. Whilst planning for maintenance operations, or any other inspection activity, the choice of the element in which lies the anomaly (the wall inside the room depicted in blue in Figure 9) identifies two associated attachments: the inspection program and a sheet of the inspection carried out on the 29 Oct. 2013, concerning an anomaly called paint blistering (Figure 10).

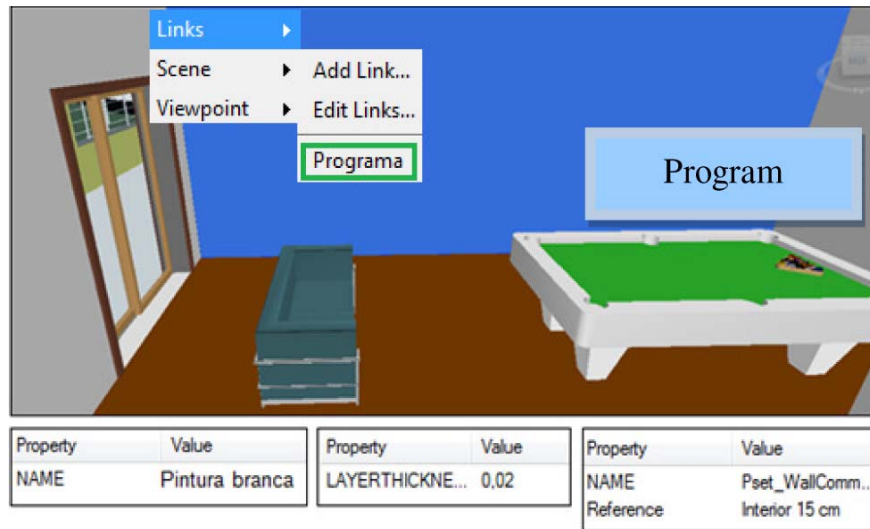


Figure 9. Selection of an exterior wall and its associated features, and of the Link "Programa"

By choosing the link "*Inspection 29 Oct. 2013 - Anomaly paint blistering*", the user is automatically opening the pdf document related to the associated inspection form, i.e. the sheet shown in Figure 10. This consultation allows us to better understand what the probable causes that originated the new anomaly are. If the problem shows a degree of severity or has been subjected to some kind of repair, the materials used and the exact location of the anomalies that have already been registered (through photography). An example of interaction can be seen in the web site refereed by [11].

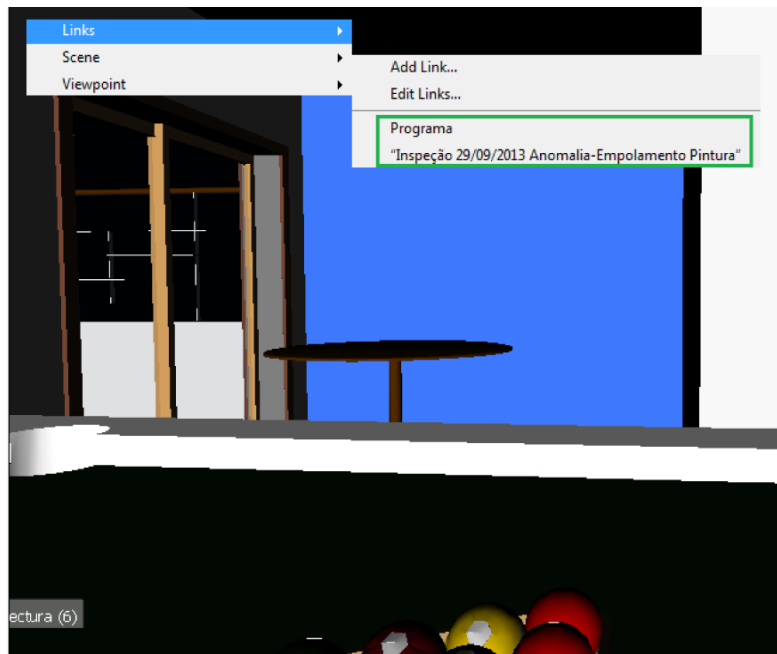


Figure 10. Selection of the inspection sheet of the anomaly associated with the inner wall

5. Implementation Problems

The creation of the inspection sheet had some problems, particularly concerning the creation of a routine that allows the insertion of any picture on the form, and in obtaining the *pdfsharp* library that would allow its conversion to *pdf* format. However, the creation of an inspection sheet to support the maintenance of buildings, based on a BIM model would be unsuccessful if the digital modelling of a building wasn't performed. Therefore, parallel to the creation of the inspection form, an architectural BIM model was developed from scratch, being described every step of its development, illustrating the procedures of its establishment and insertion of distinct data type, with the objective of providing the building relevant

information, which could be reused. Then, the modelling was exported using the IFC format to a BIM visualizer so that it could be displayed in a fast and efficient manner. The implementation of the model was done not only as a necessity, but also in order to study one of the major obstacles to the implementation of BIM, its interoperability under the IFC format. In fact, this work confirms that the IFC format is not yet fully developed in order to properly implement the information models, as despite not losing any information, it features it in a disorganized manner, not retaining the colour added to the model.

A BIM visualizer allows the representation of BIM models in a simple and fast way, allowing the user to add different models and different documents, programs or notes. As such, a program that supports the inspection of buildings was added to the BIM visualizer software. This combination's main objective is to aid in the maintenance activity of a building, because it allows the maintenance technician to perform inspections with the developed software by automatically running it after selecting the building element in the model. You can also save the inspection form in *pdf* format by entering it again in the model. So any maintenance technician can consult all the information concerning a given building element, not only its materials, dimensions and physical characteristics, but also its historical anomalies, any intervention that it has been subjected to and their exact location on the element, providing an important aid in keeping the building and therefore the comfort of their users.

Adding the program to the BIM visualizer of is done in a fairly simple way, however, it was observed that some visualizers do not support certain applications, which indicates difficult defect to overcome, when the main purpose of these is the aggregation of information in any form. It was also noted that it still wasn't possible to automatically save the inspection sheet onto the building element selected in the BIM visualizer. Overcoming this obstacle would result in even greater productivity, when filling out the forms and then associating them to the model, this being just one more aspect that would support the association between the inspection program and the BIM visualizer.

6. Conclusions

Effective facility maintenance is based on a thorough inspection for anomalies. Therefore, an inspection sheet was developed, with the purpose of enhancing the technical inspection, of a tool that lists anomalies, for the constructive element selected, automatically providing, the repair procedure, its main causes and respective solution. Thus inspections are carried out in greater detail, and hence greater chronological and productivity gains can be achieved. The ability to write in *pdf* format reveals itself most important for subsequent addition to a BIM model. It can be concluded that with this work, a useful program was established to support building inspections and future maintenance operations, which associated with an architectural BIM model, and taking into consideration that the benefits would be greater if the BIM model integrated various specialties, it was demonstrated that the great potential inherent in BIM, as a methodology, can be revealed in the actions of maintenance of a building.

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