BIM (Building Information Modelling) as a prevention tool in the design and construction phases

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ABSTRACT: BIM tools have been gaining relevance in the development and management of projects. That is not yet the case when it comes to the Health and Safety Plan (HSP) and the Technical File (TF). The current way of managing prevention often results in a long list of procedures that are hard to understand by those who should be implementing them. This whole scenario creates an environment prone to the downgrading of these problems, and it is urgent to take immediate, easy to understand and efficient management measures. This paper shares the results of a test conducted on the "*BIMSafety*" concept, which is an approach to the use of BIM methodologies in prevention when it comes to the way HSP and TF are presented. To assess the potential of this new approach, the results of a survey conducted on a panel of 42 technicians in the field will be shared. The conclusion reached showed that this methodology streamlines prevention planning, making it easier to understand while integrating prevention and production.

1 INTRODUCTION

1.1. *Current picture of prevention in the construction and operations phases*

The Health and Safety Plan in the construction phase (HSP) and the Technical File (TF) are legally mandatory documents governing and guiding risk management during the stages of construction and operation of buildings, respectively. Currently, however, apart from a few exceptions, these instruments are merely translated into a long list documents that are not easily understood, which becomes an obstacle to risk analysis and to the implementation of preventive measures (Azhar and Behringer, 2013). The enforcement of these instruments, particularly the TF, falls very short of what was to be expected and what is needed, since they are often perceived as being separate from planning (Sulankivi and Kähkönen, 2010). This makes it hard to decide what preventive measures are to be applied, when and where (Zhang et al., 2015). Also, in many cases, no risk analysis is conducted for that specific case. Instead, a template is used for all projects, regardless of the type of work (Pinto and Reis, 2012). This whole scenario creates an environment prone to the downgrading of these problems. We need to find ways to overcome these gaps, in order to bring risks down to acceptable levels (Reis et al., 2014).

1.2. *4th Industrial Revolution*

The Fourth Industrial Revolution is the merging of production methods with the latest developments in information and communications technology. It features "smart" processes, based on virtual templates, streamlining communication between people, machines and equipment (Deloitte, 2017), enabling suppliers to offer a wider range of products adapted to each individual client (Cavalcante e Silva, 2011).

1.3. *Building Information Modelling (BIM) and prevention*

Architecture, Engineering and Construction are experiencing a technological and organizational revolution, prioritizing information, sustainability and productivity. "*Building Information Modelling*" (BIM), which has taken almost two decades to reach its current state of development (Bargstädt, 2015), enables the digital representation of the physical and functional features of an infrastructure. It is therefore possible to see the Fourth Industrial Revolution embodied in BIM, since it is a way to manage the different expert fields, by facilitating the exchange of information during the construction and operation phases of an enterprise.

According to several authors, BIM presents several advantages, among which: three dimensional viewing, making designs easier to interpret; decreased potential for contradictions; less time needed to obtain detailed results than with manual design; possibility to create complex views and details; easy comparison between what was planned and what is done; decreased probability for human error in graphic modelling; and use of a computerized database, minimizing manual changes.

Every year, there is an increased interest in integrating prevention issues with BIM (Azhar and Behringer, 2013). Aguilera has analysed papers published in 11 countries regarding the use of BIM methodologies applied to prevention in construction (Aguilera, 2017) and he found that 89% of those papers had been published between 2012 and 2016, with a boost from 2013 onwards.

The "*BIMSafety*" concept was forged to help improve the currently inefficient approach to risk prevention. It is the result of a technical and scientific Research & Development partnership between the University of Minho and Xispoli-Engenharia (Reis et al., 2017). The concept links each element or equipment in a worksite to their associated construction and operation risks, throughout the service life of the building. Based on this information, a set of preventive measures are put forth, organizational, collective and personal in nature (Reis et al., 2017). Therefore, "*BIMSafety*" translates into a 3D view of the construction elements, linking them to a set of parametric information that includes the preventive measures associated with that particular construction element. This paper aims to compare the traditional model of prevention to the "*BIMSafety"* concept now presented.

2 METHODOLOGY

2.1 *Case study oresentation*

The case study presented concerns the rehabilitation of a building in the historic centre of Porto.

The software chosen to model the building was *Autodesk Revit*, a BIM modelling software increasingly used to design, construct and manage structures and infrastructures.

The whole building was modelled, by gradually modelling its construction elements: exterior walls, slabs, interior walls, doors, windows and surroundings of the building. First, all of the parameters of units to be worked on in *Revit* were defined in accordance with the *Autocad* units (the software that has been used to deliver the design). The heights of the different storeys were defined, so that the relevant blueprints could be entered. Afterwards, the construction elements were modelled, in stages, following the details on the architecture project design. The last stage was the modelling of the building's surroundings. The modelling of each element creates parametric elements, including all related information, such as their size, their materials and layers, their physical features and their appearance.

Once the modelling of the building was done, the modelling of the prevention planning elements in the HSP and the TF was carried out.

2.2 *Integrating the prevention planning into Autodesk Revit*

"BIMSafety" foresees the integration of prevention into the model in two stages. The first stage includes the identification of risks and preventive measures, through 3D viewing. The second stage is the input of prevention information into the parameters of each of the construction elements.

This study focuses on what is usually considered to be the most important specific components of the HSP and the TF. For the HSP: site plan; mechanical handling of loads plan; collective protection plan. For the TF: facade works plan; roof works plan; interior works plan.

This paper will test the 3D viewing of these six Plans, along with the input of parametric information into each of the Plans.

2.2.1 *Health and safety plan*

2.2.1.1 Site Plan

The location of the work, in an area with a high density of buildings and pedestrians on the sidewalks adjacent to it, translates into increased difficulties in the assembly and management of the worksite. The solution was to resort to the part of the sidewalk next to the facade for the assembly of the worksite, an option that interferes with the normal circulation of vehicles and pedestrians in the vicinity. The following elements were included in the worksite model (Figure 1): scaffolding; fences; access door to the site; shaded mesh and signage.

Thus, BIM tools allow us to represent the surrounding space, which is very important given the constraints present, and to anticipate risks such as run-overs or fall of materials to lower levels.

Figure 1- Site Plan

2.2.1.2 Mechanical handling of loads plan

The mechanical handling of loads plan includes the handling of loads at heights, not only for the works on the roof, but also for the works on the whole building (Figure 3).

Figure 3- Integration of load handling into the BIM model

The risk of fall of materials to lower levels and the interference of the crane with obstacles are identified, which proves that the three-dimensional viewing has the potential to plan the movements of the tower crane in detail, anticipating its reaction to obstacles

2.2.1.3 Collective protection plan

Considering that the work under study is composed of 5 storeys, 3 of them in height, the collective protections assume considerable relevance, given the risk of fall of person to a lower level. The need to adopt preventive measures of a collective nature (e.g. guardrails) is clear. Figure 4 shows a way of planning the assembly of guardrails and obtaining a three-dimensional view of the locations where the guardrails will be applied.

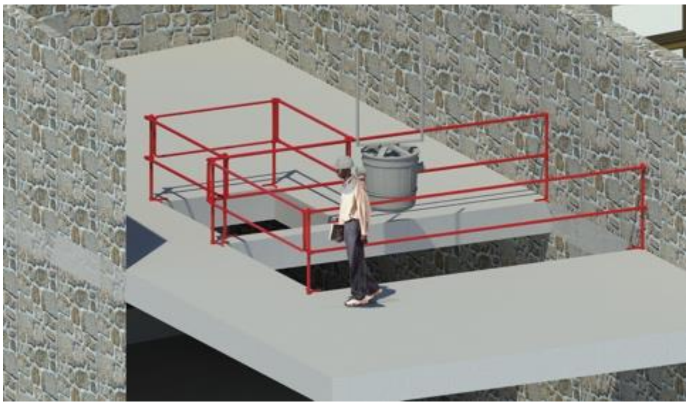

Figure 4 - Positioning of Guardrails

2.2.2 *Technical File*

2.2.2.1 Facade works plan

Maintenance and repair work on facades generally consist of works on coatings, downspouts, window frames, glazing, etc. For this study, we simulated the maintenance work on the glazing on the facade of the first floor, using a scaffold, which showed the risk of fall of person to a lower level and fall of materials (Figure 2).

Figure 2 - Placement of the scaffolds for façade works

2.2.2.2 Roof works plan

The works carried out on roofs in the operations stage are mainly to repair tiles, gutters, chimneys and to service solar panels, etc.. For this study, the simulated works are intended for the servicing of solar panels (Figure 5).

Figure 5 - Positioning of workers during servicing of solar panels

2.2.2.3 Interior works plan

The lack of preventive maintenance in air conditioning systems can cause problems to their users and require works inside their homes, as this study simulates on Figure 6.

Figure 6 - Placement of the ladder for servicing of the air conditioning equipment

2.3 *Including preventive measures in the construction elements*

The next step in integrating prevention planning is the introduction of written and parametric information on preventive measures in each of the modelled elements. The introduction of information relating to prevention was divided in three stages.

Stage I: *Shared Parameters*: Information is introduced by parameters and it is, therefore, necessary to introduce the *Shared Parameters* into the software. This option allows the parameters to be used in several projects. For the characterization of the parameters, properties like the name, the specialty to be used (Architecture, Structures, Mechanics), and the type of parameter are required. It is also required to add a description.

Stage II: Project Parameters: Afterwards, it is necessary to link the parameters to the construction elements. The difficulty here is to decide whether to have sets of parameters by instance or by family. Assigning by family has the advantage of assigning the same information to all of the objects of the family, thus saving time and work. However, it is not feasible, since each structural element may have several risks that require different preventive measures. So, there is the choice of doing the parameter assignment by instance (i.e., for each modelled element), where information differs in all elements, and is independent and unique.

Stage III: Linking the Parameters construction elements: As a result, it is possible to integrate, in written format, the parametric information on risks and measures in their respective element - in this case, a slab of an upper floor -, shown in Figure 7.

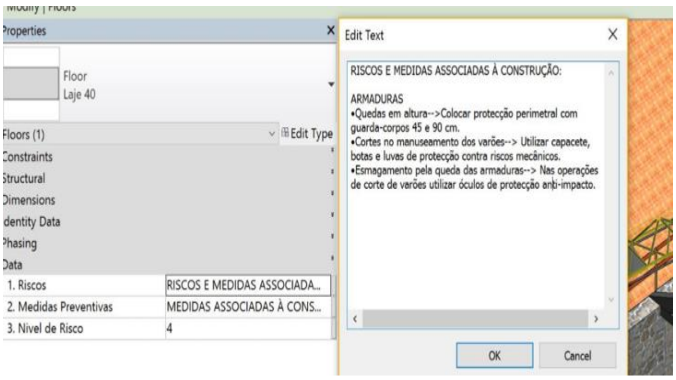

Figure 7- Inserting parametric information

3 SURVEY

The survey evaluated the usefulness of the new model regarding the way information is viewed and indexed to each constructive element. Six plans were carried out, presenting two versions for each plan: the traditional format and the new presentation format using BIM methodologies. Two surveys (HSP and TF) were conducted on a panel of 42 civil construction technicians with experience in the sector. Most of the respondents (29%) work as Safety Coordinator or Technician and have an average of 11.5 years of professional experience.

The questions established about "*BIMSafety*" were:

Question 1 (Q1): Does it simulates more effectively the work conditions allowing anticipation of hazards and risks identification?

Question 2 (Q2): Does it assists in identifying the necessary preventive measures for the identified risks?

Question 3 (Q3): Does it improves the quality of information and has the ability to be used in training?

Question 4 (Q4): Does the 3D visualization helps in preventive actions allowing comparisons between the predicted and the real?

Question 5 (Q5): Is it more advantageous than the traditional method?

4 RESULTS

The results of the survey concerning the HSP were as shown (**Erro! A origem da referência não foi encontrada.**).

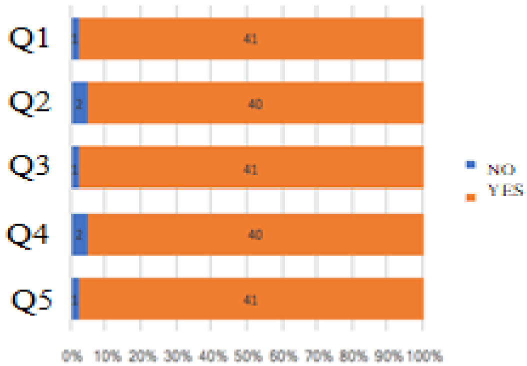

Figure 8 – Results concerning HSP

The results of the survey concerning the TF were as shown (**Erro! A origem da referência não foi encontrada.**).

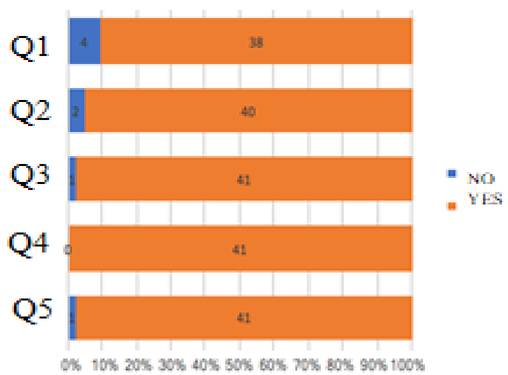

Figure 9 – Results concerning TF

5 DISCUSSION OF RESULTS

Question 1: The results of the survey concerning the HSP show that only one respondent does not agree that the new model is more efficient when compared to the traditional one. This may be justified by the routine work that the current prevention planning model offers. As for the results concerning TF, only 4 of the respondents have denied the efficiency of this model when dealing with this task. This result can be justified with a lack of experience, since the respondents have probably never had the chance to compare both methods in real life.

Question 2: In this question, most of the respondents find that the application of the "*BIMSafety"* concept enables a more efficient perception of the preventive measures, through the new visualization possibilities. Only 2 of the respondents disagree with the usefulness of the new model in the perception of preventive measures, which may have to do with a conservative opinion and a resistance to change.

Question 3: In this question, the respondents generally validate the adequacy of the quality of the information represented, and the model is considered suitable to be used for training. These results reinforce those of several authors who conclude that a 3D model allows the trainer to instruct more easily, in a virtual environment, enabling the simulation of insecure actions, so that the trainees know the hazards that are identified.

Question 4: The answers to the question asking if 3D visualization helps in the prevention of activities are enlightening and show that 3D visualization of the activity plans helps those involved to better plan construction and maintenance tasks.

Question 5: This question ends up summarizing/evaluating all of the work carried out in this research, as well as the whole purpose of the survey. The responses show that almost all of the respondents consider that linking prevention to the new approach allows a more effective simulation of the real working conditions. The minority is identified by one of the respondents who is in the age group between 40 and 50 years, which may also mean that they may have adapted and conformed to the traditional method.

6 CONCLUSIONS

By observing the survey results, it is concluded that:

- The implementation of the new approach to prevention, through the "*BIMSafety"* concept, in relation to the specific plans analysed, is well accepted by the sample of respondents.
- The adoption of the new format in the specific plans studied, allowing 3D viewing and parametric written information for each construction element, is seen as advantageous, compared to the traditional model, optimizing prevention planning, namely at the level of simulation, visualization and understanding of the real working conditions. The new way of visualization is very useful as an instrument to support training actions.
- The study and development of "*BIMSafety"* could revolutionize the elaboration of the Health and Safety Plans and Technical File, leading to a paradigm shift, providing them with a content digitization capability, implying a discussion of the problems in a virtual environment, preventing accidents at work.
- In the future, studies should be conducted to verify the applicability of "*BIMSafety"* to other components of the Health and Safety Plan and the Technical File. In addition, the range of objects available for *Autodesk Revit* should be broadened, with regard to collective and individual protection.

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