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The use of GIS tools for data collection and processing in the context of fire risk assessment in urban cultural heritage

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SUMMARY

GIS is a powerful tool that can be used to achieve better management of fire risk prevention in built heritage. This research aimed to present a GIS-based workflow for the rapid and efficient identification of urban features and their processing for index-based fire risk evaluation in heritage buildings. The workflow shows the use and benefits of three tools: QField, QGIS, and a programming language. The QField application helps to obtain and store information, while the desktop version of QGIS helps in the evaluation and mapping. The data collected in the spreadsheets of QGIS is advised to be processed using a programming language to facilitate information processing. The application of the workflow in the historic center of Guimarães that involves 269 buildings has proven to be beneficial for the fire vulnerability assessment of heritage buildings.

Keywords: QGIS, QField, fire, vulnerability assessment, heritage

Introduction

Urban fires are destructive events both for societies as to the authenticity and values of built heritage. In response to the growing frequency and impacts of fire hazards, disaster risk science has developed multi-dimensional index-based risk assessment methods that will allow the development of adequate risk mitigation solutions. In urban areas, mapping techniques are an essential part of such assessments, namely, to achieve a better management of fire risk prevention in built heritage. Several recent studies addressing the fire risk assessments of historic city centres over the past decade (Gonçalves & Correia, 2016), (Ferreira et al., 2016), (Granda & Ferreira, 2019), (Tomar et al., 2018), (Rahman, 2020) have used Geographical Information Systems (GIS) to prepare and analyze the data, showing that such tools are essential for risk assessment studies. Although these studies are based on the evaluation of simplified indices, the data collection part is still one of the most challenging steps in risk assessment at an urban scale. The first step includes field observation, building properties analysis, which usually includes construction materials, geometric features (height, area, number of floors, opening's locations), main classes (building uses), and detailed interviews with residents. Aside from being very time-consuming, three problems can occur during this step. The first is to obtain the correct building identification and its relevant information. The second is to obtain its geometrical footprint, which is hard to measure in densely built historic areas with a significant amount of adjacent buildings. The third is the correlation and analysis of the different features. In such cases, three tools can be beneficial: QField, QGIS, and a programming language (in this case, Python). In light of this, this study presents a GIS-based workflow for the rapid and efficient identification of urban features and their processing for index-based fire risk evaluation in heritage buildings. The workflow is especially relevant for large-scale vulnerability assessment in data-scarce studies.

Method

The proposed workflow uses the open-source suite QGIS to integrate geo-referenced graphical data with information about building parameters. The software enables users to plot results in a vector format and use the data tables to select and process information. For example, it is possible to calculate certain indicators such as the perimeter, area, width and length of the building, distances to fire breaks (vegetation), or define the neighbouring buildings and their functions. Those tools are suitable to handle such analysis effectively and were used in previous similar studies on building analysis (Ferreira et al., 2016; Granda & Ferreira, 2019; Siebert, 2000; Tikhonova & Beirão, 2020). Therefore, the following workflow is proposed for index-based fire risk evaluation in built heritage:

1) Import CAD obtained from municipal authorities or use shapefiles with polygons for buildings and roads exported from Open Street Map (OSM). If the CAD drawing is used, additional steps are necessary:

1.2) Save as Shapefile

1.3) Georeferenced the drawing (scale, transform – if necessary) using Vector Blender Plugin for QGIS.

2) Do the field observations using Plugin QField for QGIS. This plugin is beneficial in the field since it will capture the user's actual position or digitalize the feature on the aerial photograph (for example, users can see the trash bin on the corner of a specific building so that they can add it immediately).

2.1) Prepare the Package for using it in the field (Figure 1).

2.1.1) Create a layer with a JPEG image of the aerial photo (not necessary but helps in orientation in the field and can give some additional advantages during environment analysis)

2.1.2) Prepare the existing polygons that are necessary for data collection (usually it is a building layer, but can also be a vegetation layer, furniture, streets, hydrants if they come with the shapefile or CAD drawings)

2.1.3) Create a new layer (for example, for vegetation placement, which can influence a building vulnerability; for placing street furniture that can create obstacles for the firefighter vehicles;

photo layer as an attachment to evaluate additional features on the desktop or confirm certain visual information latter in the office)

2.1.4) Export the project as a package to a folder on the computer, which can be copied to a smartphone or a tablet.

2.2) Do the field survey using QField. With the installed application on the phone or tablet, the researcher can open and use the transferred package to add necessary data in the field. The application helps researchers to navigate around the area of study, add essential elements to the map, enrich the data linked to the building next to where the researcher is standing, or the buildings researchers can identify by their position on the map.

2.3) Save and transfer the shapefile with information to the desktop QGIS application. This allows to process the data latter at the office. To link the photos taken in the field to the polygons in the GIS database, the plugin eVis can be used.

3) The data collected in the spreadsheets can be processed using a programming language (for example, Python or/and directly in QGIS using Expressions) – to facilitate information processing.

Examples

The proposed workflow was tested during the data survey for the index-based fire risk evaluation of the 269 buildings located in the historic city centre of Guimarães, Portugal, a UNESCO World Heritage Site. This site was previously used as a case study to analyse fire risk using another fire risk index method, a simplified version of the ARICA method (Granda & Ferreira, 2019). This method comprises two main factors, four subfactors, and 15 partial factors. The ARICA method is usually used to analyze the fire risk in the built environment, but its main focus is on life safety and doesn't account for the historic value of the buildings. In the current study, an alternative and recently developed methodology was applied (Salazar et al., 2021). This method analyses the fire vulnerability of historic buildings with high cultural value, such as those in the UNESCO World Heritage Site of Guimarães. Although there are common indicators between the two methods, they are very different in calculations and purpose. While ARICA calculates the risk index per building as the weighted average of main groups (sub-factors) divided by a reference factor that depends on the building type, the method used in the current study takes the weighted sum of four group values to establish the expected damage level, and the highest of all parameters in a group defines each group value.

During the application of this method, besides the previously described benefits of using QGIS, two more valuable points were also identified which can also be helpful to other indexed-based methods. The first was related to a lack of information on the compartment area (the biggest open area in the building, which in case of residential buildings in Guimarães corresponds to the building footprint without the outer walls). The second was related to the very time-consuming identification of the functions of buildings adjacent to the building under evaluation. Therefore, the following approaches were developed to address these issues:

Compartment area calculation

Since there is no information about the building's inner area, this parameter was calculated directly in QGIS based on the polygon of each building. The calculation was done using the field calculator and the following estimate:

$$Area = Footprint - (Perimeter * 0.4)$$

The footprint and perimeter were calculated from the geo-referenced polygon of each building. According to several sources, the multiplication factor of 0.4 in the perimeter component stands for the average width of the walls (in meters) of the buildings in Guimarães (Cardoso Silva, 2018, p. 64; Loureiro de Mates, 2014, p. 99). Therefore, this expression provides the area of inner walls on the ground floor and extracting this area from the footprint will result in the area of the compartment.

Adjacent Buildings information evaluation

For these parameters, the calculation was done in two steps. First, the data about adjacent buildings were created directly in the database of QGIS using buffers and the Summary Aggregate Function for each polygon that represents the evaluated building. Second, the information with adjacent buildings' codes generated in QGIS was correlated with the construction materials and functions to check the adjacent building's type and define if there are elevated risk functions present in it (for example, restaurants).



Figure 1 Prepared building layer with IDs and overlaid with areal Google Satellite view in QGIS for use in the field survey.

Conclusions

Data collection is one of the biggest challenges that arise in front of any researcher, either in disaster and risk analysis or in morphological city analysis. Each new methodology should be tested and evaluated and, for this, well-structured and highly detailed data about the studied area is needed. Collecting these data takes a significant portion of the time devoted to the research process and can put the whole project at risk if not obtained in a planned time. In such cases, GIS tools can be extremely valuable. GIS tools are suitable for collecting and organizing information, and for extracting data from available sources or field observations for large areas and helps with the analysis and the presentation.

In the present large-scale risk assessment evaluation study, GIS was extremely valuable. Index-based studies, such as the one carried out involving indicators for fire risk assessment in cultural heritage, handles a significant amount of different alpha-numeric data about the assets under assessment that needs to be stored, used in calculations, and ultimately represented. In large-scale studies like the one carried out, data storage also needs to be geo-referenced to facilitate its identification and mapping. All these tasks can be facilitated by the selected GIS tools. The QField application helps to obtain and store information while the desktop version of QGIS helps in the evaluation and mapping. Given the referred advantages of using these tools, they were integrated in the presented workflow which was tested in the fire vulnerability assessment of the historic centre of Guimarães that involves 269 buildings.

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