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Applications of Building Information Modeling for COVID-19 spread assessment due to the organization of building artifacts

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1. Introduction

Importance of building-level disease spreading assessment and management is a major topic that gains attention as infectious diseases cause millions of death \cite{1}. The risk of infectious disease outbreaks significantly increases during a pandemic such as coronavirus disease 2019 (COVID-19) or after a natural disaster such as flood \cite{2}. Certain diseases could prove fatal without sufficient effective measures and precautions. Fast and accurate COVID-19 Spread Assessment due to the Organization of Building Artifacts (CSAOTA) is required to tackle a pandemic efficiently. This may become obligatory and unavoidable, especially for building managers \cite{3}. It is necessary to gather room measurements, appliance types, furniture location details, and material specification from buildings’ drawings to perform an accurate CSAOTA. Conducting a bottom-up-based CSAOTA from elementary parameters using 2D computer-aided design (CAD)-based documents is a laborious process leading to errors and consuming much time \cite{4,5}. There is no functional interlinking among the elements when drawings are prepared in 2D CAD such that automated data gathering is not an easy choice. Corresponding CSAOTA measures/materials are manually retrieved from 2D drawings and organized either using Microsoft Excel-based spreadsheets or in a 2D CAD software platform for complete quantification of works. In a traditional approach, the utilization of multiple platforms for CSAOTA lead to high probability for compounding errors and chances of dual work. The CSAOTA requires a quick and accurate calculation. At the same time, the
devised approach should handle massive data with ease of sharing and provide error-free validated results. Building Information Modeling (BIM) offers a better platform for CSAOBA by minimizing the abovementioned problems of existing practices.

BIM is a virtual representation of the construction concepts, providing efficient methods of project development, manipulating, processing and maintaining them. It is a collective information base of a project that forms a consistent foundation for different evaluations for different life cycle decisions. Dependable researchers have demonstrated BIM’s effectiveness in minimizing rework, construction losses, budget, time delays, and thus increasing productivity [4]. The advantage of BIM is the ease of conducting redundant tasks and statistics and automated quick information retrieval with the help of parametrically linking data.

Applications of BIM for various processes such as construction, energy analysis, quantity estimation, and facility management are being researched. It is concluded that BIM eases data extraction, sharing, visualization, and consolidation. The BIM platform provides more purposeful and design choices, reduced time, and cost savings for modeling [4]. Another aspect of the BIM process in the construction industry is to permit different kinds of code checks and simulations to evaluate design compatibility in the project’s preliminary phases [6]. It is required to insert selected codes in BIM software itself as built-in tools. However, sometimes it is essential to develop specific tools such as custom-made code checking as per localized necessities and pricing [7]. BIM applications for automated code checking and custom calculations are also well studied [8]. But the research studies related to BIM-based disease spread assessment such as CSAOBA are a few, and those studies are associated with real-time sensor deployment [9] and healthcare facility commissioning [10]. Even though many studies related to building-level disease spread assessment [11,12] and BIM are existing, the combined studies are less. By following BIM application guidelines for developing add-in tools [13,14], it is possible to combine disease spread rule and building data for CSAOBA as like [15]. Almost all the renowned BIM software provides an add-in tool developing the methodology for automating redundant jobs and retrieving tailored outcomes from BIM. An inbuilt Application Programming Interfacing (API) technique or a third-party application can be deployed or a web-based procedure for conducting custom-defined calculations can be used [16]. Third-party applications mandate efficient interoperability between applications without information loss, and the Industry Foundation Classes (IFC) is the capable file organization for switching information among BIM-based software [17].

The improvement of an appropriate city planning method is a significant step for minimizing the disease spread. The Geographic Information System (GIS) enables to view, probe, store, and assess information in order to recognize the relations, features, and extrapolations related to our project requirements [18]. A GIS and BIM integrated building’s epidemic spreading information system at the provincial level is a suitable technique for various analysis and conservation measures. GIS-integrated BIM data sharing simplifies the decision-making process by providing the required information and quantifications [19]. As shown in Fig. 17.1, BIM provides elaborate building-level
details such as system type and characteristics. GIS provides information on outdoor georeferenced objects. The integrated BIM-GIS information model for minimizing COVID-19 spread has three steps: (1) generate and conduct building-level CSAOBA from BIM according to virus transmission conditions, (2) export the extracted details to GIS, and (3) model and conduct the impact of multibuilding COVID spread at a regional level. The outcomes retrieved at the GIS level are then fed back to individual buildings, and continuous evaluations are done until the desired results are achieved. As BIM file sizes are high, only the required data can be exported to GIS platform [20]. Therefore special tools are needed to extract and export the essential COVID-19 spread parameters from BIM files to GIS.

This chapter aims to identify the potential applications of BIM for CSAOBA and develop a BIM-based add-in tool for analyzing COVID-19 spread due to the organization and material finish of chairs at open hall areas such as classrooms and waiting areas. The purpose of the given tool is to extract the chairs in a room and process it for identifying COVID-19 spread due to the seating arrangement and longevity of the virus on the material finish. Leading BIM application, Revit from Autodesk and its .NET language-based API is used to develop the add-in tool referred to as “COVID_ CSAOBA”. The API method of Revit allows a filtering method and can extract the accurate list of BIM elements as specified by the developer. One of the significant necessity for efficient add-in tool development is the classification of BIM elements according to various engineering divisions and subdivisions. This process is known as Work Breakdown Structure (WBS). Using WBS-based element filtering from BIM and extracting and processing the parameters by an efficient algorithm is the standard method for developing an add-in tool.

2. Summarizing the applications of Building Information Modeling for CSAOBA

As shown in Fig. 17.2, the application of BIM for CSAOBA are summarized and detailed in the following section.
2.1 Extracting general information

By using inbuilt or add-in tools, it is much easier to extract, segregate, and visualize building elements as required from the BIM. The custom-made BIM-authored tools (1) filter and extract the necessary information from BIM as provided by the user, (2) identify the filtered elements and their parameters accurately, and (3) do the required operations for generating accurate results as specified by the user [21]. The inbuilt tools of BIM applications can be used to gather the information that exists in the BIM, such as the type of air-conditioning system, as COVID-19-like diseases are influenced by the air-conditioning type [22]. A similar application where BIM comes in handy is when it is necessary to extract the hospital’s emergency electric load according to its load type. In case the load types are modeled according to lay-down standards, the information can be retrieved and summarized according to user requirements [23]. As BIM is a single integrated consolidated model, safety briefing for COVID-19 spread [24,25], locating...
potential zones of spread such as common halls from room tags, elevators, and washrooms [3]; virtual training [26]; and planning the activities for minimal spread are easier compared to traditional multidrawing-based 2D CAD method. For example, elevators and toilets are critical locations prone to spread COVID-19 [27]. Using the BIM, their location, visualization with graphic clearance box, area, and total count can be easily traced. BIM family files are data-rich, and this data can be extracted as required. Fig. 17.3 shows a BIM family file for a medical bed with manufacturer data related to geometry, material, mechanical, electrical and plumbing (MEP) requirements, and external links for further information.

### 2.2 To understand the material type

As the COVID-19 virus longevity depends on the type of surface material (Table 17.1), identifying material finishes of building artifacts is necessary to control the spread. BIM inbuilt tools or custom-made BIM-based add-in tools can extract material information from all BIM objects and summarize the results. By assessing the percentage of material surfaces, spread minimization strategies, such as antiviral coating [28], can be prepared.

![BIM Family File](image)

**FIGURE 17.3** Building Information Modeling (BIM) family file for a medical bed.

**Table 17.1** The survival rate of the novel coronavirus on material surfaces [12].

| Material | Survival rate (days) |
|----------|----------------------|
| Wood     | 2                    |
| Plastic  | 3                    |
| Steel    | 2—3                  |
2.3 To quantify and visualize the cleaning work

As the COVID-19 spread control requires cleaning of multiuser artifacts [29] such as computer keyboards, doors, and chairs, quantification and visualization of this work is necessary for properly executing the cleaning work. BIM-based add-in tools can quantify disease-related artifacts and present a summary of work within a few seconds. Multidimensional modeling capabilities of BIM can help in monitoring the work, by considering the variables such as three-dimensional variables, time, and cost. Previous studies show that real-time rendering system [30] and mobile phone display of the selected areas of a BIM model are possible [31].

2.4 To estimate the disease spread due to building artifact arrangements

As social distancing is required to minimize the droplet infection, the organization of building elements must be assessed to limit the spread. Many prevailing regulations profoundly govern the design, operation, and monitoring of hospitals like the COVID-19 isolation center. Previous research show that BIM can effectively conduct automated and rapid assessments such as planning and validation of available areas of the hospital [32], the indoor air quality of the healthcare system [33], and taxonomy for developing automated code checking for hospitals [34]. Custom-made BIM-based add-in tools can extract seating in a building and calculate the minimum distance between chairs and summarize the results with the aid of API. This kind of automated code checking is possible due to the consolidated parametric BIM.

2.5 Real-time monitoring

Pre- and postconstruction disease spread assessment can be done by developing BIM-based smart objects to represent as sensors for real-time monitoring and to conduct collective analysis [15]. By combining BIM with the Internet of Things (IoT)-based data, health and safety training and monitoring are possible. For example, by using IoT-based realistic sensor data, which is measured in real time, behavioral changes of a COVID-19-quarantined patient and surrounding conditions are traced. This combined method can perform space optimization, management, and risk assessments [35].

2.6 Sharing the information

As BIM is an easily sharable digitized platform, results from add-in tools can be easily exported to GIS and provincial-level disease spread assessments can be prepared. By exporting options available with applications, BIM models can be transformed into other file formats, suitable for third-party applications [36]. BIM data can be extracted and shared using add-in tools or exported to database file formats such as Open Database Connectivity or linked as it is to other compatible software platforms. As shown in Fig. 17.4, Revit-based BIM files can be read by third-party applications or exported to different file formats or interlinked by a shared database.
2.7 Building Information Modeling for prefabrication and project planning

Prefabrication of building components during emergency projects such as COVID-19 hospitals construction is possible due to the BIM nth dimensional modeling, precise scale, and improved coordination between systems [37,38]. The digitized model also enhances installation and communication between stakeholders and refurbishment in a healthcare system [39]. Energy-efficient hospital modeling with life cycle assessment and GIS interlinking is possible with BIM [40,41]. Advanced medical devices and systems integrated planning inside a room with autolayout options are carried out with data-rich BIM families for medical devices, rendering and concurrent planning processes [42,43].

Fig. 17.5 is a BIM for an intensive care unit (ICU) room developed by a manufacturer [44]. A single file is used for three-dimensional views, specifications, systems coordination, sensor data integration for assessments and analysis [15], data retrieval by schedule tools, and data sharing for third-party use.

3. An add-in tool for building-level communal spread due to seating arrangements within a room

The creation of COVID_CSAOBA has three programming steps. Step 1 consists of the significant part of programming and coding using C# language. As given in the flowchart in Fig. 17.6, the coding for step 1 is done. Step 1 details are explained in the following section. In step 2, by using necessary codes as described by the Revit Software Development Kit, a button is created on the add-in section of the Revit application for COVID_CSAOBA. The path of the main program and the icon details are to be specified in step 2 coding. In step 3, the codes developed in steps 1 and 2 are registered by preparing a manifest file in the note file format and converting it to a “.add-in” file format. The created file is to be stored in an appropriate file specified by Revit API. The
The abovementioned steps complete COVID_CSAOBA add-in programming, which makes a new functionality in the Revit application. The graphic user interface for the developed tool is shown in Fig. 17.7.

**S1**: By Revit API filtering method extract all chairs from the BIM model, add to a list, and count the total number of chairs.

**S2**: Using C# “for each loop” every chair’s data is processed as per steps S3–S8.

**S3**: Using the Revit API-based parameter extraction method, material information is extracted and concatenated as a string. Chairs are segregated according to plastic, steel, wood, and none of these by searching for the respective terms in extracted data.

**S4**: Using C# “for each loop” method, every chair’s data is processed as per steps S5–S8.

**S5**: The distance of the current chair (S2) from other chairs (S5) is quantified by extracting the location details of both chairs and the distance is found in meters.

**S6**: To avoid COVID-19 spread a distance of 1.5 m is necessary between seating. If the distance is greater than 1.5 m, then return to S2/S4. Else the chair is considered as “potential seating for communal spread”. Then return to S2/S4.

**S7**: All “potential seating for communal spread” is counted here.

**S8**: Display the final results of the total number of potential chairs for the communal spread and percentage chart of chairs’ materials.

## 4. Case study

A case study of a classroom with 21 chairs is developed as given in Fig. 17.8 by using Revit 2017. The dimension of the classroom is 10m × 6m, and there are 21 chairs inside this classroom. The results obtained by using the proposed tool are shown in Fig. 17.7.
FIGURE 17.6 Flowchart of developing the add-in tool.
Compared with manual data gathering and 2D CAD-based method, the proposed approach takes only a few seconds to deliver the results. Automated results, time savings, and digitized consolidated data are the advantages of BIM compared to the 2D CAD approach. This method is to be improved by considering walls, quantification of disinfection work, and other disease spread parameters, such as type of air-conditioning, as future work. As shown in Fig. 17.9, extracted and processed data is to be compared with standard data or any suitable method by using ontologies to improve the reliability of the developed tool.

The extracted results are exported to GIS by linking a database between BIM and GIS to conduct a regional-level analysis. For example, the percentage of potential chairs can be transferred to an Excel sheet by developing a function using C# codes and by adding corresponding coordinates of the project. This Excel file is read by the GIS application. In Fig. 17.10, a group of classrooms in which one was shown in Fig. 17.7 are denoted as buildings. The building’s particulars are added to Excel, and the estimated CSAOBA are added as point features of a GIS layer. With the aid of GIS, a raster dataset is generated for the percentage of potential chairs for COVID-19 spread, as shown in Fig. 17.7. Using
GIS tools, various statistical studies, data standardization, and infrastructure availability assessment such as regional-level average values and standard deviation are estimated. It is possible to compare district by district or at any administrative level using the zonal statistical method in GIS applications.
5. Discussion

This chapter aims to outline and analyze the applications of BIM computational capabilities for CSAOBA. Due to the absence of parametric and arithmetic interlinking between building artifacts in the 2D CAD method, it is essential to manually keep updating all the related data, resulting in more time delays and budgetary losses. The emergence of information technology for designing and modeling buildings, such as BIM, provides an improved methodology to resolve the shortfalls in the current approach. The information system concept and data extraction using developed applications is the key concept behind BIM-based automation and fast data processing compared to the conventional method. It is impossible to combine the CSAOBA data, infrastructure model, and sensor data using a 2D CAD-based approach. However, the BIM facilitates the integration of the CSAOBA data, infrastructure model, and sensor data. BIM and GIS are capable and proven technologies for construction planning, modeling, and project management, and their integrated approach offers a better method for CSAOBA. Numerous BIM and GIS integration levels are necessary to generate a bottom-up-based CSAOBA at the regional level.

Innovations in BIM technology deliver plenty of opportunities for novel BIM-based tools that can automate the modeling and analysis of epidemic control activities. There should be powerful algorithms behind tools to detect errors in extracted and processed data. At present, the BIM for CSAOBA or other communal diseases is not officially standardized, which causes more concerns for developing BIM-based automated tools [45]. Uniformity in modeling, application of standardized common families, and unique identification codes are mandatory for reliable BIM-based tools. Many written codes are available for CSAOBA in a human-interpreting style. However, converting the necessary codes to develop an add-in tool and generate efficient results is a challenging deed [8]. So for continuous add-in tool improvement, a human-based cyclic feedback system is to be in effect. BIM modeling requires a highly qualified engineering team compared to 2D CAD modeling, and the major hindrance for BIM acceptance is the lack of interest from top management.

6. Conclusion

Applications of BIM for building-level COVID-19 spread assessment is presented, along with an example add-in tool development. Compared to the traditional 2D CAD approach, BIM offers a digitized consolidated model for disease spread assessment, management, data sharing, real-time monitoring, and GIS integration. BIM can minimize the labor and cost compared with the 2D CAD-based method for conducting CSAOBA. Accurate data gathering, filtering, and processing from the BIM model is possible only if a standardized framework is followed. At present, this is the main issue for CSAOBA. Further research in this field is necessary to incorporate complicated building systems, organization and behavioral patterns, and CSAOBA-related modeling rules and regulations, which may ease handling emergencies.
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