A Simulation Model for Logical and Operative Clash Detection

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The introduction of the Building Information Modeling (BIM) approach has facilitated the management process of documents produced by different kinds of professionals involved in the design and/or renovation of a building, through identification and subsequent management of geometrical interferences (Clash Detection). The methodology of this research proposes a tool to support Clash Detection, introducing the logical-operative dimension, that may occur with the presence of a construction site within a hospital structure, through the integration of a BIM model within a Game Engine environment, to preserve the continuity of daily hospital activities and trying to reduce negative impacts, times and costs due to construction activities.

Keywords: *Construction site, Hospital, Game Engine, Gaming, Building Information Modeling (BIM), Simulation*

INTRODUCTION

The aim of this research is to propose a tool to support Clash Detection, introducing the logical-operative dimension, through the integration of a BIM model (Building Information Modeling) within a GE (Game Engine) environment.

Prior to the introduction of the BIM approach into the design and/or renovation of a building, a considerable amount of imperative documents was drawn up, checked and validated separately for each sector, by one or more specialists, without any strict implementation of sector-wide cross-checking revision, and then sent directly to site for execution.

The spread of BIM has facilitated multidisciplinary project model management by enabling identification and subsequent management of interferences (Clash Detection) (Eastman 1992). Through Clash Detection 3 kinds of geometrical interference can be determined:

- **Hard clash:** clashes between 2 or more elements;
- **Clearance clash:** element A may/may not intersect element B, occurring at a lower distance than the tolerance (e.g. Due to overheating two elements must be placed at a determined safety distance);
- **Duplicate clash:** two elements have the same geometry and are placed within range of tolerance. If the tolerance is zero, they occupy the same position.

Management of detected interferences is usually simplified through chrome-classification as such:

- **New(RED):** interference identified for the first time through a new test;
- **Active(ORANGE):** interference identified in a previous test, not yet resolved;
- **Reviewed(BLUE):**previously identified interference, manually tagged as detected;
- **Approved(GREEN):** previously identified interference, manually approved;
- **Resolved(YELLOW):** previously identified interference now resolved.

Analysing the building context of renovations and/or maintenance of complex structures and directing more focus towards those obliged to maintain different daily activities functional e.g. hospitals, greater care must be taken with interferences that are not strictly tied to the geometry, or rather those that are not detectable via Clash Detection carried out by today's BIM software.

In fact, in this case, not being solely limited to detection of interference between technical elements lends an operational-logical dimension to Clash Detection, through identification of interferences between technological elements and localised activities.

The presence of construction sites inside these structures adds different elements of complexity, such as noise, vibrations and dust, generating interference for daily activities due to negative impacting determined by the surrounding environment and actors involved (Zhang 2013).

STATE OF ART

Noise risk evaluation is a technical process that, through knowledge of known noise levels present affecting the production process object to evaluation, accomplishes risk reduction/control by adopting specific organisational and procedural technical measures.

European regulatory approach (UNI EN ISO11690-1:1998), within healthcare structures, defines the environment's soundproof characteristics, the background noise and the exposure levels. Establishing how long the noisiest equipment will be in use is essential considering it may only take a few minutes to exceed acceptable levels of exposure (LEX) to 80dB(A).

Healthcare site environments, depending on their intended use (e.g. A&E, operating theatres, laboratories), necessitate specific acoustic requirements; therefore, relative noise-exposure problems mainly concern healthcare staff and patients, compromising quality and efficacy of healthcare services offered more so than the actual risk of auditory damage.

For each hospital environment, an internal noise limit is provided, as proposed by Professor J. Van den Eijk in the early 1970's. In 1986, the Italian Ministry of Health supplied the following internal noise limits: 35dB *hospital rooms*, 40dB *connection zones*, 45dB *nurses room* and *physician offices*, 50dB *operating theatres* and *delivery room*, and *external outpatient clinics* or *general service areas* 55dB. These values refer to noise limits, expressed in dBA, allowed only from 7:00 to 19:00, the time span during which construction works are carried out. UNI 8199-1998, then replaced by UNI 8199-2016, provides for a more detailed classification and a reduction of about 5dB, as shown in Table1. (G. Uguccione 2005)

Environment	Noise limit
hospital rooms	30 dB(A)
wards	40 dB(A)
operating theatres	35 dB(A)
connection zones	40 dB(A)
visitors area	40 dB(A)
general service areas	40 dB(A)

Table 1
Noise limit for hospital environments

Concerning dust particle risk, however, it is internationally agreed to adhere to a proactive approach in accordance with the proposed classification system by the Canadian Center for Infectious Disease Prevention and Control, which frames site activities -both maintenance and ex-novo construction- within hospitals, according to these categories (D'Alessandro et al. 2007):

- Type-A: Non-invasive activities and inspections which will not generate dust or construction work on walls and ceilings (e.g. on water and electric systems, suspending operation less than 15 minutes)
- Type-B: Brief activities generating low dust emissions (e.g. on wall and water systems, suspending operation less than 30 minutes)
- Type-C: Partial demolition/removal activities (e.g. false ceilings, electrical wiring chases, water systems, suspending operation more than 30 minutes but less than 60 minutes)
- Type-D: Significant demolition/reconstruction (e.g. new construction, water systems, suspending operation longer than 60 minutes).

This classification has been revised to enable site activity development without suspending hospital services.

In recent years research has been geared evermore towards the possibility of integrating BIM models and simulation environments (Game Engine) as support for architects, engineers and social educators, making an interactive and 360° immersive experience within the model possible, to the point of including accessibility tests and fire evacuation drill simulations (Yan et al. 2011).

The use and relative development of BIM technology have made possible the exemplification of continual maintenance and refurbishment management in a hospital keeping with an accurate monitoring of financial resources aimed to lower costs.

For this reason, healthcare owners and industry partners created the Healthcare BIM Consortium (HBC) in order to favour interindustry cooperation between software vendors, designers, builders and consultants to support the increase in data interoperability for the Facility Life Cycle Management.

Utilising a BIM 6D model, other than taking into consideration time and costs, the entire lifecycle of the hospital can be monitored. Currently, the BIM model can be integrated with real-time infrared localisation in order to allow medical instrumentation tracking directly within the 3D model, therefore facilitating its successive outplacement (Linehan and Andress 2013).

METHODOLOGY

As previously mentioned, cost reduction in both trial and management for the refurbishment of complex structures such as Hospitals is crucial.

Forecasting potential risk factors in the preliminary planning stage allows for negative-impact reduction, on present actors and environment, and avoidance of resource waste and/or additional costs incurred. Regarding noise issues, for example, many feasible though often overlooked interventions are low cost when done in the planning stage.

Given this premise, the proposed methodology of this research is founded on one hand on the BIM, aiming to identify in the initial site planning stages the spatial and environmental units involved in the refurbishing and/or maintenance activities, and on the other on the GE, in this case Unity3D, which utilises the BIM model to generate an environment to reproduce and verify physical phenomena and user behaviour simulations.

Contextual analysis and Logical and Operative Clash Detection is defined by 6 stages:

Identification and modeling of the environment and technological components of the building in BIM

The large quantity of information characterising a complex building, in this case a hospital, is made available because BIM facilitates their exchange and interoperability. These characteristics, geometric or not, all collected and managed by a database (e.g. Excel, MS Access) represent the information structure of the scenario at the base of the final stage of simulation.

Starting from the premise that the BIM model of the hospital, in this case modelled with Autodesk Revit, refers to an existing and functioning hospital, each parameter, characteristic of the architectural elements (e.g. Sound Insulation Capacity, see Table 2) or the space constructed by these (for example, the Rooms label, or rather the differentiation of environments within a ward) can be managed by defining and modifying categories and families directly within aforementioned model.

Table 2
Sound Insulation Capacity

Sound Insulation Capacity	
Architectural elements	**Rw**
Wall 1 [2cm plaster + 30cm poroton + 2cm plaster]	55 dB
Wall 2 [1,5cm plaster + 8cm poroton + 4cm insulating + 8cm poroton + 2cm plaster]	53 dB
Partition Wall 1 [1,2cm plaster + 10cm terracotta block + 1,2cm plaster]	42 dB
Door 1 [220x90cm]	43 dB

This information is extracted through Autodesk's Dynamo software (see Figure 1) that allows to collect them in a comma-separated values (CSV) database, in this case in Excel. The hospital or department, or rather the simulation scenario, is modelled directly into Revit assuming it has been constructed in accordance with best practice and that problems had been resolved, at the design stage, for example those related to lateral or structural noise transmission.

Definition of Work and associated quantitative risk analysis

The data inherent each construction site activities are managed via either database implemented by other validated database, measurements or technical literature data. This research the attention has been focused on 3 specific parameters: *Noise quantification*, *Dust dispersion* and *Vibration quantification*.The first parameter refers to the amount of noise produced by each single construction site activity (e.g. Concrete mixer LAeq 80,3dB(A), Rotary hammer-drill LAeq 97,7dB(A)). The second parameter, on the other hand, concerns the dispersion of the dust produced by different construction site activities relating to the

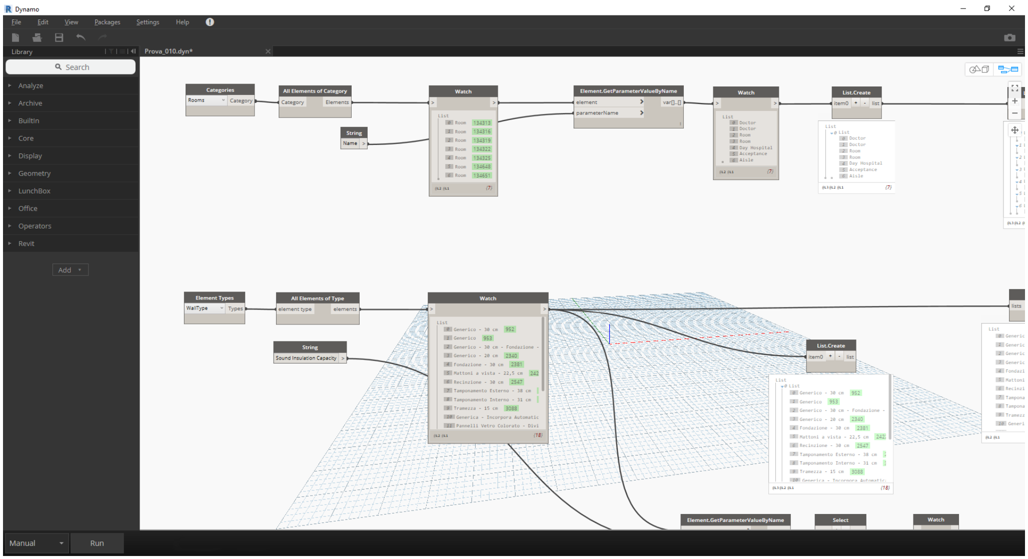


Figure 1
Making of CSV(Excel) database of Revit Parameters

level of risk where they are classified, as reported in the Qualitative Risk Matrix (see Table 3)(Moscato et al. 2007). The last parameter taken into consideration in this research is the amount of vibration produced by the equipment used to carry out some work activities.

Identification and classification of the type of risk factors based on required project maintenance operations

For example, noise risk factors are attributable to:

- **External Sources:** transmission occurs through building perimeter walls or the concerned internal environment;
- **Technical Systems within the building:** noise can travel through the structure;
- **Functional activity equipment:** either construction site or hospital related;
- **Anthropics:** from human voices to impacting noises related to human behaviour.

Environments exposed to excessive noise could induce fatigue and consequently cause distractions and errors in daily activities, whilst sudden noise in work situations requiring extreme concentration could cause involuntary reactions. The identification within the Revit model of the different typologies of hospital environments and the subsequent cataloguing in an Excel database allows us to classify these environments according to, for example, the maximum noise levels allowed. These values allow a qualitative simulation of environments exposed to acoustic impact.

BIM model integration within the GE environment

The decision to import the BIM model (Revit) within the GE environment (Unity3D) is dictated by them compatibility and easiness of reading in FBX format. Additionally, once integrated, the model can be added directly to the virtual environment, extending the BIM representation from its Static level (Revit) to Dynamic (Unity3D). Through this stage the Model becomes the scenario of simulation, or rather the environment within which it's possible to link the law of physics phenomena with the corresponding construction site activities.

Inserting and settings of the sources and receptors within the GE environment

The model of simulation have to be populated and set of sources and receptors depending on the expected work activities, their characteristics and risk factors. All the values that have been collected so far in the database (e.g. Sound Insulation Capacity, Internal Noise Limits, Risk Factors, Dust Dispersion, Vibration quantification) are imported into the Unity environment through scripts that allow them to connect to objects (e.g. walls, doors, floors) that make up the model of the hospital, or rather the scenario of the simulation. The graphical interface developed in the Unity model to characterise and facilitate interaction with the end user (e.g. engineer, architect, hospital manager) allows, once the construction site activity is selected, to populate the model.

Simulation by using algorithms and particle systems

The management of Noise, Dust and Vibration within the GE environment is eased through the use of simplified entities which enables creation, management and animation of many more particles than using a single object for each one. Unity3D's particle system can generate hundreds of particles and move them around, varying their colour and dimension. These characteristics are tied to the time variable beginning the instant in which the particle is created, or randomisation. In this case, we had to use a customised particle system to solve the problem of particle collisions with architectural elements, which can't be handled using one of the standard particle system provided by Unity. Thanks to the customised scripts it is possible to see, relatively to the construction site activity selected and located within the Unity model, the propagation in real time of noise within the ward/hospital and, moreover, the change of colour due to the noise attenuation caused by the collision with, for example, a wall (see figure 2, where noise propagation is reported by comparing the case where the door is open or closed).In addition to the propagation of sound and its classification through the chromium scale (*very high*-red, *high*-orange, *middle*-yellow, *low*-cyan, *ok*-green), thanks to these scripts are highlighted, according to a qualitative simulation, the hospital environments subject to the impact of construction activity.

CONCLUSIONS

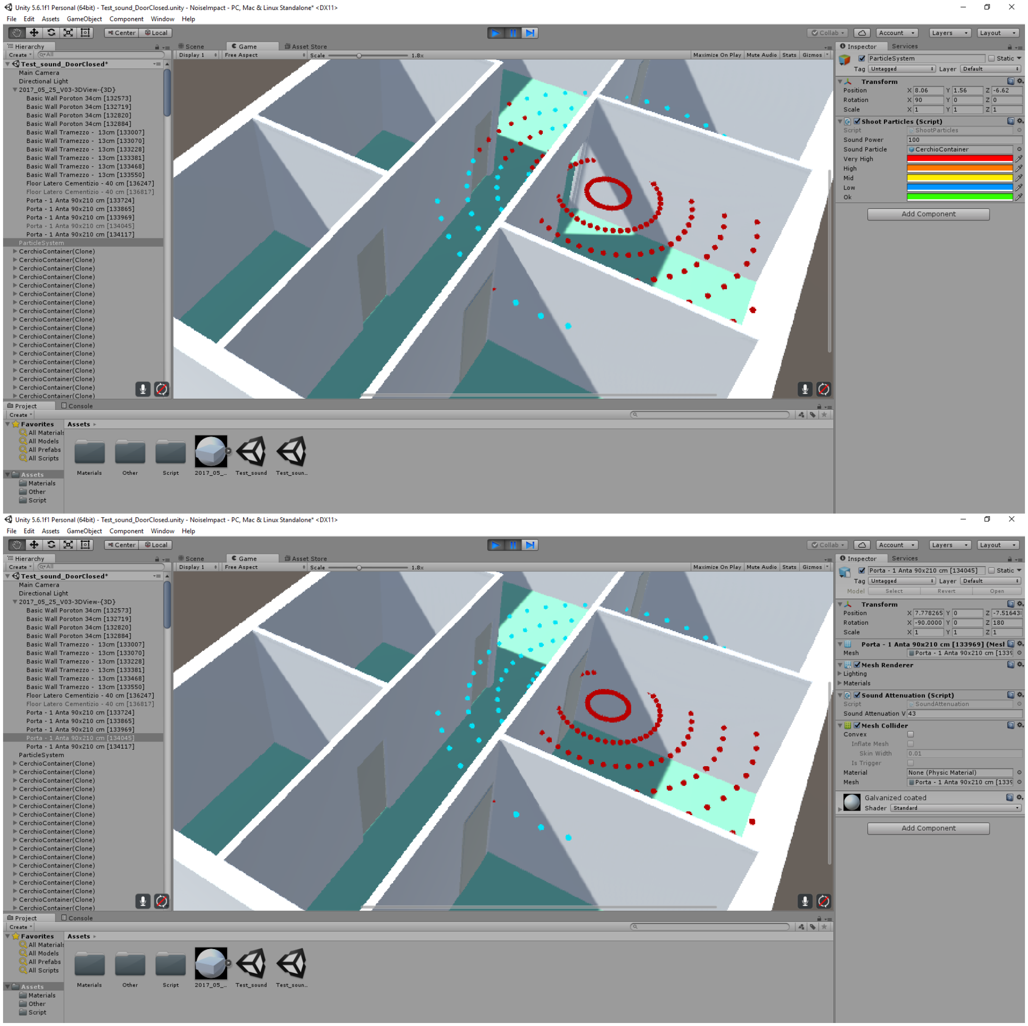
Statistical data reports roughly 85% of hospitals in Italy were built in the early 1900s and roughly 80% of operating theatres do not fulfill suitability requirements (Moscato et al. 2007), thus predicting steep increases of requalification and refurbishing of existing hospital structures.

Through the tool offered in this research, it is possible to visualise, in real time, the impact of the con-

Table 3
Risk matrix of construction activities

Types of Construction Activities	Examples of Construction Activities	Level of Risk
Type A Inspection and non-invasive activity, without generating dust and drilling walls	Removal of false ceiling panels for visual inspection; Painting; Re-paneling walls; Small electrical work; Small interventions on ventilation or terminal hydraulic Systems that require no more than 15 minutes.	Low
Type B Small scale and duration activities, generating small amounts of dusts	Skylight well access; Drilling or cutting walls or false ceilings or paneling; Repairing cracks in the walls, scraping or shaving for painting; Installation of lines of electrical or telephone or internet cable in wall; Medium interventions on ventilation or hydraulic (final section) in multiple environments that require less than 30 minutes.	Medium
Type C Interventions that generate from a moderate to a high amount of dusts and require demolition or removal of fixed structures.	Removing floor or wall coverings; Partial reconstruction of walls until scraping or shaving for plaster or painting; Installation of pipes of hydraulic ducts, of ventilation, of lines of electrical or telephone or internet cable in ceiling or false ceiling; Medium interventions on ventilation or hydraulic (final section) in multiple environments that require 30 minutes up to 1 hour.	Medium-High
Type D Noteworthy work on demolition, reconstruction and renovation.	Complete removal of floor or wall coverings or ceilings; Complete reconstruction of walls until scraping or shaving for plaster or painting; Complete installation of pipes of hydraulic ducts, of ventilation, of lines of electrical or telephone or internet cable; Interventions on ventilation or hydraulic system in multiple environments that take over 1 hour to be completed.	High

Figure 2
Noise propagation of a construction activity (customised particle system in Unity3D)



struction site activity on the specific hospital environment where they are carried out and on the surrounding environments.

The methodology elaborated in this research aims to support the detection of logical-operational interferences by BIM model integration within a Game Engine environment, aimed to reduce impact that maintenance, within a healthcare structure, can generate on the actors' health and safety, preserving as much as possible the continuity of daily hospital activities, as well as determining cost reduction and time optimisation of the activity stages that characterised the site.

REFERENCES

D'Alessandro, D, Mura, I and Vescia, N 2007 'Recommendations for the risk management of hospital yard: international guidelines', *Proceedings, 34th Course – Building Yards in Hospital*, Erice (TP), Italy, pp. 107-123

Eastman, CM 1992, 'Modeling of buildings: evolution and concepts', *Automation in Construction*, 1(2), pp. 99-109

UNI EN ISO, 11690-1 : 1998, *Linee guida per la valutazione del rischio rumore negli ambienti di lavoro*

Linehan, M and Andress, B 2013, 'Medical equipment and BIM', *HFM-Magazine*, 11

Moscato, U, La Pietra, L and Ricciardi, G 2007 'Non-viable particles and hospital yards', *Proceedings, 34th Course – Building Yards in Hospital*, Erice (TP), Italy, pp. 173-191

Uguccioni, G 2005 'L'evoluzione della tecnologia impiantistica al servizio degli edifici ospedalieri', *XXXII Convegno ANIMP - OICE - UAMI*, Rimini, pp. 33-34

Yan, W, Culp, C and Graf, R 2011, 'Integrating BIM and gaming for real-time interactive architectural visualization', *Automation in Construction*, 20, pp. 446-458

Zhang, S, Teizer, J, Lee, JK, Eastman, CM and Venugopal, M 2013, 'Building Information Modeling (BIM) and Safety: Automatic Safety Checking of Construction Models and Schedules', *Automation in Construction*, 29, pp. 183-195