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AN INTEGRATED FRAMEWORK FOR MANAGING BUILDING FACILITIES

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ABSTRACT

Buildings portray a significant aspect of urban infrastructure and function as the main share of non-residential infrastructure due to the huge network of their facilities. Building facilities are amongst the core aspects, which should be retained in order to guarantee their prosperous service delivery and to enhance their financial advantages. Operation and maintenance phase of existing building facilities resembles a huge share of the entire building facilities' life cycle expenses that may lead to excessive expenses and inadequate fund assignment. In fact, there is arising proof that building facilities are crumbling, due to the deficiency in building facilities knowledge and inaccurate management processes. This research attempts to propose an integrated framework for the management and the condition assessment of existing building facilities components, focusing on as-constructed data and scoping the operation and maintenance of existing building facilities. The fundamental purpose of this paper is to provide a workflow for creating a detailed as-is condition BIM model for operation and maintenance of existing building facilities with their specific information using BIM capabilities and open standards. The proposed architecture introduces five consecutive steps to accurately portray the unique nature of the maintenance system.

KEYWORDS: Operation and maintenance, facility management, building information modelling, 3D point clouds, condition assessment.

1. INTRODUCTION

Nowadays, governments are searching for enormous funds to be employed in infrastructure facilities, due to the growing interest in maintaining infrastructure facilities for optimal service delivery [1]. Buildings constitute a key asset in the urban infrastructure; they act as the main ration of the infrastructure of non-residential structures, due to extensive network of buildings facilities. Buildings are amongst the essential aspects that must be retained in order to guarantee their profitable service

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delivery and to optimize their economic advantages. The operation and maintenance phase in buildings is the significant participator to the entire building's lifecycle expenses by almost around 60 % [2]. Previous research endeavors have highlighted the essence and value of operational and maintenance phase with relevant to the entire building lifecycle cost. It was indicated that the building's lifecycle value is five to seven times higher, compared to the original value of capital and three times the value of construction process [3]. The significant proportion of practices occurred during operation and maintenance phase are concerned with the facility's maintenance and repair (M&R) process. The main reasons behind that are the unnecessary costs arise during M and R process [4].

In this context, Facilities Management, (FM) is considered an integrated profession that involves distinct operational tasks and maintenance facilities to promote the primary tasks of an unutilized facility through extensive data sets [5]. Despite the advent of FM in monitoring the operation and maintenance phase in building, the constrained adoption of open standards, which often identify information demands for precise FM activities is still regarded as a significant obstacle for enhancing information transaction to the FM procedures. Open systems and standardized data libraries are deeply demanded, which can be employed by FM scheme [6]. The accessibility of these kinds of open standards and information specification constitutes an essential potential, unless they are effectively implemented on new and already existing building facilities.

The use of Building Information Modelling, (BIM) during the project phases can upgrade the performance of FM activities. For currently existing buildings, constructed before BIM emerged, the difficulty increases as their FM systems do not promote open BIM criteria. One of the main functions of managing building facilities is assessing the current conditions of these facilities, which begins with the acquisition of the as-is conditions of building facilities [7]. Accordingly, BIM open standards and information specifications are widely utilized to create as-is conditions BIM models, which act as a unified 3D models of an existing building facilities that employ data to portray the current situation of existing building facilities.

1.1 Problem Definition

Throughout the operation and maintenance process, FM staff frequently waste significant time and effort, gathering data from multiple sectors of digital data and hardcopy records, so data could be lost or misrepresented. Interoperability researches conducted by the US National Institute of Science Technology (NIST) reveal that around 70% of the anticipated cost is wasted in the United States, owing to operational and maintenance processes incompetency [8]. Failures correlated with unsatisfactory interoperability of building data are due to expenditures associated with manual information re-entry, information identification, tasks duplication and unproductive time undertaken by worker, navigating for relevant information, which is always nonexistent. Furthermore, there is an emergent indication that building facilities are deteriorating and are in inappropriate conditions due to lack of building facilities knowledge and inadequate condition assessment, which rendered maintenance management of existing building facilities as a complex mission [9].

1.2 Research Methodology

This research aims at proposing an integrated framework for managing and evaluating existing building facilities that focuses on as-is condition data and scoping the operation and maintenance of current building facilities. This research is carried out with a deep concentration on automating the process of data gathering for building facilities using emerging technologies as 3D laser scanning to automate the process of data acquisition for building facilities. The major goals of this research is to deliver a workflow for installing and portraying maintenance demands into and from BIM to assist clients and building's facility managers to the actions and resolutions regarding the operation and maintenance phase of existing building facilities, to ensure optimum results for operation and maintenance process. The proposed framework attempts at constituting a detailed as-is condition BIM model for the operation and maintenance of the various building facilities with their specific information using BIM capabilities, specifications and open standards through five sequential phases as clearly depicted in Fig. 1.

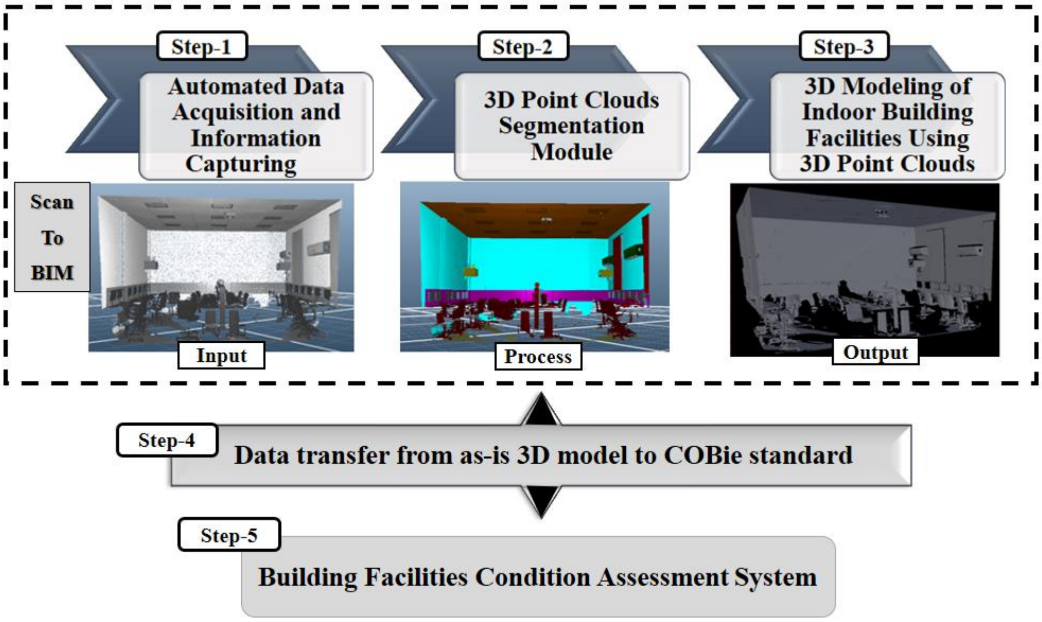


Fig. 1. Integrated framework for managing building facilities.

2. LITERATURE REVIEW

The emergence of BIM innovations and open standards generates possibilities to merge the FM process with the crucial phases of project delivery. BIM innovations and procedures enable FM to maintain and incorporate information utilizing open standards via the building life cycle phases. Recently, open BIM standards including Construction Operations Building Information Exchange (COBie), created by buildingSMART, is being consistently supported with generic feedback from the architectural, construction, manufacturing and operational industries [10] .The ultimate objective of BIM standards is facilitating the transmission of data all across the construction industry and building life cycle processes. The idea of broadening the applications of BIM via the operation and maintenance process is essential to decline the expenditures of operation and maintenance and to gain the tangible significance of the functionality of BIM as a platform for information management. Indeed, in many other recent practices, in which BIM is introduced to promote FM procedures, FM staffs do not commonly utilize BIM database schemas mostly due to the misunderstanding of the ways to transmit data from BIM models to FM schemes. This renders the flow of data between BIM and FM processes in a monotonous and excessive way [11]. There are always technical difficulties to be addressed, primarily by maintaining the method of information sharing and addressing interoperability dilemmas between BIM and FM schemes [12].

Many research efforts have attempted to enhance the BIM and FM integration process; for instance, the dilemma of operation and maintenance phase of healthcare facilities was tackled, which is considered a sophisticated system, by proposing a framework that is based on BIM to assist facility managers in maintaining healthcare facilities [13]. A framework was developed that relies on integrating BIM with Mobile Augmented Reality (MAR) to permit adequate information accessibility through handheld mobile devices that can improve already existing FM procedures [14]. The dilemma of approaching BIM-based FM from the construction phase was addressed, in order to be adopted concurrently within the operation and maintenance phase by proposing a way to adequately maintain BIM-related FM data through integrating the BIM-related building components and FM task data in a FM database [15]. A Facility Maintenance Management (FMM) framework was also proposed, which relies on BIM and facility management systems “FMSs” to automatically schedule the maintenance work orders (MWOs) and to improve the taken actions or responses in FMM [16].

Many obstacles have been raised in constructing as-is BIM model. Erroneous or incorrect building data may negatively influence the actions and responses taken in the operation and maintenance phase, which may lead to inducing momentous postpones in reacting to necessities and occupants’ periodical demands [17]. In this context, BIM should be regarded as a broad platform that can remedy problems associated with imprecise hypothesis about the situation of the building. In fact, BIM creation for an existing building is a crucial process, which is ringed with many obstacles and challenges such as: 1) data acquisition for adequate documents of the existing building that requires time, cost and skilled labors; 2) building components should be properly mapped with its comparable building information [17]. Extensive literature review have revealed many complications in the establishment of as-is condition BIM. These can be summed up in the enormous efforts and costs required to identify the geometry and non-geometry essential information for constructing fully complete as-is BIMs; and the imprecision that may occur in BIM creation, as an outcome of the variance between design requirements and operation and maintenance phases [8, 17].

3. PROPOSED FRAMEWORK

One of the primary roles of maintaining existing building facilities is appraising the as-is condition of these facilities. To assess the current situation of building facilities, BIM as a data-rich and object-oriented model has been employed in the area of data acquisition for existing building facilities to construct as-is conditions BIM model. Within this context, Scan-to-BIM provides a means of physically 3D laser scanning the indoor space to construct a precise digital portrayal of this space. Scan-to-BIM process is employed to generate a database of existing indoor environment and adjoining structures. The Scan-to-BIM process is divided into three phases as seen in Fig. 1.

3.1 Automated Data Acquisition and Information Capturing

The construction of an as-built 3D model demands the acquisition of the as-is conditions of the building facilities. Techniques of data or information capture depend deeply on the required level of details needed to scan and to reconstruct the existing building facilities for establishing as-is BIM model. The most commonly employed approach for building facilities data scanning and retrieving is laser scanning using Terrestrial Laser Scanner (TLS). TLS is considered fast progressing instrument, which minimizes the data acquisition duration per each scan and enables for further configurations, leading to huge coverage of information. Moreover, TLS are characterized by its data acquisition acceleration, which reaches up to a 1,000,000 HZ, and its increased precisions to up to 6 mm/100 m. This research adopts TLS that is considered a multi-disciplinary scheme, employed for scanning building environments and is regarded as the most feasible approach for conducting as-is condition BIM of existing building facilities. TLS is the only instrument that is capable of delivering a standalone alternative to scan or retrieve indoor built environment for building facilities. Data acquisition of indoor building environment result in sets of 3D point clouds of indoor spaces, generated via terrestrial laser scanner that widely represent 3D spatiality information of indoor building facilities and is regarded as an applicable data source for recognizing and reestablishing geometric objects from 3D scenes

3.2 3D Point Clouds Segmentation Module

The process of data acquisition of existing building facilities results in conducting a combined BIM model that includes information from distinct records and varies on the basis of associated characteristics. The main aim of this task is to segment BIM objects into clusters representing distinct domains. Thus, a segmentation process for engendered 3D point clouds is an integral stage in scene clarification and understanding. The goal here is to decompose the 3D point clouds into sets of workable clusters with similar properties. The purpose of this section is to introduce and to assess a segmentation and classification pipeline for segmenting objects in existing indoor building facilities. This study uses Point Cloud Library (PCL) engine functionality as a manner of processing indoor environment 3D point clouds. Regional growing algorithm is employed in the segmentation module, which is accessible in PCL. Figure 2 illustrates the sequential steps required by region growing algorithm to undertake the segmentation process of 3D point clouds data for existing indoor building facilitates. The 3D point clouds segmentation method is implemented in C++ using Microsoft Visual Studio with the support of the PCL library. The PCL is a huge-scale open source network for decoding 2D or 3D images and point clouds. The PCL architecture includes multiple state-of-the-art algorithms such as filtering and segmentation algorithms, as well as multiple techniques for point clouds visualization and processing. The PCL library is also utilized to facilitate the processing of point clouds information, particularly for filtering, ground processing, visualization, and segmentation. The proposed framework for segmenting 3D indoor point clouds is composed of three sequential steps as illustrated in Fig. 3.

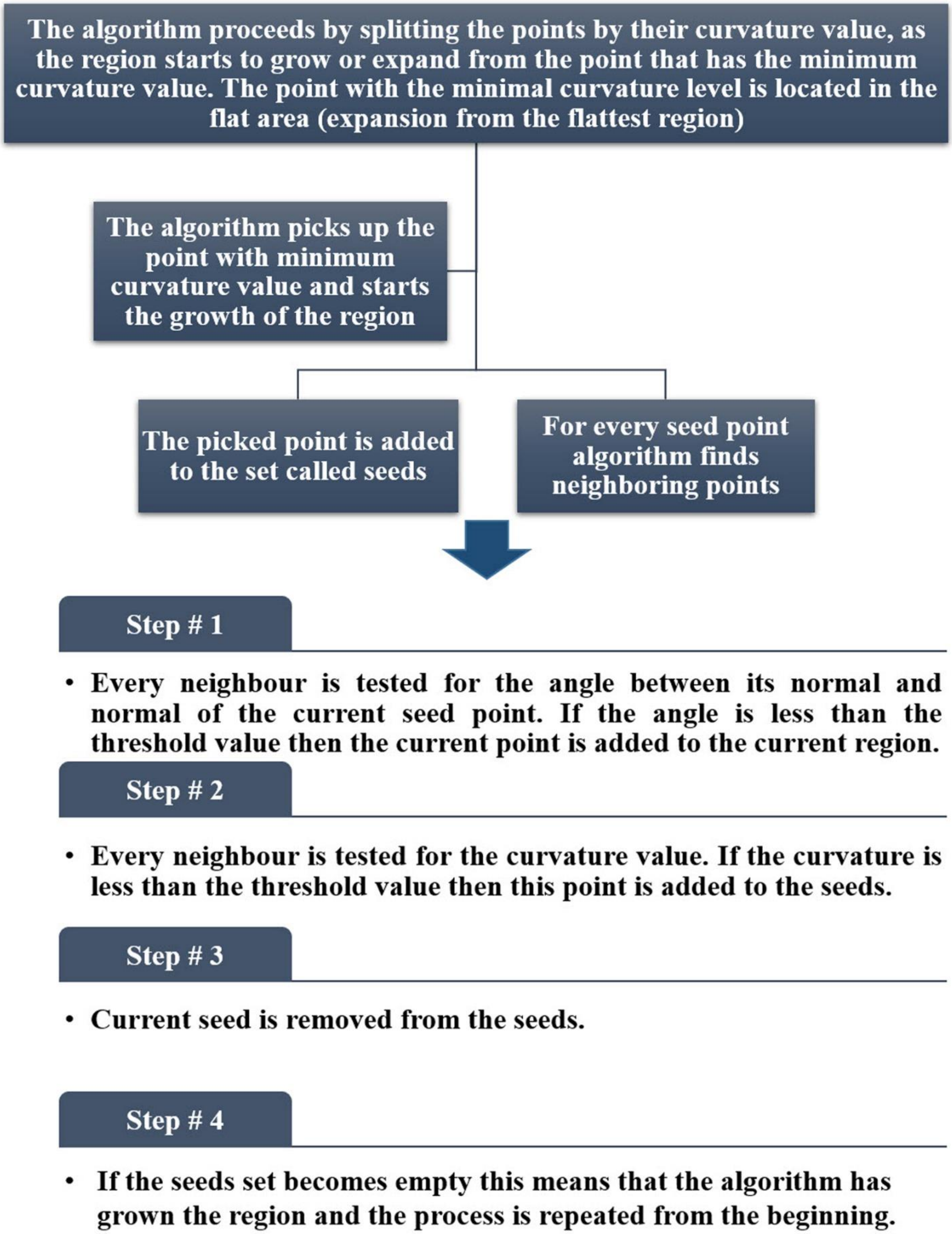


Fig. 2. Sequential steps undertaken to construct the region growing algorithm.

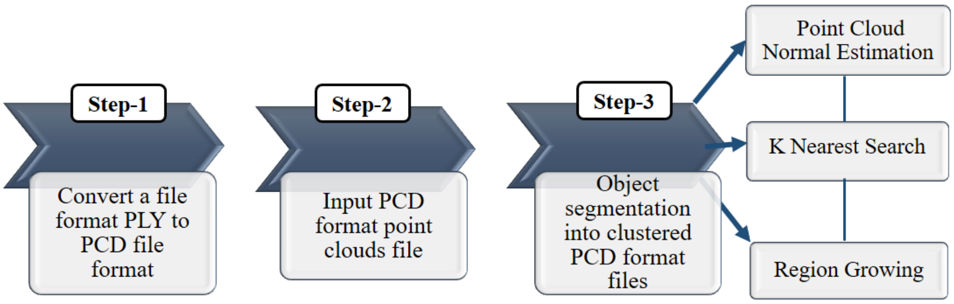


Fig. 3. Pipeline of segmentation module.

3.2.1 Framework of 3D point clouds segmentation module

The first step is accountable for converting a file format PLY (Polygon File Format) to PCD (Point Cloud Data File Format). The 3D point clouds data generated via TLS is a Polygon File Format (PLY), thus it is required to be transformed to PCD, used by region growing segmentation algorithm. This is implemented through a MATLAB code as follows:

cloud = pcread('file_name.ply'); pcwrite(cloud,'output_file_name.pcd');

In the second step, input PCD point clouds are loaded into the PCD point structure format, as this format is used internally by PCL's algorithms. In this case only the geometry is needed, so only the X, Y and Z coordinates are taken into the structure.

The third step is responsible for creating a file algorithm name_segmentation.cpp in any editor that includes the C++ segmentation code for point clouds PCD file. This is followed by creating a CMakeLists.txt file, including running and compiling code. C-Make is an interoperable, accessible-source, boundary-platform scheme that performs the construct process in an operating system and in a compiler-independent way. Configuration files are stored in the project source folder, called CMakeLists.txt documents, which are utilized to create and to construct visual studio solutions. After the executable is done, the generated C++ code can run, assuming the PCD point clouds file is in the same folder as the executable.

3.3 3D Modelling of Indoor Building Facilities Using 3D Point Clouds

Objects identified and segmented in the preceding step using region growing algorithm become a semantically prosperous BIM in this step. Setting-up as-is condition BIM relies deeply on as-is building data in details with high precision. The procedures for establishing as-is condition BIM are modeling scanned and segmented 3D indoor point clouds, which designates the establishment of BIM features that resemble building element. Modeling process depends heavily on commercial applications and software; hence, this step focuses on the modeling of indoor existing building facilitates from 3D point clouds, which is regarded as a huge dilemma, since the emergence of BIM in engineering and construction industry. This research employs Pointfuse commercial software that provides a fully automated 3D reconstruction from 3D point clouds. This software overpasses the gap between digital construction and reality capture by converting 3D point clouds data from laser scanners into affluent and intelligent as-is 3D models.

3.4 Data Transfer from As-Is 3D Model to COBie Standard

Existing building facilities generate vital data and information, which are generally stored in a paper-based format or in files format. Lately in 2006, the Construction-Operations Building Information Exchange, (COBie) was created with BIM standards. COBie is an essential, doable spreadsheet template that contains digital information about any building facility, in spite of its proportion and its technological complexity. COBie spreadsheet decomposes of an array of distinct sheets, in which lots of information can be registered, relevant to the facility, floors, levels, spaces, zones, type, component, attributes, and contact information. COBie aims at delivering an innovative method for allocating raw data during building life cycle and dematerializing building information to improve building data interoperability by loading information about maintenance and operations.

Given its full title COBie is viewed as a structured format to send data from, as-is conditions BIM model to the operations phase. In this research, Autodesk COBie Toolkit for Navisworks is adopted that permits setting up Navisworks models to capture

COBie data. This study make use of previously segmented surfaces and elements "as-is condition mesh model", which are exported as NWC file format from Pointfuse software. The exported NWC file format is imported into Autodesk Navisworks for mapping model object properties to the COBie standard. A typical COBie project workflow in Navisworks initiates by setting up the project, and selecting the COBie table to add the property. This step is followed by dragging and dropping the property from the property tree panel into the required fields in the COBie template. Additional properties of scanned objects are inserted by employing Selection Inspector and DataTools plugins in Navisworks, which is a feasible option to adjust or add countless properties to graphical elements. This process starts by mapping a MS Excel file that includes all data required to be imported with the graphical element in Navisworks through creating a SQL string as seen in Fig. 4. Once the new data is added to the excel worksheet, the file is saved as xls; this is essential to be reimported using DataTools.

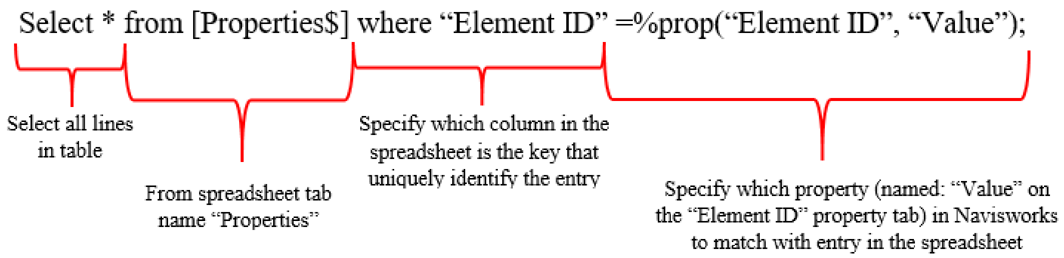


Fig. 4. SQL string to link excel file data to objects in Navisworks.

3.5 Building Facilities Condition Assessment System

After creating the as-is condition BIM, the performance of building facilities components should be assessed and evaluated. Building Facilities Condition Assessment (BFCA) is considered a method of anticipating the preventive maintenance policies and repairs requested for existing building facilities components, and assessing their physical condition. Coherent assessments of facilities components condition on a continuous basis are thus mandated to monitor building facilities components before and after repairing demands to figure out the outcome of enhancement and to record any substantial alterations in conditions, before they can have an influence on the efficiency of building facilities components.

3.5.1 Facility components condition index scale

Regarding, building facilities condition assessment, this study proposes a Building Facilities Components Condition Index, (BFCCI) scale, which ranges from "0" to "100," in which "0" indicates the seriousness of the facility components condition “Full Deterioration” , while "100" portrays the ideal facility components condition “Exemplary Quality”. The proposed BFCCI scale is broken down into five point scale as depicted in Fig. 5.

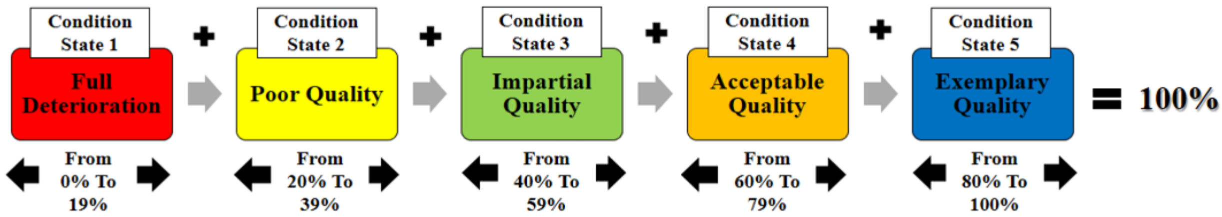


Fig. 5. Proposed facility components condition index and rating scale.

3.5.2 Artificial neural network model for condition assessment prediction

In order to implement an appropriate strategic building facilities management scheme to allow for a constructive maintenance and rehabilitation system, it is crucial to have a trustworthy strategy to anticipate the condition of building facilities components. Hence, this paper aims at the construction of an artificial neural network, (ANN) model to forecast current status ratings for each facility component in building spaces. The type of ANN employed in this research is Back Propagation Multi-Layer Perceptron, (BP MLP). ANN model can efficiently record the potential effects of several parameters influencing the current condition of the predictive model by tracing the connection between input and output parameters, utilizing the behavior of the network. Figure 6 illustrates the sequential steps and procedures undertaken to design the ANN prediction model and to achieve its outcomes. MATLAB-R2018a is employed for the construction of the ANN model.

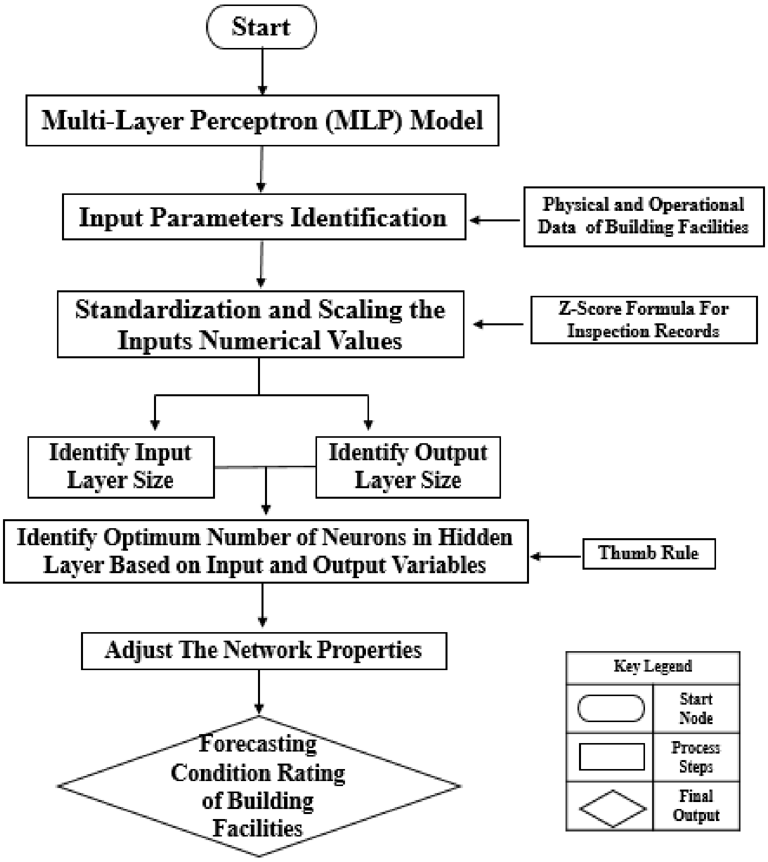


Fig. 6. Framework of ANN prediction model.

3.5.2.1 Input parameters identification

The input parameters have a major effect on output parameters, thus great concerns have to be taken into account, while selecting the input parameter of the ANN model. To identify the significant input variables of the network parameters, factors listed in prior research endeavors; in addition, experts and facility managers are asked to identify the substantial variables for building facilitates components, which act as input parameters to the network [18]. The final selected input parameters are age in years, warranty duration in years, expected useful life in years, annual average daily usage, (AADU) as a percentage, recent replaced facility duration, (RRFD) in years and efficiency factor as a percentage. ANN model is an experience-based and learns from the sample data to identify the relationship between input and output data. Hence, the inspection records, maintenance histories, inventory information, previous research data for each facility component are collected as numerical values [18]. The numerical values of the data gathered for the condition monitoring per each facility component are standardized and scaled using the standardization Z-score equation, Eq. (1) to meet the criteria of the transfer function utilized in ANN model.

$$z = \frac{X - \mu}{\sigma} \tag{1}$$

Where z depicts the standardized or scaled values; μ depicts the mean or average value of each input variable; X depicts the non-standardized or raw data; and σ depicts the standard deviation of each input variable.

3.5.2.2 Input and output Layer of ANN

The size of the input variables matrix for each facility component in each building space is designed and represented as $n^1 \times n^*$, in which n^1 is the number of input parameters to the network "n^1=6", and n* is the number components in each building space. The inputs number prescribes nodes number on the input layer of the MLP model. On the other hand, the size of the output layer for the ANN model is $n^2 \times n^*$, in which n^2 is the number of output parameters "n=5", and n* is the number of components in each building space. The output layer of the network comprises of five nodes, initiating from condition state 1 to condition state 5 as shown in Fig. 5.

3.5.2.3 Hidden layer and activation function

The hidden neurons number in a single layer is computed utilizing the below-mentioned thumb rule Eq. (2) that is commonly adopted in several research efforts.

$$n = \frac{2 \times (Ip + Op)}{3} \tag{2}$$

Where, n depicts the optimum neurons number in a single hidden layer; Ip depicts the size of input layer; and Op depicts the size of output layer. In the network properties, the transfer function used for the hidden layer is (TANSIG), which allows transition from input layer to hidden one, and from hidden layer to output one. The Bayesian Regularization function is employed during training the network to update weight and bias values. The (TRAINBR) training function is selected to train the neural network.

Moreover, (LEARNGDM) learning function is opted to calculate weight and bias fluctuations for the back-propagation.

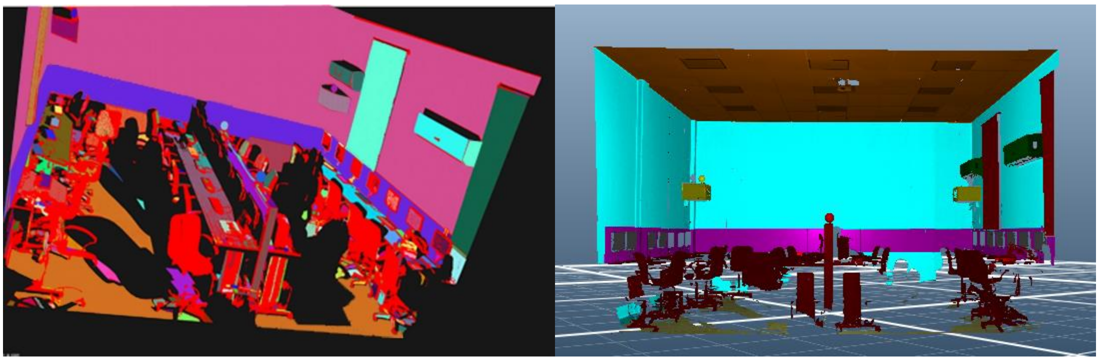
4. CASE STUDY

4.1 Data Acquisition Process to As-Is-BIM Model

The verification and validation approach is carried out by incorporating the proposed framework throughout an actual application context to assess the efficacy of the conducted work. The Construction Engineering Technology Lab (CETL) located in the Civil Engineering building at Cairo University is chosen as a case study. The initial step in the proposed framework is data acquisition of existing indoor building environment via terrestrial laser scanner, which delivers sets of 3D point clouds of the computer lab facilities and components as seen in Fig. 7.

Fig. 7. Indoor 3D point clouds scene for the computer lab.

The segmentation and classification pipeline employed for clustering indoor building facilities and components using Region Growing algorithm, resulted in segmented 3D mesh workable clusters with similar properties, which are: Interior Brick Walls Finish, Ceiling Tiles, Desktop Computers, Air Conditioning, and Wall Curtains as displayed in Fig. 8. As previously mentioned, Pointfuse software is adopted to generate a fully 3D reconstructed mesh model for the segmented indoor environment components as depicted in Fig. 8.



(a) (b)

Fig. 8. Segmented 3D mesh model for the computer lab; (a) Segmented indoor environment using Region Growing algorithm, (b) Modeling of segmented indoor environment using Pointfuse.

4.2 Transition of Data from As-Is 3D Mesh Model to COBie Standard

This stage tends to make use of the already segmented components portrayed in Fig. 8, which are exported as NWC file format from Pointfuse software and imported into Autodesk Navisworks to integrate the properties of the segmented elements to the COBie spreadsheet template. Ancillary properties of scanned elements are incorporated by using Selection Inspector and DataTools in the Navisworks model. This stage is established by generating Properties DataTools Link and composing a SQL String to attach properties with scanned elements as shown in Fig. 9.

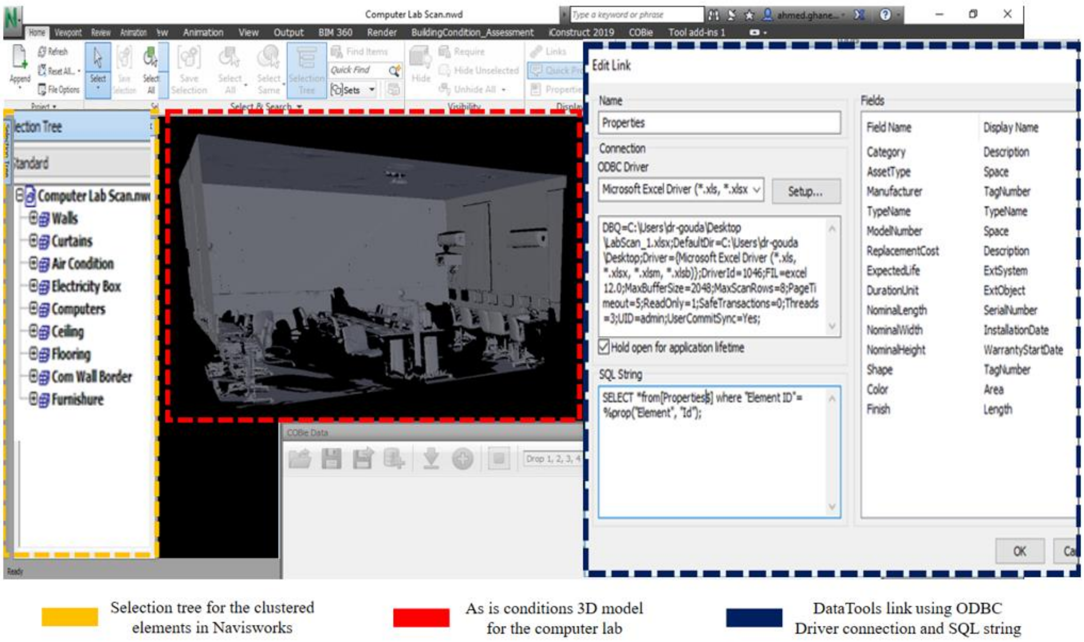


Fig. 9. Data transmission tool.

4.3 Condition Assessment Prediction Using ANN Model

To predict the physical condition of building facilities components, input layer, hidden layer "optimum number is 8 according to Thumb rule" and output layer are defined in ANN model. After running the model, the ANN model generates condition ratings of components already segmented using Region Growing algorithm, as illustrated in Table 1. Table 1 shows the input parameters values for each component, generated from inspection records and literature [18], and their standardized values, in which OV stands for original value and SV stands for the standardized value.

Table 1. Input parameter values and standardized values per each component.

Components vs. Input Parameters	Age		Warranty Duration		Useful Life		AADU		RRFD		Efficiency Factor	
	OV	SV	OV	SV	OV	SV	OV	SV	OV	SV	OV	SV
Walls	15	1.6	0	-1	13	-0	55	-1	5	1.7	55	-2
Flooring	13	1	5	-0	15	0.4	85	0.8	0	-1	65	-1
Ceiling	8	-1	9	0.9	15	0.4	45	-2	0	-1	70	0.1
AC	6	-1	10	1.1	14	0.1	80	0.5	3	0.7	65	-1
Curtains	7	-1	3	-1	16	0.6	50	-1	0	-1	80	1.4
Desks	10	0.1	2	-1	20	1.4	70	-0	0	-1	70	0.1
Chairs	10	0.1	2	-1	18	1	75	0.2	4	1.2	65	-1
Computers	6	-1	12	1.6	10	-1	90	1.1	2	0.2	70	0.1
Projector	14	1.3	8	0.6	7	-1	65	-0	0	-1	80	1.4
Lighting	8	-1	3	-1	5	-2	95	1.4	3	0.7	75	0.7

Table 2 outlines the anticipated condition ratings of each component as an output value, in which the output layer of the network comprises five nodes that depict the five condition states shown previously in Fig. 5. For instance, by considering the walls shown in Table 2, its output values reveal that 3.46% of the walls are located in full-deteriorated condition state, 64.83% in poor condition state, 6.28% in impartial quality condition state, and 25.43% in accepted quality condition state, respectively. The developed ANN model could generate condition ratings of any other building component, relying on connection weights and biases already stored to compute the output of the network. Figure 10 presents the regression plots of the ANN model. It is seen that the coefficient of determination "R-squared" value is 0.99 for training, 0.62 for testing, and overall 0.89. The value of R-square is a measure of the developed model prediction's precision, where the higher precision is achieved, as the value approaches 1.

Table 2. Output condition rating values per each component.

Target Variables	Condition 1	Condition 2	Condition 3	Condition 4	Condition 5
Walls	0.0346	0.6483	0.0628	0.2543	0
Flooring	0.3045	0.5941	0.0556	0.0158	0.03
Ceiling	0.2621	0.4527	0.154	0.053	0.0782
AC	0.045	0.358	0.4075	0	0.1895
Curtains	0.346	0.2055	0.305	0.1435	0
Desks	0.035	0.75	0.035	0.125	0.055
Chairs	0.245	0.5	0.255	0	0
Computers	0	0	0.0635	0.905	0.0315
Projector	0.713	0.085	0.065	0.1	0.037
Lighting	0.5215	0.35	0.05	0.04	0.0385

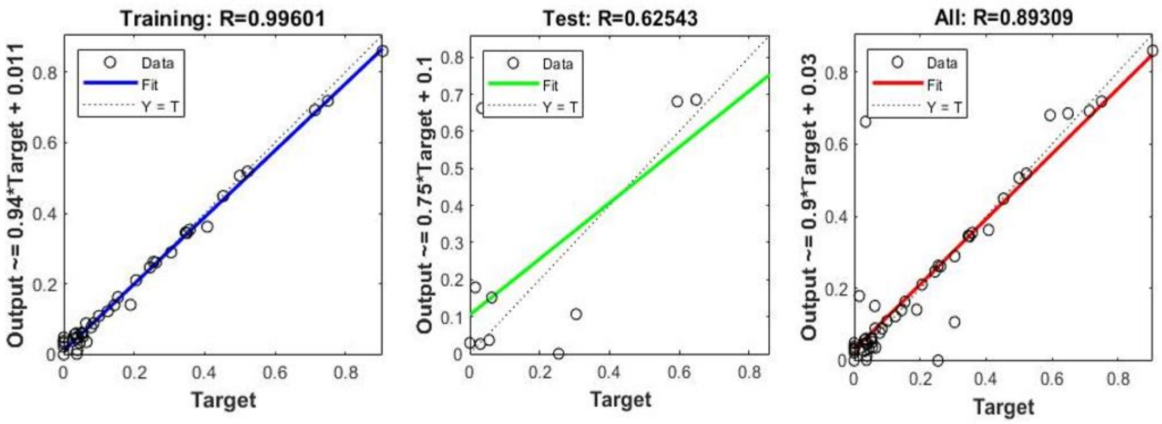


Fig. 10. Regression plot of condition rating predictive ANN model.

5. CONCLUSION

Sustaining building facilities, with their distinguished categories is deemed as an important attribute that ensures adequate, lucrative service delivery and optimizes economic advantages for building facilities. In the meantime, several buildings are deteriorating and maintaining their sustainability from a steady maintenance process has become an enormous task, particularly while considering the unsatisfactory interoperability of building facilities. Building’s operation and maintenance phase is perceived as the significant participant in building lifecycle expenses; however its cost may be greater than the building's initial value and the construction process value. There is rising evidence that building facilities are crumbling and unreliable due to the absence of knowledge of building facilities and incorrect management processes. This paper shows BIM's framework to improve the effectiveness of BIM open standards for FM operations. The research extends to the creation of a detailed as-is condition BIM model for operation and maintenance of existing building facilities with their specific information using BIM capabilities and open standards. The presented framework constitutes a reference for facilities managers to implement the recommended methodology for embedding, extracting and managing building facilities-based data during the operation and maintenance phase. This can be extended by the implementation of the proposed framework for distinct building types, which will concede several challenges. The research methodology also can be extended to prioritize and find best fund allocation to assure optimum fund distribution.

DECLARATION OF CONFLICT OF INTERESTS

The authors have declared no conflict of interests.

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إطار متكامل لإدارة مرافق المباني القائمة

يهدف البحث الى وضع اقتراح لاطار عمل متكامل لادارة واستعادة المباني القائمة أليا باستخدام أحدث التقنيات من خلال المسح الضوئى بالليزر ثلاثى الابعاد لعملية جمع البيانات لمرافق المبانى القائمة وتتمثل الأهداف الرئيسية للبحث فى تقديم خطة عمل مبنية على متطلبات درجات الصيانة المطلوبة لمرافق المبانى القائمة حسب حالتها على الطبيعة ومن خلالها يتم تزويد القائمين على أعمال الصيانة بالتوصيات اللازمة للصيانة لضمان أفضل نتائج للتشغيل وللصيانة. الاطار التفصيلى المقترح فى البحث يعمل كنموذج وفقا لمعايير ومواصفات ال BIM ويتضمن خمس مراحل متتالية للوصول الى نموذج الBIM للوضع القائم لمرافق المبانى.