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An EP Journal on Architectural Education

Aims and Scope

An EP Journal on Architectural Education is a National Journal. It Publishes Original Research Papers in Different Areas of Architecture Education. It Publishes 3 Issues in a Year from 2018 in purpose of enhancing architectural scholarship in design, history, urbanism, cultural studies, technology, theory, and practice.

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Contents

The Importance of Conceptual Design for Undergraduate Students in Product Design

[1] **Veerapol Suwankarjank,** [2] **Kasemrut Wiwitkunkasem**

[1,2]Faculty of Architecture, King Mongkut's Institute of Technology Ladkrabang

E-mail: [1]veerapol_s@yahoo.com, [2]kwkasemrat@gmail.com

A B S T R A C T

Conceptual design is one of the most important processes in product design. However, for design students, conceptual design processes have been overlooked and ignored while they work at design. As a result, the final designs are not able to answer or solve product design problems effectively. This paper presents the importance of conceptual design processes by studying and collecting information on those of undergraduate design students for comparison. The results found that students who use conceptual design processes can create effective designs and meet the purposes of design better than those who do not use conceptual design processes, including how this impacts the sketch design process as well as the final design.

Keywords - Design concept, Conceptualization, Design education, Design studies, Design process, Product design.

I. INTRODUCTION

"Product design" has become a part of everyday human life. So many things that humans touch and use are the result of design processes carried out by a designer. The benefits of design products help make the lives of human beings more convenient. They serve to respond to human needs that commonly arise. These product designs help meet the needs of humans and create comfort in their daily life. These products have to go through a good design process to get a new product that is effective [1].

The product design process involves a variety of steps from the early stages to a definition of problems, information collection, data analysis, conceptual design, sketch design, design selection, detailing design and final design evaluation as seen in fig.1. All the steps in the product design process are important, but the conceptual design process is perhaps the most influential. The purpose of the conceptual design process is to create ideas and experiment with new design directions to serve as the best solution for the design. The designer needs to extract knowledge from the data to synthesize a new creative thing called the"design concept" [2]. The design concept is based on data analysis of design issues. It's consisted of ideas to solve design problems, target needs, creativity and inspiration [3]. The design concept's role is design the core of what will be necessary for the designer to use in the product design process. It presents an overall view of function, form, materials and details, including user behavior [4].

The design concept is applied in the sketch design process, a process in which ideas are transferred from the designer's brain as abstract ideas to concrete sketches. This process represents a "thinking" step used to create designs that serve the needs of design issues. Sketch design expands and generates ideas, a step that uses divergent and convergent thinking by drawing. The designer uses sketch drawing as a tool to communicate design concepts and sketch designs which show a variety of ideas used to solve problems in design work. Sketches can track ideas and design concepts [5]. From the sketch design stage, the design will be further developed and detailed in design work to the final design stage in order to achieve the most effective design. Therefore, each stage of the design process takes part in a larger domino effect. If the conceptual design phase is marred by error, this will result in a bad concept, increasing the amount of work needed for the designer unnecessarily.

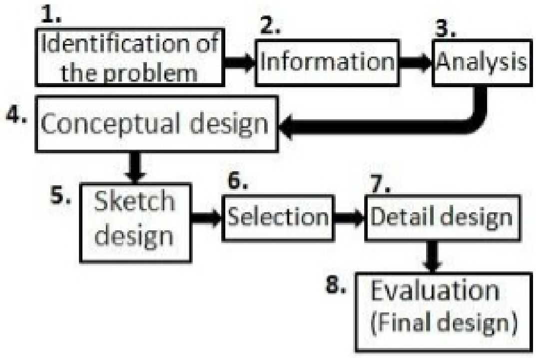

Fig.1Product design process diagram

Education is a necessity, especially in undergraduate study, because it is a period of learning specialized knowledge in each field. At the undergraduate level of this research, teaching is about design. Design students learn basic knowledge in the field, including design processes that are necessary to use in conceptual design processes. This is the core of the process that helps students learn how to create an effective final design. The "design student phase" is regarded as the starting point of being a professional product designer in the future, a major force in the design industry. Through teaching experience and observation of design students in the design process, this researcher has discovered the problems that occur

during the design process. The problem is that conceptual design has been neglected for the simple reason that design students do not see the importance and role of design concepts. This paper looks at the design process of undergraduate Thai design students to present the importance of the conceptual design process through main processes, especially sketch design and evaluation final design.

II. OBJECTIVES

The goal of this paper is to present the importance of conceptual design and its effects by observing the design concepts that occur within the product design process of undergraduate students.

III. PROCEDURE OF THE RESEARCH AND METHODOLOGY

The researcher performed this study by using qualitative research consisting of documentary research, design process diaries and in-depth interviews with 24 participants who are undergraduate students at Chiang Mai University with basic knowledge of product design and the design process, as well as several design instructors. The data collected was as follows:

1) Documentary research reviews the related literature concerning research about conceptual design and design concepts for product design, including roles and functions of the design concept that is used in the design process.
2) The design process diary collects data from notebook samples that record information, research data, sketch design and detail the process of design work, as well as describe the ideas used in design. This group of samples starts to take note on the design process from the beginning of the process to completion, as seen in fig.2.

Fig.2Inside the design process diary

Furthermore, the researcher defines design questionsin the field of product design and determines the equality time factor for the sample. 3) An in-depth interview is conducted with the design instructors to evaluate the potential and result of the final designs. The interview results are data, which are indicative of efficiency in design and good solutions to solve design problems. 4) A comparison of design process data is made between the design process diary and the in-depth interviews conducted with design instructors to analyze the importance of the design conceptualization process that significantly impacts other design processes.

The content analysis in this research is divided into 3 phases from the design process diary as seen in fig.3.

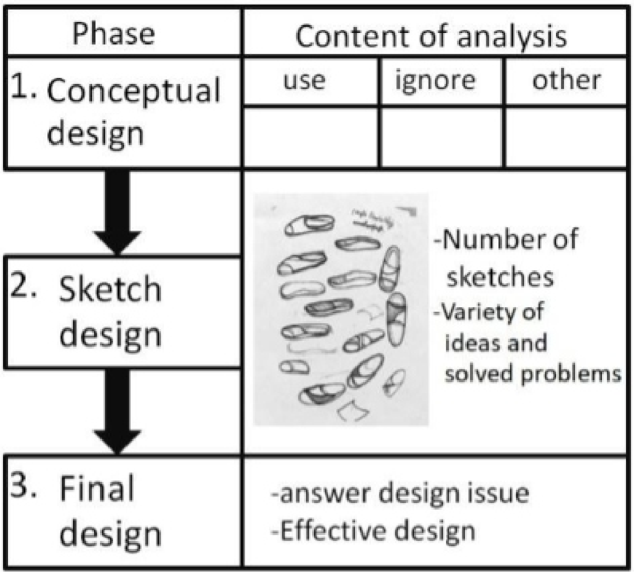

Fig.3Contents of analysis used in this paper

Phase 1: Analyze design behavior of a sample group in the conceptual design phase by using a checklist of phase-specific activity. In order to check the implementation of this phase, the samples have been used or ignored in this phase.

Phase 2: Analyze data from the sketch design phase. Use the sample's sketch to analyze it in terms of number and variety of ideas used to solve design problems. This phase shows design thinking as well astrans formation of the sketch design from its original draft in the design process diary, in terms of things like form and function [5].

Phase 3: The researcher uses interview data from the design instructors which evaluates the result of final design products and analyzes in terms of design efficacy, as well as determining how they answer design issues in such a way that satisfies user needs.

IV. RESULTS OF RESEARCH

From data collection, the data can be divided into 3 groups as table 1.

Table 1: The results from the design process diary

Phase \ Student no.	Group1 14	Group2 6	Group3 4
Phase1: Conceptual design	- *Ignore* Not use design concept	- *Ignore* use inspiration instead of design concept	- *use* use this phase to crate design concept

Phase2: Sketch design	- 5-12 sketches - scattered ideas - lost design direction - Sketch does not nearly answer design problem	- 1-6 sketches - unvaried ideas - Monotonous sketch - Sketch does not nearly answer design problem	- 5-18 sketches - Generate variety ideas - Sketch is answer design problem
Phase3: final design	- design is not effective - cannot solve design problem	- design is not effective - cannot solve design problem - Monotonous design	- efficient design - New design to solve design problem

In Group 1,there are 14 participants from 24 samples. In this group there are samples that ignore the conceptual design process and are not interested in the design concept. Thus in the sketch design process, which is the next process after the conceptual design process, there are 5 – 12 sketches that reveal confusion and a scattering of ideas. Each of these sketches show ideas going in different directions, but they do not relate to the purpose of design nor do they answer any design problems. As a result, the final design is not effective and features poor solutions to solving design problems.

Group 2 has6 participants who mostly ignore the conceptual design process and instead use inspiration to power their sketches. The samples of sketch design here number in a small amount, only about 1-6 sketches. In addition, the sketches are not diversified and have unvaried ideas. Thus, the final design is monotonous and effective and cannot solve any design problems.

Group 3 has 4 participants whose samples in this group use the conceptual design process and create design concepts within the sketch design process. There are 5-18 sketches that generate a variety of idea sketches and different design directions, which are related to the design's purpose. Most importantly, the final design is an efficient design and a good solution to design problems.

From the research's result of these3 groups, the data and details of 3 phases of the design process are compared as shown in fig 4.

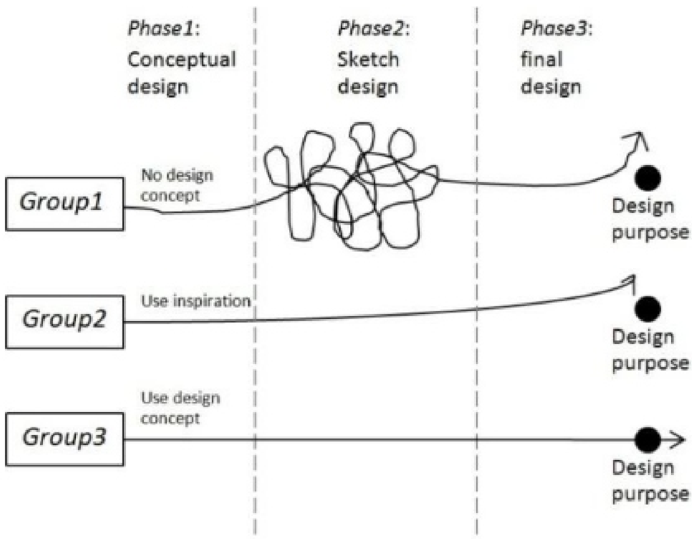

Fig.4Sample of sketch design and final design from group 1's design process diary

Comparison shows the difference in results after the conceptual design process. Group 3 used the conceptual design process. They can create a variety of sketches in the sketch design process and the final design can answer the design purpose. In contrast, with group 1 and group 2 the final design cannot meet the design purpose. Particularly, group 1is lost and confused in the sketch design process.

V. RESULT DISCUSSION

The results from data collection in the design process diary show design process, especially sketch design process and final design which are directly related to the conceptual design process. Moreover, the 3 groups of samples demonstrate different results. The results are as follows:

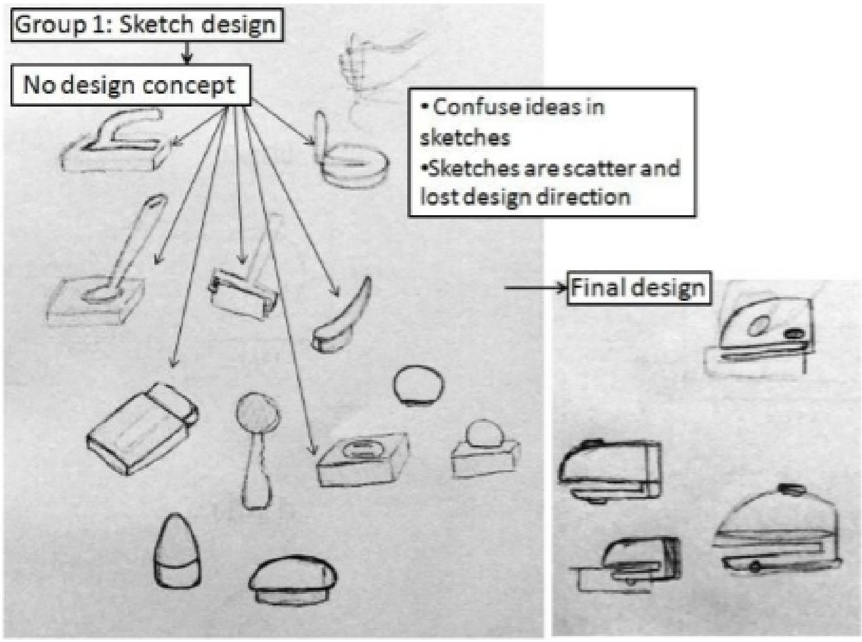

Fig.5Sample of sketch design and final design from group 1's design process diary

In fig.5, group 1 does not use conceptual design processes or design concepts. For this reason, the sketch design shows confused ideas from a very early stage. Moreover, the sketches are scattered and there are no directions in design or design concept, which in accordance with Vijay Kumar [6], should act as a way to organize and compile ideas into a system that is comparable to a framework that provides overview of the design. Therefore, the final design comes out ill-formed and proves to be ineffective in solving any design problem.

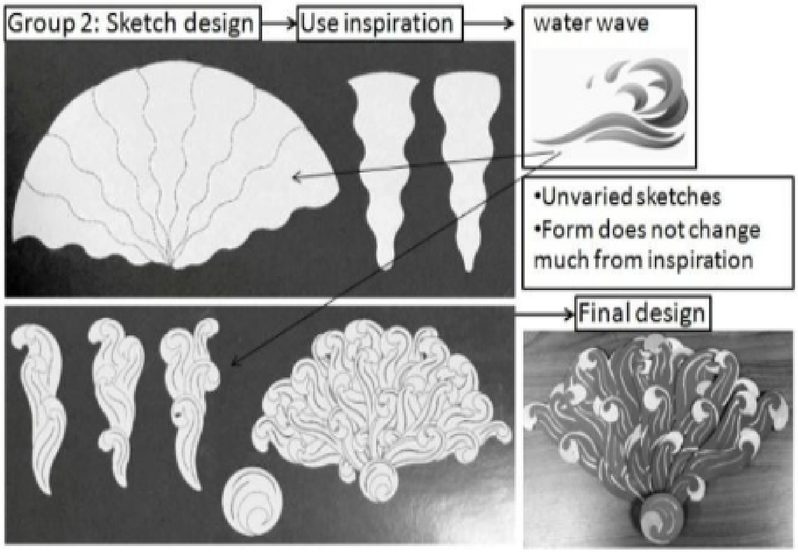

Fig.6Sample of sketch design and final design from group 2's design process diary

In fig 6, sketches of group 2 show the result of sketches that use water waves as inspiration. Inspiration is the cause of visual memory in the brain. The samples show a fundamental difficulty on the part of the designer to delete or remove the visual memory of inspiration from the design. As can be seen, the form and shape in the sketches do not change much from the initial phase of inspiration. The final result in the design is a certain redundancy, as it is too similar to the original inspiration and, as a result, focuses on form rather than function. The design ultimately cannot solve the design problem.

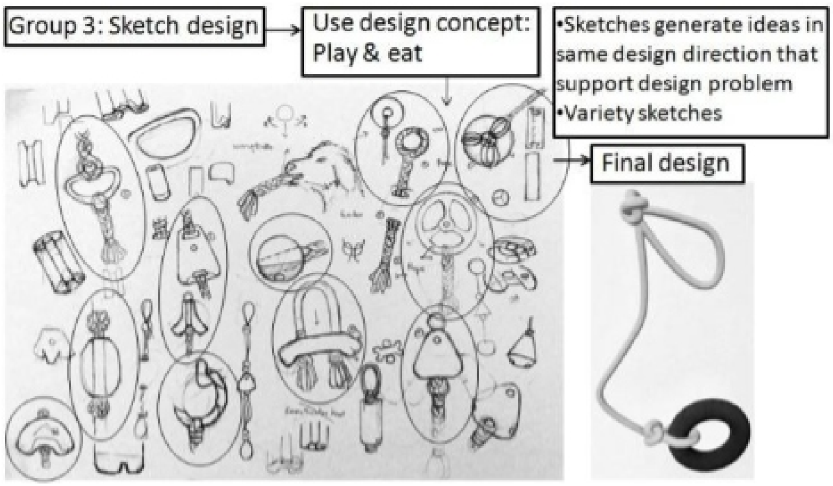

Fig.7Sample of sketch design and final design from group 3's design process diary

In Fig 7, group 3 is working on a design concept that is proving to generate good ideas in the sketch design phase. There are various sketches, but all of them are still pointed in the same design direction, intending to solve a specific design problem. The design concepts help the designer to target the design problem effectively[7].

CONCLUSIONS

By comparison, the data of these 3 groups show that conceptual design is an importance process that affects different phases of the design process. Thus, design concepts make the designer's work easier and help to organize ideas for use in design. It also reduces confusion in the generation of ideas which is a big problem for many design students. That is why the conceptual design process has such great importance in the product design process, something that students would do well to focus on a lot more in the future.

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Concept and Practice of Effective Buildings Maintenance Management through BIM Utilization: Dammam Metropolitan Area as A Case Study

[1] Mohammad B. Hamida, [2] Abdul- Mohsen Al- Hammad
[1,2]Architectural Engineering Department, King Fahd University of Petroleum and Minerals (KFUPM), Dhahran, Saudi Arabia
E-mail: [1]g201703050@kfupm.edu.sa, [2]amhammad@kfupm.edu.sa

ABSTRACT

Building Information Modeling (BIM) is considered as a strategy and technology that is significantly growing and involved in different phases of built environments projects such as design and construction. Recently, it has been enhanced in the occupancy phase, specifically Operation and Maintenance (O&M). It has offered various supports to the used maintenance information systems due to its visualization and integration. Thus, this paper aimed to present the effective maintenance management of buildings through the use of BIM tools and techniques, in addition to the assessment of the utilization of these tools and techniques in the industry by considering Dammam Metropolitan Area as case study. The followed approach in this paper was firstly started with identifying BIM tools and techniques contributing to accomplish effective maintenance management, then secondly conducting a survey questionnaire (n = 20) to assess the rate of using these tools techniques. The adopted method for evaluating the data was frequency analysis, and severity index. The study has revealed the followings: (1) BIM is representing a valuable tool for buildings' maintenance management due to its integrated modules as well as the 3D visualization; (2) based on the review of literature, 14 BIM tools and techniques are effectively utilized in the maintenance management of buildings, in which these tools and techniques they have been categorized under four elements; and (3) the assessment of these tools and techniques has found on one hand that the most utilized technique and always used was "computerized maintenance planning based on a set pf pre-acquired information", while on the other hand it has found that tools and techniques regarding to modeling of building and maintenance information in BIM platform were the lowest utilized tools and techniques. Accordingly, the authors have proposed a set of recommendations.

Keywords- BIM, Buildings, Maintenance Management, tools, techniques, Dammam Metropolitan Area.

I. INTRODUCTION

There are numerous of the advanced approaches and techniques for facilities maintenance management. One of these techniques is the Computerized Maintenance Management Systems (CMMS). CMMS is basically can be defined as the systems that provide the complete cycle of management information system for maintenance, starting from the requirements identification and ending on purchasing analysis and inventory control of the maintenance [1]. On the other hand, Building Information Modelling (BIM) is one of the advanced technologies that are growing recently, while the researches regarding to BIM in maintenance are relatively new [2]. It represents one of advanced means that provide an endless kind of 0s for constriction as well as facilities management projects. One of the main advantages of the BIM is the 3 dimensional view (3D) which is not offered in all CMMS [3]. In addition, the BIM provides an integrated model for endless building information and systems with the base of the visualization/ 3D view. Therefore, BIM could facilitate of maintenance works through providing an accurate planning, systematic implementation, and effective analysis tools which offer information relating to location as well as on a three-dimensional representation.

Review of previous reaches indicated that BIM is one of the new technologies that provide a supportive mean which facilitates the maintenance works in facilities [3],[2]. On the other side, the review also revealed that efforts of utilizing BIM technology in building maintenance is not unified yet among researchers. Hence, collection of these efforts would shape a perspective of the effective utilization of BIM in building's maintenance management. Unfortunately, the rate of using BIM in facilities maintenance management has not investigated yet in the national and international levels.

Consequently, the prime goal of this paper was to investigate the concept and real practices for the effectively used BIM tools and techniques for buildings' maintenance management, where the real practices were assessed by considering maintenance departments of Dammam Metropolitan Area in KSA as a case study. The accomplishment of the research goal has based on the following objectives:

1. To identify BIM tools and techniques that are effectively utilized in facilities maintenance management.
2. To assess the effective utilization of the BIM tools and techniques management of buildings in Dammam Metropolitan Area.

Regarding scope and limitation of the research, the present paper was a questionnaire-based, where the survey structuring has been depended on review of literature for relevant researches. Basically, the conducted review of literature has contributed to: create a theoretical background about BIM for buildings' maintenance management in general, as well as identify the BIM tools and techniques that are effectively utilized in buildings' maintenance management in particular. Hence, the survey was structured accordingly, and it has been distributed randomly among different maintenance departments in Dammam Metropolitan Area (comprising: Dammam, Khobar and Dhahran cities) of KSA.

II. METHODOLOGY

Overview

The adopted methodology in this paper was based on an approach consisted of three-main phases: input, process and output. Firstly, the input phase was a literature review for the three aspects below:

- Discussions and case studies about BIM in maintenance management
- Developed BIM applications and systems for maintenance management.
- Developed approaches for involving/using BIM in maintenance management.

Secondly, the process phase was consisted of five stages which were as follows:

- Identify BIM tools and techniques that are effectively utilized in maintenance management of buildings.
- Structure the survey accordingly to query about the rate of using the BIM tools and techniques in buildings' maintenance management in the study area.
- Distribute the questionnaire among different departments and experts of buildings' maintenance management in Dammam Metropolitan Area.
- Analyze findings of the survey using applicable statistical technique.

Finally, the output phase of the research has comprised of: formulating concluding remarks, and proposing recommendations for action plan. Fig.1. illustrates the followed research methodology.

Survey Structure

In overview, the survey has comprised 3 sections in which they have been indicated as section (A), (B), and (C) respectively.

Section (A) is regarding to general information of respondents. Therefore, it was developed to acquire the profile of respondents through asking key questions regarding to their personal information as well as professional practice.

These questions have comprised: name, organization, organization address, phone, email address, number of years' experience, respondent position, and verification for the use of BIM by the respondent.

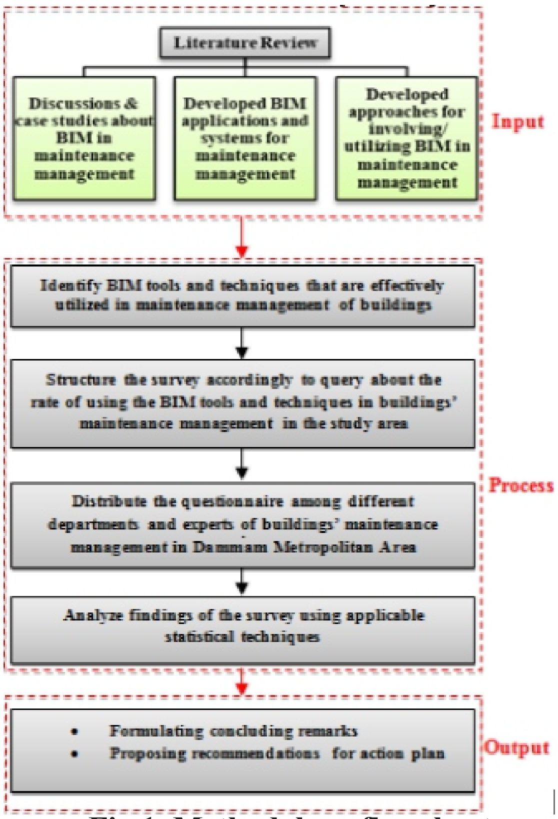


Fig.1. Methodology flowchart

Section (B) is representing the core part of the survey, because it has included the questions regarding to assessing the effective utilization of BIM tools and techniques in the maintenance management of buildings in Dammam Metropolitan Area. It has asked respondents to rate the frequency of utilizing 7 BIM tools and 7 BIM techniques (which have been categorized under four BIM elements) in buildings' maintenance management. The adopted scale for assessing the usage frequency rate of the various BIM tools and techniques was consisted of 5-point scales, in which they have been assigned the description as follows: always, often, sometimes, seldom and never respectively. Volume of use for each frequency rate has been assigned in percentages (See Section 2.3).

Section (C) is an optional section which allows respondents to state additional remarks and/or comments. It was provided in the end of the survey to enable respondent to conclude or add additional feedback according to what he/she has read and filled.

Data Analysis

Severity Index (SI) was the statistical technique used in this paper. It was calculated to investigate the usage rate of all tools and techniques, then the ranking of all tools and techniques was performed accordingly. A high SI for a tool/technique indicates that the tool/ technique has a high utilization rate.

$$\text{Severity Index (IS)} = \frac{(\sum_{i=0}^{4})(a_i)(X_i)}{(4\sum)(X_i)} \times 100$$

(Equation 1)

Where:

SI: is the Severity Index (utilization rate in this paper) in percentage.

a_i: is constant expressing weight given to i (the weight of each rate ranging from 0 to 4).

xi: is the variable expressing frequency of i (which is in number)

i: is the frequency rate (which is in 5-points scale).

As mentioned before that a specific volume (range in percentage) of the utilization rate has been assigned for each frequency rate, also similarly weighting of each frequency was also assigned through adopting the constant expressing weight for each frequency rate. In summary, Table 1 illustrate the assigned range and weight for each frequency rate.

Table 1: The assigned range and weight for each frequency rate

Rate of Frequency (The Scale Points)	Range of Frequency (%)	Weight of Frequency (Constant Expressing Weight)
(1) Always	76 – 100 %	4
(2) Often	51 – 75%	3
(3) Sometimes	26 – 50%	2
(4) Seldom	1 – 25%	1
(5) Never	0%	0

III. REVIEW OF LITERATURE

Based on a review of literature, the authors have identified 14 BIM tools and techniques that are effectively utilized in enhancing buildings' maintenance management. Hence, these tools and techniques have been categorized under four elements as below:

1. Maintenance Planning and Management.
2. Integrated BIM Modules and Systems.
3. Data and Information Management.
4. Pattern of Practicing the BIM in the Maintenance Management.

The first element (Maintenance Planning and Management) is basically encompassing tools/ techniques that are regarding to administering and planning of maintenance activities and resources based on available information. Hence, this element includes three techniques: maintenance planning, maintenance management, records of previous maintenance.

The second element (Integrated BIM modules and system) was categorized to be the element that comprises and coordinates different modules as well as systems in the BIM for maintenance management of building(s). Therefore, it includes: as-built 3d model of the building, module of external factors, module of building specifications/ description and conditions, module for saving information/ case- based reasoning, and integrating module for coordinating and searching of other modules and information. The third element (Data and Information Management) is the element that is responsible for offering, preserving and linking the basic-relevant information that are needed for the maintenance department/personal to manage the O&M effectively. This element encompasses the offering of the following two tools and one technique which are: design documents, operation documents and coordination between both documents design and operation.

The fourth element (Pattern of Practicing the BIM in the Maintenance Management) is regarding to the pattern of utilizing BIM in maintenance management of buildings. It includes three techniques: commitment in performing administrative tasks in the BIM, computerizing all implemented works in the system/ platform, and commitment in updating the computerized building information.

In summary, each element consists of a set of tools/techniques that are used in the building maintenance domain. Hence, each tool has a specific role seeking to fulfill the effectiveness in utilizing the BIM in buildings' maintenance management. Table 2 illustrates a brief description for the identified tools and techniques.

The authors have developed a conceptual model that illustrates the effective maintenance management through utilizing tools and techniques of BIM (Fig.2.). The model is basically a translation and representation of the correlations and relations among the identified tools and techniques.

Table 2: Brief explanation for the identified BIM tools and techniques that are effectively utilized in buildings maintenance management

Elements	Tools/ Techniques	Description
Maintenance Planning and Management	Computerized maintenance planning based on a set of pre-acquired information	Planning of maintenance and repair (M&R) based on a set of input data on the BIM (such as type of works, location of work and previous records) [3].
	Maintenance management through computerized monitoring and administration	Computerized tracking/monitoring and administration of maintenance through the 3D-BIM model [3],[5].
	Recording of previous maintenance works in 2D/3D representation	Historical records of implemented works of maintenance and repair are stored in the BIM through either 2D or 3D representations [3],[5].
Integrated BIM Modules and Systems	As-built 3D model of the building	Three-dimensional model of the building layout (as-built) [3],[5],[6],[7].
	Module for external factors (e.g. location)	Module of external factor such as building location and conditions of a building [5],[7].
	Module for building specifications/ description and conditions	Module of the building specifications such as construction systems and materials, and MEP's equipment [6], [7].
	Module for saving information/ Case-Based Reasoning (CBR)	Module for storing information and other related files, as well as to capture the knowledge of the maintenance professionals also [3],[5],[6].
	Integration module /system for combining, coordinating and searching of other models and information	Module that integrates all modules and systems, also offering tool for searching and access among all related modules [5],[8],[9].
Data and Information Management	Design documents and specification in BIM format	Having the original design documents and specifications[8].
	Operations documents in BIM format	Digitizing, grouping and arranging all as built drawings, that are needed for Operation and Maintenance (O&M), including technical information for Mechanical, Electrical and Plumbing systems (MEPs) [8],[7].
	Coordinate between design and operation documents	Coordinating database between both documents, design and operation [8].
Pattern of Practicing the BIM in the Maintenance Management	Commitment in performing administrative tasks in the BIM	Utilizing the BIM in all administrative works regarding to maintenance management, work orders and planning. [3],[5][6],[7].
	Computerizing/digitizing all implemented works in the system/platform	Recording all the works and information regarding to the maintenance in the software/system of the maintenance, in order to offer a history about maintenance for the department [3] [5],[6][5].
	Commitment in updating the computerized building information	Digitizing and updating as-built information including: specification, drawings, and systems technical information in the BIM. [3],[5],[6],[7].

IV. FINDINGS AND DISCUSSIONS

Respondents Profile

The questionnaire was distributed randomly among several maintenance departments in Dammam Metropolitan Area, where 20 samples were received and analyzed. Regarding to respondent's position, 15.0 % were manager of maintenance department, 10.0 % head of maintenance unit, 10.0 % facility manager, 20.0% maintenance engineer, and 45.0 % had other positions regarding to the building maintenance.

The other positions of respondents have differed, also had different job titles such as supervisor of facilities maintenance of a university, head of the supervision committee of projects of a university, mechanical engineer at maintenance department, supervisor of facilities maintenance and manager of maintenance contracts (Fig.3.).

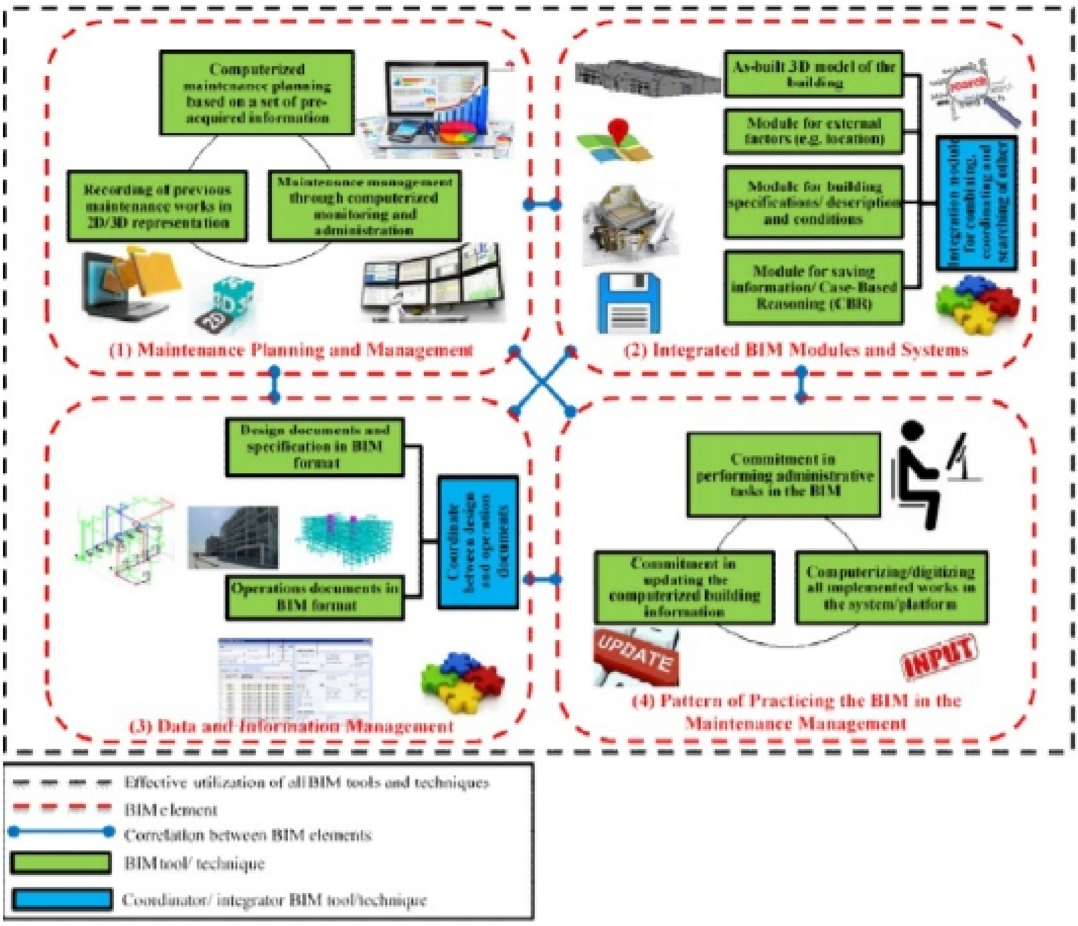


Fig.2. A conceptual model for the effective maintenance management through utilizing tools and techniques of BIM

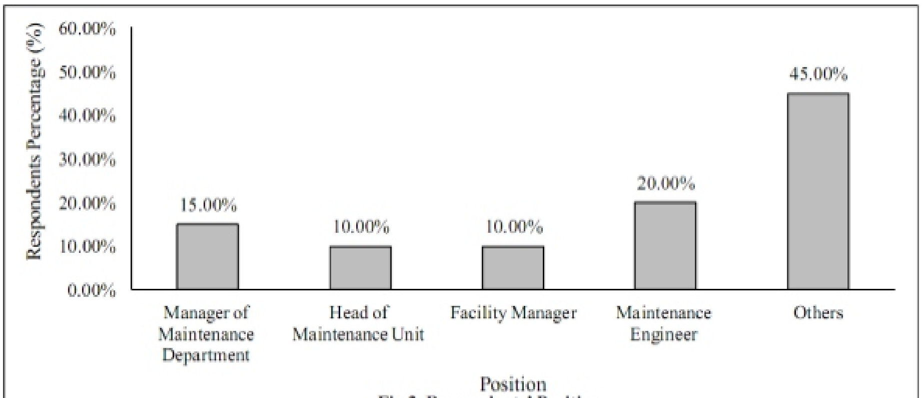


Fig.3. Respondents' Positions

Regarding to the number of years' experience for respondents, the survey found that respondents were varying in their years of experience. 35.0% had an experience of less than 5 years, 15.0% between 5 to 10 years, 30.0% between 10 to 20 years, and 20.0% had an experience of more than 20 years. Fig.4. illustrates the distribution of respondents among different rate of years' experience.

The survey has investigated that BIM is used in moderate rate among the respondents. This was determined from a question that verifies if respondents have used the BIM before or not. Hence,55.0% have answered "No, where 45.0% have answered "Yes" (Fig.5.a).

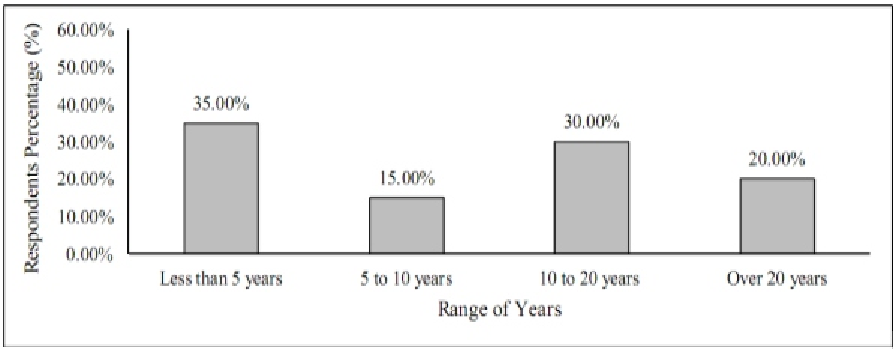
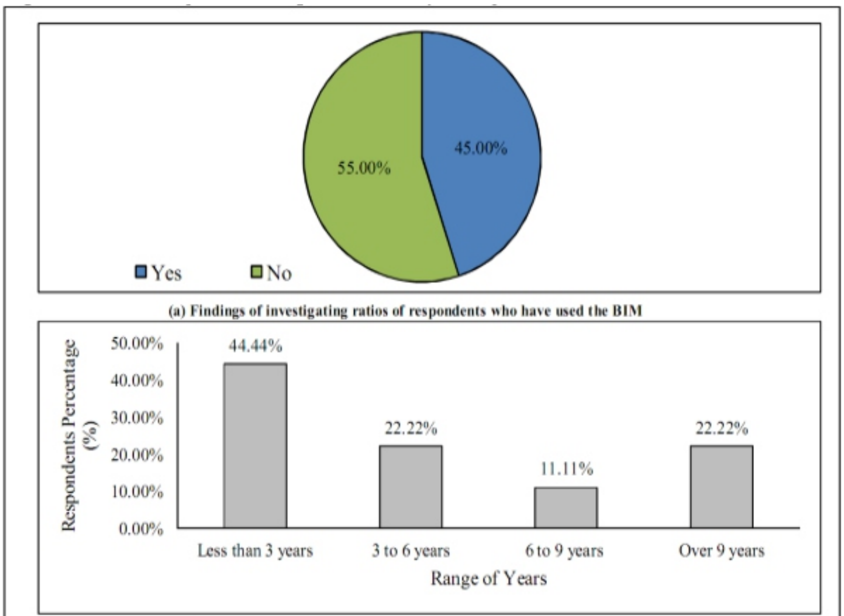


Fig.4. Distribution of respondents among different rate of years' experience



(a) Findings of investigating ratios of respondents who have used the BIM

(b) Number of years of experience in using BIM for respondent who have used it

Fig.5. Respondents' background with the BIM

This finding might be impressive because it indicates that close to the half of respondents who are working in maintenance field in the study area have previously used BIM.

On the other side, another question was asked those respondents who have used the BIM about the number of years of using the technology. It has revealed that 44.44% of them have used the BIM for a period of less than 3 years, 22.22% between 3 to 6 years, 11.11% between 6 to 9 years and 22.22% have used it for a period of more than 9 years. Fig.5. illustrates respondents' background with the BIM. In overview of the survey results, Table 3 presents findings of assessing the utilization rate of BIM tools and techniques in buildings' maintenance management in the region of study (Dammam Metropolitan Area). It has mentioned before that each frequency has assigned a specific weight and color, in which the blue is for "always" utilization, green for "often", yellow for "sometimes", orange for "seldom" and red for "never" use.

According to the calculated SI, it has found that only one technique that was used in a frequency rate of "always" which was the first tool. Most of the tools and techniques were "often used", in which 9 tools have fulfilled that frequency rate. Finally, four tools were used in frequency rate of "sometimes".

Maintenance Planning and Management

The assessment of the utilization of BIM techniques regarding to maintenance planning and management revealed that the first technique (computerized maintenance planning based on a set of pre-acquired information) got a utilization frequency rate of 76.25% which means it is always used. The second technique (maintenance management through computerized monitoring and administration) has fulfilled a utilization frequency rate of 55.00% which indicates it is often used. Finally, the third technique (recording of previous maintenance works in 2D/3D representation) has got a utilization frequency rate of 43.75% which reflects that it is used sometimes among the studied departments. Fig.6. illustrates the utilization rate of BIM tools relating to maintenance planning and management.

Integrated BIM Modules and Systems

The assessment of the utilization of BIM tools regarding to integrated BIM modules and systems revealed that the first tool (As-built 3D model of the building) fulfilled the lowest utilization frequency rate which was 43.75%. This means the 3D-model is sometimes used among the involved departments on this study.

On the other hand, the other four tools (module for external factors, Module for building specifications/ description and condition, Module for saving information/ Case-Based Reasoning (CBR), and integration module /system for combining, coordinating and searching of other models and information) have got a utilization frequency rate of often, in which they got the percentages of: 57.50%, 73.75%, 68.75%, and 52.50% respectively. Fig.7. illustrates the utilization rate of BIM tools relating to the integrated BIM modules and systems.

Data and Information Management

The assessment of the utilization of BIM tools and techniques regarding to data and information system revealed that the first tool (design documents and specification in BIM format) got a utilization frequency rate of 48.75% which was the lowest rate in the element of data and information management. This rate indicates it is sometimes utilized according to the assigned scales.

On the other side, the other second tool (operations documents in BIM format) and the technique of "coordinate between design and operation documents" have fulfilled a utilization frequency rate of 57.50% and 52.50% respectively. These rates indicate that both tool and technique are often utilized. Fig.8. illustrates the utilization rate of BIM tools and techniques relating to information and data management.

4.5 Pattern of Practicing the BIM in the Maintenance Management

The assessment of the utilization of BIM techniques regarding to pattern of practicing the BIM in the maintenance management found that the first technique (commitment in performing administrative tasks in the BIM) has fulfilled a utilization frequency rate of 42.50% which was the lowest rate in the element of pattern of practicing the BIM in the maintenance management. This rate indicates it is sometimes used.

However, the other two techniques (computerizing/digitizing all implemented works in the system/platform, commitment in updating the computerized building information) have got a utilization frequency rate of 71.25% and 65.00% respectively Hence, these rates indicate that both techniques are often utilized according to the assigned scale. Fig.9. illustrates the utilization rate of BIM techniques relating to pattern of practicing the BIM in maintenance management.

Summary of Findings

As summary of results, utilization of BIM tools and techniques among the involved departments and experts in this paper was generally above the moderate level. The followings are the summarized findings:

- For maintenance planning and management element, 1 technique was always used, 1 often, and 1 was sometimes used respectively.
- Regarding to the element of integrated BIM modules, 1 tool was sometimes used, while the other 4 tools were often used.
- In regard to data and information management element, 1 tool was sometimes used, 1 tool was often used and similarly 1 technique was often used.
- For the element of pattern of practicing the BIM in the maintenance management, it has found that 1 technique was sometimes used, while the other 2 techniques were often used.

Table 3: Findings of assessing the utilization rate of BIM tools and techniques in buildings' maintenance management in the region of study (Dammam Metropolitan Area)

Elements	Tools/Techniques	Rate of Frequency					Total	Analysis	
		Always	Often	Sometimes	Seldom	Never		Severity Index "Rate of Utilization" (%)	Rank
(1) Maintenance Planning and Management	Computerized maintenance planning based on a set of pre-acquired information	12	2	3	1	2	20	76.25%	1
	Maintenance management through computerized monitoring and administration	6	3	4	3	4	20	55.00%	8
	Recording of previous maintenance works in 2D/3D representation	6	1	3	2	8	20	43.75%	12
(2) Integrated BIM Modules and Systems	As-built 3D model of the building	4	3	3	4	6	20	43.75%	12
	Module for external factors (e.g. location)	8	3	1	3	5	20	57.50%	6
	Module for building specifications/ description and conditions	8	6	4	1	1	20	73.75%	2
	Module for saving information/ Case-Based Reasoning (CBR)	9	4	3	1	3	20	68.75%	4
	Integration module /system for combining, coordinating and searching of other models and information	6	3	3	3	5	20	52.50%	9
(3) Data and Information Management	Design documents and specification in BIM format	5	2	5	3	5	20	48.75%	11
	Operations documents in BIM format	7	4	1	4	4	20	57.50%	6
	Coordinate between design and operation documents	6	4	2	2	6	20	52.50%	9
(4) Pattern of Practicing the BIM in the Maintenance Management	Commitment in performing administrative tasks in the BIM	4	5	1	1	9	20	42.50%	14
	Computerizing/digitizing all implemented works in the system/platform	10	3	3	2	2	20	71.25%	3
	Commitment in updating the computerized building information	8	5	2	1	4	20	65.00%	5

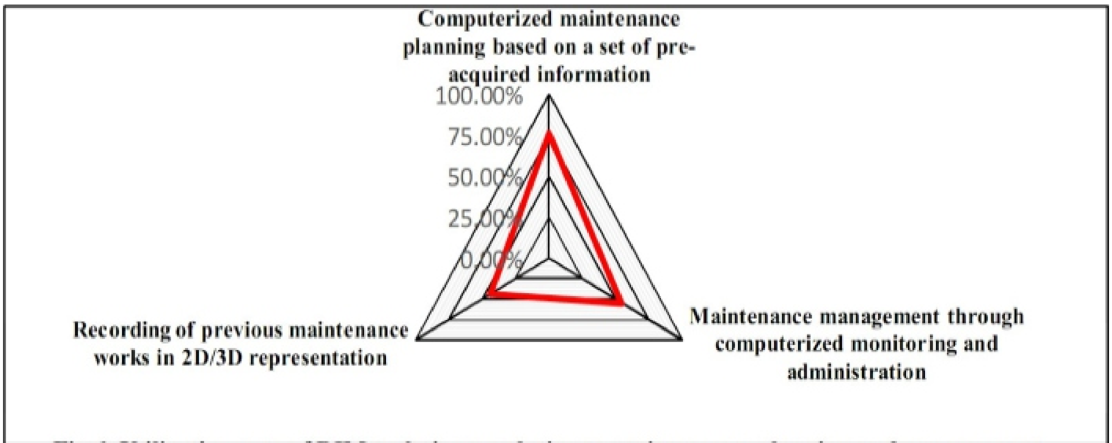


Fig.6. Utilization rate of BIM techniques relating to maintenance planning and management

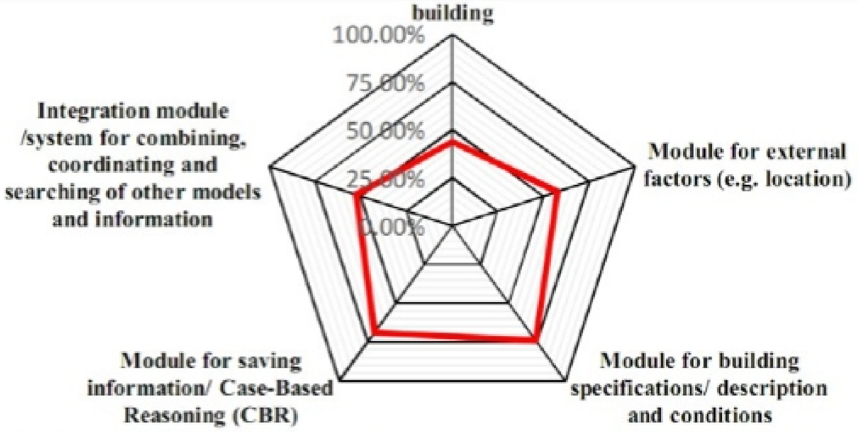


Fig.7. Utilization rate of BIM tools relating to the integrated BIM modules and systems

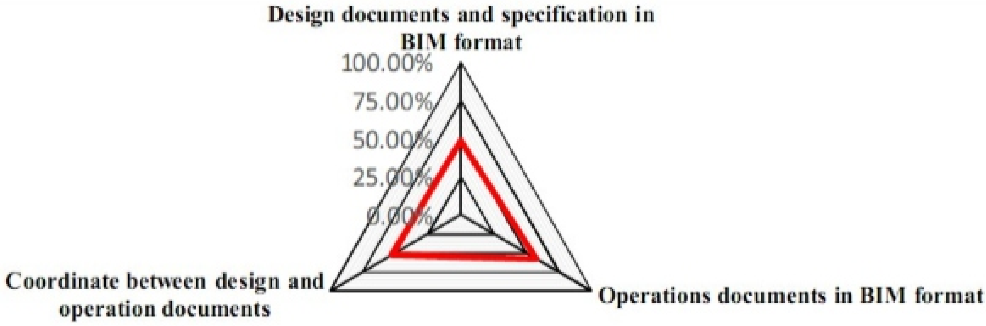


Fig.8. Utilization rate of BIM tools and techniques relating to information and data management

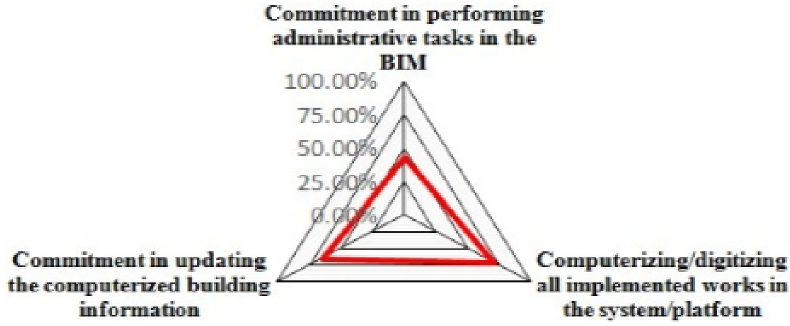


Fig.9. Utilization rate of BIM techniques relating to pattern of practicing the BIM in maintenance management

CONCLUSIONS

Concluding Remarks

Base on the performed review of literature and the conducted survey in this paper, the followings are the main outcomes of the research:

1. BIM is representing a valuable mean and strategy to enhance buildings' maintenance management due to its integrated modules as well as the 3D visualization.
2. Based on review of literature, the authors have identified 14 BIM tools and techniques which are effectively used in buildings maintenance management, in which they have been categorized under four elements according to the relevant relation among the tools/techniques.
3. The assessment of the 14 tools and techniques in Dammam Metropolitan Area has revealed that the most utilized technique was "computerized maintenance planning based on a set of pre-acquired information" in which it is used in a frequency rate of "always", while "module for building specifications/ description and conditions" was the tool in second rank in its utilization rate in which it is used in a frequency rate of "often".
4. Also, the assessment has revealed that tools and techniques regarding to modeling of building and maintenance information in BIM platform were the lowest utilized tools and techniques and they are utilized in a frequency rate of "sometimes".

RECOMMENDATIONS

According to the outcomes of the study, the followings recommendations have been proposed:

1. Enhancing and emphasizing the involvement of BIM tools and techniques in the departments of buildings maintenance.
2. Develop holistic guidelines/instructions about the used methods of the BIM in buildings maintenance management.
3. Establish a systematic framework/approach for the effective utilization of BIM tools and techniques for the activities relating to buildings maintenance management, in order to unify efforts through that.

ACKNOWLEDGMENTS

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A New Approach for Analyzing Connectivity in Atria

[1] Alagamy S., [2]Al- Hagla K., [3] Anany Y., [4] Raslan R.
[1,2,3]Alexandria University, Faculty of Engineering, Architectural Department, Alexandria, Egypt
E-mail: [1]asherinealagamy11@gmail.com, [2]bkhalid@pylon-group.com, [3]cdrenany@hotmail.com, [4]drania.raslan@gmail.com

ABSTRACT

Traditional observation analysis techniques are widely used by researchers to analyze public spaces, in terms of visibility, and movement patterns. This paper focuses on developing a new methodology for evaluating and analyzing visual and physical connectivity inside atrium spaces using two different techniques. It was conducted using a hybrid system of analysis, which merges traditional observation analysis technique, with Space Syntax analysis using Depthmap software. Both analysis techniques were applied on two atria inside "City Stars Mall" shopping center, located in Cairo city. The first atrium has a larger scale, while the second has a smaller scale. The study highlights the importance of applying Depthmap analysis technique along with observation method to assist and validate the results. Results show that Depthmap analysis technique is better in smaller scaled atrium spaces, while observation is more realistic in larger scaled spaces. However, the paper proves that in order to reach a clear and accurate analysis, both techniques must be applied together for accurate and reliable results.

Index Terms- Atrium, Observation, Depthmap, Connectivity.

I. INTRODUCTION

Atria play an essential role in enhancing the interior of public buildings, and connecting different spaces from different floor levels, both visually and physically. They also primarily act as places for orientation and circulation, and strengthen the visual coherence of a building. In Lazaridou's research (2013), about Ashmolean museum atrium, she mentioned that "Their strategic locations constitute them as gravity points which draw people to the deeper part of the museum; opening up its spatial structure for them to explore visually and decide on their horizontal or vertical movement".

On-site observations and Depthmap software analyses are used to evaluate visual and physical connectivity inside atria. Observation technique is widely used by researchers to investigate connectivity inside public building spaces like atria. However, Space Syntax techniques using Depthmap is used to assist with traditional observation techniques. Researchers turned to space syntax analysis methods because, although observation allows the researcher to gain a realistic understanding about the environment and the users of the space, Depthmap is a more accurate tool than observation.

The paper addresses the different types of analysis techniques of connectivity inside atria. The main aim is to review the advantages and limitations of each technique separately when applied on connectivity and, eventually, develop a hybrid system that merges both techniques to accurately analyze connectivity inside the atrium. The analyses were applied on two atria in the same building which differ in scale, in order to know the effect of changing space characteristics on the results of each method. Results from both techniques are compared with theoretical data and previous research outcomes.

II. ANALYZING CONNECTIVITY USING OBSERVATION TECHNIQUE

Analyzing connectivity using observation technique involves studying visibility and permeability inside the space through on-site observations, and evaluating how successful they are in fulfilling user needs. Zeisel (2006) describes this method as "systematically looking at physical surroundings to find reflections of previous activity that was not produced in order to be measured by researchers. Traces may have been unconsciously left behind (for example paths across a field), or they may be conscious changes people have made in their surroundings." (Zeisel, 2006).

Through observation, it is possible to determine realistic visibility relations and movement patterns inside the space, and predict specific factors that aid or interfere with visual and physical connectivity patterns. Observation is "used as a way to increase the validity of the study, as observations may help the researcher have a better understanding of the context and phenomenon under study" (DeWalt, DeWalt, 2002). Observation techniques also allow the observer to "check for how much time is spent on various activities" (Schmuck, 1997).

However, Observation "is conducted by a biased human who serves as the instrument for data collection" (Kawulich, 2005). Therefore, sometimes it may lack accuracy and have errors. Kawulich also mentioned that "The quality of the participant observation depends upon the skill of the researcher to observe, document, and interpret what has been observed. "It is important in the early stages of the research process for the researcher to make accurate observation field notes without imposing preconceived categories from the researcher's theoretical perspective, but allow them to emerge from the community under study" (Kawulich, 2005).

Aydogan and Salgamcioglu (2017), in their paper about User Behavior in Shopping malls, used observation analysis technique to undertake a comparative study between two shopping malls. The observations disclosed that users mainly flow through the spaces that were at the same direction with their walking route, and they did not tend to deviate to corridors out of their directions whereas this situation was ascertained with last studies, people tend to walk straight and not to turn at the edges (Dalton, 2001). This conclusion is not accurate though, which required more accurate analysis technique to validate these results like Depthmap software.

III. ANALYZING CONNECTIVITY USING DEPTHMAP ANALYSIS TECHNIQUE

Depthmap software is a tool that studies visual and physical connectivity inside a space, by determining visual and physical relations between different locations in the space. Noah (2009) held several interviews with software users. It was found that some "acknowledged that space syntax's strength is its ability to objectively measure spatial structure and relationships". However, other people argued that the terms used in space syntax "such as "integration" and "choice" represent abstract topological relationships, not physical objects that people can see and experience directly".

It is suggested that "people tended to center upon the places with high connectivity while low connected places tended to be less used" (Nubani & Wineman, 2005). Depthmap accurately determines areas with high and low circulation patterns. Hillier (1996) also mentioned that “related spaces, almost by definition, cannot be seen all at once, but require movement from one to another to experience the whole". This particularly relates to atrium spaces. The reason why Isovist fields are very important to determine fields of view of a specific user route.

Visibility and accessibility inside an atrium needs to be determined between ground floor and upper floor levels not just in the bottom floor, and Depthmap is a multi-layered analysis technique. Marriage and Bakshi (2013), in their paper, suggested that "methods of analysis involving three-dimensional multi-level spaces such as atria are not reliably informative using two-dimensional analysis tools, and analysis of plans is not enough for understanding complexity and connectivity within a three-dimensional space". Therefore the analysis was not only applied on plans, but also on sections for the results to be more reliable.

IV. COMPARISON BETWEEN THE TWO TECHNIQUES


(a)


(b)

Fig. 1. Interior images of the two Atriums: (a) Atrium A, (b) Atrium B. There is a clear difference in scale between A and B.

Depthmap analysis depends primarily on spatial configuration and visual and physical obstacles inside the space, however, other factors may have significant effects and may affect the results greatly. These factors can only be determined using observation technique. Aydogan and Salgamcioglu (2017) suggest that "Other factors like types and quantity of stores, a temporary activity, having a target product that is making an attraction etc. could sometimes be more effective than spatial configuration", which makes observation technique a more realistic method than Depthmap.

On the other hand, Depthmap technique has some advantages over observation technique. Lazaridou (2013) used observation, as well as Depthmap analysis in her paper, mentioned about atria that, "they are intended to aid the exploration of the three-dimensional visual relations through the extensive use of transparent, semi-transparent and opaque surfaces in its design". A more accurate analysis of connectivity is determined using.

Depthmap analysis because it is able to accurately identify areas with transparent or opaque surfaces, However, observation technique only identifies general data about visibility through different types of surfaces, which is identified by the researcher. El Dessouki (2015) argues that "Different space configurations produce different patterns of visibility and accessibility interplay", which is only accurately identified using depthmap.

Moreover, the fact that the atrium is a 3 dimensional space, requires the analysis taking place to be applied horizontally as well as vertically. Depthmap is a multi-layered analysis technique which allows the users to analyze space vertically and horizontally, using the plan and the section of the atrium through several analysis methods . This increases its accuracy and makes it a more professional and accurate method of analysis than a single-layered analysis technique such as observation. In which the researcher observes and takes notes about connectivity. The data from observation is not accurate like the data retrieved from Depthmap as it is determined from the researcher's point of view.

V. A STUDY OF THE EFFECT OF ATRIUM SCALE ON CONNECTIVITY INSIDE CITY STARS MALLATRIA

City Stars Mall has 3 main atria called A, B, and C. Two of which were studied in terms of the effect of visual and physical connectivity. Atrium A, and B where specifically chosen because they have similar space characteristics and nature, and they only vary in scale. Atrium A is significantly larger and has a monumental scale compared to atrium B, which has a smaller scale. The following study is an integrated research method, which involves two methods of analysis applied on atriums A and B. The first is Observation method and the second is analysis using Depthmap software. Data gathered from both studies were then compared.

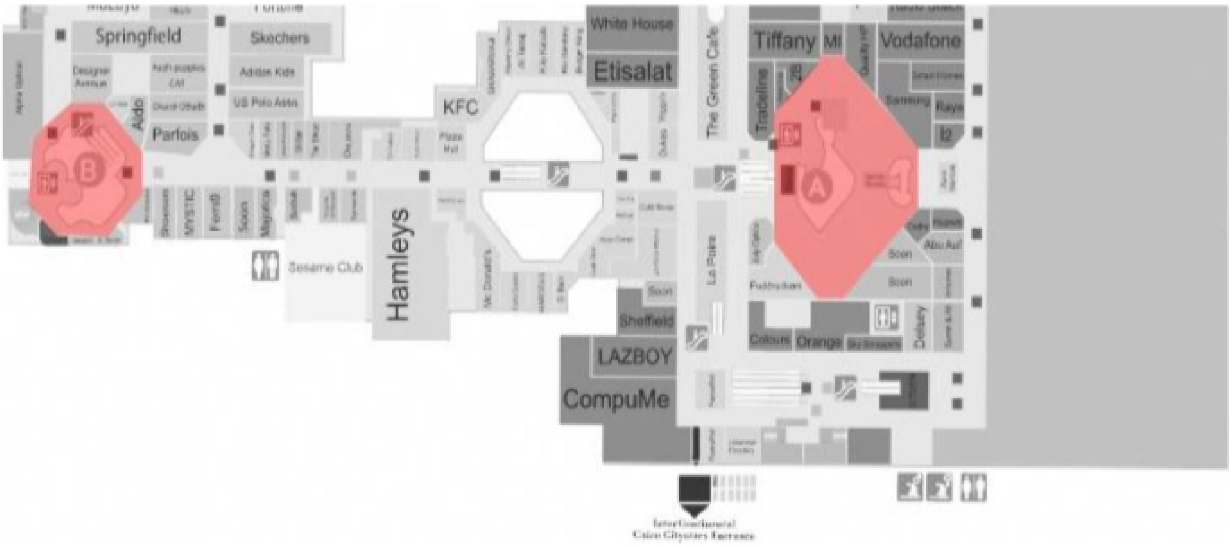

Fig. 1. Part of the first floor map of City Stars Mall. Atrium A on the right (starts at first floor), atrium B on the left (starts at groun floor).

Study1: Observation Method

a) Atrium (A):

The first atrium is a large-sized , irregularly shaped, central atrium with a monumental scale. Comprised of six upper floors, and has two access points from two opposite sides of the atrium. The atrium fulfills the basic requirements for a successful atrium design. The bottom floor is at the first floor level of the mall. It has significant green areas and a stage, designed to hold any activities taking place within the space. It also has cafe's, and plenty of seating areas surrounding them. The space is surrounded by restaurants and shops, as well as services, which serves the atrium. The atrium has plenty of daylight admitted through the large area of the above skylight. Balconies, and walkways with glass handrails surround the space at upper floors levels.

Data gathered from observation shows that some obstacles block while others helped in enhancing visual and physical connectivity inside atrium A, shown in tables (I) and (II). Examples of obstacles that block visibility are columns, cafe partitions, elevators, and stairs. Other factors that enhance visual connectivity within the atrium include glass walls of the surrounding spaces, which results in strong visibility between the space and surrounding shops. The glass handrails surrounding upper floors also strongly assist visibility between the bottom and upper floors. Moreover, the transparency of elevators, results in strong visual connection between elevator users and the space. There are more obstacles that significantly affect movement and circulation like columns, cafe partitions, fixed, and temporary seating areas, stairs, elevators, and green areas. They occupy a significant portion of the space, leaving less areas for circulation.

Table I Factors affecting visual connectivity in atrium A.

Factor	Indicator	Effect on Connectivity
Obstacles	Palm trees,Columns, Partitions, Stairs , elevators	Palm trees and columns partially block visibility inside the atrium, while partitions fully block visibility to areas behind it
Boundaries (Glazed Surfaces)	Panoramic elevators Surrounding spaces	Strong visibility between the atrium space and elevators as well as surrounding shops
Boundaries (Glass handrails)	Cafes, Stairs, Upper floor corridors, Balconies	Strong visibility between different spaces in the atrium , and between the atrium space and upper floors.
Layout	Octagonal	Dynamic layout is visually interesting.
Lighting	Daylighting	Visibility enhanced by natural lighting
Location	Central	No visibility to exterior only interior.
Complexity	Complex space	Visually exciting, vital space.

Table I Factors affecting physical connectivity in atrium A.

Factor	Indicator	Effect on Connectivity
Obstacles	Columns, Partitions Fixed/temporary seating Stairs , Elevators	Columns, and temporary furniture partially interferes with the circulation, while fixed furniture, elevators, stairs, and partitions strongly affects circulation inside the atrium.
Layout	Dynamic	Dynamic layout resulted in a dynamic space (more circulation).
handrails	Cafes, Solid handrail , Stage Green areas	The stage, green areas, and handrails surrounding cafes and circulation elements also affects circulation inside the atrium.
Furniture	Fixed/ temporary furniture	Furniture interfered with circulation inside the space.
Scale	Monumental scale	Hardest to navigate
Lighting	Highest daylight	Better visibility, and better navigation

a) Atrium (B):

The second atrium has a smaller scale than atrium (A). The atrium also has an irregular layout, and is comprised of four upper floors. It has less daylight, than the first atrium, entering through the above skylight, it also has limited green areas. The ground floor level of the atrium has escalators extending to lower floor levels, while stairs and elevators are placed at one side of the atrium. The atrium also has cafe' partitions like atrium A. The space is surrounded by restaurants at ground floor level. Balconies, and walkways with glass handrails surround the space at upper the floors.

There are also some obstacles that block or enhance visibility and permeability inside this atrium, shown in tables (III) and (IV), such as columns, partitions, elevators, stairs, and escalators block visibility, while glass walls of the surrounding spaces result in strong visibility between the space and surrounding shops. The panoramic elevators also result in strong visual connectivity between elevator users and the space. Moreover, the glass handrails surrounding upper floors, strongly assists visual connectivity between bottom floor and upper floor levels. Obstacles that affect movement include columns, fixed seating areas, stairs, elevators, and escalators. These obstacles significantly interfere with movement and circulation, as they take a significant portion of the space, leaving less areas for movement inside the space, and block circulation around the area they occupy.

Table II Factors affecting visual connectivity in atrium B.

Factor	Indicator	Effect on Connectivity
Obstacles	Escalators, Columns	Columns partially block visibility inside the atrium, while elevators fully block visibility to areas behind it
Boundaries (Glazed Surfaces)	Panoramic elevators Surrounding walls	Strong visibility between the atrium space and elevators as well as surrounding shops
Boundaries (Glass handrails)	Escalators, Stairs, Upper floor corridors, Balconies	Strong visibility between different spaces in the atrium , and between ground and upper floors.
Layout	Triangular	Dynamic layout is visually interesting.
Lighting	Less daylighting	Less visual connectivity
Location	Corner	No visibility to exterior only interior
Complexity	Complex space	Visually exciting, vital space.

III Factors affecting physical connectivity in atrium B.

Factor	Indicator	Effect on Connectivity
Obstacles	Columns, Fixed/temporary seating, Stairs , Elevators, Escalators	Columns, and temporary furniture partially interferes with the circulation, while fixed furniture, elevators, stairs, and partitions strongly affects circulation inside the atrium.
Layout	Static	Static layout resulted in a static space (less circulation).
handrails	Solid handrail , Glass handrails	Physical connectivity affected by solid and glass handrails.
Furniture	Fixed, and temporary, furniture	Furniture interfered with circulation inside the space.
Scale	Normal scale	Easiest navigation.
Lighting	Lowest daylight	Less physical connectivity

a) Findings of observation method:

After studying both atria, it is concluded that atrium A is a well connected space, with stronger visual connectivity than atrium B. In the bottom floor level, both atria have similar boundaries surrounding the space, therefore, both have strong visibility to the surrounding spaces. Moreover, similar obstacles were found in both atria, however, areas with low visual connectivity , like those behind stairs elevators, and columns, in relation to the whole floor area are less in A than B, due to its larger scale, and floor area. In addition, there are no escalators interfering with visibility inside atrium A, unlike B, where escalators coming from upper floors project through the space, blocking visibility significantly.

Several facts can also be drawn about Physical connectivity. In general, both atria proved to be a key element of circulation, and an essential link between the several parts of the building, providing a key route for users circulating the space. In addition, both atria have similar access to stairs, and elevators. Some obstacles were observed and have an effect on both atria to different extents. However, movement and circulation within the space is better in atrium A than B, due to the larger floor area, so there are less areas available for users to move and circulate inside atrium B than A. In addition, more services like restaurants and shops surround atrium A than B, which enhances movement patterns in atrium A.

B. Study 2: Depthmap Analysis

This type of analysis is done using Depthmap software, which was used to analyze both visual, and physical connectivity inside the space through several methods of analysis. There are three types of analysis applied. Visibility Graph Analysis (VGA), and Isovist fields were used to analyze visual connectivity. VGA is represented using color codes while isovists are represented by overlaying several visual field layers taken from separate points within the space. The third type of analysis is Agent based analysis which analyzes circulation patterns inside the space also using color codes to distinguish areas with with high and low physical connectivity.

a) Atrium A:

Figure (3) shows visibility graph analysis applied on the plan and section of the atrium. The analysis of the plan shows a significant area with very strong visual connectivity, trapped between the columns surrounding the space, illustrated by a red color. This area have highest visibility, and is called a hotspot. There are also less areas with medium connectivity represented by an orange color. Elevators and stairs on the left, the partition on the right, and the columns weakened visual connectivity in the areas behind them. Visibility between these locations and any location within the atrium is very weak. The VGA applied on the section shows very strong visual connectivity also illustrated by the red and orange colors, because no elements block visibility between the bottom, and upper floors.

At the bottom level of the atrium, the Isovist fields, shown in figure 4(a) taken from different locations show that the central part, between barriers like columns, stairs and elevators, represented by dark blue color, is the most visible, while areas behind stairs, elevators and partitions have weak visibility. Stairs and elevators appear to be highly visible from any location inside the atrium space, but they block visibility for areas behind them. The section also shows very strong visual connectivity between any point within the bottom floor level and upper floor levels. In addition to this, the section also shows very high visibility to and from the panoramic elevator, which are very effective in enhancing the physical connectivity between different floor levels.

Figure 4(b) shows traces of the possible routes taken by 100 users circulating the space for 15 minutes. The results show traces ranging from red to blue colors. As illustrated in the plan, a large red area is found in the space between the physical obstacles found inside the space. The red area also extends behind stairs and elevators from side and connects to the same red area on the other side. These are the areas with highest accessibility (hotspots), and strongest physical connectivity, and actual users are believed to move within these areas the most. The rest of the plan hasless, scattered blue/green areas. These are the areas with lowest accessibility, and weakest physical connectivity. The following are the traces obtained from Agent-based analysis applied on atrium A.

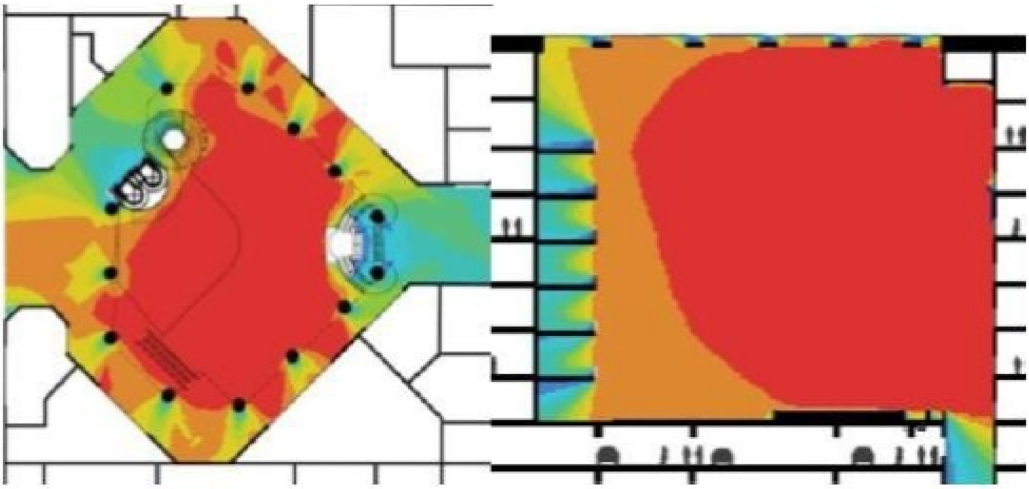

Fig. 2. Graph Analysis of atrium A applied on plan and section.

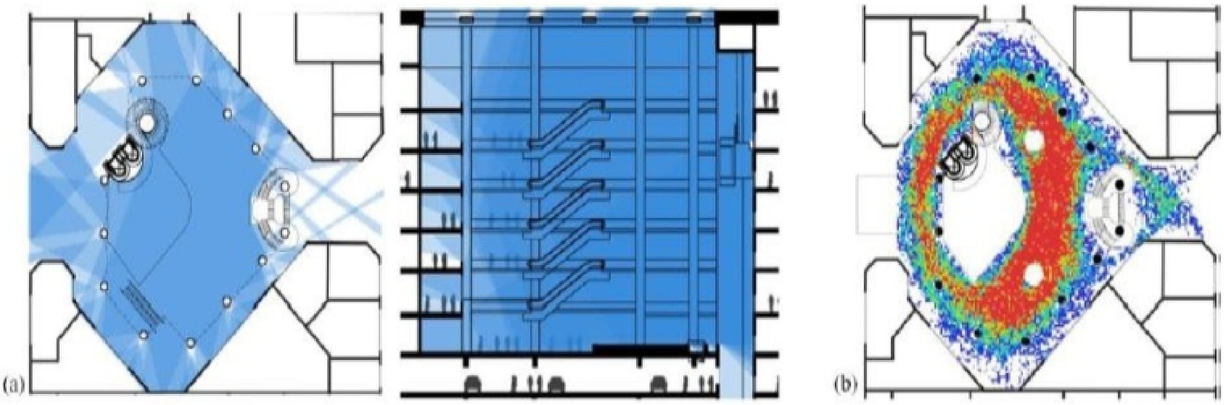

Fig. 3. (a) Isovist fields of plan and section from different locations inside the atrium, (b) Agent-based analysis.

a) Atrium B:

Figure (5) shows visibility graph analysis of the plan and section of the atrium. The analysis of the plan shows a significantly large area with very strong visual connectivity, bounded by the visual obstacles found within the space, illustrated by a red color. There is also a significant area with medium visual connectivity represented by an orange color. Elevators and stairs at the bottom left side weakened visual connectivity in the areas behind them. Visibility between these locations and any location within the atrium is very weak. The VGA applied on the section shows very strong visual connectivity between bottom and upper floor plans.

Isovist fields, shown in figure 6(a), were also applied on the plan as well as the section, to show visual fields from different locations inside the atrium. At the bottom floor level of the atrium, the isovist fields taken from different locations show that the area trapped between barriers like stairs, elevators, columns and escalators, is the most visible, and areas behind these obstacles have the weakest visual connectivity. Very strong visual connectivity is found at elevators, stairs and escalators, visibility to these elements is strong from any location inside the atrium. The section on the right also shows very strong visual connectivity vertically between any two points in the atrium.

a) Atrium B:

Figure (5) shows visibility graph analysis of the plan and section of the atrium. The analysis of the plan shows a significantly large area with very strong visual connectivity, bounded by the visual obstacles found within the space, illustrated by a red color. There is also a significant area with medium visual connectivity represented by an orange color. Elevators and stairs at the bottom left side weakened visual connectivity in the areas behind them. Visibility between these locations and any location within the atrium is very weak. The VGA applied on the section shows very strong visual connectivity between bottom and upper floor plans.

Isovist fields, shown in figure 6(a), were also applied on the plan as well as the section, to show visual fields from different locations inside the atrium. At the bottom floor level of the atrium, the isovist fields taken from different locations show that the area trapped between barriers like stairs, elevators, columns and escalators, is the most visible, and areas behind these obstacles have the weakest visual connectivity. Very strong visual connectivity is found at elevators, stairs and escalators, visibility to these elements is strong from any location inside the atrium. The section on the right also shows very strong visual connectivity vertically between any two points in the atrium.

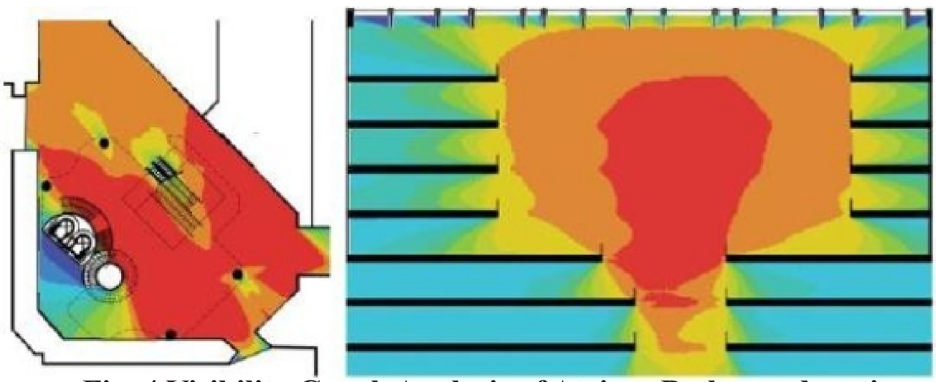

Fig. 4 Visibility Graph Analysis of Atrium B plan and section.

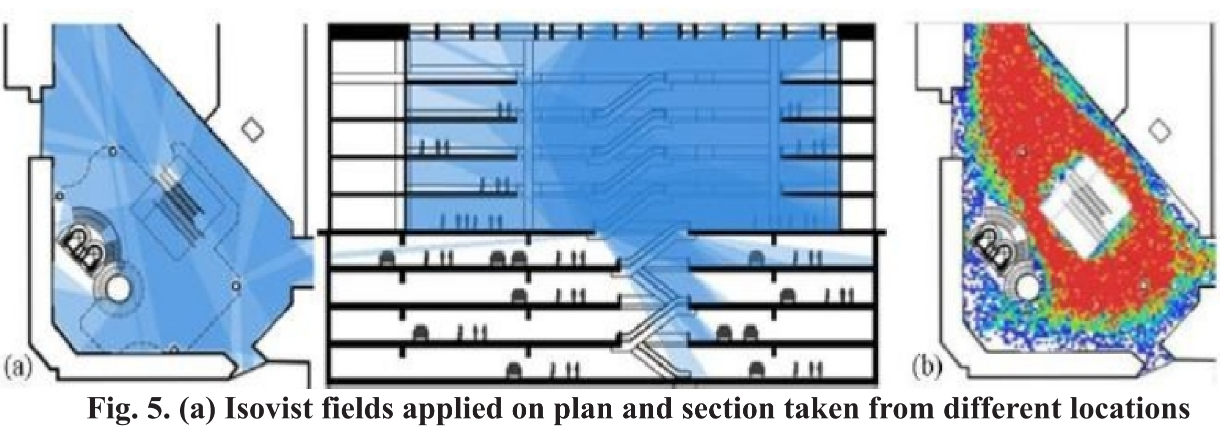

Fig. 5. (a) Isovist fields applied on plan and section taken from different locations inside atrium B, (b) Agent-based Analysis.

Agent-based analysis, shown in figure 6(b), shows traces of the possible routes taken by 100 users circulating the atrium for 15 minutes. The results show traces ranging from red to blue colors. As illustrated in the plan, a large red area (hotspot) is also found in the space between the physical obstacles inside the space. This area has highest accessibility, and strongest physical connectivity, and actual users are believed to move within this region the most. The rest of the plan has less, scattered blue/green areas. These are the areas with lowest accessibility, and weakest physical connectivity. Analysis shows that the space is easily navigable (no blank areas).

a) Findings of Depthmap analysis:

After analyzing visual and physical connectivity inside both atria using Depthmap, several conclusions can be drawn. In general, the results of Visibility graph analysis, and Isovist fields applied on the plans and sections of both atria show that the overall visual connectivity is better in atrium A than atrium B. In addition to this, traces of Agent-based analysis show that atrium A has very strong physical connectivity, but atrium B is more easily navigable, and that is because traces of agents filled the space in the same time with no blank spaces, unlike atrium A, in which the analysis showed some blank areas.

Conclusions about the Visibility Graph Analysis and Isovist fields showed that atrium A has stronger visual connectivity than atrium B. By comparing results of VGA in both atria, it is noticed that more areas with very strong visual connectivity are found in atrium A. In addition to this, although both atria had similar barriers, visual connectivity in atrium B was affected to a larger extent than atrium A, because atrium B had less floor area than A, due to its smaller scale. By comparing Visibility Graph Analysis applied on the section of both Atria, atrium A has better visual connectivity between the bottom floor level and upper floors than B, represented by a larger red area.

Agent-based analysis was applied to both atria with the same number of agents, 100 agents, and were left to circulate the space for the same amount of time, 15 minutes. By comparing agent traces, atrium B traces covered the whole floor plan, while atrium A had some blank areas. This shows that atrium B is more easily navigable, which means that it is circulated in less amount of time, than atrium A. However, both atria showed strong physical connectivity, but stronger physical connectivity was found in atrium A.

CONCLUSION

In conclusion, after applying both techniques on the two atria, it is obvious that each method had its own strengths and weaknesses. Observation technique allows the observer to experience the atrium space, and have access to real situations inside the atrium. On the other hand, Depthmap is more accurate in calculating visual and physical connectivity than just observing. By comparing results from each technique it is clear that observation technique is more accurate in larger scale atria and in identifying factors affecting

connectivity, that may not be possible to identify using Depthmap. On the other hand, Depthmap analysis is more suitable to be applied on smaller scale atria, despite of its accuracy, it is not suitable enough to be applied on larger scale atria, the results need to be verified using observation. Therefore, both techniques are dependent on each other and cannot be applied separately.

Some data retrieved from observation method data were more realistic than Depthmap. In general, both studies suggested that atrium A, with the larger scale, is a better connected space. Depthmap shows that the only factor interfering with movement is the presence of obstacles. However, other factors interfered with circulation specially in atrium B, such as the availability of services, which is only possible to identify using observation technique. This reflects the difference in usage patterns between both atria, that was only identified by observation technique, where A has a significantly higher usage pattern.

Moreover, Depthmap analysis showed that visual connectivity is very high throughout the height of the larger scale atrium. However, observation showed that visibility in atrium A was weaker at very high floor plans because visual contact between people fades away inside spaces with very high ceilings, which is a more realistic explanation. Therefore, observation is better in large scale spaces, while Depthmap is useful in smaller scale ones. Other than this, Depthmap proved to be a very accurate tool in analyzing connectivity.

However, variations in visibility and accessibility, depending on differences in space configurations of the two atria, is only accurately identified using Depthmap, unlike in observation, as it is not easily identified by observer's eye. However, very accurate Visibility graph analyses and Isovists are produced using Depthmap. Through observation, it is only possible to identify areas with high and low connectivity and not accurately identify specific spots. To sum up, for the analysis to be reliable several aspects must be present during the analysis. Depthmap analysis is a multilayered analysis technique that saves time, it is also a more professional way of analysis and has better performance. on the other hand, observation is a single-layered technique with less accurate performance, and can result in some inaccurate speculations, however, it provides more realistic results, that can significantly affect analysis results. Therefore using both techniques together as a hybrid system provides all four aspects of time, accuracy, performance, and reliability, resulting in more reliable analysis results. Table (V) summarizes the advantages and disadvantages of each technique compared to the other.

Table IV Comparision between Depthmap and Observation Analysis Techniques.

Analysis technique	Depthmap	Observation
Scale	Better in smaller scaled spaces	Better in larger scaled spaces
Factors affecting results	Obstacles, and space characteristics.	Obstacles, space characteristics, and surrounding services.
Accuracy	More accurate	Less accurate
Efficiency	Less time and effort	More time and effort
Realism	Less realistic	More realistic
Performance	Better performance	Lower performance
Analysis Results outcome	Diagrams	Images and notes about the space

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Understanding Evidence- Based Design as an Innovative Approach in Healthcare Settings: Evidences from Empirical Research Literature

[1] **Patrick Chukwuemeke Uwajeh**, [2] **Timothy Onosahwo Iyendo**

[1]Department of Architecture, Eastern Mediterranean University,Gazimağusa,Northern Cyprus, Via Mersin 10, Turkey.

[2]Department of Architecture, European University of Lefke, Lefke, Northern Cyprus, Via Mersin 10, Turkey.

E-mail: [1]uwajehpatrick@gmail.com, [2]tiyendo@eul.edu.tr

ABSTRACT

Healthcare designs have experienced tremendous growth in innovative design approaches and design practice including evidence-based design (EBD). Designers have moved progressively closer to the future, taking into consideration the needs of users and new dimensions in the changing landscape of healthcare.EBD has made remarkable imprints in healthcare design and other design disciplines, with a specific interest centered on the end users. This review paper is aimed at understanding EBD and its role as an innovative design approach in healthcare settings. A qualitative method of research using literature survey was used in this study. The results of this review revealed that, adopting EBD approach to the design of healthcare facilities can offer opportunities toalleviate stress, improve job satisfaction and increase general wellness outcomes in healthcare ecosystem.

Keywords - Evidence-based Design, Healthcare, Design Process, Wellbeing, Healing Environment.

I. INTRODUCTION

In the past few decades, studies on healthcare design and planning has been a key focus on the relationships between physical environmental factors and wellbeing. This supports the evidence-based design (EBD) practice which embodies several factors revealed to have benefits that can influence the design of healthcare facilities as well improve the wellbeing of patients, care givers, and family members by reducing their stress outcomes. The roots of EBD could be traced back to the 1860s, when the provision of fresh air was placed as the very first canon for linking the hospital physical environment with improvement of patients, staff safety, wellness and satisfaction. This concept extends to include the importance of quiet, proper lighting, warmth and fresh water. With the advances made in EBD and technology development in the 1970s, there was a gradual shift, which transformed the hospital landscape into a 'medical machine' that promoted social, physical and psychological wellness. The EBD approach is based on sourcing available information from both research and project evaluations to create spaces that are therapeutic, supportive for family involvement, efficient for staff performance, restorative for patient and healthcare workers under stress (Smith, 2007), as well as for improving the design of hospital environment, healthcare management and policymaking (Mc Cullough, 2010). Studies have revealed that a well-designed physicalhospital environment affects patients' health and wellness (Ulrich, et al. 1991).People visiting healthcare facilities general expect a suitable and supportive healing environment. Hospitals have evolved from an institutional feel to a warm and welcoming environment which integrates physical, social and psychological factors that have been proven to have positive effects on health outcomes (Molzahn, 2007). In accordance with Mroczek, et al., (2005), the need for a continuous empirical analysis, focused on the identification of more definite and advanced design approaches that improves wellness in healthcare environment should be strengthened with an emphasis on design solutions that improves stress and perceived health outcomes.

Problem statement

The psychological and social needs of patients have been often disregarded in the design of healthcare facilities (Ulrich, 2000), rather, moreemphasis is laid on functionality which produces environments perceived by users as institutional, stressful and detrimental to care quality (Ulrich, 1992; Horsburgh, 1995). Since the adoption of EBD from evidence- based medicine (EBM), an approach in medical practice proposed to improve clinical decision-making by the utilization of credible evidence from well conducted research, EBD has made remarkable imprints as an innovative approach to design in the healthcare development, utilizing facts, figures, research findings, user preferences, pre and post implementation feedbacks, from existing designs. However, it is yet to gainoptimum recognition and implementation by architects and their collaborators. Since the design of healthcare facilities greatly rest on the shoulders of architects, landscape designer and other related professionals in the field of design, a clear understanding of EBD as an innovative approach or a strategic design tool in healthcare development, is indeed of utmost importance.

Aim and objective

The aim of this study is to understand the role of EBD approach in healthcare settings. The objective ofthis review paper is to document a clear understanding of EBD principles, process and the stages of implementation in the design process as well as findings and health outcomes form existing empirical studies.

Methodology

A review of existingresearch literature was adopted for this study. To achieve this, search in various electronic databases was carefully reviewed. The results of the search comprised of data sources from Web of Science, SAGE, PubMed Central, Springer and The Center for Health Design (HCD).

II. DESCRIBING THE EBD CONCEPT

The EBD concept has been shown to promote stress- free environments and based its focus on strategic opportunities to influence the design of healthcare facilities. EBD approach in healthcare planning is a method that began with the general aim of providing EBM (Huisman et al., 2012) and has now extended to become the theoretical concept of what are called healing environments (Iyendo et al., 2016). Therapeutic environments create a shared atmosphere that strengthens the self-healing capacity of both patients and hospital providers. In other words, the healing environment should reflect the values, beliefs and philosophies of the patients served. The integration of EBD strategies in the hospital environment has created a sustainable and ecological healthcare ecosystem (Anåker, 2017) which improves clinical outcomes (Ulrich et al., 2008; Iyendo, 2016), economic performance and job satisfaction (Pati et al., 2008).

Healthcare designs have experienced significant transformation in recent times. This includes the application of innovative design approaches in the design of healthcare facilities that have created new domains within the healthcare milieu, such as user- centered design and EBD (Reay et al., 2017; Quan et al., 2017; Djukic&Marić, 2017). According to the Center for Health Design (CHD), EBD is described as "the deliberate attempt to base design decisions on credible evidences from research to improve design outcomes and critically evaluate post-occupancy results" (Zimring et al., 2004). In the last few decades, pioneering establishments and industries have adopted the knowledge of EBD approaches and have integrated it to suit their context (Smith, 2007), in different type of buildings, but is mainly used in healthcare facilities (Hamilton & Watkins, 2009).The relevance of EBD in healthcare cuts across challenges including cost control, financial stability, safety and hygiene, quality improvement, better patient experiences, and sustainability (Ulrich et al., 2010). Thus, improving healthcare buildings is integral to improving health care. The underlying factor in EBD approaches is that design evidences and strategies need to be integrated into different phases of the building design process. To achieve this, the EBD process needs to be stratified into steps that would correspond with the conventional design stages. The CHD documents EBD process into eight steps namely: Define evidence-based goals and objectives; find sources for relevant evidence; critically interpret relevant evidence; create and innovate EBD concepts; develop a hypothesis; collect baseline performance measures; monitor implementation of design and construction as well as measure post-occupancy performance results (CHD 2012; Rashid, 2013).

Integrating these steps into practice necessitates the collaboration between healthcare organizations, research and expert design firms. The EBD process requires an understanding of the design, construction process, research and healthcare delivery industry collectively. Fig. 1 represents a schematic wheel showing the stages; (organizational readiness, pre- design, design phase, construction and occupancy/post occupancy) of integrating the eight EBD process in different phase of projects from start to finish. Consequently, designers should realize that adopting EBD approach is not a rejection of creativity, but a means to improve their design solutions (Martin, 2009). As stated by the CHD, Table 1 highlights the integration of EBD steps as it relates to various project designs phase.

Figure.1The EBD process integration in Stages of projects (Adapted from CHD 2012; Rashid, 2013; Martin, 2009).

Pre-Design Stage in EBD			
Reference	Design Task	EBD Steps	EBD Tasks
	• Institute interdisciplinary teams. • Visualize anticipated goal. • Develop Functional and space programs.	• Define EBD goals and objectives. • Research and discover relevant evidences. • Interpret evidences critically. • Create EBD concepts/themes.	• Document project Vision. • Define Desired Outcomes. • Establish goals that link design to desired outcomes. • Evaluate the evidence. • Create design Concepts. • Translate Project goals to research hypothesis. • Collect baseline data.
	Design Stage		
	Design Task	EBD Steps	EBD Tasks
[CHD 2012; Martin, 2009 Rashid, 2013]	• Conceptual design development. • Schematic Design development. • Full Design Development. • Construction Documents.	• Develop a hypothesis. • Collect baseline performance measures.	• Create and innovate design concepts. • Test conceptual diagrams. • Construct a mock-up environment. • Integrate EBD features into design strategy.
	Construction and Occupancy stage		

Design Task	EBD Steps	EBD Tasks
• Bidding/ Negotiation. • Construction/Project execution. • Move-in. • Post Occupancy Evaluation.	• Monitor the implementation of design and construction. • Measure Post-Occupancy results.	• Ensure that the design intent is directly linked to EBD goals. • Ensure that the selected design interventions and hypothesis are maintained during bidding and negotiation. • Monitor the implementation of design and construction. • Communicate the interface between construction and research plan to the construction team. • Prepare for Post-occupancy. • Ensure the building complies with the intended research plan, design, interventions and business plan during the commissioning phase of project.

Table 1 - EBD process and their integration in design stages

2.1. Results of EBD applications in hospital physical environments

Studies have revealed the relationship between the physical design of hospitals and significant out comes. Substantial data suggests that user centered information gathered from evidence-based studies have been implemented to enhance the hospitals physical environment and patient safety through architectural design impact (Selami & Cifter, 2017; Ulrich et al., 2008; Calkins & Cassella, 2007; Dettenk ofer et al., 2004), reduced hospital-acquired infections (Prussin & Marr, 2015; Allegranzi & Pittet, 2009; Ulrich et al., 2008; Ulrich & Wilson, 2006; Mineshita et al., 2005; Griffiths et al., 2005; Blanc et al., 2004; Conger et al., 2004; Sehulster et al., 2004), improved staff outcomes (Bayramzadeh & Alkazemi, 2014; Weinel, 2008; Miller et al., 2006; Chhokar et al., 2005; Keir &Mac Donell, 2004; Nelson et al., 2003) as well as other factors, including Landscape, gardens and nature-based views (Iyendo et al., 2016; Beyer et al., 2014; Thompson et al., 2014; Lottrup et al., 2013; Ulrich et al., 2008; Kearney & Winter bottom, 2005; Ulrich, 2002), reduced noise, Medical Errors and wellness related factors (Ulrich et al. 2008; Gardner et al., 2009; Akansel&Kaymakçi, 2008; Cmiel et al., 2004; Baldock, 2003; Mazer, 2012; Gurses&Carayon, 2009; Orellana et al., 2007).Specifically, a mile stone review by Ulrich et al. in 2008, documented ample evidence that afforded practitioners a wider accessible to, evidences which has aided in numerous future research in healthcare (Iyendo, 2016 2017; Iyendo et al., 2016; Hofhuis et al., 2012; Watkins& Keller, 2008; Becker et al., 2011; Zadeh et al., 2015; Jiang&Verderber, 2017). This is consistent with a review on environmental outcomes in healthcare, which confirms the importance of improving the healthcare outcomes associated with a range of design characteristics or interventions, such as single-bed rooms rather than multi-bed rooms, effective ventilation systems, a good acoustic environment, appropriate lighting, better ergonomic design, and improved floor layouts and work settings (Ulrich et al., 2008).Table 2provides detailed information about these findings.

EBD factor(s) and references	Findings	EBD Interventions
Architectural design impact: [Selami&Cifter, 2017; Reay	• Poorly designed environments that deny privacy can be stressful for patients.	• EBD approach can expand the sphere of influence in the private sector, urban redevelopment, areas of public policy, entrepreneurship, and the mind of the general public.
et al. 2017, 2015; Ulrich et al. 2008; Calkins &Cassella, 2007; Dettenkofer et al. 2004]	• Poorly designed and located nursing stations can increase nurses' level of stress and reduce the quality of care.	• Floor layouts for patient-care units should provide corridors organised around a central nursing station, where medications and charts are centrally located to reduce staff fatigue and increase time for care.
	• Stress reducing hospital environments support patient wellbeing and recovery process.	• Private patient rooms allow for greater flexibility in operation and management and have a positive healing effect on patients.
		• Housing patients in single bedrooms can reduce the spread of contagious airborne diseases such as; influenza, tuberculosis, measles, and chickenpox infection.
Improved staff outcomes: [Bayramzadeh&Alkazemi, 2014; Weinel, 2008; Miller et al. 2006; Chhokar et al. 2005; Keir &MacDonell, 2004; Nelson et al. 2003]	• The integration of ceiling-lift technology for patient- handling created a practice setting that promotes safe patient handling and patient dignity in a healthcare environment.	• Evidence report fewer musculoskeletal injuries in caregiver with the use of ceiling lift when compared to floor lifts.
	• Blinking lights, alarms, and equipment noise in intensive care units heightens staff stress levels.	• Lifting and transferring patients with a ceiling lift reduces stress on trunk and shoulder muscle than with a floor lift.
		• Installation of assistive devices reduces staff back injuries.
		• Nursing stations should be designed to meet healthcare needs in terms of communication as evidence reveals that nurses hold positive attitudes toward communication technologies.
Infection abatement: [Prussin& Marr, 2015;	• Water fixtures such as showers, sinks, aerators, faucets, and toilets are key sources for pathogenic microorganisms to collect.	• Installing effective filters, appropriate ventilation systems, air change rates, and using various control measures during construction or renovation.
Allegranzi&Pittet, 2009; Ulrich et al. 2008; Ulrich & Wilson, 2006; Mineshita et al. 2005; Griffiths et al. 2005; Blanc et al. 2004; Conger et al. 2004; Sehulster et al. 2004]	• Patients, staff, and visitors within the buildings are often carriers of Pathogens in healthcare settings, through contact with infected patients and other airborne related sources.	• In acute healthcare settings, mostly in ambulatory care facilities and operating rooms, the installation of high-efficiency particulate air filters, to optimize efficiency in removing particulates as small as 0.3 ì m in diameter, such as (Aspergillus spores), 2.5 ì m to 3.0 ì m in diameter, is a best practice approach.
		• The design of easy-to-clean hand- washing sinks made of the continuous impervious surface, automatic faucets, use of alcohol-based gel, as well as the location of sinks and gel dispensers close to staff movement paths to reduce contact transmission of infectious diseases among patients and caregivers.
		• Design adherence to recommend guidelines for water provision that healthcare facilities should maintain cold water at a temperature below 68ºF (20ºC), store hot water above 140ºF (60ºC), and circulate hot water with a minimum return temperature of 124ºF (51ºC).

Noise,Medical Errors and wellness related factors: [Iyendo, 2016, 2017; Iyendo et al. 2016; Hofhuis et al. 2012; Gardner et al. 2009;	• Noise contributes to medical and nursing errors,tracking and monitoring tasks.	• The utilization of sound-absorbing materials for noise reduction, can help minimize distractions, reduce stress and medical errors, and improve sleep and overall staff work efficiency.
Akansel&Kaymakçi, 2008; Ulrich et al. 2008; Cmiel et al. 2004; Baldock, 2003; Mazer, 2012;	• Noise from doctors and nurses paging device can increase patient anxiety.	• Technological innovations to reduce noise sources from doctors and nurse paging devices, and fall alert sensors installed on patient beds.
	• Ambient noise causes sleep deficiency,confusion which can increase medication and use of patient restraint.	• Pleasant natural sound intervention which includes singing birds, gentle wind and ocean waves, revealed benefits that contribute to perceived restoration of attention and stress recovery in patients and staff.
Gurses&Carayon, 2009; Orellana et al. 2007].	• Noise can have major effects on stress and annoyance levels, perceived work pressure, burnout, and emotional exhaustion among staff.	• Listening to soothing music was shown to reduce stress, blood pressure and post-operative trauma when compared to silence.
	• Noise affected memory, exacerbates agitation, aggressive behavior, depression, anxiety, and worsens speech difficulties.	
Landscape, gardens and nature-based views [Iyendo, et al., 2016; Beyer et al. 2014; Thompson et al. 2014; Lottrup et al. 2013; Ulrich et al. 2008; Kearney & Winterbottom, 2005; Ulrich, 2002].	• Heart-surgery patients reported less anxiety and stress on picture with a landscape scene, trees and aquatic bodies.	• The design of gardens with, aquatic bodies, natural sounds such as bird sound, and the sound of breeze to create healing spaces and enhance wellbeing.
	• Hospital residents prefer windows with rich views of nature, to window views that lacked nature features.	• Introduce indoor plants to purify indoor air, reflect, diffract, or absorb sound of varied frequencies.
	• Symptoms of depression, anxiety and stress can be	• Plants reduce high-frequency sounds in rooms with hard surfaces and are argued to be as effective as adding carpet.
mitigated through exposure to nature in healthcare.	• Incorporating natural green or landscape features in the healthcare ecosystem to enhance health outcomes of patients, and create a positive environment for visitors and healthcare givers.	
• Studies document less post-operative stays in hospitals, reduced pain medications and improved results on patient's outcomes by those who viewed trees, compared to those exposed to views of a brick wall.	• Nature scenes function as pleasant distractions that may block worrisome and stressful thoughts.	

Table 2.Heightenedstudieson EBD interventions.

III. CONCLUSION

This intensive documentation of literature manifested, that EBD is rapidly evolving into a domain of research, which healthcare designers and providers must use to improve the healthcare design for better outcomes. It is evident from this review that there is a growing amount of research to support the application of specific design characteristics to improve healthcare outcomes. Thus, creating a healing environment through thoughtful design approaches that focused on end-users can ultimately influence the success of a design. Adopting EBD approach to the design of healthcare facilities can offer a tremendous potential for alleviating stress, improving job satisfaction and increasing general wellness outcomes in healthcare contexts. Evidently, hospital environments are confronted with the challenges of poorly designed environments. Conversely, a well-designed hospital environment may reduce noise, patient falls, infections, medical errors and stress outcomes for both staff and patients. Similarly, healthcare settings that incorporate pleasant landscape and gardens, as well as nature- based views, can promote environmental comfort that restore individuals from stress associated conditions. This can only be achieved through incrementally investing in experts armed with sound research, best practice evidence and the most recent innovative approaches in the design of the healthcare ecosystem.

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Construction Planning and Schedulling for A Construction Projectusing Building Information Modelling (BIM)

[1] Thet Thet Soe, [2] Aye Mya Cho

[1,2]Civil Engineering Department, Mandalay Technological University Mandalay, Myanmar

E-mail: [1]thetthetsoe87.eng@gmail.com, [2]amcho.civil @gmail.com

ABSTRACT

Nowadays, there are less compatible model which is integrated with each of structure, architecture and plumbing. In reality, there are many facing problems such as uncertainties on location, number of structural members, same space occupation by different disciplines, low quality, time and cost overruns and so on. Therefore, it is necessary to reduce these before commence of actual construction by using appropriate techniques. This paper aims to plan and schedule the construction project by using Building Information Modelling (BIM). This attempted to explain modeling combined with time for better coordination, communication and share information among project team which is useful for projects in terms of performance and time as compare to 2D traditional technique. In this case study, commercial software such as Autodesk Revit 2017, MS Project and Autodesk Navis works Manage 2017 are used. This technique can detect clashes before coordination of building. And then, it can make the better coordination for this construction. After doing coordination, it continues to plan and schedule of building. So, this causes more accurate estimate time for construction.It can be observed that the commercial building is checked by using Revit software and it improved collaboration using integrated project delivery. When BIM model is individualized as phases in preconstruction stage, more accurate visualization of the design can be found by clients, engineers, contractors and sub-contractors compared to 2D technique. Moreover, according to the planning and scheduling, project duration is shorter than that by using the 2D traditional technique. The duration of the construction which was of about 7 years according to the traditional method, it was also reduced by three years using BIM method. So, it was observed that the difference of these schedules were 40%. It can be seen that time control makes cost control. This paper concludes that time control by using BIM is the best alternative to traditional project scheduling tools like CPM networks, bar charts. Thus, BIM technique is more effective than traditional technique.

Index terms - Building Information Modelling, BIM software‟s, 2D technique, Scheduling, Time control.

I. INTRODUCTION

A. Introduction

The Architecture, Engineering and Construction (AEC) industries have required techniques to reduce project delivery time, decrease project cost, increase productivity and quality so that AEC industry is applying new technology such as Building Information Modelling (BIM) to assist better the productivity of construction Project Management. Building Information Modelling (BIM) is an integrated process of development and utilizes of a computer generated model to simulate the design, planning, construction schedule, cost information and clash detection such as physical and functional characteristics digitally before it is built on construction field. According to a recent McGraw- Hill Construction Report, BIM implementation in the USA extended from 55 percentage in 2013 to over 79 percentage in 2015.

The traditional planning method such CPM, Bar chart which is currently used in construction planning is found unsuccessful. Due to the problem observed in using the traditional scheduling and monitoring methods such CPM, Bar charts the construction industry has recognized that itcurrent scheduling and progress reporting practices are in need of significant improvements in quality and efficiency so 3D model combined with time visualization have been motivated by the failure of traditional methods. It means 3D model islinked with the desired schedule through particular software such like Navisworks (Autodesk Incorporated) and Microsoft Project are examples of such programs that provide a collaborative environment to extend, review, and modify the 3D model.

A 3D model combined with time is presented to define the order in which the segments should be constructed or demolished. The result of this step is a sequence which will be used as the process chain for simulation techniques. Then, a probabilistic time control model is introduced by linking the 3D model of the project with generated probabilistic schedules from suitable scheduling software. Then a time control simulation is created in suitable software which lists the sequence of works to be carried out in a date wise manner. The simulation model determines the idleness of resources and locates any potential bottlenecks. To achieve this, the developed simulation model should reflect the real world system [4].

B. Problems facing in 2D traditional method

There are many problems in 2D traditional method. They are;

1. The critical problems faced by the construction industry are the inability to complete projects on schedule, low quality work and high cost overrun.
2. The common criteria for project success by mostliterature on construction projects are generally considered to be cost, quality and time.
3. The causes of construction cost overruns were attributed to inflationary pressures, increases in material prices and workmen‟s wages, difficulties in obtaining construction materials, construction delays, deficiencies in cost estimates prepared by the consultants and the unexpected sub-soil conditions.
4. Lack of coordination and clash detection between design team, clients, engineers, consultants, general contractor and subcontractors.
5. Inaccurate cost estimation
6. Poor relationship between management and labor
7. Improper planning
8. Delays in time

9. Poor planning for implementation: Inadequate time plan, inadequate resource plan, inadequate equipment supply plan, inter-linking not anticipated, poor organisation poor cost planning.
10. Lack of proper contract planning and management: Improper pre-contract actions, poor post-award contract management.
11. Lack of project management during execution: Insufficient and ineffective working, delays, changes in scope of work and location, law and order.

II. LITERATURE REVIEW

A. Clash Detection

A clash occurs when elements of different models occupy the same space. A clash may be geometric (for example, pipes passing through walls), schedule based (when different aspects of work that are supposed to be sequential are scheduled to occur together or in reverse), or changes/updates not made to drawings. There are 3 main types of clashes that clash detection seeks out: 1. Hard Clash: when two objects pass through each other. Most BIM modelling software eliminate the likelihood for this using clash detection rules based on embedded object data. 2. Soft Clash: work to detect clashes which occur when objects encroach into geometric tolerances for other objects (for example, a building being modelled too close to a high tension wire). 3. 4D/Workflow Clash: clash resolves scheduling clashes and abnormalities as well as delivery clashes (for example, work crews arriving when there is no equipment on site) [10].

B. Coordination Procedures

Coordination procedures include three components. They are;

1. Quality Check includes visual check and clash check by using Revit software.
2. Documentation includes record views and clash reports.
3. Coordination includes system and trade coordination

C. Planning and Scheduling of Construction Scheduling is the vey essential part of construction management point of view. Without proper planning and scheduling successful completion of any project of any organization will not be possible. Proper scheduling of the various activities before beginning of work and controlling the operations in systematic manner is the heart of planning [2]. Modelling combined with time is a planning process to link the construction activities represented in time schedules with 3D models to develop a real-time graphical simulation of construction progress against time. Adding the 4th dimension „Time" offers an opportunity to evaluate the buildability and workflow planning of a project. Project participants can effectively visualize, analyse, and communicate problems regarding sequential, spatial and temporal aspects of construction progress. As a consequence, much more robust schedules, and site layout and logistic plans can be generated to improve productivity [3].

A traditional construction schedule is a complex chart or network which consists of various activities and the time desired to deliver those activities. When project starts, the construction manager collects the data and measures the progress in order to update the schedule with respect to any change especially related to the design. The consistency of the schedule mainly relies on the accuracy of construction managers in reviewing the data and drawings and in considering the availability of resources of each time period. This process is a time consuming procedure and would lead to a high potential of errors due to the manual data collection. Traditional scheduling methods i.e. CPM Diagram, Bar charts, Gantt chart can be difficult to understand and do not identify the spatial aspect to the construction activities nor are they directly linked to a design or building model. Due to the failure these traditional methods there should be need significant improvements in construction scheduling which having the ability to watch the elements of a design come together onscreen gives the design and construction team improved accuracy in construction sequencing so that in less time and avoiding manual errors instated of traditional scheduling. So that it is necessary to apply 3D Modeling with time procedure overcomes the deficits and results in better collaboration and more efficient schedule [2].

III. METHODOLOGY

To understand implementation of BIM, a conceptual case study (Commercial Building) is taken. It consists of twelve storey commercial building. Different softwares such as Autodesk REVIT, MSProject (MSP), and Naviswork manage were used to create planning and scheduling model. The steps are mentioned as follows;

1. Collection of AutoCAD 2D drawings of the project from site and project manager.
2. Creation of 3D model by importing 2D drawingsin REVIT software.
3. Conversion of the REVIT 3D model into Naviswork readable (.nwf) format by using an extension tool in REVIT.
4. Preparation of work breakdown structure for the project and creation of task schedule using the quantity data from REVIT in Microsoft project.
5. Creation of planning model by importing and attaching 3D model and the MSP schedules (time)in Naviswork software.
6. Simulation and visualization of planning and schedulling model in Naviswork software [2].

IV. 3D MODELLING AND SIMULATION RESULTS

After doing analysis by using Revit, clashes are detected and deviations are found as follow. Then coordination was done.

A. Clash Detection

Many clashes are found in architectural, structural and plumbing models. It is found in structural column and architectural wall clashes, architecture, structure and plumbing clashes, structural wall and architectural floor clashes, structural column and architectural floor clashes and architectural model and plumbing model clashes as shown in the following figures.

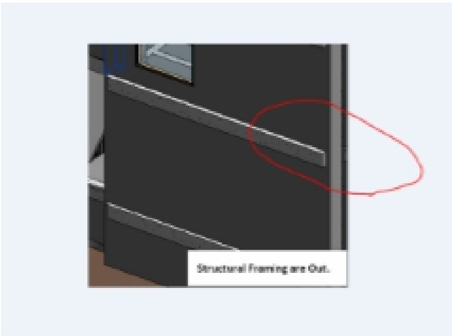


Figure 1: Before coordination

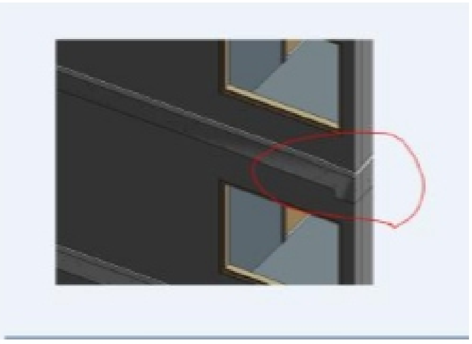


Figure 2: After coordination

According to civil framing system, frames in structural model are not in line with frames in architectural model as shown in figure.1. So, it is fixed to connect the wall in architectural model as described in figure.2 by using coordination in Revit software.

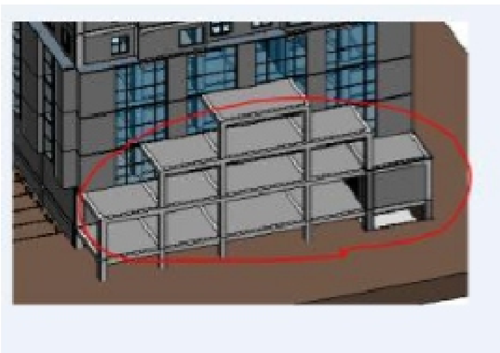


Figure 3: Before coordination

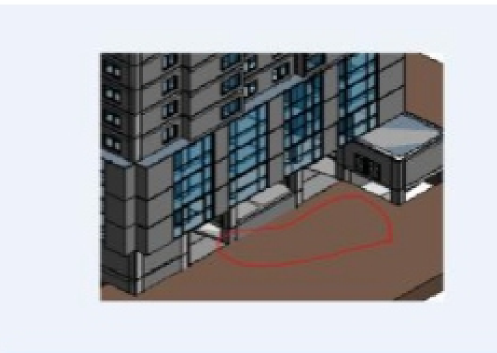
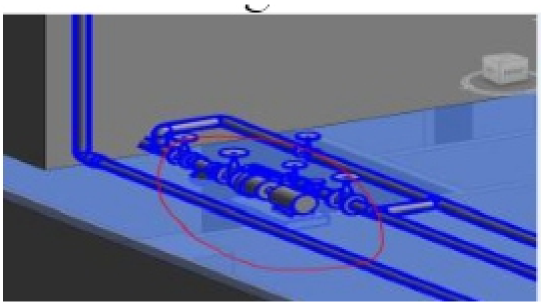


Figure 4: After coordination

When structural model and architectural model are matched, it is found that structural columns, slabs, and beams are included as extra framings in structural model as shown in figure.3. So, it is necessary to maintain by using Revitsoftware because structural and architectural models are not coincident. From this, it has no function to build. Thus, it is removed to see the front side of the model as shown in figure.4.

Figure 5: Before coordination **Figure 6: After coordination**

As shown in figure.5, there are extra two columns in the roof when structural model and architectural model are matched. Really, this columns are not required to build. When it is coordinated by Revit software, this columns are omitted from the roof as shown in figure.6.



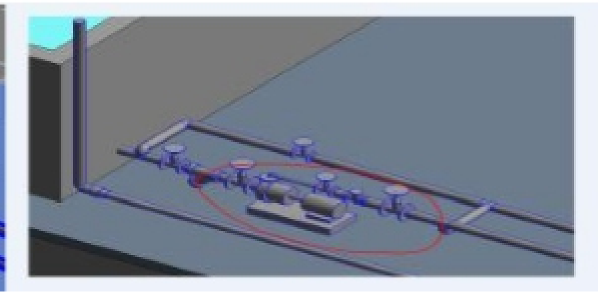


Figure 7: Before coordination **Figure 8: After coordination**

Figure.7 shows the clash of roof slab and water pipe. It shows water pipes are embedded the roof slab. It is not possible to submit the roof slab. So, M&E engineers rise the location of water pipes to convenient in the site as shown in figure.8.

B. Coordination of the results

We checked the commercial building by using Revit software and it improved collaboration using integrated project delivery. Structural, architectural and MNE engineers collaborated to see the clash of the model. After clashing the model, it can be seen that the least errors of this in the actual site. The following figures show the results of the coordination building.

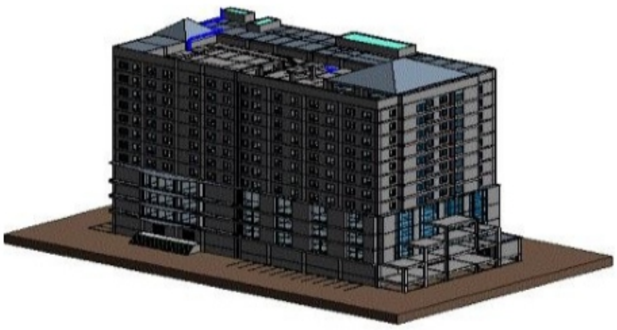


Figure 9: Before coordination of architectural, structural and MNE model

Figure 10: After coordination of architectural, structural and MNE model

From the above results, 2D technique can‟t performed the coordination and collaboration of the building so errors can found in actual site condition and cause time delays. However, 3D modeling BIM can performed the coordination and collaboration of the building so errors can reduce in actual site condition and reduce time delays and cost control.

C. 3D Phasing in Revit During Pre-construction

The modeling process in Revit involves 32 phases for coordination of structural and architectural building. The following figures show the construction sequence of phases in 3D model.

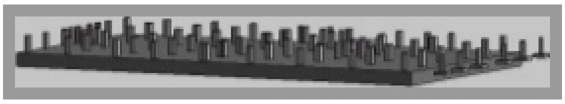


Figure 11: Mat foundation and Figure 12: Basement level footing for phase 1column for phase 2

Figure 13: Ground level beamand slab for phase 3

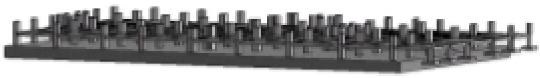


Figure 14: Groundlevel column and basement shear wall for phase 4

Figure 15: 1 Ground floor level beam and slab for phase 5

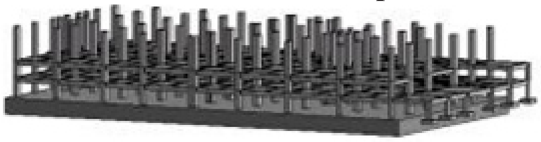


Figure 16: 1st floor level column and ground level shear wall for phase 6

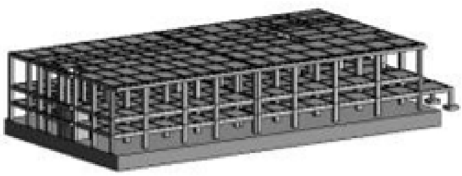


Figure 17: 1st floor level beam slab for phase 7

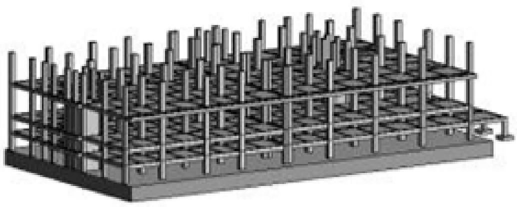
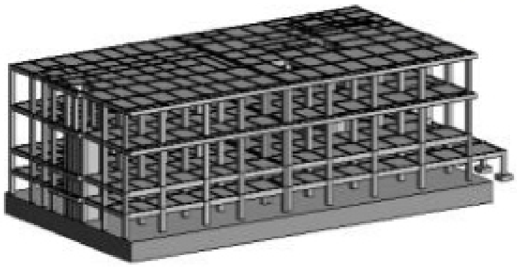


Figure 18: 2nd floor level and column and 1stfloor level shear wall for phase 8



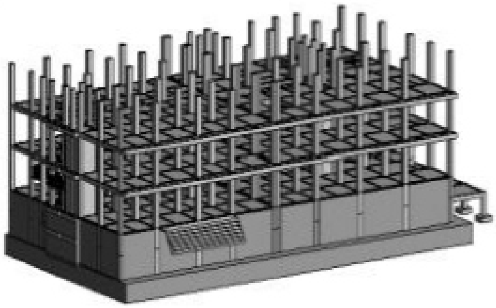


Figure 19: 2nd floor level beam Figure 20: 3rd floor level and slab for phase 9column and 2nd floor level shear wall, GFL wall and floor and stair for phase 10

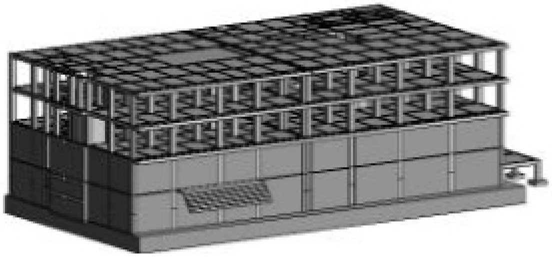
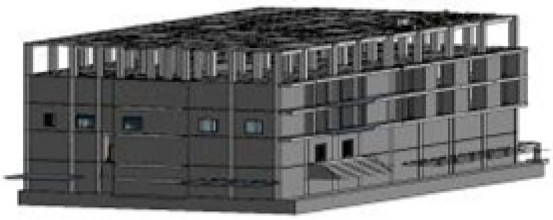


Figure 21: 3rd floor level beam Figure 22: 4th floor level and slab, GL wall and floor and column and 3rd floor level stair for phase 11 shear wall,1st floor level wall and floor and stair and GL doors and windows for phase 12



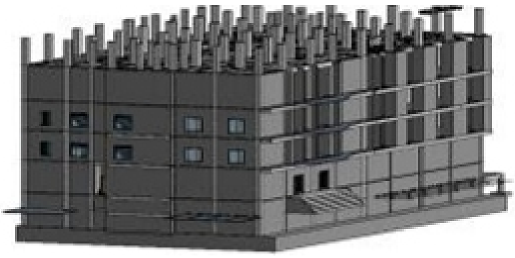
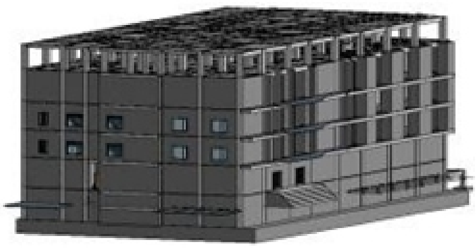


Figure 23: 4th floor level beam Figure 24: 5th floor level and slab, 2nd FL wall and floor and column and 4th floor level stair and 1st FL D & W for phase 13 shear wall,3rd floor level wall and floor and stair and 2nd FL doors and windows for phase 12



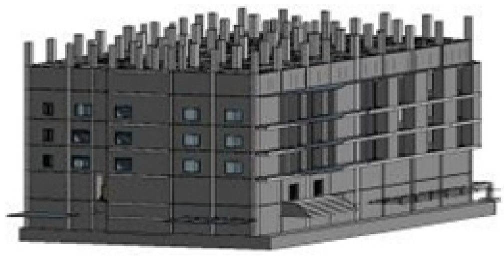


Figure 25: 3th floor level beam Figure 26: 6th floor level and slab, 3rd FL wall and floor and column and 5th floor level stair and 2nd FL D & W for phase 15 shear wall,4th floor level wall and floor and stair and 3rd FL doors and windows for phase 16

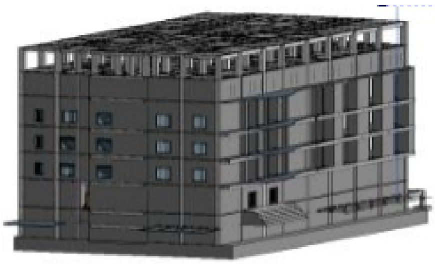
 

Figure 27: 6th floor level beam Figure 28: 7th floor level and slab, 4th FL wall and floor and column and 6th floor level stair and 3rd FL D & W for phase 17 shear wall,5th floor level wall and floor and stair and 4th FL doors and windows for phase 18

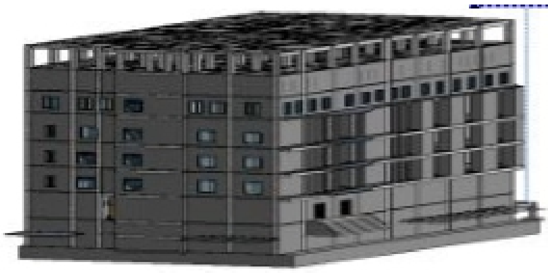
 

Figure 29: 7th floor level beam Figure 30: 8th floor level and slab, 5th FL wall and floor and column and 7th floor level stair and 4th FL D & W for phase 19 shear wall,6th floor level wall and floor and stair and 5th FL doors and windows for phase 20

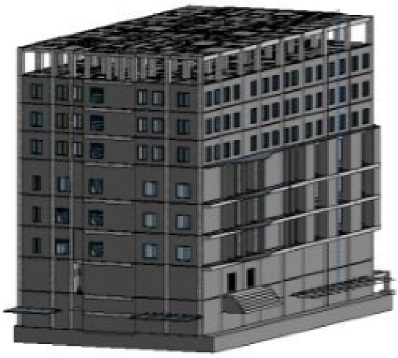
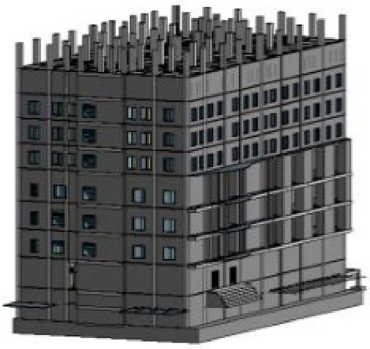
 

Figure 31: 8th floor level beam Figure 32: 9th floor level and slab, 6th FL wall and floor and column and 8th floor level stair and 5th FL D & W for phase 21 shear wall,7th floor level wall and floor and stair and 6th FL doors and windows for phase 22

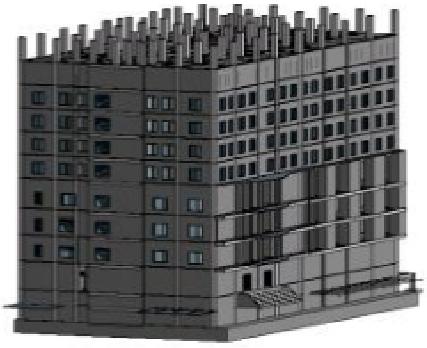
 

Figure 33: 9th floor level beam Figure 34: 10th floor level and slab, 7th FL wall and floor and column and 9th floor level stair and 6th FL D & W for phase 23 shear wall,8th floor level wall and floor and stair and 7th FL doors and windows for phase 24

Figure 35: 10th floor level beam Figure 36: 11th floor level and slab, 8th FL wall and floor and column and 10th floor level stair and 7th FL D & W for phase 25 shear wall,9th floor level wall and floor and stair and 8th FL doors and windows for phase 26

Figure 37: 11th floor level beam Figure 38: 12thtop FL and slab, 9th FL wall and floor and column and 11th floor level stair and 8th FL D & W for phase 27 shear wall,10th floor level wall and floor and stair and 9th FL doors and windows for phase 28

Figure 39: 12thtop FL beam Figure 40: 13throof level and slab, 11th FL wall and floorcolumn and 12thtop floor and stair and 10th FL D & W for phase 29 level shear wall, top floor level wall and floor and stair and 11th FL doors and windows for phase 30

Figure 41: 13throof level beam Figure 42: 13throof level and slab, top roof and top floor wall and furniture for phase level topping for phase 31 32

According to the above figures, these phases paved the way for other accurate and simplified options to overcome the problems experienced by a professional using the 2D technique. So, Clients, project managers, consultants, engineers, contractors, and sub-contractors can know easily about the building easily during preconstruction stage. More accurate visualization of a design can be found by clients, engineers, contractors and sub-contractors compared to 2D technique.

D. Time Simulation

Time simulation includes 3D Model, Microsoft project schedule and Navisworks Manage.

1. Scheduling in MS Project

On the basis of the information and details provided by the Construction Manager of the building, a MS project schedule is created according to the duration planned by the Builder which is shown in the figure 43.

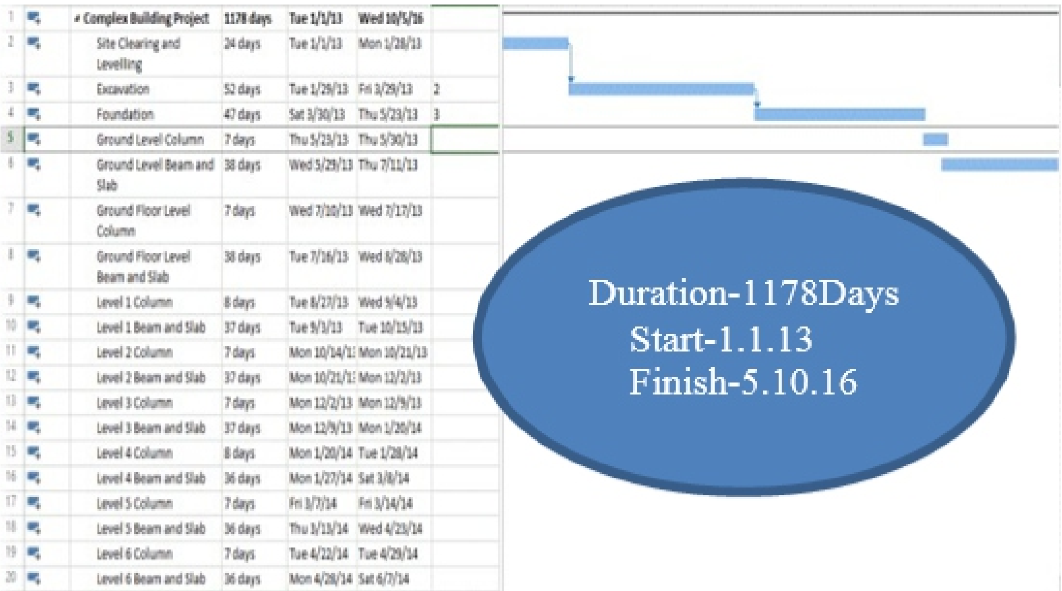


Figure 43: As planned MS Project Schedule for the project

According to the above schedule, the total duration of the building is almost four year. The actual schedule is seven years for this. So, it can be concluded that MS project is the exact result that combined with BIM technique.

2. Labor Management by Naviswork Manage

The Timeliner feature of the Naviswork Manage software enables you to view the work tasks of the schedule along with the visual of the 3D model. Before executing any particular work task the required amount of Labor and Resources associated with the task is determined from the schedule. This feature of Naviswork enables to visualize the task and pre-plan the requirements without any error. This feature appears in Naviswork as shown in the figure 44.

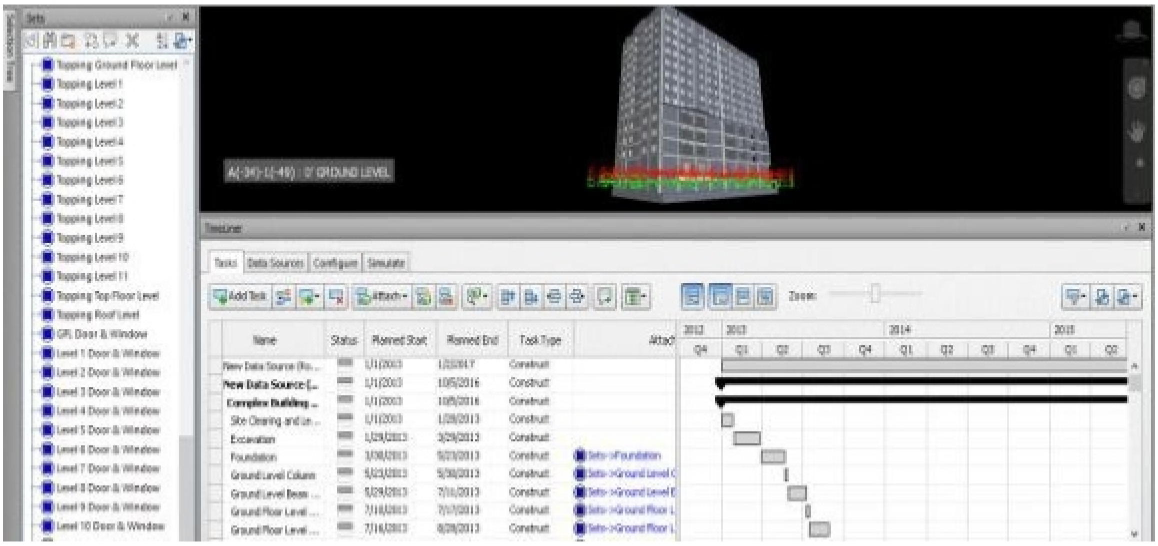


Figure 44: Showing the selection set and timeliner for 4D simulation

3. Simulation in Navisworks Manage

Simulation involves the step by step construction animation of the building tasks. Here, the work task from MS project is linked to its corresponding building components. For example, the task of Laying Ground floor slab in schedule is linked or attached to its corresponding 3D slab element in the model. This integrating work of schedule and the 3Dmodel is carried out in Navisworks Manage 2017 as shown in figure 45.

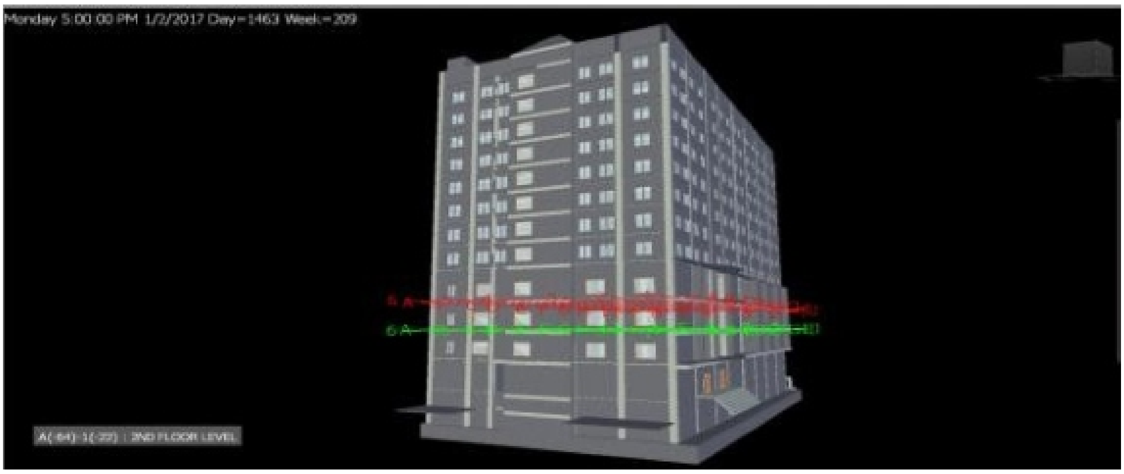


Figure 45: 4D Simulation on day-2.1.17

Once all the tasks from the schedule are linked to their corresponding 3D elements, the time simulation can be viewed. The simulation shows the progress of tasks taking place on a Day-to-Day basis. Planning of the labor and resources can be done for any particular element of the building by simply scrolling down to a particular date in the course of construction in the simulation. The figure 45 shows the building elements which are planned to be executed as on date of the building. A video of the simulation from the start to the finish date can be exported to give a demo of the project to the client.

4. Activities by using 2D traditional technique and BIM

The following figure describes the time schedule of and BIM techniques.

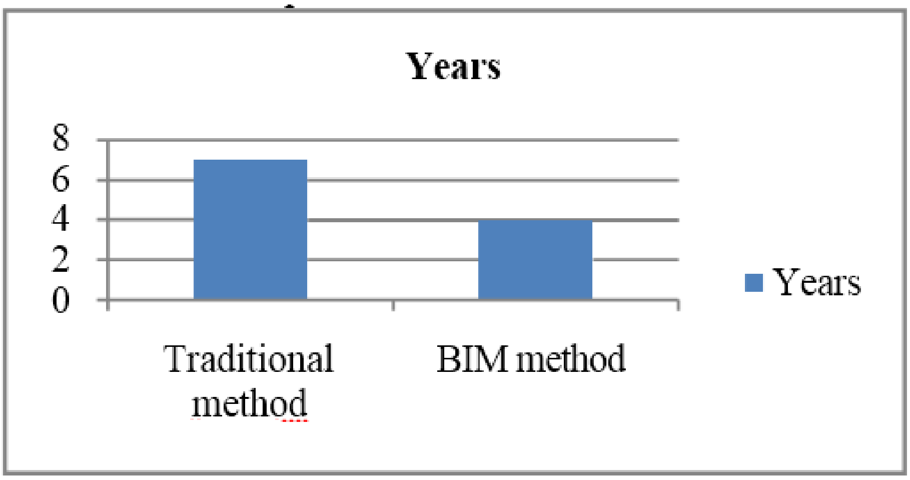


Figure 46: Compare Activities of two technique

From the above figures, actual site schedule is more longer than BIM schedule by using Microsoft Project 2013.The duration of the construction which was of about 7 years according to the traditional method, it was also reduced by three years using BIM method. So, it was observed that the difference of these schedules were 40%. It can be seen that time control makes cost control.

V. DISCUSSION OF RESULTS

After doing interference check of commercial building by using Revit software, the results show the deviations of floors, walls, columns, beams, pipe lines and assembly valves, etc. Structural frames become compatible with each other. Unnecessary extra framing could be eliminated. Unuseful two columns on the roof could omit. Right location of base plate of motor could point out. Wrong allocation of water tap could correct. So, detecting clashes can reduce uncertainties before construction commence. Coordination among various construction teams is well established after detecting clashes by using BIM.The modeling process in Revit involves 32 phases for coordination of structural and architectural building. These phases make concurrent activities for accurate planning and scheduling. It leads accurate time estimates.

Based on the experience gained from the case study, the following benefits are in hand.

1. Improved collaboration using integrated project delivery
2. Earlier and more accurate visualization of a design
3. Discovery of design errors and omissions before construction
4. Better management and operation of facilities
5. Integration with 1facility operation and management systems

A. Comparison between 2D technique and 3D Modelling

The following table shows the comparison on results of 2D technique and 3D BIM.

Table .1 Comparison between 2D technique and 3D modeling

2D Technique	3D Modelling BIM
Lack of coordination & collaboration between clients, project managers, contractors, subcontractors, consultants and engineers.	Improvement of coordination & collaboration between clients, project managers, contractors, subcontractors, consultants and engineers.
Schedulling and planning are not exact.	Schedulling and planning are exact.
It is impossible to count quantities of materials from 2D technique.	It is possible to count quantities of materials are taken from 3D modelling easily and can see the preview of model.
Models are not visible clearly between clients, project managers, contractors, subcontractors, consultants and engineers.	Models are visible clearly between clients, project managers, contractors, subcontractors, consultants and engineers.
Clashes can not be found in 2D technique so prolems are facing in construction stage.	Clashes can be found in 3D technique so prolems are solving in preconstruction stage.
It makes time and cost overruns.	It reduces time and cost overruns.

As shown in Table 1, BIM method is an economical technique because of the following options.

- Increased speed of delivery (time saved)
- Better coordination (fewer errors)
- Decreased costs (money saved)
- Greater productivity
- Higher-quality work
- New revenue and business opportunities

CONCLUSION

According to interference check of commercial building by using revit software, clashes can reduce before construction commence. Coordination among various construction teams is well established after detecting clashes byusing BIM. The case study shows that BIM technology brings many advanced construction management skills to project scheduling, monitoring and even project controls for project team.The duration of the construction which was of about 7 years according to the traditional method, it was also reduced by three years using 4D BIM method. So, it was observed that the difference of these schedules were 40%. It is obvious that accurate time estimate leads to cost effective also. This technique can detect clashes before coordination of building. And then, it can make better coordination for this construction. After complete coordination of design, it makes effectively actual implementation phases of building. So, this causes more accurate estimated time for construction. Therefore, time and cost overruns will significantly reduce as well as quality improvement will dramatically achieve in construction.

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