Role of BIM 6D Energy Analysis Model (EAM) and ISO 19650- A Case Study

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Abstract: The construction industry has become much more complex than ever due to large number of people and documentations involved. BIM is a new promising tool to Architecture, Engineering, and Construction (AEC) industry, which allows constructing building virtually before actual construction on field. An Energy Analysis Model is an abstract of overall form and layout of a building into a computational network that can capture all of the key paths and processes of heat transfer throughout the building effectively. ISO 19650 describes and defines information management across the whole life cycle of an asset. To support this there need to be close links with the approaches taken to asset and project management, and to organizational management.

Keywords — Building Information Modelling, Common Data Environment, 3D Modelling, Energy Analysis Model, Facilities Management, ISO 19650.

I. INTRODUCTION

Building Information Modelling (BIM) is an advanced portrayal of the physical and functional characteristics of a facility. A BIM is a common information asset for data about an office shaping a solid reason for choices during its life-cycle; characterized as existing from earliest conception to demolition. Building Information Modeling (BIM) is a keen 3D model-based cycle that gives engineering, designing, and development (AEC) experts the understanding and apparatuses to all the more proficiently plan, develop and oversee structures and framework.

The utilization of BIM permits the Project team to investigate space and comprehend the complexity of space standards and land guidelines which saves time and gives them the chance of accomplishing more worth added exercises. 3-D portrayals can be created from the structure model at any stage in the plan. These can go from straightforward wireframe models/complex photorealistic renders. This gives consistency in consistency in data that is extracted from the model, helping designers imagine and validate their designs. BIM develops the structure virtually before actual construction. Thus the owner or client can recommend the modifications early in the planning and design phase according to their requirement. Additionally, contractors can participate early in the design phase to add to their field insight.

The development business has customarily been centred on the forthright capital expenses of development. Moving this concentration to more readily comprehend the entire life cost of resources, where the most cash is proportionately spent, should settle on for better choices forthright as far as both expense and manageability. This is the place where 6D BIM comes in.

Sometimes referred to as integrated BIM or iBIM, 6D BIM includes the consideration of data to help facilities management and operation executives to drive better business results. This information may include data on the manufacturer of a component, its installation date, required maintenance, and subtleties of how the thing ought to be arranged and worked for ideal execution, energy performance, alongside life expectancy and decommissioning information.

Basically, architects can investigate an entire scope of stages across the lifecycle of a fabricated resource and rapidly get a comprehension of effects including costs. Notwithstanding, it is at handover, that this sort of data adds value as it is passed on to the end-user.

To fully understand a construction project, we must familiarize ourselves with BIM dimensions such as 2D, 3D, 4D, 5D, 6D & 7D.because these dimensions help enhance the data of a construction model. Enhancing the data of a construction model will help us know the delivery time, the cost and how to maintain the project.

The major demand of the design, engineering, and construction (AEC) trade square measure is to effectively manage data gathered from totally different project stakeholders. A structured guideline needs managing the method and knowledge productively. The primary

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international Building data Modeling (BIM) standards, BS ISO 19650-1 and BS ISO 19650-2, are recently published for managing data over the entire life cycle of a built asset using BIM. The analysis objective of this study is to develop and implement a BIM execution set up (BEP) based on BS EN ISO 19650-1 and BS EN ISO 19650-2, and determine the advantages of using BS EN ISO 19650 standards in the BIM-based construction projects.

1.1 BIM in India

In India BIM is otherwise called as VDC:-Virtual Design and Construction. Because of its populace and monetary development, India has an extending development market. Despite this, BIM use was accounted for by just 22% of respondents to a 2014 study. In 2019, government authorities said BIM could assist save with increasing 20% by shortening development time, and encouraged more extensive reception by infrastructure ministries.

Functions of BIM-

Clash detection, Constructability, Construction drawing, Database information management, Design of complex structures, Estimation, Facility management, Initial presentation, Interior environmental analysis, LEED, Municipal code, Parametric design, Performance optimization, Site analysis, Restoration and renovation, Sustainable design, Value engineering, Visualization.

Simplified coordination: BIM brings everyone involved in the project together on one platform at the planning phase only, thus it saves many coordination steps.

Efficiency: Quick access to detailed building data for all parties involved enables efficient cooperation between planners and building owner's right through to building technicians and facility managers.

Transparency: In BIM, every correction is done automatically implemented in the entire construction plan and is transparent and comprehensible for all parties involved just because of common database. Changes have an immediate effect on parts lists, delivery dates and construction costs.

Flexibility: Virtual models are used to test and stimulate the functions, early detection and elimination of errors and inconsistencies can be done.

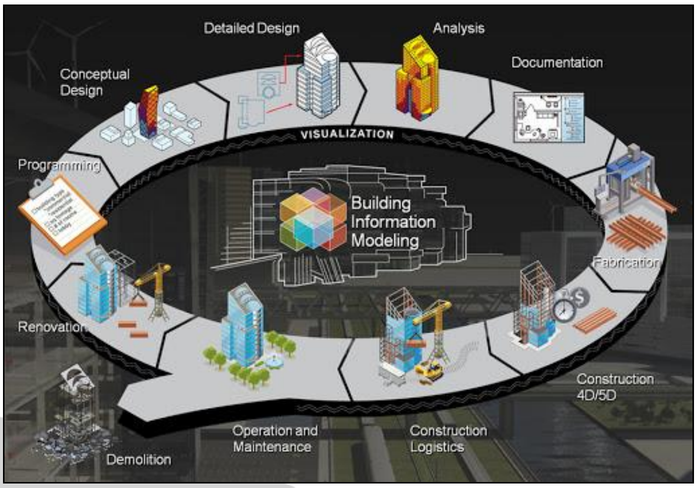
Life cycle: BIM is not only used in the construction industry for construction planning and execution but also in ongoing operations and facility management.

Different forms of BIM-

Contingent upon the product arrangement utilized, the execution of BIM can for the most part be isolated into, Open BIM and Closed BIM measures. Notwithstanding shut BIM and open BIM measures, the terms little BIM and large BIM make a further differentiation.

Open BIM Process: With the open methodology, the decision of programming items is free, yet the task accomplices organize themselves on an arranging stage. Maker unbiased open information designs are utilized, which empower information trade between items from various makers.

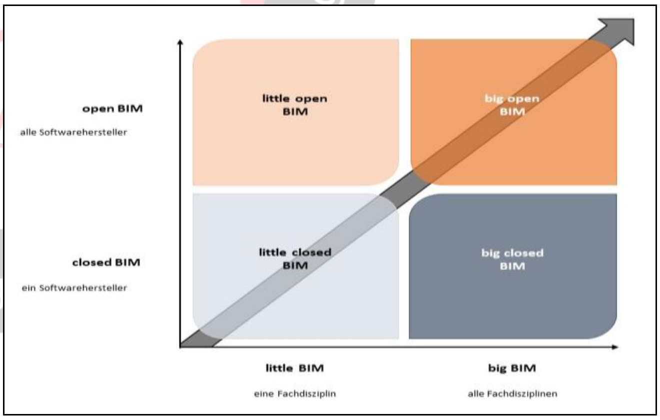
Closed BIM Process: With the shut system, all arranging members work with a similar programming in one model. An issue with this variation can be that exchange explicit model necessities can't generally be planned because of the uniform arranging programming.



Understanding of Building Information Modelling

Little BIM: At little BIM, a BIM programming is utilized by a solitary organizer for his particular arranging. The BIM arrangement is utilized as a segregated arrangement in the particular field of movement of an expert organizer and correspondence with the rest of the world keeps on being founded on drawings. Productivity gains can be accomplished with little BIM, however the capability of a reliable utilization of computerized constructing data stays undiscovered.

Big BIM: In this variation, a cooperative, multidisciplinary model-based correspondence happens between all members over all life cycle periods of a structure. Information trade and coordination happen through Internet stages and data set arrangements.



Degree of Implementation:

BIM Level-

The switch to Building Information Modeling - as mentioned - cannot be carried out from one day to the next in the construction industry. Infact, it makes sense to gradually introduce this technology.

BIM Level 0: Working with 2D- AUTOCAD and exchange of plans which are paper printed.

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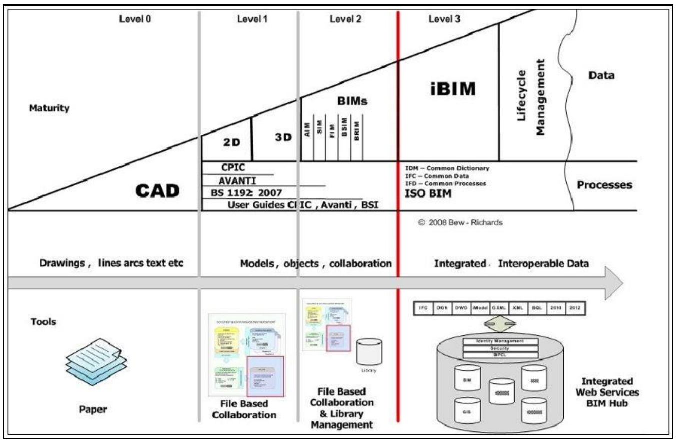
BIM Level 1: Creating 2D drawings and 3-D models, data formats doesn't need no specifications, no central project platform needed, and data is exchange by sharing individual files.

BIM Level 2: Use of 3D-BIM continuously by all parties, planners and specialists generate their own, independent models, which are compared regularly, data exchange is basis of manufacturer-specific formats.

BIM Level 3: Digital model is integrated over the entire life cycle, cloud server manages the central data, ISO standards are used for data exchange and process description.



Degree of Implementation: BIM Dimensions-

In addition to the defined BIM levels 0 to 3, the degree of implementation of Building Information Modeling is also categorized according to the BIM dimensions.

2D Model: 2D measurement is the soonest type of development model. It establishes a straightforward X-Axis and Y-Axis. These models are for the most part made by hand utilizing manual cycles or using CAD drawings.

3D Model: 3D BIM is likely the most familiar type of BIM and also known as "The shared information model" or "coordinated model", and is the way toward collecting graphical and non-graphical data to build 3D models that is the X-axis, the Y-axis, and the Z-axis of a building and sharing this data in a Common Data Environment (CDE). Collaborating parties of a project must provide accurate inputs of information so that potential flaws can be identified and resolved before any construction or building work takes place and avoid unnecessary rework costs. BIM permits multidisciplinary groups to cooperate all the more viably from a solitary source of truth. Advantages of BIM include:

Reduction in rework – meaning less time and money spent on fixing errors before construction takes place.

Improved collaboration between multidisciplinary teams & it also aids communication among the workers keeping them updated on the latest design trends.

3D BIM would give you a full 3-dimensional visualization of the project to help with communication of design intent, and to support logistics. Throughout the entire project, It helps to check for possible collisions & ensures transparency during the entire project. Also, it helps creating a detailed model of the impact the project would have on the environment

4D Model: A 4 dimensional BIM model brings additional dimensional information, known as a scheduling data or time element to create an even richer source of information for the project. This information could be installation time,curation of materials, time until operational etc.This type of information is entered directly into the model and can help project planners in creating and shaping proposals from a much earlier stage in the project compared to traditional workflows. This model starts with a (3D BIM), and then an application of the 4th dimension i.e. 4D BIM, also known as the time element. Therefore, 4D BIM is 3D BIM + Schedule & as the project progresses, this detailed data is added to the components that are being built.

Timely data also allows collaborators to visualise the progress of the project at different stages. This also positively impacts the timeline of the project where project planners are able to forecast how assets come together sequentially and feedback any issues before any construction takes place, creating a much safer working environment for site workers, and a project that can meet timelines and project deadlines.

Advantages of 4D BIM dimension:-

It helps in planning the construction site properly, including the schedule of all the construction stages & also helps in increasing the quality of the building site planning.

It brings out a good working relationship and cooperation among the stakeholders with clear deadlines.

It reduces disputes, clashes and unnecessary delays.

5D Model: At the core of 5D BIM is data identified with costs for example the capital expense of buying a segment, the client having the option to extricate exact expense information from the model, and furthermore see changes in the expense information over time. Having cost data in the CDE assists with budget tracking and cost analysis of a project, carrying more prominent precision to the estimate of the entire project.

This is 4D BIM + Estimate or cost & the feature of 5D BIM modelling is to integrate expense, schedule, and plan in a 3D output. This model is charged with anticipating/foreseeing the progression of money for a project and anticipating the advancement they have made concerning the project. Visualization achieves the practicality and unrivalled precision in any structure project.

A significant contrast between the conventional methodology and 5D BIM demonstrating is the rate at which the project cost is updated and modified. 5D methodology implies the expense reports can be changed at any given time. This emerges because of unanticipated conditions like change in design or other modifications.

Benefits of 5D BIM dimension:-
Cost Visualization at the beginning of the project.
Achieves more limited project cycles.
Modification in project cost at any given time
All the more effectively comprehended project scope.
Assists with estranging any type of budgetary offshoot.

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6D Model: 6D BIM is cantered around the sustainability of a resource, and is known as the 'project life cycle data' or also referred to as Facilities Management. Information may incorporate data from the manufacturer including, expected lifespan, configuration of the component for ideal execution, maintenance schedules etc. and so forth Better choices can be made for instance on resources that have a longer life span and make better sense economically. With this degree of information in a model, facilities managers can even pre-plan maintenance exercises well ahead of time.

This BIM dimension is otherwise called iBIM or integrated BIM. 6D BIM includes the expansion of other significant data that supports the facility management and activity in the expectations that it will achieve a superior business result.

The 6D process implies that a model that was made by a planner gets updated or modified over the span of the construction. This specific model can be submitted to the owner as an "as-constructed" model. The model will contain the fundamental data that will be required if there should arise an occurrence of any future maintenance. The data incorporates things like guarantee data, manual data, activity/ operation, and maintenance information, etc. It settles on dynamic exceptionally simple and quick. During the lifecycle of the project, 6D BIM achieves a detailed analysis of the monetary and operational aspects of the project.

Helps plan for any maintenance stage.

7D Model: 7D BIM essentially contains 3D + time plan + cost knowledge + sustainability. Builders and project managers utilize 7D building information modeling in the maintenance and operation of a project throughout its whole life cycle. Utilizing a 7D CAD in BIM would help optimize the project management from its design stages, up until its demolition phase.

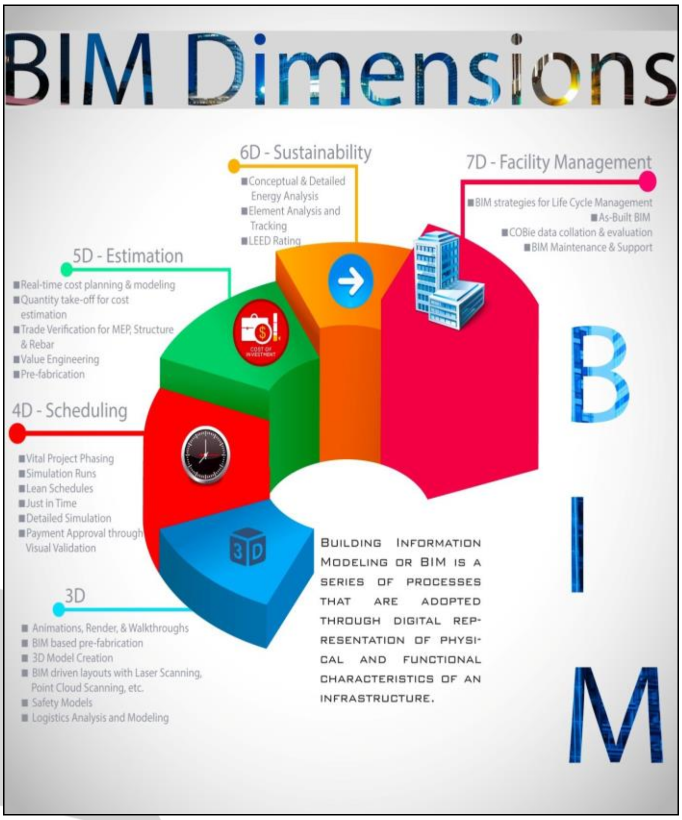
Warranty data, operation manuals, technical specifications are some of the assets information that can be followed utilizing this dimension.

Benefits of 7D BIM dimension-

7D BIM helps in monitoring the management of the facility or asset right from the design phase to the demolition phase.

It makes the tasks like changing of building parts and general repair of a building/project throughout its entire cycle very easy.

Pinpoint to the project worker, the maintenance process that should be followed.



Dimensions BIM	Properties	Aspects Developed in the Model
2D	2D Basic Documentation	Traditional two-dimensional (2D) plans Lines, planes images
3D	3D three-dimensional model	Graphic documentation in three dimensions (3D) Special geometric information Objects with properties 3D visualization of the project
4D	Programming the Execution Plan (Deadlines)	Simulation of Project phases Installations Simulation Design of the execution Plan
5D	Planning, Monitoring and Cost Control	Budget estimate of expenses Measurements of materials and labor Analysis of operating costs
6D	Sustainability and energy efficiency	Energy analysis Envelope variations and interactions Analysis of simulations and energy efficient and environmentally sustainable proposals
7D	Facility Management	BIM Life Cycle Analysis (LCA) Strategies BIM as built Building Operations and Maintenance Plan Model Logistical Control of the Project

ENERGY EFFICIENC Y

Buildings as they are designed today, contribute to serious environmental problems because of excessive consumption of energy. The close connection between energy use in buildings and environmental damage arises because of energy-intensive solutions sought t o construct a building and i ts demands for heating, cooling, ventilation and lighting cause severe depletion of invaluable environmental resources [1]. Energy resource efficiency in new constructions can be affected by adopting an integrated approach to building design [2][4][5].

Energy Efficiency-

Today as the buildings are being designed, are creating serious environmental problems due to excessive consumption of energy. The close connection between energy use buildings and environmental damage arises because of energy intensive solution sought to construct a building and its demands for heating, ventilation, cooling

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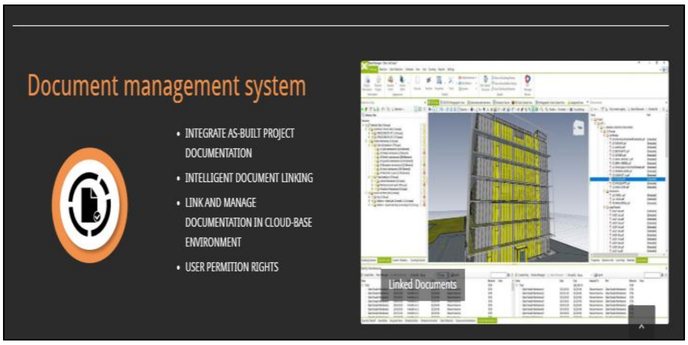
and lighting cause severe depletion of invaluable environmental resources. As a result of fast urbanization exploitation of the available energy resources are being exploited. The maximum usage of the mechanical system resulted greenhouse emission for the building's active cooling, and this has impacted on our fragile ecosystem badly.

BIM 6th Dimension: Making a Structure Self-Sustainable & Energy Efficient-

6D structure data demonstrating assists with investigating the energy utilization of a structure and come out with energy gauges at introductory plan stages. Representing different life phases of a construction, 6D BIM guarantees precise forecast of energy utilization necessities.

6D BIM innovation makes the business a stride past the customary methodology that simply centers around the forthright expenses related with an undertaking. This methodology helps in finding out about the whole expense of a resource and how the cash ought to be spent on accomplishing manageability and cost-effectiveness.

6D BIM is otherwise called incorporated BIM as it includes itemized data that can help in supporting office the executives and activities sometime not too far off. This basically includes data about a part's maker, establishment date, and upkeep plan, arrangement subtleties for best execution, energy prerequisite and decommissioning data.



Benefits of 6D BIM-

Reduced energy consumption in the long run.

Faster and more accurate decision making related to component installation during the design process.

Detailed analysis and impact of a decision on economic and operational aspects over the entire lifecycle.

Better operational management of the building or structure after handover

Keep up cutting-edge office and hardware information including client manuals, gear determinations, upkeep plans, guarantees, cost information, redesigns, substitutions, harms and weakening, support records, maker's information, and gear usefulness.

• Include data about the first plan purpose, possession subtleties, study work, operational execution subtleties just as 3D models created during development.

• Access all FM data including field information from a unified model.

• Pre-plan support exercises – a long time ahead of time

• Anticipate activity costs.

• Test various situations essentially.

• Automatically create booked work orders for upkeep staff.

• Track use, execution, and upkeep of a structure's actual resources for the proprietor, support group, and monetary office.

• Use the 6D BIM model to design situations, arrange office remodel works and oversee usable space all the more proficiently.

• Use the 6D BIM model as an electronic proprietor's manual, and furthermore as a significant instrument for re-dispatching measures.

• Streamline change the executives – permit future updates of the record model to reflect current structure resource data after remodel works or substitutions.

• Consistent and open document configuration and easy to use interface.

• Process in consistence with PAS1192-2 and PAS1192-3 guidelines.

6D BIM services includes-

Energy Analysis Models (EAM) are utilized in entire structure energy recreations. Deciphering from a Building Information Model (BIM) to an Energy Analysis Model has truly been a mistake inclined and tedious interaction.

Basically, an Energy Analysis Model (EAM) is a reflection of a structure's general structure and design into a 'computational organization' that can catch the entirety of the key ways and cycles of warmth move all through the structure adequately.

BIM administrations offers completely better approach to make an EAM consequently from Revit building components and two projects like Autodesk Revit and

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Autodesk Insight 360 can be utilized to make unrivaled energy and natural execution inside the structure.

Working in Revit simplifies it to discover information about the structure being demonstrated, for example, its life cycle energy use or its sustainable power potential.

Instead of defining boundaries to plan structures as in more seasoned CAD programs, real dividers and building components are being attracted Revit. Along these lines, as the model is drawn, the program is noticing the materials and protection esteems just as different properties of those materials. When the model is made, Revit has the data it needs to concoct an energy model for the structure.

7.3 Potential Value:

Save time and expenses by acquiring building and framework data naturally from the structure data model as opposed to contributing information physically.

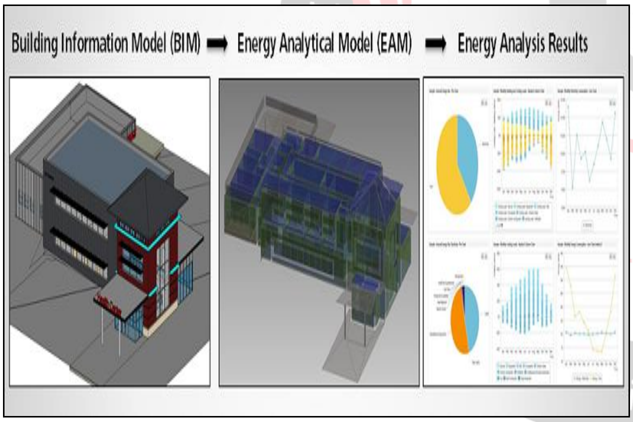
Improve building energy forecast exactness via auto-deciding structure data like calculations, volumes correctly from BIM model.

Help with building energy code confirmation.

Optimize building plan for better structure execution proficiency and decrease building life-cycle cost.

7.4 Assets Required:

- Building Energy Simulation and Analysis Software(s).
- Well-changed Building 3D-BIM Model.
- Detailed Local Weather Data.
- National/Local Building Energy Standards.



ISO 19650- What exactly it is-

ISO 19650 is a series of international standards that defines the collaborative process for the effective management of information related to the operational phase of assets & delivery while using Building Information Modelling (BIM).

Based upon the UK 1192 series. The ISO 19650 series enables teams to minimize wasteful activities and increase predictability about cost and time & is achieved through a common approach to the management of information.

8.1 ISO 19650 and the benefits to the organization-

In 2011, the UK government introduced the "BIM level 2" initiative which is a series of national standards and publicly available specifications.

These documents were known as the "UK 1192 Series" and they defined BIM Level 2 in the UK.

Following their publication, it enabled international asset owners and clients, particularly in Australia and the Middle East to recognize their benefit.

They started to require the adoption of these administration measures characterized inside the UK 1192 series on their own development projects.

Numerous global organizations felt that it was out of line to request that they work as per UK guidelines. In this way, the international community approached ISO to request that the United Kingdom 1192 series be elevated to a world level.

The framing of a worldwide series of guidelines presently makes a level battleground for organizations and suppliers all throughout the world. Empowering them to compete, collaborate and innovate. Despite where they are located.

8.2 How internationally organizations can take advantage of ISO 19650-

This is a positive move from a worldwide viewpoint. Indeed, the ISO 19650 series currently presents a genuine chance for the UK construction industry. Furthermore, for those organizations who have effectively aligned their business cycles to the UK method of working?

It will empower them to exploit their investment and foreknowledge.

The circumstance of the publication of the ISO 19650 has additionally been significant. Progressively we are seeing delivery teams formed of organizations from various nations.

They work in varying manners yet are meeting up on projects. The ISO has assisted these groups with embracing a typical way to deal with overseeing data.

There are likewise enormous advantages for huge global associations as well.

For a long time, these associations have struggled to accommodate the contrasting requirements from their clients, customers and suppliers.

The ISO 19650 series has assisted these organizations with building up a bound together methodology across every one of their areas and workplaces.

Making quick efficiencies and expanding the versatility of their internal resources.

8.3 Building information modelling according to the ISO 19650 Series-

"Building information modelling (BIM)" as per the ISO 19650 series is tied in with improving specification and delivery of the perfect measure of data concerning the design, development and the management of buildings and infrastructure, utilizing suitable technology tools.

This conveys the efficiencies and investment funds imagined by the UK Government and others.

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The standard is about good practice all through the entire project and asset management team.

It applies all through the entire life cycle of a resource, including operation, construction, refurbishment, decommissioning, and it applies to a wide range of resources in the built environment i.e. structures, infrastructures, systems and the components inside them.

The benefits of adopting the processes in “BIM according to the ISO 19650 Series” would be as follows:-

Clear definitions for the data required by the undertaking customer or asset owner, and for the techniques, cycles, deadlines & conventions that will administer its production and checking;

The quantity and quality of data delivered is only adequate to fulfill the characterized data needs, while not bargaining wellbeing and safety or security.

An excessive amount of data addresses wasted effort by the supply chain and too little information means customers/owners take clueless decisions about their assets/projects

Proficient and effective transfers of data between those engaged with each part of the life cycle – especially inside projects and between project deliveries and asset operation.

8.4 ISO 19650-1

Allows an unpracticed designating party to look for help with finishing its information management activities. This could be from one of the forthcoming lead designated parties or from an autonomous outsider. Additionally, on any one project there can be different lead designated parties every one of which may have their own delivery team.

8.5 ISO 19650 Pros-

As far as ISO guidelines and BIM, other ISO norms are comparative with BIM and the development area, for example, the ISO 12006, Building development association for data about development works and the ISO 16739, the IFC worldwide principles, and others. The ISO 19650 is the standard that addresses the "Digitization and association of information about structural designing works and structures, including BIM".

As a rule, norms help the development business make more compelling and productive tasks by building up plan, development, and assembling measures. A global norm for BIM can uphold the diverse development markets to cooperate dependent on a typical language. A typical meaning of BIM will assist distant groups with working together and increment development area effectiveness and quality.

The explanation that principles are fundamental to the development business is that the area has huge issues that can be addressed while applying a framework or design. The building site is an unpredictable environment; without a framework and an organized methodology postponements and mistakes happen with a significant effect on schedule and financial plan.

Another advantage of utilizing ISO 19650 is that the new worldwide standard builds up the Employer/customer/delegating party giving an organized cycle to help BIM project execution. The standard features the customer's driving job in the beginning phases of the advanced joint effort to build up the undertaking's data prerequisites and the shared stage, the Common information climate, CDE. These necessities will set the reason for the plan, development, and activity of the resource. Subsequently, the customer impacts the advanced cooperation and the nature of expectations. Assuming the customer doesn't furnish data prerequisites in accordance with ISO, we can say that the undertaking did not depend on ISO 19650.

8.6 ISO 19650 Cons-

ISO 19650 arrangement, as ISO distributions, are conventional. For every idea clarified, the peruser needs to allude to different reports and principles, nearby, territorial or global. The various gatherings have explicit errands, reports to create, and assets to allude to. These associations with different sources are not all around clarified in the records.

The peruser needs to distinguish the connections to other industry guidelines, which can make one's BIM ISO venture a difficult undertaking. To completely comprehend ISO, one necessities extra direction to comprehend the connections between the different ideas, and this is given by the UK National BIM Framework Guidance set-up of reports.

In any case, in the event that you are not situated in the UK, the direction ought to be considered cautiously and analyzed regarding your tasks nearby setting. All things considered, the direction is nitty gritty, very much organized, and gives important bits of knowledge coordinated by the particular themes. The direction is accessible to download on the UK National Framework site for nothing.

The shortfall of subtleties in the ISO records is a negative point. Subsequently, specialists peruse and decipher the norm in their own agreement, and this can be a debilitating errand that could bring about misconceptions and delayed discussions.

The wording is another negative part of ISO. Terms, for example, the naming party, lead named party, and delegated parties, or the expression the selecting party names the lead named party, and the lead designated party names the named parties, etc. This wording can be befuddling when you read the report. Likewise, the illustrations remembered for ISO are essential and hard to peruse and don't uphold the visual correspondence that an elevated expectation ought to give.

It is obvious that when we share data carefully, the utilization of organized and justifiable naming shows for data is essential.

9. Case Study-

The Diagnosis and Treatment Centre of the University Hospital of Jaen is a wellbeing focus of the Andalusian Health Service, which has a place with the Health

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Department of the Andalusian Government, located in Jaén, relating to environment zone C4, as per the Technical Code of the Building (CTE) and which meets the typology of an grand tertiary (GT) building. The development of the structure dates from 1972, as a specific care centre. The structure's fundamental activity is the consideration of the external consultation of the University Hospital of Jaén. Complimentary activities in the structure are the clinical inspection ones (U.M.V.I.), records in the basement of the building and community mental health. The thermal conduct of the building components was obtained by noticing interventions carried out after the execution of the structure, for instance opening gaps in the façade wall for emergency exit. The thermal characteristics of the structure envelope components are shown in below table,

Table 2. Characteristics of the building's thermal envelope in the BIM model.

Building's Thermal Envelope	Thickness (mm)	Thermal Transmittance (W/m² K)	Solar Factor
Facade wall	550	0.93	-
Roof	390	1.44	-
Floor structure	250	2.27	-
Basement floor	250	2.78	-
Glass (windows)	6	5.56	0.86

Figure 1: Characteristics of the building's thermal envelope in the BIM model

9.1 Description of the Building Facilities

The production of cold for cooling is carried out by means of two chillers for each direct extension floor with ducts. Regarding heat generation, to supply hot water for cooling, boilers are utilized which are fed with natural gas. The boilers are situated in the thermal power station of the University Hospital of Jaén, and supply a series of water radiators arranged along the perimeter of the building. The production of water for sanitary use (DHW) is carried out with hot water boilers fed with natural gas, situated in the H.U.J. The luminaires in the structure are for the most part fluorescent lights. It doesn't have control components for inside lighting. The depiction of the building technical equipment can be seen below,

Table 3. Characteristics of the building's thermals systems in the BIM model.

Thermal System	Generator Equipment	Distribution Network	Terminal Units	Energy
Heating	Water Boiler (0.9 AFUE [1])	Water	Radiators	Natural gas
Ventilation and air cooling	Chiller (3.5 SEER [2])	Refrigerant	Duct system	Electricity
Hot sanitary water	Water Boiler (0.9 AFUE [1])	Water	-	Natural gas

Note [1]: AFUE (Annual Fuel Utilization Efficiency rating). Note [2]: SEER (Seasonal Energy Efficiency Ratio).

Figure 2: Characteristics of the building's thermals systems in the BIM model.

9.2 Building Definition in BIM for Energy Simulation-

In this part, it is important to characterize all the information needed to carry out the energy simulation of the health centre with the BIM software. Said information are those alluding to the calculation, spaces, thermal envelope, environment, geographic area, and operational and word related qualities of the spaces, as well as the meaning of the building's systems and facilities and the task of said system and facilities to the corresponding spaces. To start with, the structural plans were used in "dxf" design, which filled in as a layout for the development of the structure's calculation and BIM architecture utilizing the REVIT program. When the engineering model was acquired, the materials of the thermal envelope of the structure, the operational and occupational characteristics of all the spaces were designed to obtain the energy model, likewise with the REVIT programming.

9.3 Architectural Model of the Building-

Below picture shows the BIM architectural model of the health centre consisting of 226 spaces with (242 door) and (354 windows),

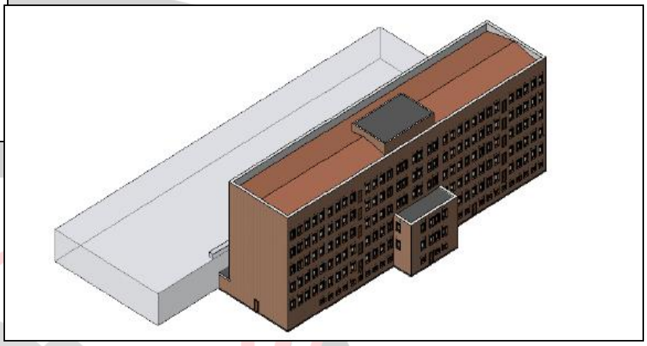

Figure 3: Architectural model of the building in REVIT software.

9.4 Building Energy Model (BEM)-

With the engineering model and furthermore utilizing the REVIT programming, the energy model of the structure was acquired, where the air conditioning system was defined, and the energy design of the structure was completed, and its occupational characteristics allocated. In this way, the reproduction and energy investigation were performed with the REVIT add-on, INSIGHT into the cloud. At long last, the perception and cooperation with the results obtained on this stage were analysed through graphs and execution diagrams directly in a virtual model.

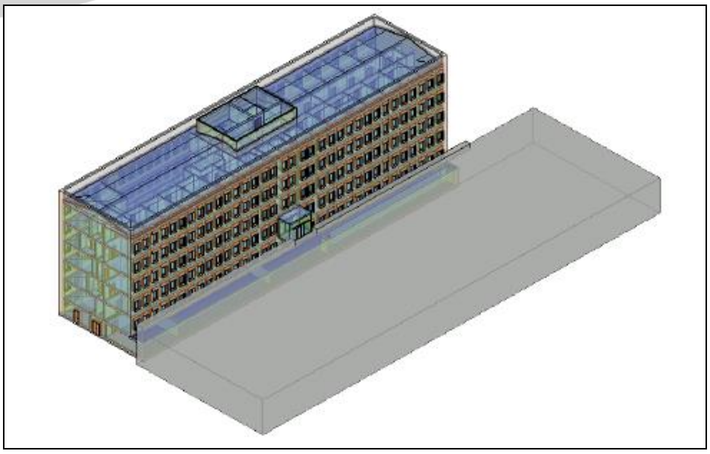

Figure 4: Building energy model in REVIT

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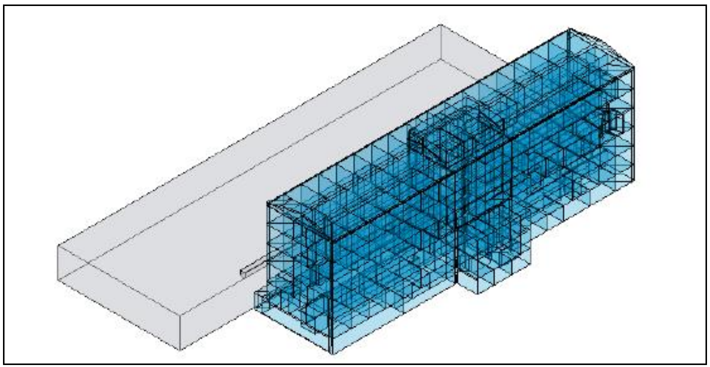

Figure 5: View of analytical spaces of the energy model of the building in REVIT

Figure 6: View analytical surfaces of the energy model of the building in REVIT

9.5 Result of the Different Alternatives for Improving Energy Efficiency over the Initial Situation

Based on the application of different proposals to improve energy and environmental efficiency we obtained the following results shown in table below,

Improvement	Scenario Name	Consumption (kWh/(m^2 year)).	Energy Saving (kWh/(m^2 year)).
Existing building	*Existing building*	*259.11*	-
Air conditioning system	HVAC	198.02	61.09
LED Lighting system	LED Lighting	232.31	26.8
Windows glass	Window Glass	250.45	8.66
Lighting control system	Daylighting and Occ.C.	252.16	6.95
Efficient electrical power	Plug Load	244.57	14.54
Photovoltaic panels	PV—Panels	241.10	18.01
Simulated global improvement	**Energy Saving Package**	**138.17**	**120.94**

Figure 7: The results obtained in the different scenarios analyzed for the building.

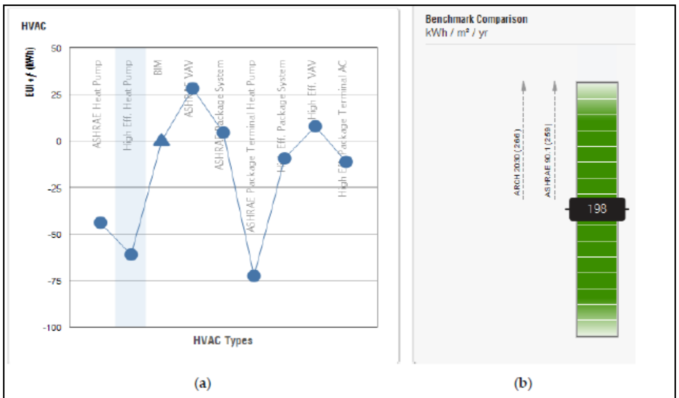

Figure 8: a) Diagram with the selected HVAC improvement in INSIGHT 360. b) Result obtained on the INSIGHT 360 platform for the building after applying the air conditioning improvement.

9.6 Improvement of the Building's Air Conditioning System-

This improvement consists of replacing the current air cooling systems with a new system based on highly efficient heat pumps. The results obtained after applying the improvement in the energy simulation are as follows (See Figure 9 and Table4):-

Consumption: 198.02 kWh/ (m2 year);

Energy-saving: 61.09 kWh/ (m2 year).

9.7 Improvement of the Building's Lighting System. (LED Lighting System)-

This improvement consists of replacing current fluorescent-type luminaires with others with LED technology. The results obtained after applying the improvement in the energy simulation are as follows (See Figure 10 and Table 4):

Consumption: 232.31 kWh/ (m2 year);

Energy-saving: 26.8 kWh/ (m2 year).

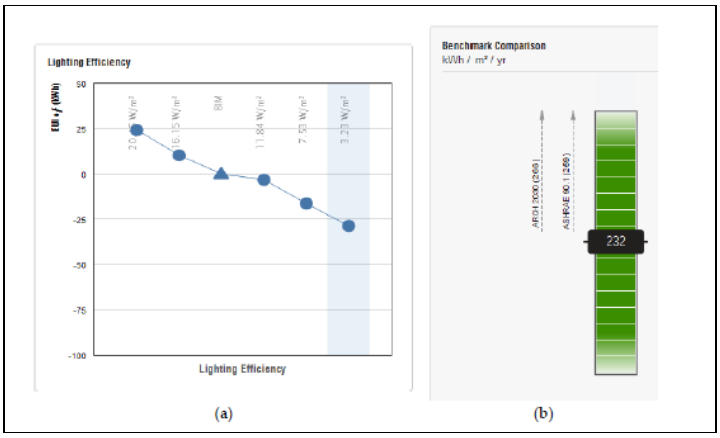

Figure 9: a) Diagram with the lighting improvement selected in INSIGHT 360. b) Result obtained on the INSIGHT 360 platform for the building after the application of the lighting improvement.

9.8 Improvement of the Quality of the Holes in the Building Envelope. Exterior Quality of the Cladding of Windows Glass-

This improvement consists of replacing the current single glass windows with low-emissive double glass. The results obtained after applying the improvement in the energy simulation are as follows (See Figure 11 and Table 4):-

Consumption:-250.45 kWh/ (m2 year).

Energy-saving:-8.66 kWh/ (m2 year)

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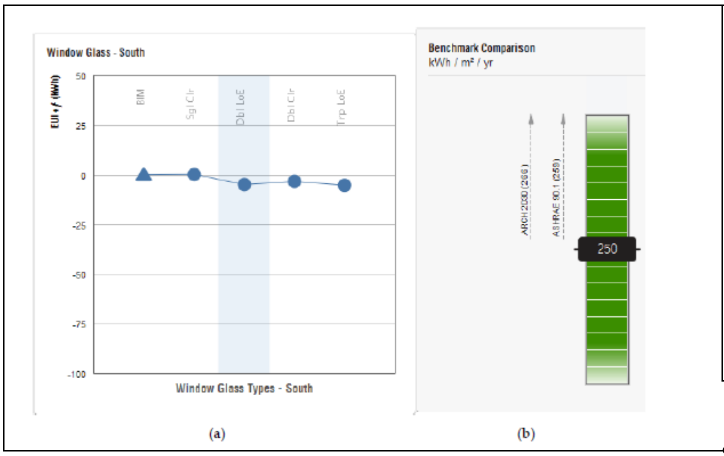

Figure 10: a) Diagram with the lighting improvement selected in INSIGHT 360. b) Results which obtained the improvement consisted of replacing the current single glass windows with low-emissive double glass.

9.9 Improvement of the Building Lighting Regulation and Control System. (Lighting Control System)-

This improvement consists of the installation of a regulation system for the lighting, combining presence detectors and twilight sensors to optimize electricity consumption of the building. The results obtained after applying the improvement in the energy simulation are as follows (See Figure 12 and Table 4):-

Consumption: - 252.16 kWh/ (m2 year).

Energy-saving: - 6.95 kWh/ (m2 year).

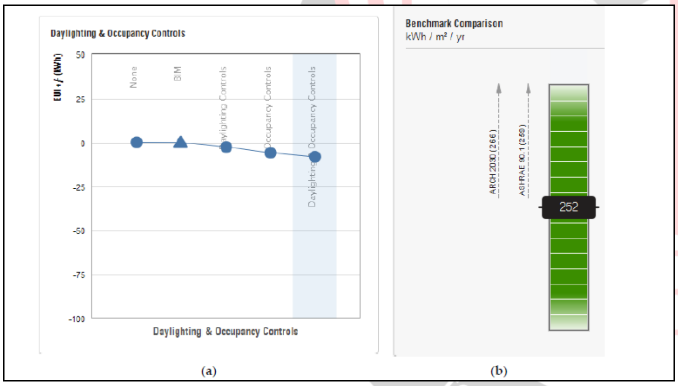

Figure 11: a) Diagram with the improvement of the lighting system through regulation and control selected in INSIGHT 360. b) Result obtained on the INSIGHT 360 platform after the application of the lighting control.

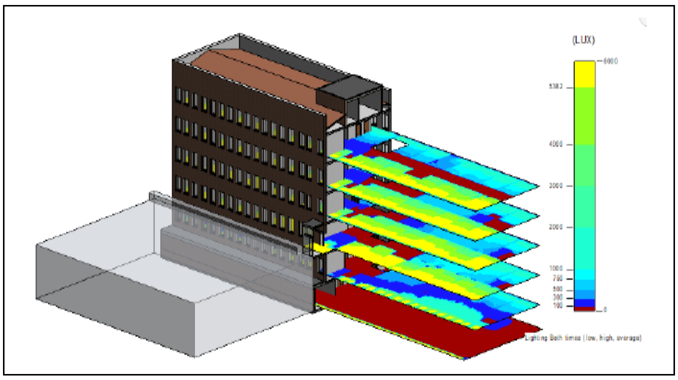

Figure 12: Day-light simulation. 3D view of the illuminance analysis in REVIT INSIGHT.

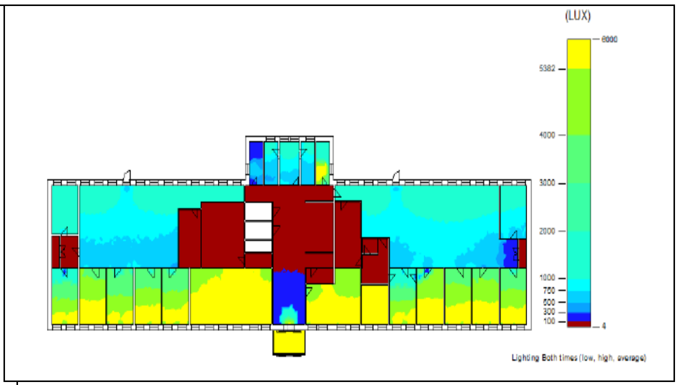

Figure 13: Daylight simulation both times (low, high, average) of 9/23. Low floor view of the illuminance analysis in REVIT INSIGHT.

9.10 Improvement of Installed Electrical Power of Equipment in the Building. (Efficient Consumption Equipment)-

This improvement consists of the installation of more efficient equipment than that currently installed ones in the building i.e. elevators, electro medical equipment (RX), oce equipment, etc. The results obtained after applying the improvement in the energy simulation are as follows (see Figure 25 and Table 4):

Consumption: 244.57 kWh/ (m2 year).

Energy-saving: 14.54 kWh/ (m2 year).

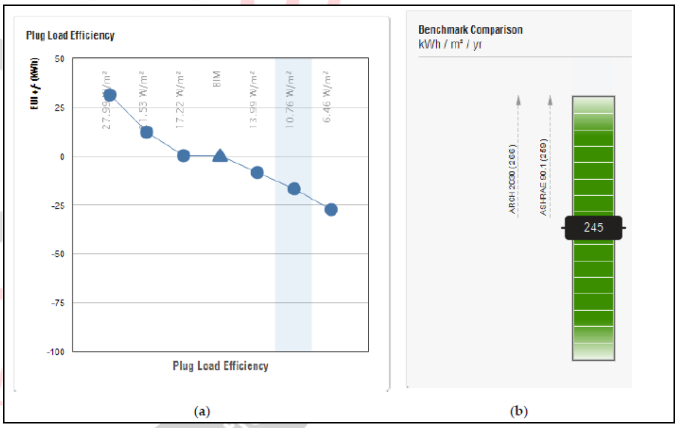

Figure 14: a) Diagram showing the improvement in installed electrical power selected in INSIGHT 360. b) Result obtained on the INSIGHT 360 platform after applying the improvement in installed power.

9.11 Improvement of Electric Power Generation. Installation of Photovoltaic Panels on the Roof-

This improvement consists of the installation of photovoltaic panels (PV) of high efficiency on 75% on the building's roof. The results obtained after applying the improvement in the energy simulation are as follows: - (See Figure 26 and Table 4):

Average consumption: 241.10 kWh/ (m2 year).

Average energy saving: 18.01 kWh/ (m2 year).

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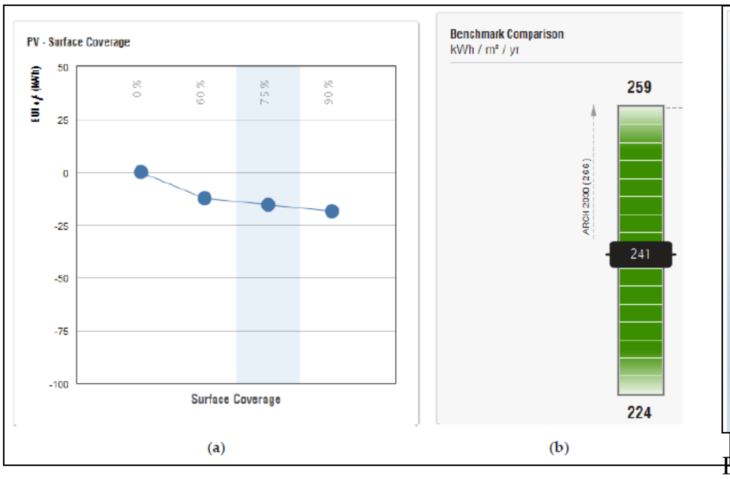

Figure 15: a) Diagram showing the improvement in electrical power installed with photovoltaic (PV) panels on the selected deck at INSIGHT 360. b) Result obtained on the INSIGHT 360 platform after applying the PV power generation upgrade.

9.12 Simulated Joint Global Improvement of All the Proposed Alternatives Applied:-

In this section the previously studied from Sections 4.2–4.7 were combined, to obtain the total overall improvement of applying all the proposed measures. The results obtained after applying the global improvement in the energy simulation are as follows: - (Figure 28).

Average consumption: 138.17 kWh/ (m2 year).

Average energy saving per m2: 120.94 kWh/ (m2 year).

Total average energy saving (useful area 4908 m2): 593,573.52 kWh/year

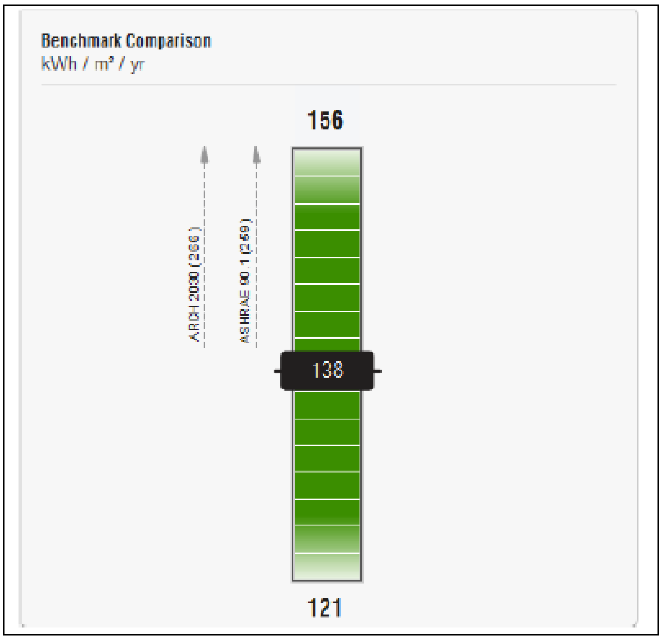

Figure 16: Result obtained on the INSIGHT 360 platform for the building after the global application of the proposed improvements.

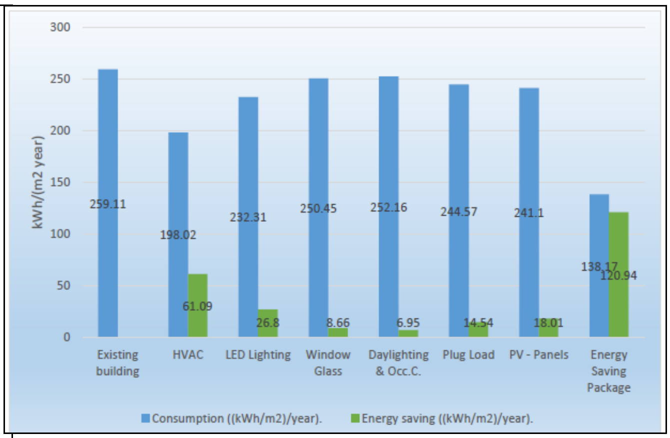

Figure 17: Graph with the different scenarios analyzed for the building.

With the outcomes appeared, we can say that the BIM6D model permitted us to play out a thorough investigation of the effect of the rehabilitation, contrasting the current state and the future state as far as energy and economic balance. That will empower us to evaluate every one of the upgrades in general so it will be feasible to choose options of more prominent energy proficiency, less environmental impact and greater comfort for the users of the building, which thus will prompt an improvement in the energy certificate of the structure.

It ought to be noticed that the Treatment and Diagnostic Centre, being an old structure, doesn't have its own energy meters however shares the meters of energy supplies with the rest of the structures that are important for the University Hospital of Jaén. It is, in this way, hard to confirm the utilization determined in the energy simulation with the genuine utilization of the building. In any case, the energy utilization of all the buildings of the University Hospital of Jaén, in 2019, was 380 kWh/m2, the outcome obtained in the 259 kWh/m2 energy simulation would be acceptable, considering that the examined building has a 12-h working time since it doesn't house hospitalization, intensive care or emergency department that require 24-h working hours and are housed in different buildings. Considering the above mentioned, it would be relevant for future work to introduce meters or measuring equipment that would permit the real utilization of the building to be acquired and check the computation performed by the simulation software.

It ought to be noted in regards with the software used, that in the model used, no impediment was found concerning the number of spaces or components characterized in the building, which, as effectively expressed in the comparing segment, is 226 spaces, with 354 windows and 242 doors. In the BIM model, it was immediately seen that the main improvement measures were those of HVAC, Plug-load, and lighting. Conversely, different measures, like improving the insulation of the building envelope, implied less energy savings, which along with the financial expense discouraged such measures of improvement in the energy demand of the building.

At last, the 13% energy saving that was accomplished with energy efficiency enhancements in lighting is a highlight. These are measures which are effectively appropriate to hospital buildings since they don't interfere in the hospital's

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constant activities, as well as being momentary amortized investments compared to other measures to enhance energy effectiveness in the hospital buildings.

II. Conclusions

With the outcomes applied and analysed in this work, it very well may be perceived how the proposed methodology may turn into an amazing energy analysis and simulation tool. The applied methodology permits the analysis and energy simulation of the BIM 6D model of a modelled building. In this manner, we can simulate the most sustainable measures according to the perspective of energy-saving and energy efficiency, assessing the capability of applying these measures either independently or as a global or joint application of these measures.

Thus, we can assert that the proposed methodology can turn into a viable tool to help in decision-making and to be considered when rehabilitating and modernizing a building according to the perspective of energy proficiency and sustainability. Also, it enables a tool for the analysis of the quantifiable standards for assessing the proficiency and sustainability of public buildings. In spite of the fact that it ought to be borne as a top priority that to utilize these models, in open obtainment of works, the outcome shown should have the option to be appeared in an open standard, which right now makes an interpretation of this methodology into open BIM, for example, the IFC standard (Industry Foundation Classes) kept up by the Building SMART Alliance. This issue is being dealt with perseveringly, both by programming designers and by public and international public organizations.

We can demonstrate that, in BIM energy analysis programming, an energy-saving of 47% was accomplished from the present status, i.e., reducing consumption from a 50 years old hospital centre down the middle, with the consequent decrease in CO_2 emissions, which converts into a more sustainable building.

Further, the economic savings because of the decrease in energy utilization should be thought of. With the proposed measures (LED + lighting control), an energy saving of 13% was accomplished, which, in energy terms, would be 165,645 kWh/year in the BIM model. Further, in regards to the improvement of lighting, this proposition can regularly be carried out without the need to stop hospital activity, which makes this alternative strongly suggested for these buildings.

These proposed energy-saving estimates increase the sustainability of the structure. Finally, it ought to be noticed that the energy model studied with the BIM energy analysis programming used is exportable to different formats, like Open BIM, where a considerably more detailed energy and lighting analysis can be done. Nonetheless, these studies would lose interoperability with the BIM energy model. This is a key field where analysts are right now focusing on BIM 6D and 7D.

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Papers

[1] Information management according to BS EN ISO 19650

[2] BIM in planning & controlling the construction phase on site carbon emission.

[3] Building Information Modelling (BIM)

[4] A framework for facilitating multi-dimensional information integration, management and visualization in engineering projects.

[5] Zero energy buildings and sustainable development implications—A review

[6] BIM as a tool for Green Building Certifications: An evaluation of the energy category of LEED, BREEAM and DGNB.

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