Application of 6D BIM in Designing of Energy Efficient Building

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Abstract- **The use of BIM (Building Information Modelling) software is promising for design of wide range of construction, from small units to bigger buildings. There is a growing requirement to forecast energy usage of building during design stage and consider alternative energy conservative measures and design considerations for more energy efficient building. This kind of work can be possible with the help of BIM. This study works on the impact of orientation of building and material selection of building on energy consumption in small scale construction and evaluates how BIM can make this process easier. It was a stage wise process having 5 main stages. (1) Realistic building is designed with the help of Revit (one of the best BIM tool for 3-D modelling). (2) Exported file to Green Building Studio by converting Revit file to gbXML (green building extensible mark up language). (3) Different building orientations are taken in the Green Building Studio. (4) Effects of different building orientation on the whole building energy consumption are investigated. (5) Simulation of best oriented alternative with the modification in materials. The results showed that properly oriented building can save a significant amount of energy throughout its life cycle. And by providing best material alternatives building can work more efficiently by means of energy consumption.**

Keywords: Building Information Modelling, Revit, Green Building Studio, Orientation, Energy Efficiency

I. INTRODUCTION

Globally, buildings are responsible for over one third of final energy consumption and the greenhouse gas emissions related to the generation of that energy. It has been asserted that it is simpler to save energy than to produce it, thus, the importance of ensuring the energy efficiency of buildings for a range of reasons is now well established. Energy efficiency measures are employed to minimize the energy consumption of a building relating to thermal comfort, lighting, vertical transportation, and hot water(1). Energy consumption and greenhouse gas emissions to the environment attributed to buildings are significant contributors to this environmental impact. The consumption of operational energy by buildings has the single largest impact on the environment. The building sector accounts for about 40% of total energy consumption and 38% of the CO2 emissions(2). With growing threats of global warming, it is not a surprise that the construction industry is now beginning to address the need for energy efficient buildings.

There are several factors that can influence the energy needs of a building, many of which can be managed to improve building energy efficiency. The energy performance of the building envelope and its components (external walls, roofs, windows etc.) can be critical in determining how much energy is required internally. Studies have suggested that lower energy consumption can be due to improved insulation and more efficient

building elements. Occupants' behavior is suggested to impact the level of energy required for space heating in dwellings. For example, the use of heating systems, space and appliances will differ significantly between occupants with dissimilar behavior. The shape and size of a building can have an impact on energy consumption. In order to minimize heat loss, a compact shape (e.g. a cube) is required. The ability that a building has to use solar radiation for heating and lighting may influence energy efficiency, which is often determined by building orientation. It is vital to correctly orient a building so that it can receive a large solar contribution. The use of heating and lighting systems is two major factors that influence energy consumption in buildings, both of which relate to building orientation. In order to maximize solar gain (which is important during colder seasons), it is vital to correctly orient a building so that it can receive a large solar contribution. Among the parameters that have an impact on passive solar gain, orientation as one of the most important. Building orientation is one of the greatest repercussions on the energy demand of a building(3).

Based on review of different papers, it became necessary to highlight one thing that most studies have grounded evidence of impact of orientation on building energy consumption. But, from the methods and techniques which were using earlier it was seen that are too slow with chances of errors. Maximum numbers of studies about orientation on building performance have focused on limited numbers of orientation alternatives. Unluckily opportunities and abilities of emerging BIM were being missed due to lack of knowledge about it.

BIM has often been recognized in research and practice as a suitable tool for support of collaborative planning, facilitating communication and information exchange between diverse planning process participants. More practice oriented publications often advocate BIM benefits as maximization of efficiency, quality and reducing time effort. It is largely understood as object- oriented digital representation of a building or built environment, which enables interoperability and data-exchange in digital form. BIM, in addition to support of collaborative processes, can through its capability of attributing both spatial and geometrical as well as non-geometrical attributes to building elements be implemented in various areas of the AEC industry, such as sustainability analysis, thermal simulation, daylight simulation etc(4).

The aim of this study is to find the impact of orientation and material modification of the building on to the energy use for small scale construction using emerging BIM (Building Information Modeling).

II. RESEARCH METHODOLOGY

Method comprises of number of steps to meet specific research objectives.

First step was all about considering an immense literature review about different important domain pertinent to this study, which includes reviews about BIM, Energy analysis software, factors affecting building energy consumption etc. That would guide to the suitability of use of BIM and energy analysis software for this study and provided the base to understand the relation between building orientation and building energy consumption. Secondly, the best suited software for modelling and simulation work for this study were scrutinized for further work. Third step was to implement modelling work and simulation work on the selected case study with enough information about it. It was necessary to choose building with sufficient information as it allows the author to model and simulate the building with enough precision and facileness. That permitted for thoroughly analysis of differently oriented building alternatives in a BIM environment. After finding the best orientation alternative, it will again be simulated with the modification in materials of roof and side walls for the best possible results. And finally, the computed results of case study analysis are collated with real energy consumption data, in this case a bills, which provided the justification of all computation works.

Literature review

What is BIM (Building Information Modeling) and GBS (Green Building Studio)?

BIM (Building Information Modeling)

The BIM Handbook defines Building Information Modeling (BIM) as ‘‘a modeling technology and associated set of processes to produce, communicate, and analyze building models’’, where building models are digital objects associated with computable graphics, parametric rules and data attributes which could be managed, shared and exchanged in an interoperable way(5). According to the Autodesk Committee, “Building Information Modeling (BIM) is an integrated process for exploring a project’s key physical and functional characteristics digitally before it is built.” “Building Information Modeling (BIM) represents the process of development and use of a computer-generated model to simulate the planning, design, construction and operation of a building facility”(6). BIM is currently the most common denomination for a new way of approaching the design, construction and maintenance of buildings(7). The BIM (Building Information Modeling) can be treated as advanced evolution of CAD (Computer-Aided Design) and implementation of BIM technology will contribute to greater construction industry efficiencies through increased collaboration between different project participants, less collisions and repeat work on corrections and adjustments. Extensive research and development in academia and industry has brought many powerful and practical building information modeling tools for analysis, design and detailing(8). To the most utilized BIM Tools count Autodesk Revit (as one stop shop, offering possibilities for architectural, structural and MEP modeling and even proprietary tools for thermal and day- light analysis)(4). Autodesk Revit is a BIM software which is used to model designs with precision, optimized performance and conceptualization. It is specifically built for BIM which allows the construction professionals to implement their ideas into a view in the early stages of design. Revit is a single application which includes the features for Architecture, MEP (Mechanical, Electrical and Plumbing), Structures and Construction(6).

GBS (Green Building Studio)

GBS is a flexible cloud-based service that allows the designer to run building performance simulations and optimize energy efficiency earlier in the design process, helping to extend the ability to design high performance buildings consuming less time and at lower costs when compared with conventional methods(9). Green Building Studio is a service that allows running building performance simulations to give all energy performance results. Through those reports, energy usage and carbon emissions can be optimized early in the design process. GBS uses the DOE-2 simulation engine for an hourly calculation of the whole building energy usage. It is possible to use GBS with conceptual models from Revit, more detailed Revit models or a gbXML file created by other authoring tools. Energy simulation can be displayed on GBS website or with its own models(10). The Autodesk Green Building Studio web service provides:

Annual energy cost • Lifecycle energy costs • Annual energy consumption (electric and gas) • Peak electric energy demand (kW) • Lifecycle energy consumption (electric and gas) • Water use analysis • Assistance with day lighting using glaze factor calculations • Natural ventilation potential calculations • Carbon emission calculations. Analysis results are presented in a highly-visual, graphical format for easy interpretation. It can also facilitate collaborative design, allowing to transfer essential information on your building design to the applications used for engineering design or code analysis. The Autodesk Green Building Studio service can help to change the way building energy analysis is used in the building design process(11).

There were some reasons to choose the software used in this study. Revit is one of the most popular BIM authoring tools currently being used in the construction industry. This was corroborated by surveys conducted by the NBS (National Building Specification), that has consistently placed Revit top two by usage and preference. Green Building Studio was chosen because of the fact that so many orientations can be chosen and impact generated in real-time, without the need to revert to the original geometric model. To support building data transaction between BIM applications and building energy analysis tools, significant success has been reported with the development of XML (extensible markup language) e based schemas. One of the most common data format for such information exchange or interoperability is the gbXML (Green Building XML) format. gbXML is the schema for the writing of BIM models, due to its capacity to incorporate thermal descriptive data. The gbXML schema can be conceived as a database where descriptive information is linked with geometry. The use of gbXML suggests that by importing geometric models from BIM software into energy simulation tools without the need to recreate the building geometry within the simulation interface, significant time savings can be realized. The last reason for choosing Revit and Green Building Studio was the fact that both can seamlessly communicate through gbXML(3).

III. CASE STUDY

Scenario Description

The case study building is small-scale domestic construction currently being occupied by a family.

A 2- storey house having three members is located in Vadodara, Gujarat. Building consist of living room, kitchen, bed room, small store room, WC and bathroom on ground floor and two bed rooms with attached WC & bathroom, study room, a big balcony on first floor and a room for storage on second floor. The reason behind choosing this building is having good connection with the owner of the house so it would be easy to gain access to the building to reform the drawings and to get bills for validation of results.

A series of tests were conducted firstly to measure the impact of orientation on building energy consumption. Energy analysis of the initial building model (front of the building facing directly north) will provide data for test 1. Test-2 will evaluate the case energy use at +30°, test-3 at +60°, test-4 at +90°, test-5 at +120°, test-6 at +150°, test-7 at +180°, test-8 at -150°, test-9 at -120°, test-10 at -90°, test-11 at -60°, test-12 at -30°. From these the best alternative was chosen and simulation was conducted on that alternative by changing the materials of the building.

Modelling Process

With the help of drawings provided by the owner modelling work is taken into consideration. For conducting energy analysis, Building model was exported from Revit using gbXML . When model is converted to gbXML, it can be use in GBS.

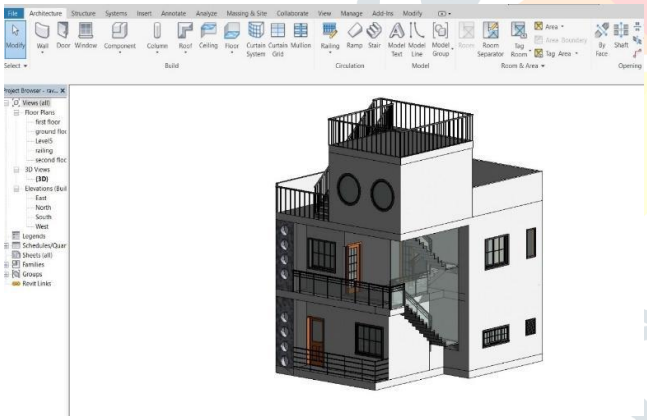


Figure 1-CASE STUDY BUILDING

Energy Simulation in Green Building Studio

When new project was created in Green Building Studio, it required a details as shown in fig. By providing the details to the Green Building Studio it will automatically select the project's nearest weather station in order to acquired relevant information which will be used during simulation work.

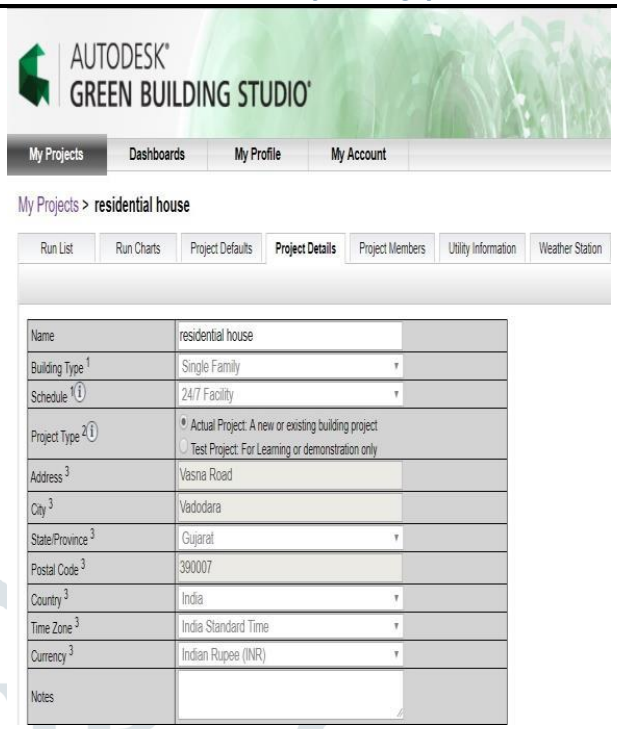


Figure 2-PROJECT INFORMATION

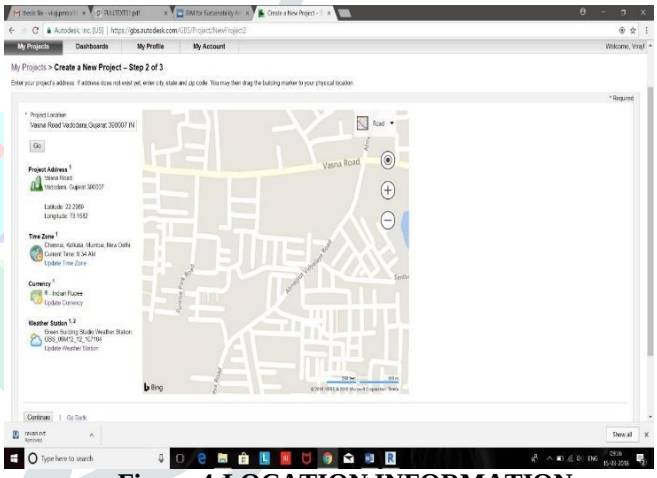


Figure 4-LOCATION INFORMATION

Furthermore, the current utility rates that are representative of the location were inputted. Average current energy consumption rates were used in this instance and were obtained from MGVCL. An electricity cost of Rs. 4.13/kWh and a gas cost of Rs. 59/Therm were used.

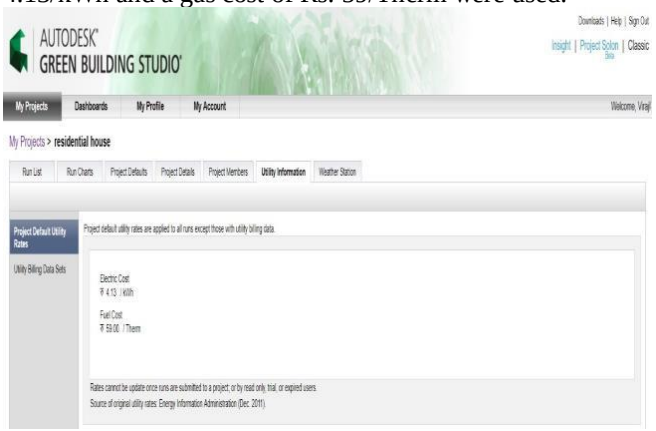


Figure 5-UTILITY RATES

Green Building Studio automatically calculates various energy use information including total annual energy use as shown in fig. In order to compare and observe the impact that building orientation has on energy use, a number of additional 'runs', or design alternatives were added to the project. This is the major strength of Green Building Studio. To do this, the design alternatives tab is selected, and changes to the base run are made. The data used for initial base run would be again use for alternative test runs with the change of orientation at 30° changes. As building's orientation changes, a different elevation will vulnerable to the sun's radiation. An ability of building to naturally heat an internal space depends on its external component and the way in which they interact with the sun rays. The building is situated in India (Northern Hemisphere) and sun rises in the east and sets in the west, therefore building should face south to get maximum benefits of sun's energy. But due obstacles of other buildings by which the case study building is surrounded, it gets maximum benefits of sun's energy in north direction.

The model tested in its natural position without any alterations in Green Building Studio is named as base run. The model is then rotated to 30° clockwise and so on to make 11 more tests. After that the best test alternative was again going to be simulated with material changes

Building Analysis and Discussion

The results can be analysed, discussed and presented initially for understanding of relationship between orientation of the building and energy consumption. Some assumptions need to be taken during working in Green Building Studio. Loss of energy during transmission is not going to be included. A term 'Fuel' in Green Building Studio was basically used for gas consumption.

IV. SCENARIO ANALYSIS

BASE RUN

In this case, the front of the building is North facing, and the rooms at the front facing are living room study room, balcony and store room. The total electricity and fuel consumption for this run was 6266 kWh and 4155 MJ respectively with total annual costing of Rs. 28,203.

+90° RUN

At 90° run, the south face of the building incorporate only one window, although the windows on the front and back and the balcony may influence the solar gain of a low level. The total annual electricity and fuel usage are 6661 kWh and 4225 MJ respectively having total costing of Rs. 29,874.

+120° RUN

This is the face of the building with a bit lower volume of window units and is orientated a bit of towards South. The total annual electricity and fuel energy consumed are 6757 kWh and 7219 MJ both costing Rs. 30266 in total.

+150° RUN

This face of the building is quite in a direction of south and having lower amount of volume of space for solar gain. The total annual electricity and fuel energy consumed are 6766 kWh and 4149 MJ both costing Rs. 30,264 in total.

+180° RUN

With big open space of balcony and a set of two windows, facing directly to the south. The total annual electricity and fuel energy consumed are 6778 kWh and 3996 MJ both costing Rs. 30,229 in total.

-150° RUN

Test suggests that prices begin to rise as the building is re-oriented. The total annual electricity and fuel energy consumed are 6832 kWh and 4088 MJ both costing Rs. 30,502 in total.

-120° RUN

Still price is on increment as building is re-oriented. The total annual electricity and fuel

energy consumed are 6842 kWh and 4165 MJ both costing Rs. 30,587 in total.

-90° RUN

At an orientation of -90°, the total annual electricity and fuel energy consumed are 6743 kWh and 4174 MJ both costing Rs. 30,182 in total.

-60° RUN

At an orientation of -60°, the total annual electricity and fuel energy consumed are 6582 kWh and 4323 MJ both costing Rs. 29,602 in total.

-30° RUN

At an orientation of -30°, front façade of the building was relatively in the direction of north. The total annual electricity and fuel energy consumed are 6382 kWh and 4388 MJ both costing Rs. 28,810 in total.

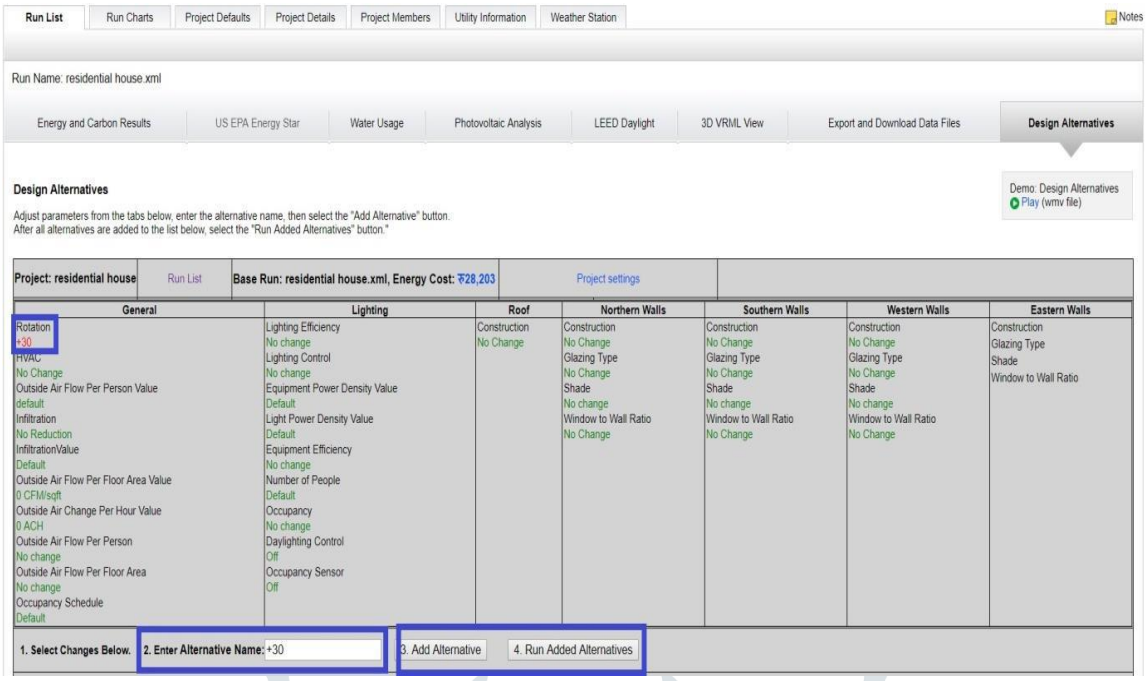


Figure 6-ORIENTATION ALTERNATIVE

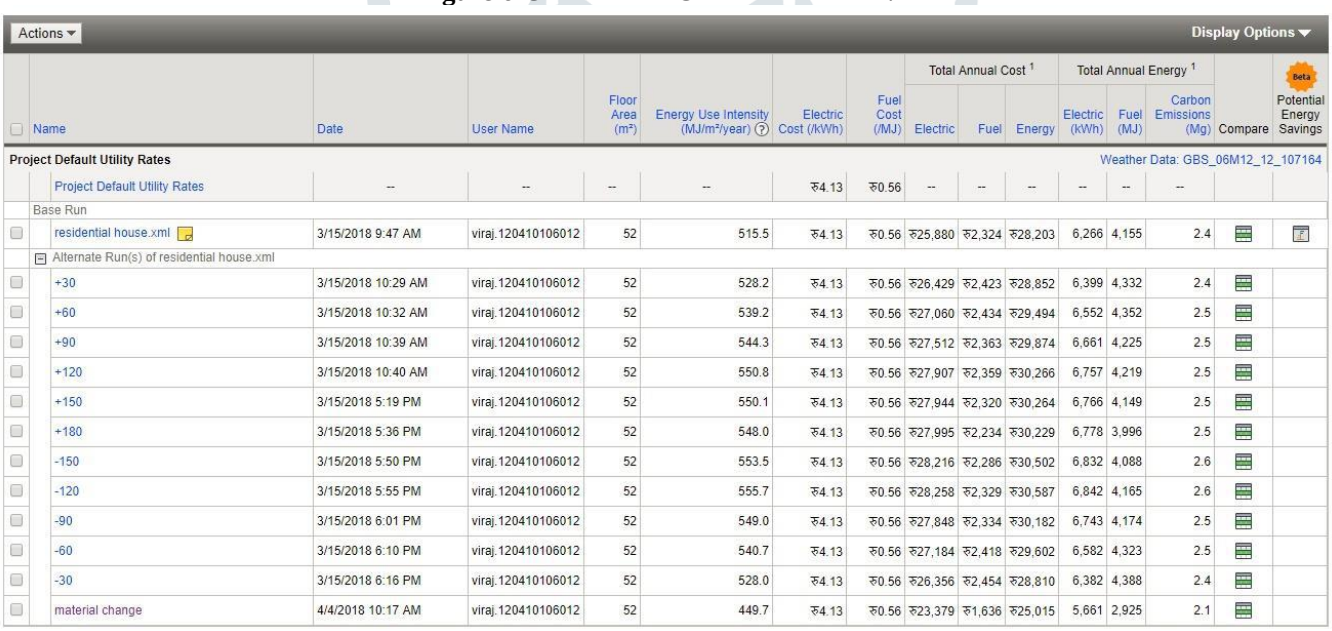


Figure 7-SIMULATION DETAILS

V. RESULT DISCUSSION

By performing the case study, researcher was able to generate quantitative data to fulfil the research objective. Initially, the case study was focusing on manipulation of BIM model with the help of Green Building Studio to test its energy use for different orientation. The way in which the building is orientated related to the sun's path is greatly affecting the ability of building to naturally heat its envelope through solar gain.

The best orientation for the building was in the direction of north (Base Run). That orientation provided the maximum solar gain and natural lighting to the building due to big open space of balcony and a set of big windows. For the best results base run was going to be simulated again with the changes in material selection for different components of the building. In addition to this analysis, life cycle energy and life cycle cost have been computed and summarised in Table 1.

VI. VALIDATION OF RESULTS

The actual orientation of the building was already explained and its energy consumption and cost values were computed earlier in run analysis. This was done to compare the results obtained with the bills collected from the building. Real bills are quite empirical data or true data with which the auditing data can be compared. Moreover, simulation results obtained by building energy simulation software should be validated by comparing with measured data for an actual building(12). So, based on that comparison between the building bills and simulation results obtained by the Green Building Studio was taken into consideration.

The total annual cost paid by the owner last year was around Rs. 28,061. And according to the results generated by the Green Building Studio it was approximately Rs. 30,182. So, the obtained result by Green Building Studio was 7.55% higher than the actual annual bills results. There were main two reasons behind this difference. Firstly, the unit rates for the bills were for the year 2017 and the rates taken by Green Building Studio according to location provided were for year 2018, which is giving some difference between actual data and simulated data. Secondly, the utility rates provided to the Green Building Studio were an average value of unit rates for different range of unit consumption. The accepted percentage error between computer simulation results and empirical or measured data should be in the range ±15% for the software to be considered accurate(13).

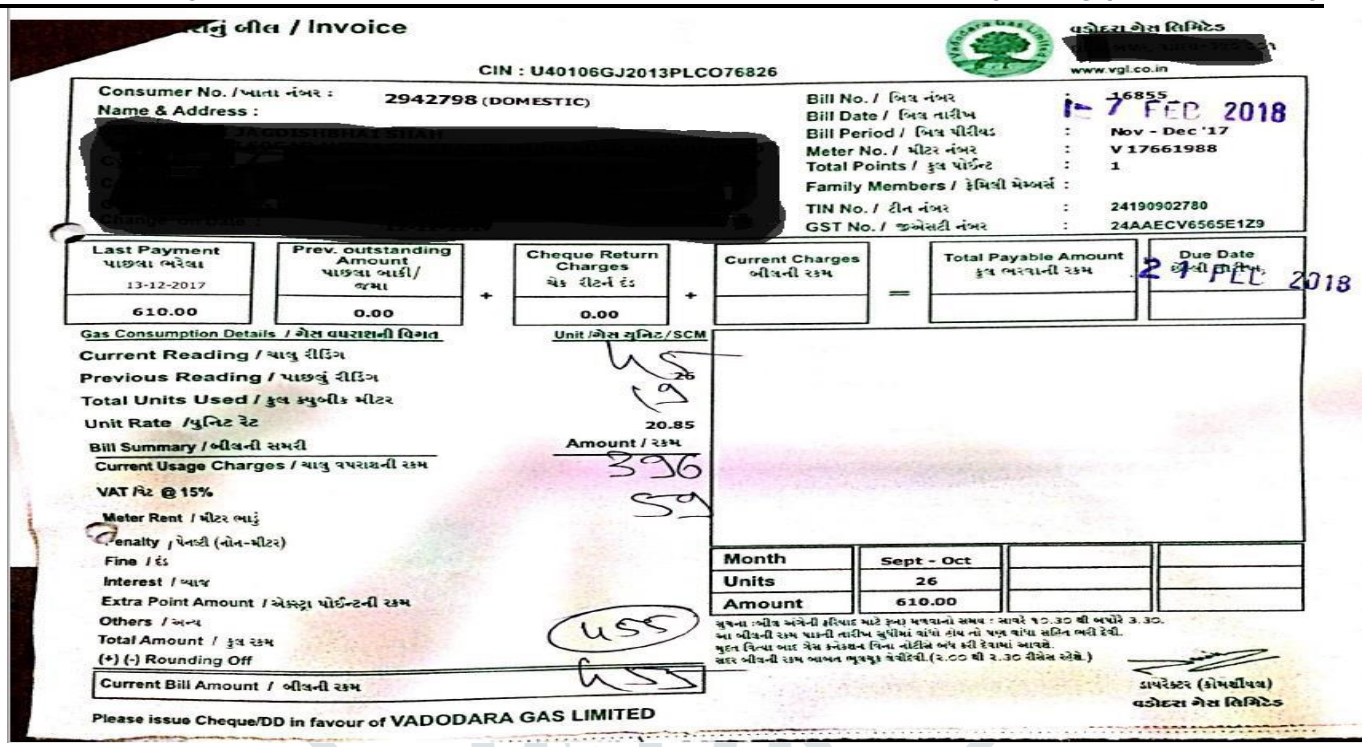
It is must to highlight the error possibility sources by which the results can be influenced.

- It is difficult to carry out the actual and precise orientation of the building. That's why the orientation used for simulation might be having some error with respect its precise orientation.
- Actual building values may differ from the assumed co-efficient values for Green Building Studio.

A sample bill copy of gas bill and electricity bill given below in Figure 7 & 8.

Table 1

TEST	ANNUAL		LIFE CYCLE		ANNUAL ENERGY COST(Rs.)	LIFE CYCLE COST(Rs.)
	Electricity(kWh)	Fuel(MJ)	Electricity(kWh)	Fuel(MJ)		
Base Run	6266	4155	3,13,300	2,07,750	28,203	6,40,212
+30	6399	4332	3,19,950	2,16,600	28,852	6,54,943
+60	6552	4352	3,27,600	2,17,600	29,494	6,69,518
+90	6661	4225	3,33,050	2,11,250	29,874	6,78,143
+120	6757	4219	3,37,850	2,10,950	30,266	6,87,037
+150	6766	4149	3,38,300	2,07,450	30,264	6,86,987
+180	6778	3996	3,38,900	1,99,800	30,229	6,86,205
-150	6832	4088	3,41,600	2,04,400	30,502	6,92,388
-120	6842	4165	3,42,100	2,08,250	30,587	6,94,330
-90	6743	4174	3,37,150	2,08,700	30,182	6,85,138
-60	6582	4323	3,29,100	2,16,150	29,602	6,71,960
-30	6382	4388	3,19,100	2,19,400	28,810	6,53,978



...નું બીલ / Invoice

વડોદરા ગેસ લિમિટેડ

CIN : U40106GJ2013PLCO76826

www.vgl.co.in

Consumer No. / ખાતા નંબર : 2942798 (DOMESTIC)

Name & Address :

[redacted]

Bill No. / બિલ નંબર : 16855

Bill Date / બિલ તારીખ : 7 FEB 2018

Bill Period / બિલ પીરીયડ : Nov - Dec '17

Meter No. / મીટર નંબર : V 17661988

Total Points / કુલ પોઈન્ટ : 1

Family Members / ફેમિલી મેમ્બર્સ :

TIN No. / ટીન નંબર : 24190902780

GST No. / જીએસટી નંબર : 24AAECV6565E1Z9

Last Payment પાછલા ભરેલા	Prev. outstanding Amount પાછલા બાકી/ જમા	+	Cheque Return Charges ચેક રીટર્ન દંડ	+	Current Charges બીલની રકમ	=	Total Payable Amount કુલ ભરવાની રકમ	Due Date છેલ્લી તારીખ
13-12-2017								27 FEB 2018
610.00	0.00		0.00					

Gas Consumption Details / ગેસ વપરાશની વિગત — Unit /ગેસ યુનિટ / SCM

Current Reading / ચાલુ રીડિંગ

Previous Reading / પાછલું રીડિંગ

Total Units Used / કુલ ક્યુબીક મીટર 26

Unit Rate /યુનિટ રેટ 20.85

Bill Summary / બીલની સમરી — Amount / રકમ

Current Usage Charges / ચાલુ વપરાશની રકમ 396

VAT વેટ @ 15% 59

Meter Rent / મીટર ભાડું

Penalty / પેનલ્ટી (નોન-મીટર)

Fine / દંડ

Interest / વ્યાજ

Extra Point Amount / એક્સ્ટ્રા પોઈન્ટની રકમ

Others / અન્ય

Total Amount / કુલ રકમ 455

(+) (-) Rounding Off

Current Bill Amount / બીલની રકમ 455

Month	Sept - Oct		
Units	26		
Amount	610.00		

સૂચના : બીલ ભરવાની મુદ્દત પછી ભરવાનો સમય : આપને ૧૦.૩૦ થી આપે ૩.૩૦. આ બીલની રકમ પાકની તારીખ સુધીમાં ચાંપ તાપ નો ખર્ચ ચાંપા સહિત ભરી દેવી. મુદત વિત્યા બાદ ગેસ કનેકશન વિના નોટીસ બંધ કરી દેવામાં આવશે. વધુ બીલની રકમ બાબત ખુલાસા પહોંચી. (૨.૦૦ થી ૨.૩૦ ટીકેન એરીયા)

Please issue Cheque/DD in favour of VADODARA GAS LIMITED

ડાયરેક્ટર (કોમર્શીયલ)
વડોદરા ગેસ લિમિટેડ

Figure 7-GAS BILL SAMPLE

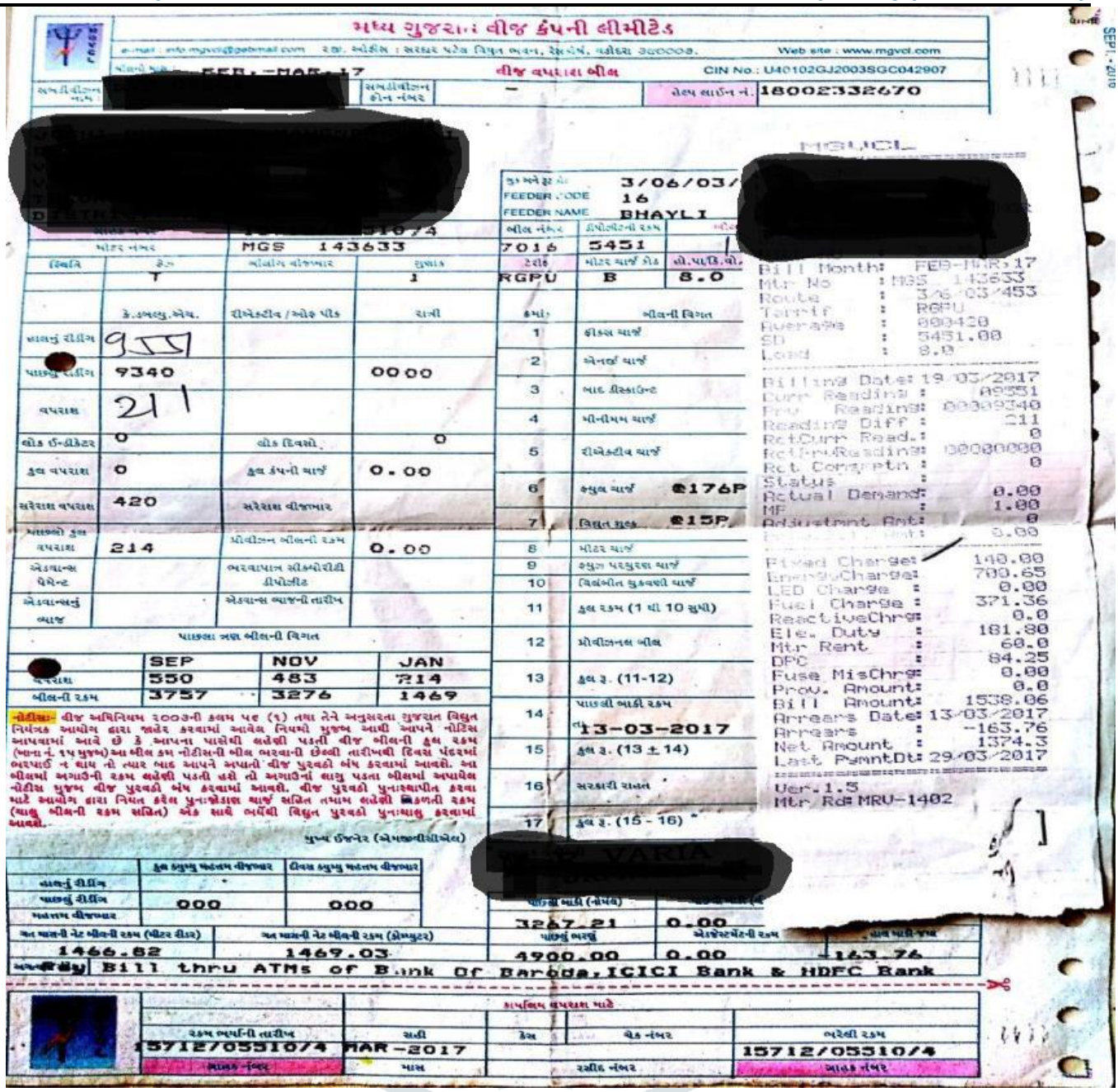


Figure 8-ELECTRICITY BILL SAMPLE

VII. CONCLUSION

This paper offers the opportunity to understand the capability of BIM to evaluate the energy consumption of the building for parameter like orientation and come up with the best for building even without putting single brick on field. It is providing the best opportunity to avoid mistakes happened by assessing the building manually or by any other traditional techniques. Building energy consumption can be affected by many ways number of occupants, shape, size, orientation, material selection, building envelope etc. The building's ability to gain maximum natural light to internal space can definitely affect the use of artificial light requirement. And selection of building material can greatly affect the energy requirements to maintain internal temperature of the building.

In the study, Revit and Green Building Studio both were used to perform the energy simulation initially for different orientation alternatives. And can see from the results that the savings in energy and money is quite good by just applying some alterations to the building. The case study can proposed that effectively oriented building could save a worth of Rs. 1, 26, 500 throughout its life. The examination has been successful to proving the ability and applicability of BIM for energy efficient building. It has also explained that how Revit and GBS can work with each other via gbXML for energy simulation works.

However, It is must to note that there might be a chances of minor errors in both Revit and Green Building Studio and virtual manipulation will take place independently for both Revit and Green Building Studio. And finally the results are validated with actual data so it can be said that Green Building Studio results are within range.

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