Architecture and Planning Journal (APJ)

Volume 23 Issue 2
SPECIAL ISSUE
RETHINKING ARCHITECTURAL EDUCATION
2016 - TOWARDS A BETTER PRACTICE

Article 16

ISSN: 2789-8547

March 2016

ATTAINING THE APPROPRIATE SIMULATION PROGRAM TOWARDS BETTER ENVIRONMENTAL DECISIONS

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DOI: https://doi.org/10.54729/2789-8547.1085

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Abstract

Global Warming is one of the greatest environmental threats of the 21st century. Many parties around the world like governments, corporations, and researchers, etc. are working hard to find solutions. Architectural education is concerned with global warming issues, and trying to achieve reliable design related solutions for a sustainable environment. Majority of the students use simulation programs to determine with accuracy some variables that can support designers to take decisions about the best strategies to apply for any type of building. These simulation programs are usually selected based on their straightforward and user-friendly interface. The most common programs among architecture students at the Beirut Arab University are Ecotect, DesignBuilder and CFD. However, not all the results are precise nor are they based on an accurate scientific basis. This paper will discuss the scientific background, interface, and capability of these programs. In addition compare them in order to establish their differences, besides a brief overview about energy simulation concepts. In addition the research will conduct a survey measuring the awareness and benefit of the three programs among students as a design decision supporting tool. Furthermore students that already implemented these programs in their design will be selected, to show how they dealt with these programs and how these programs interfered with their design decision making. The selection of the students will show the appropriate year to add this program as a supporting tool for architectural design studio.

Keywords

Architectural design studio. Building simulation programs, CFD, DesignBuilder, Ecotect

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ABSTRACT

Global Warming is one of the greatest environmental threats of the 21st century. Many parties around the world like governments, corporations, and researchers, etc. are working hard to find solutions. Architectural education is concerned with global warming issues, and trying to achieve reliable design related solutions for a sustainable environment. Majority of the students use simulation programs to determine with accuracy some variables that can support designers to take decisions about the best strategies to apply for any type of building. These simulation programs are usually selected based on their straightforward and user-friendly interface. The most common programs among architecture students at the Beirut Arab University are Ecotect, DesignBuilder and CFD.

However, not all the results are precise nor are they based on an accurate scientific basis. This paper will discuss the scientific background, interface, and capability of these programs. In addition compare them in order to establish their differences, besides a brief overview about energy simulation concepts. In addition the research will conduct a survey measuring the awareness and benefit of the three programs among students as a design decision supporting tool. Furthermore students that already implemented these programs in their design will be selected, to show how they dealt with these programs and how these programs interfered with their design decision making. The selection of the students will show the appropriate year to add this program as a supporting tool for architectural design studio.

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1. INTRODUCTION

Energy performance simulation programs are powerful tools to analyze energy performance and thermal comfort during the building's life-cycle, such as energy use and demand, temperature, humidity, costs, daylighting, and ventilation (Rosenbaum, 2003). Hundreds of reliable building energy programs have been developed over the past 50 years. Building simulation is the process of using a computer to build a virtual replica of a building. Such tools differ in many ways; in their thermodynamic models, graphical user interfaces, life-cycle applicability, and compatibility with other programs. A simulation is performed by taking that building through the weather conditions in a specific time. In a way, building simulation is a way to quantitatively predict the future and thus has considerable value. Environmental simulation programs consist of an engine with complex algorithms which enables detailed thermal simulations based on simple text-based input and output files. Most important for the friendly use of these tools is the program interface that eases the generation of input and the evaluation of the output, and exposes the functionality of the engine to the user (California Commissioning Collaborative, 2012). These simulation software can determine

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air conditioning loads (the amount of cooling/heating energy needed, volumetric air flow requirements (the amount of air needed to cool/heat), equipment capacities, supply Temperatures, hydronic Plant capacities (worst case simultaneous load), Similarities and differences between equipment options for heating and cooling a space. In addition these programs can also predict the monthly energy consumption and bills, the annual energy cost, annual CO2 emissions, Compare and contrast different efficiency options, determine life cycle payback on various options (eQUEST, 2010). Recent developments lead to a broader use overall design phases. Building simulation programs are not considered as graphic support tools to the same extent as CAD tools or costing software for this reason Data exchange, from other graphic software is very important. Some CAD modeling tools are compatible with these programs, like Revit and 3Ds Max.

In this paper the three simulation programs will be analyses according to their functionality, models, limitations, usage within the life-cycle and the usage of data exchange possibilities are being addressed. Since more and more 3D building geometry models are becoming available, building geometry programs can be changed to be compatible with simulation tools however, only thorough automated conversion of building geometry will support the use in practice.

Usually, these tools are developed to be used during the design phase of the building, including the energy simulation programs in the design phases is called "energy design process" (Hayter et al, 2000).The design phases are classified to four main categories (Gordon, 2013):

- **Concept design phase:** Considers major design options. Includes concept design, research and development, feasibility and risk management.
- **Schematic Design phase** Several concepts will be, discussed, reviewed and evaluated. A master plan of the building showing access & circulation throughout the site and building Relevant Elevations, and Sections.
- **Preliminary design phase** Focuses more on the elements that of the design.
- **Detailed design phase** Develops the selected design to its final state. It includes research and development, feasibility studies, concept and detail design, technical and functional specifications, plans and drawings, operational systems, construction.

In conceptual design phase it is important to be able to evaluate multiple concepts, and to quantify, rank-order, and even to be able to semi-automatically generate design alternatives. Choose the right simulation program that will assist in the design process and will help choose the site location.

In the schematic design phase the simulation programs assist in the implementation of the building in the site selected, including building orientation, aspects and views, nevertheless it will give a brief on certain materials to be considered.

Design Development Phase majority of building decisions are made, operating and non-operating environmental simulations, for all the building technologies and systems. This will help take the decisions in renewable energy installation.

Detailed Design phase the simulation programs will give the final tests and the results will be an overlook of how the building will operate after execution, and if there is some changes to consider. In addition helps in verifying the certification level that could be achieved from example in LEED, or other green building rating system (Rosenbaum, 2003).

1.1 Methodology

The first topic will give an overview of the three programs the way they function and their specialties, secondly the paper will discuss the three programs with an analytical point of view. Then a comparison among these programs will be conducted between the interphases and process in an indoor and outdoor environment. Thirdly a survey will be conducted to show the awareness and benefit of the three programs among architecture student. The final strategy will review the application of these programs that were already implemented in the design, a group of students from different years will be selected this will show how they dealt with these programs and how these programs interfered with their design decision making. In

conclusion the listed strategies will show the appropriate year to add this program as a supporting tool for architectural design studio, and in which design phase.

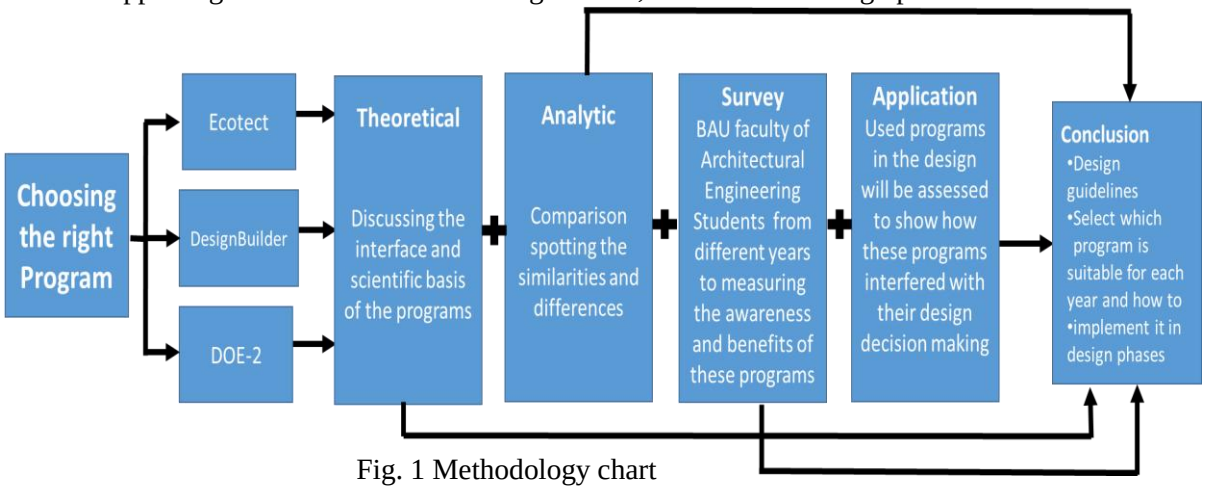

Fig. 1 Methodology chart
Reference: By Authors

2. THEORETICAL

The following programs where chosen based on their familiarity to the BAU students, in addition the Design Builder is being taught in a course named Environmental Design for fourth and fifth academic years 2014/2015. While students use Ecotect since it is fast to learn and dealt a lot with. DOE-2 was chosen since it have the same components and results of both Ecotect and Design Builder but more advanced with reliable data and scientific based, few students use this program. This part will identify the use of each program, including the compatibility with CAD and other geometry based software, nevertheless will show the interface of each program.

2.1 Ecotect

Autodesk Ecotect Analysis is an environmental analysis tool that allows designers to simulate building performance from the earliest stages of conceptual design. It combines analysis functions with an interactive display that presents analytical results directly within the context of the building model. Ecotect was acquired by Autodesk from Square One Research and adds to an array of tools that augment the Revit BIM environment including Sketchup, AutoCAD, 3D Max or Rhinoceros in DXF or 3ds format. Ecotect is different from other analysis tools in that it targets the earliest stages of design, a time when simple decisions can have far-reaching effects on the final project. (Autodesk, 2015)

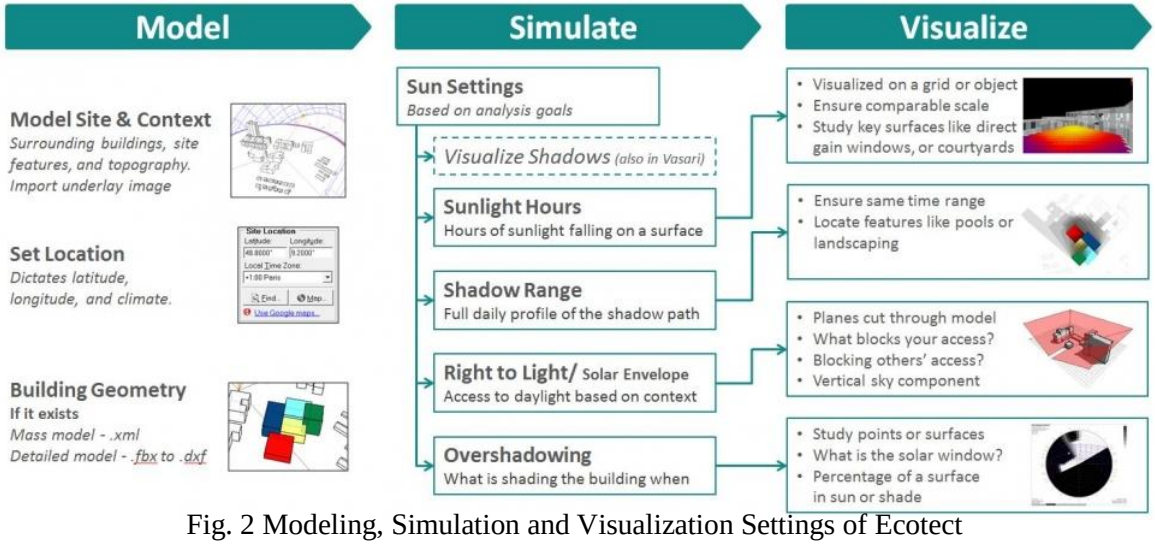

Fig. 2 Modeling, Simulation and Visualization Settings of Ecotect
Reference: http://sustainabilityworkshop.autodesk.com/buildings/ecotect-shadows-sunlight-hours

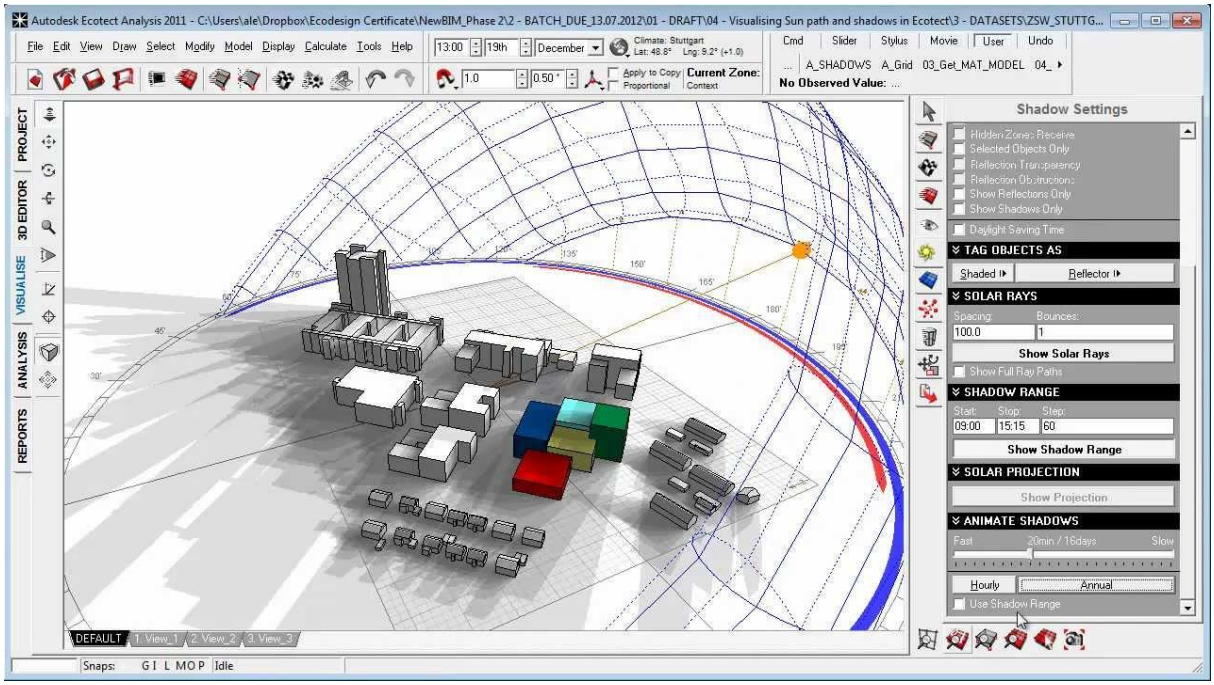

Fig. 3 Ecotect Interface, and Visualizing sun path and shadow
Reference: http://sustainabilityworkshop.autodesk.com/buildings/ecotect-shadows-sunlight-hours

2.2 DesignBuilder

Provides advanced modelling tools in an easy-to-use interface. This enables the whole design team to use the same software to develop comfortable and energy-efficient building designs from concept through to completion. allow you to link with BIM solutions, analyze solar shading, maximize the use of renewable technologies, test facade options and check the potential for natural ventilation to provide cooling all in one place, adjusting as you go according to client requirements. High quality technical and rendered outputs help communicate findings to clients in a way they can easily understand. Key performance indicators such as energy consumption, carbon emissions, thermal comfort, daylight availability and cost can be provided throughout the design process in both naturally ventilated and air-conditioned buildings. Some typical uses are:

- Calculating building energy consumption.
- Evaluating façade options for overheating and visual appearance.
- Thermal simulation of naturally ventilated buildings.
- Daylighting models lighting control systems and savings in electric lighting.
- Visualization of site layouts and solar shading.
- Calculating heating and cooling equipment sizes.
- Communication aid at design meetings.
- An educational tool (DesignBuilder, 2010)

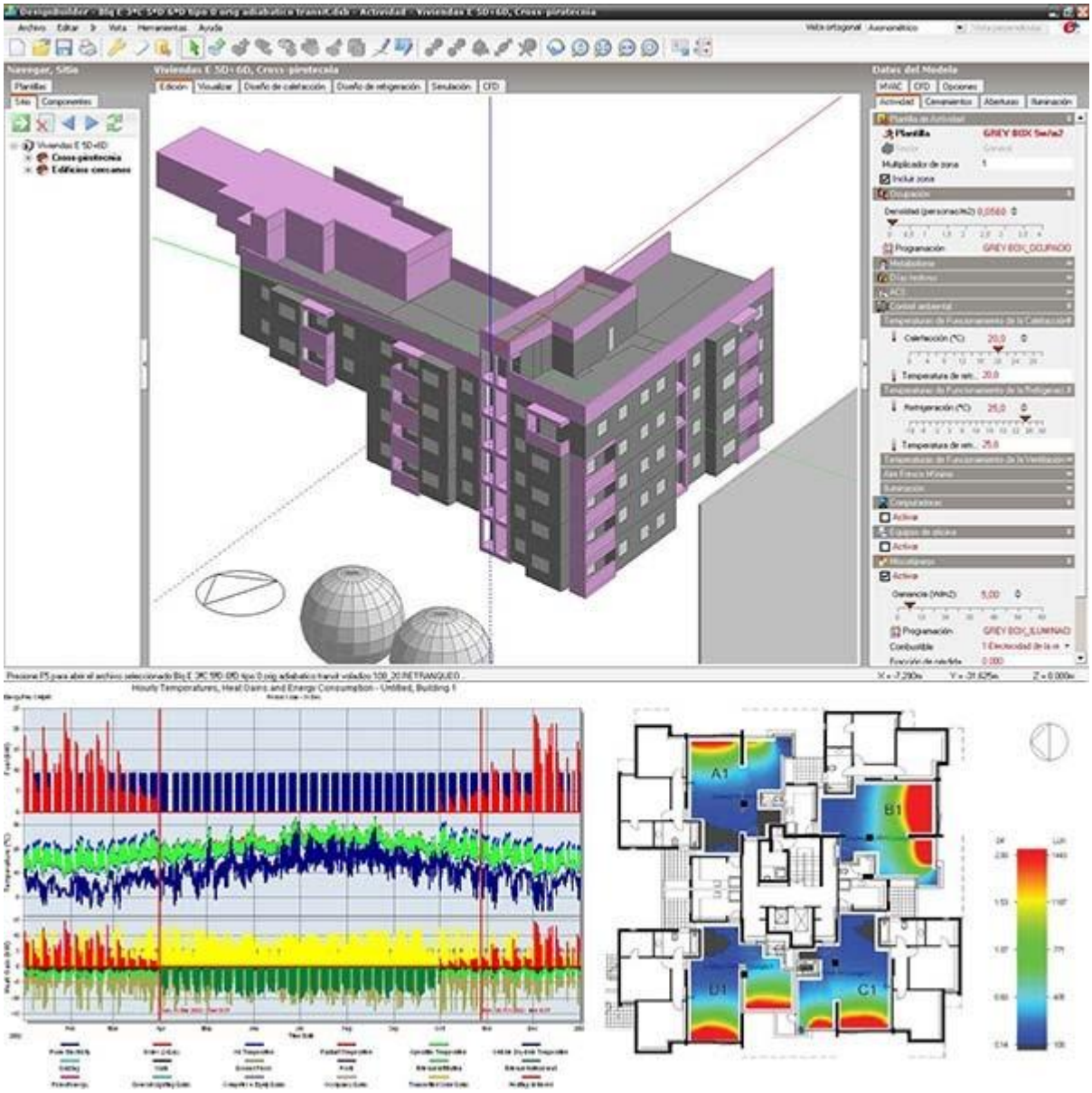

Fig. 4 Design Builder Interface Graphs and internal zones showing heat and lighting
Reference: http://www.designbuilder.co.uk/

2.3 DOE-2

DOE-2 with the given building geometric, HVAC description and hourly weather information can predict the energy use and energy cost of a building. DOE-2 has one subprogram for translation of input (BDL Processor), and four simulation subprograms (SYSTEMS, LOADS, PLANT and ECON). SYSTEMS, LOADS and PLANT are executed in sequence, with the output of LOADS becoming the input of SYSTEMS, etc. The output then becomes the input to ECONOMICS. Each of the simulation subprograms also produces printed reports of the results of its calculations. DOE-2 has been used extensively for more than 25 years for both building design studies, analysis of retrofit opportunities, and for developing and testing building energy standards in the U.S. and around the world. The private sector has adapted DOE-2 by creating more than 20 interfaces that make the program easier to use. (Hirsch, 2012)

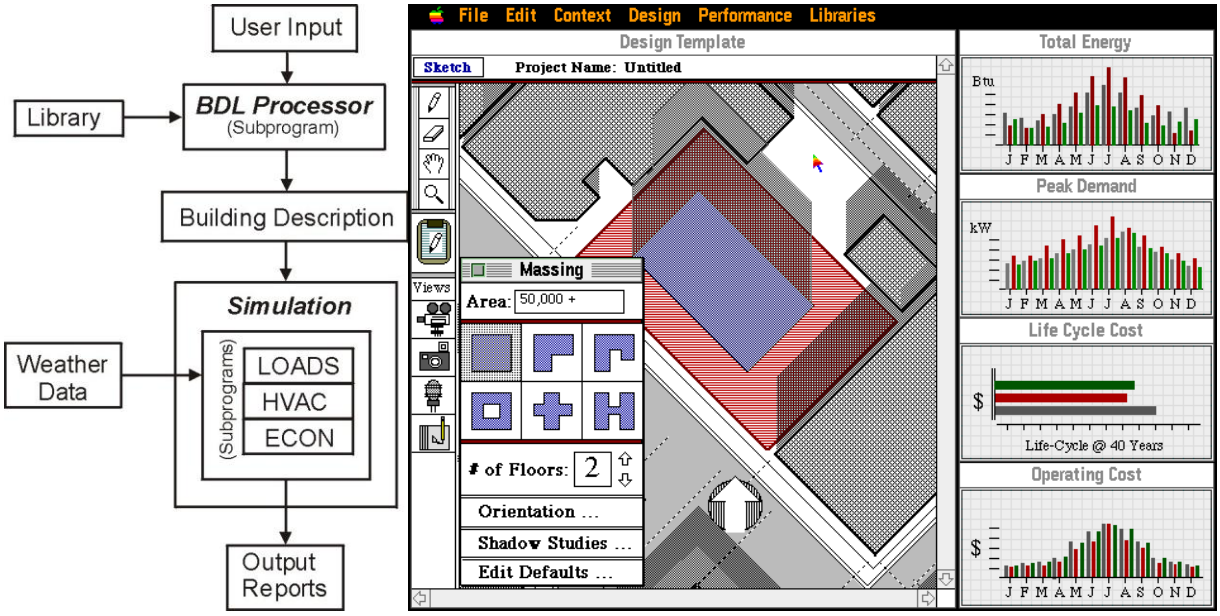

Fig. 5 Flowchart of DOE-2 (Left), DEO-2 Interface Geometry and Data Analysis (Right)
Reference: www.electricianmath.com (Left), Reference: http://eetd.lbl.gov/ (Right)

3. ANALYTICAL

This part will be a comparison between the three programs that will give an overview of how the programs compute, deal with the air flows, handle the output and input, interact with renewable energy, and how they are affective interior and exterior wise, nevertheless the following will also cover the specialty of each program and the precision and accuracy of the outcome, and engines that help each one.

3.1 Comparison

Table 1. Comparison between DOE, Ecotect and DesignBuilder.
Contrasting the Capabilities of Building Energy Performance
Simulation Programs: Drury B. Crawley

Zone Loads	**DOE-2**	**Ecotect**	**DesignBuilder**
Interior Surface convection			
dependent on temperature			x
dependent on air flow			P
dependent on surface coefficient from CFD			E
User-defined coefficient (constants, equations or correlations)	x	x	x
internal thermal mass	x	x	x
Automatic design day calculation for sizing			
Dry bulb temperature	x	x	x
dew point temperature or relative humidity	x		x
User-specified minimum and maximum	x		x
user-specified steady-state-periodic of fully dynamic design conditions			
Building Envelope, Daylighting and solar			

outside surface convection algorithm			
BLAST/TARP			x
DOE-2	x		x
MoWiTT			x
ASHRAE Simple			x
Ito, Kimura and Oka correlation			
user-selectable			x
inside radiation view factors			x
Radiation-to-air component separate from detailed convection (exterior)			x
Solar gain and daylighting calculations account for inter-reflections from external building components and other buildings		x	x
Infiltration, Ventilation, Room Air and Multizone Airflow			
Single zone infiltration	x	x	x
Automatic calculation of wind pressure coefficients			P
Natural ventilation (pressure, buoyancy driven)			x
Multizone airflow (via pressure network model)			x
Hybrid natural and mechanical ventilation			
Control window opening based on zone/external conditions			x
Displacement ventilation			x
Mix of flow networks and CFD domains			
Contaminants, mycotoxins (mold growth)			
Renewable Energy Systems			
Renewable Energy Systems (12 identified, X+O)	1	4	4
Idealized HVAC systems		x	x
User-configurable HVAC systems			x
Pre-configured systems (among 34 identified, X+O)	16	0	28
Discrete HVAC components (98 identified, X+O)	39	0	66
Economic Evaluation			
Simple energy and demand charges	x	x	x
Complex energy tariffs including fixed charges, block charges, demand charges, ratchets	x		x
Scheduled variation in all rate components	x		x
User selectable billing dates	x		x

P: partial, E: essential

3.2 Comparison results and discussion

The difficulty in the interphases of the three programs varies from the Ecotect being the most user friendly and the DOE-2 being the hardest they changed the interface over 20 times to make it easier for the users. The numerical input of each programs concerning the material

properties, reflectivity, heat transfer and resistance differ which is hard on some students to acquire as for DOE and DesignBuilder in case of Ecotect it is easier but not very accurate, according to the ASHRAE standards Ecotect isn't compatible on the other hand site location and climate condition is mostly the same in all programs.

Flexibility of the geometry for each program is a major difference in creating and editing the models, DesignBuilder is limited in this area which is hard to have a fluid shape or a complex design, while Ecotect is much easier when it comes to geometric forms, DOE is mainly friendly with the straight lines as the DesignBuilder, not good with fluid designs. As for the compatibility of CAD programs, it is also a big difference since design builder is only compatible with Revit, AutoCAD files will enter as a 2D drawing and should be traced to run the simulation, Ecotect is compatible with most of the design programs like Sketchup, AutoCAD, 3D Max or Rhinoceros in DXF or 3ds format and DOE is compatible with DWG formats after 2009 but should be traced as well.

The specialties of these programs are different, as for the Ecotect this program since it is compatible with most of the modeling and geometric programs and friendly interface it could be used and could support all design interphases. DesignBuilder on the other hand have accurate results and variety of computation that could be made easily, with a wide library for building materials to choose from so this could be used after the conceptual phase in the design process. The DOE-2 is the most accurate program with the most engines that gives a wide range of computes options and renewable energy implementation and computation, this program should be used in the final stages the design since it is the most accurate but isn't very flexible to use.

Since few years ago Autodesk is no longer giving new licenses for Ecotect, only people with old licenses can run the program and it is replacing it with a new program called Green Building Studio which is a Cloud-based energy-analysis software [4].

4. SURVEY

A group of people will be selected from level2 till postgraduate students. The aim of the survey I to measure the awareness of the students for these programs and in these levels for how important it is for the design and as a tool for decision making. In addition to categorize the programs according to the difficulty level of the interface and how the outcome was expressed. Finally, the students will be asked about how affective it is on their design.

4.1 Survey Results

The answer of Q1: what simulation program do you know?

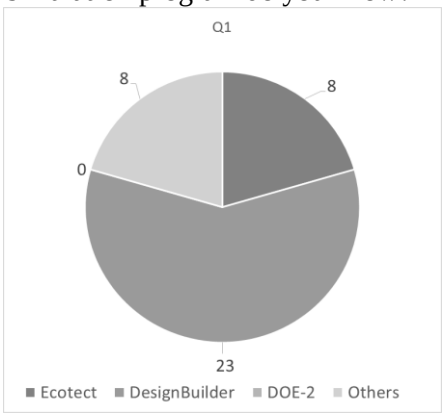

Fig. 6 Statistics of the first question in the survey
Reference: By Authors

The answer of Q2: Did you work on any simulation program or apply it to your project? If yes which program did?

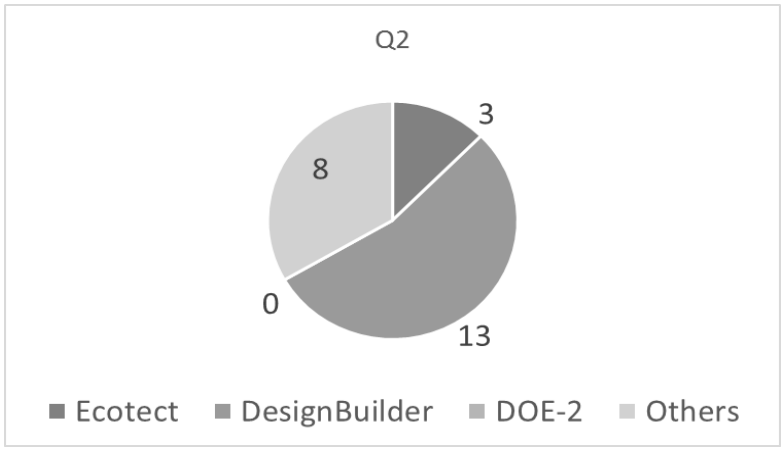

Fig. 7 Statistics of the second question in the survey
Reference: By Authors

The answer of Q3: How satisfied where you with the results you got?

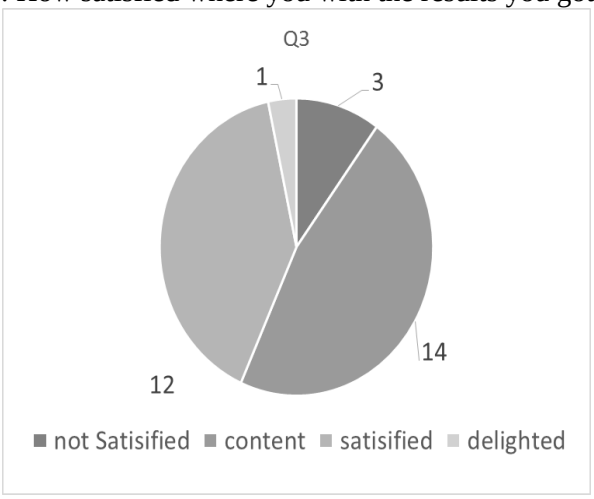

Fig. 8 Statistics of the third question in the survey
Reference: By Authors

The answer of Q4: How much time did it take to achieve the results of the simulation?

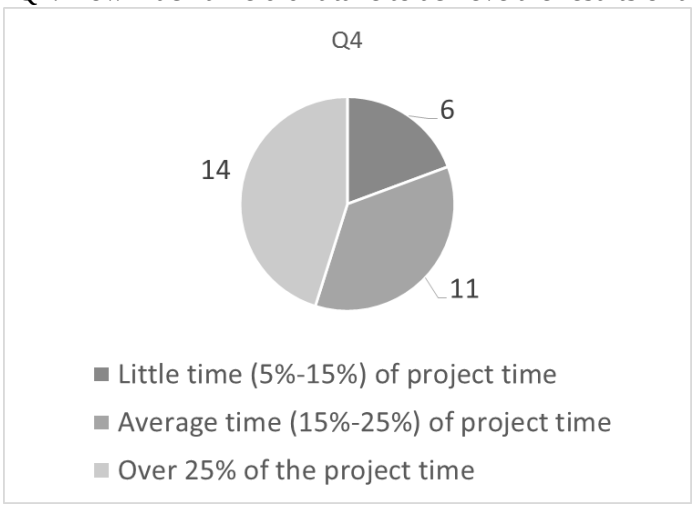

Fig. 9 Statistics of the fourth question in the survey
Reference: By Authors

The answer of Q5: What where the difficulties you encountered while using the program?

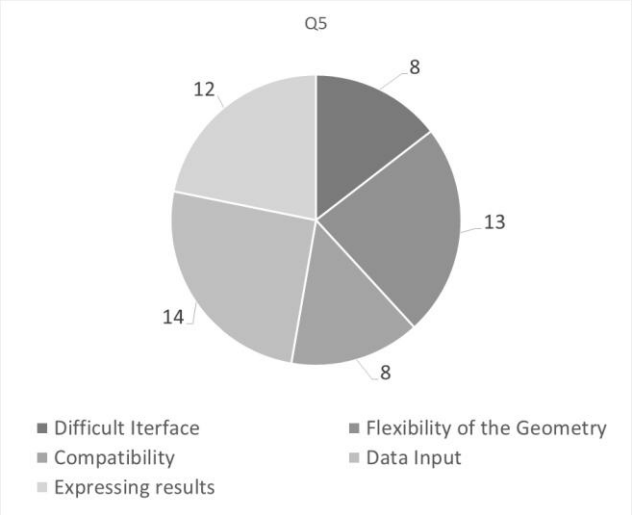

Fig. 10 Statistics of the Fifth question in the survey
Reference: By Authors

The answer of Q6: Do you recommend any simulation Program to be applied to your academic year? If yes which and why?

The students recommended mostly the design builder for its easy use for mainly in the fourth academic year, but it was mentioned twice that it's not enough. On the other hand Ecotect was recommended about 5 times to be used for its easy interface for the second and third level students, several other programs was mentioned like Green Studio energy and Lady Bug, and other program plug-ins.

5. APPLICATION

The simulation project of a student will be shown in this research paper as an example for the outcome of this programs. The project is selected from master of architecture educational levels, the selected project was for its clarity and effectiveness of the design decision.

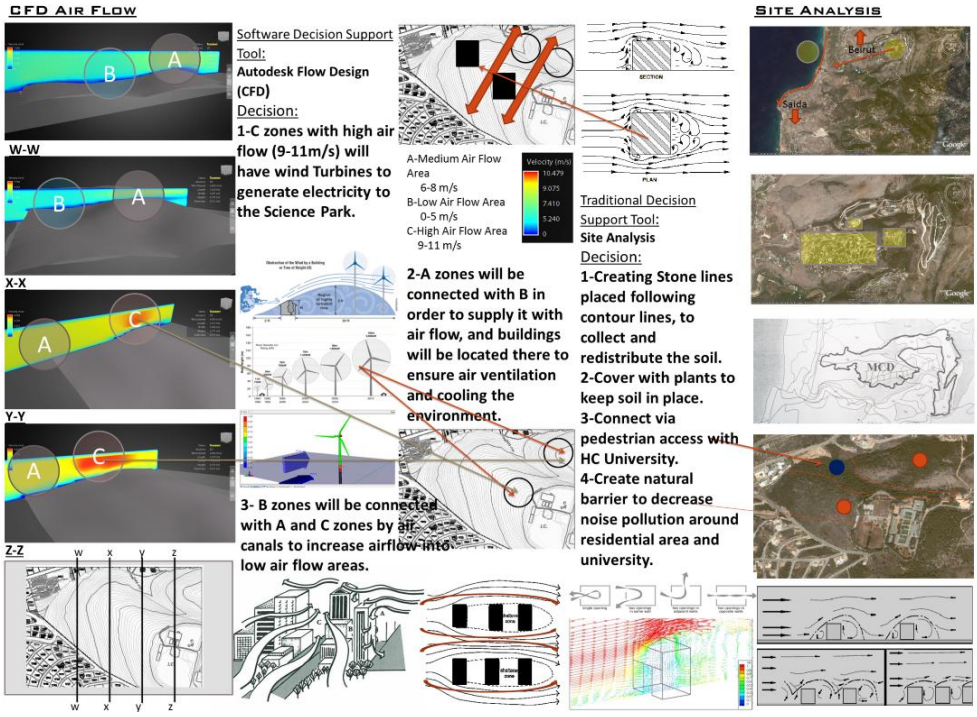

Fig. 11 sample of student work
Reference: By Authors

5.1 Application Results

From the study of the application the following points were shown which are:

1. The implementation of the building on the given site in the right place according to the wind movement.
2. Choosing the appropriate place for wind turbines in the site selected (zone with no wind obstruction and the highest reaching speed)
3. The integration of the simulation program on the environmental diagram to allocate the project elements in the site.
4. The use of the simulation program only in the first stages (conceptual phase) is not the most effective way to acquire the ultimate solution.
5. The student had a difficulty in extracting the results from the program and expressing it in the poster presentation.

6. CONCLUSIONS

In the last decade architecture education was focusing on sustainability and environmental issues, the simulation programs are the ultimate tool to a better design decisions. The students only know the programs that are being taught to them in final years without any background about the simulation programs in the second and third year, this was shown in the survey, so we recommend to implement different simulation programs among different educational levels. The selection of the programs to suit the appropriate education level is due to the friendly inter phase and the complexity of the input data required example (Ecotect/ green studio energy for second year, design builder for third year and DOE-2 for fifth and graduate studies). Since according to the comparison results of the three programs DOE-2 cover most of the environmental studies and meets the approved standards, and it is the most satisfactory in its results, but it has the hardest interphase and the input is very advanced. In addition in different design stages we can encourage students to use different simulation programs to enhance their design decisions in their projects.

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APPENDIX

Survey

Beirut Arab University

Faculty of Architectural Engineering
Debbieh

Beirut Arab University requests your help. Please complete the following Student Survey based on the research paper we are recently completing for your University. Thank you for your time.

Student Name: Year: Project Type:

1. What Simulation Programs Do You know?

☐ Ecotect ☐ DesignBuilder ☐ DOE-2 ☐ Other ……

2. Did you work on any simulation program or apply it to your project? If yes which program did you use?

☐ No ☐ Yes ☐ Name of the program ……

3. How satisfied where you with the results you got?

☐ Not Satisfied ☐ Content ☐ Satisfied ☐ Delighted

4. How much time did it take to achieve the results of the simulation?

☐ Little time (5%-15%) of project time ☐ Average time (15%-25%) of project time ☐ Over 25% of the project time

5. What where the difficulties you encountered while using the program?

☐ Difficult Interface ☐ Flexibility of the Geometry ☐ Compatibility ☐ Data input
☐ Expressing the Results ☐ Other ……

6. Do you recommend any simulation Program to be applied to your academic year? If yes which and why?.

Thank you very much for taking the time to complete this survey. Your feedback is valued and very much appreciated!

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DOI: 10.54729/2789-8547.1085