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Evaluation of Easy-to-Use Energy Building Design Tools for Solar Access Analysis in Urban Contexts: Comparison of Friendly Simulation Design Tools for Architectural Practice in the Early Design Stage

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***Abstract*—**Current building sector is focused on reduction of energy requirements, on renewable energy generation and on regeneration of existing urban areas. These targets need to be solved with a systemic approach, considering several aspects simultaneously such as climate conditions, lighting conditions, solar radiation, PV potential, etc. The solar access analysis is an already known method to analyze the solar potentials, but in current years, simulation tools have provided more effective opportunities to perform this type of analysis, in particular in the early design stage. Nowadays, the study of the solar access is related to the easiness of the use of simulation tools, in rapid and easy way, during the design process. This study presents a comparison of three simulation tools, from the point of view of the user, with the aim to highlight differences in the easy-to-use of these tools. Using a real urban context as case study, three tools; Ecotect, Townscope and Heliodon, are tested, performing models and simulations and examining the capabilities and output results of solar access analysis. The evaluation of the ease-to-use of these tools is based on some detected parameters and features, such as the types of simulation, requirements of input data, types of results, etc. As a result, a framework is provided in which features and capabilities of each tool are shown. This framework shows the differences among these tools about functions, features and capabilities. The aim of this study is to support users and to improve the integration of simulation tools for solar access with the design process.

***Keywords*—**Solar access analysis, energy building design tools, urban planning, solar potential.

I. Introduction

THE role of passive solar design is becoming increasingly important to reduce energy demand in building sector and to improve the well-being of people in urban areas. It is possible to summarize national and international policies about the energy and the sustainability in two main topics: the near zero energy building and the urban regeneration. Many recent laws and regulations have been set out on these topics by the European Union and the single nations. Considering the energy saving targets by 2020 and the improvements of the existing urban areas, which will involve very efficient environmental performances, it is possible to assume that more detailed and comprehensive analyses, also about solar potential, will be needed. These refurbishment processes involve buildings, infrastructures, green areas etc. The cities and the urban areas are the core field to solve these challenges and the capability to take advantage from solar potential is a fundamental and strategic approach.

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A. The Solar Access Analysis

The solar access analysis, defined as the study of solar potential benefits, represents a preliminary way to evaluate different but related aspects such as solar radiation, availability of daylighting, overshadow conditions, overheating phenomena, renewable solar systems and to optimize urban layouts in urban regeneration contexts [1]. In this sense, the study of the solar obstructions represents the most important assessment, from which all the above aspects depend, because the outdoor and indoor comfort and the energy requirements are affected by the availability of the solar radiation. For example, the height, the orientation and the density of building volumes affect the possibility to produce energy from active solar systems [2], or the natural airflows in urban areas, useful for the outdoor comfort and the mitigation of heat islands, are related to the urban layouts [3].

The capacity to fully utilize the solar potential in urban contexts depends on the ability to integrate various criteria into the planning process, introducing solar access assessments that can advise more efficient solutions. In this sense, it is necessary to perform solar access analyses during the urban design process, evaluating the design solutions also in relation to the solar-energy aspects [4], [5].

In order to achieve maximum benefits from solar energy, obstacles and limits in the design process have to be removed or reduced. If is possible to assume that the most of building interventions will be focused on urban renewal and on energy-efficient buildings, then it is necessary that architects or other technical figures improve their design with reliable and comprehensive analyses about solar access, using design support tools able to provide useful results in easy and rapid way.

The study of solar access, considering all the types of evaluations about solar energy, is a topic widely investigated with a very large literature, constantly updated, with several studies [6], [7]. At the same time, solar access analysis is not to be considered as a recent aspect. Many nations, during the time starting from the doctrine of Ancient Light of 1832 until today, have set out regulations and building codes in order to ensure access to sunlight and improve efficient use of solar energy. Nowadays, the higher energy performances, required for new buildings and for the refurbishment of the existing ones, represent a very difficult and important design challenge that can be achieved only thanks to the recent digital technologies and to the advanced simulations.

B. The Energy Building Design Tools

In the last decade, architecture and urban design, as well as all areas of knowledge, have received a fundamental support from the development of digital technologies and simulation tools. Nowadays, simulation softwares are widely used by architects and engineers to predict and evaluate solutions and behaviors in every discipline and design sector. In the specific field of urban and building design, the study of solar potential benefits represents an aspect that has many available support tools [8]. Starting from the traditional manual techniques, as the Sun path Diagrams, the Shadow Masks, the BRE Sunlight availability protractor and the Solar Gains Diagrams [9], nowadays there are other tools specifically dedicated to solar access analysis.

The use of energy building design tools as support during the design process is widely recommended, in particular at the early design stages. The design process in the urban planning, including refurbishment of urban blocks and urban regeneration interventions, involves the study of complex and multidisciplinary aspects and the aid provided by the building energy design tools is fundamental [10]. The solar access analysis is considered as an early analysis into the design process and can be evaluated by these tools. Several parameters affect the solar access, including building orientation and shape, surrounding conditions, density and site layout, and these parameters should be considered in the early design stages of the project. According to some previous studies, it is possible to summarize some main factors from which the environmental performances depend: Urban design parameters, such as street width and building density, and building design parameters, such as building orientation and building outlines [11], [12]. These key parameters can be optimized to achieve buildings with very low energy demand and high environmental comfort conditions. All these factors should be investigated using dedicated energy simulation tools. In reference to the purpose of this study, a selection of these tools has been made, among the most popular and most valued ones, and three tools have been selected: Ecotect, Townscope and Heliodon. These tools with different capabilities and functions are able to support architects and designers in general in the decision making process, by understanding impacts about energy, visual parameters of urban and building configurations. This selection of tools is based on some common features: All of these tools provide user-friendly interfaces, the output of results is generally with tabular data and graphics, and they use 3D models, produced by CAD techniques.

Ecotect (Autodesk Ecotect Analysis - 2011) is defined as a whole energy building design tool able to simulate many energy aspects [13]. Many functions, through the possible simulations and analyses executable by the Ecotect tool, are related to the solar access analysis such as the analysis of the right to light, the overshading analysis, the 3D sun path diagram visualization and the solar exposure analysis, with the capability to perform further and more detailed simulations such as: monthly heating/cooling loads, daylighting simulations and environmental impact analysis.

Townscope (Towncope 3.2- 2010) is defined as a multi-disciplinary consultancy tool dedicated to sustainable urban design with which it is possible to evaluate and to compare different design solutions quickly [14], [15]. According to US department of energy [16], it combines a user-friendly graphical interface with powerful analysis tools. Townscope provides different functions: assessments of direct, diffuse and reflected solar radiation, evaluation of outdoor environmental comfort, and qualitative analyses about sky opening and visibility.

Heliodon (Heliodon™ 2.7- 2010) is a tool designed to control energetic and visual aspects of the solar radiation in urban and architectural projects. It can provide representations of the apparent motion of the sun with shadows, sun path diagrams and simulations about solar radiation for different time periods, using 3D models [17]. It allows to study shadow conditions on any surface and to analyze direct and diffuse solar radiation or the lighted surface ratio on any building surface or urban area, taking into account the obstructions produced by the surroundings.

II. Methodology

The aim of this study is to evaluate and to compare the three simulation tools in relation to the ease-to-use, analyzing capabilities, functions, types of simulations, types of results and providing useful information for the users. The evaluation of these three tools is focused on specific functions related to the solar access and further types of simulations are not considered. Each single tool offers different approaches, different ways to inform the virtual models, different requirements of detail levels, different calculations techniques and different types of output of results.

In order to study and to highlight differences among the three tools, a common case study is used to run simulations with selected tools. The use of a case study provides a common scenario with well-known conditions that can be modelled and informed by every tool and where it is possible to compare the differences. With the case study is possible to set some equal data, such as location and climate data, shape of buildings, street layout, etc. After the modelling of the urban case study with each tool, it is possible to run simulations to examine detail levels and reliability of simulations and to see the features of output results. In this sense, the analysis and comparison of tools is based on easiness for users to run simulations, to manage the required information, and to understand results.

III. The Case Study

A part of a district of the city of Ascoli Piceno, in Regione

Marche, is identified as the case study: The district of Monticelli. This district was built between 1975 and 1985, starting from the Urban Plan made by L. Benevolo and G. Zaini in 1968, and it is located at East in relation to the inner city centre of Ascoli Piceno. The district of Monticelli is a very large urban area with heterogeneous buildings, and multifunctional services, such as public buildings, green areas, squares and residential houses, and it represents a typical sub-urban area, built up in Italy during the second part of XX sec.

Fig. 1 Overall plan of Monticelli district. The perimeter of the district is highlighted with a dot line and the case study area is highlighted with a continuous thick line

In particular, the eastern area of Monticelli is selected as case study. This area, that extends for 15 ha, has a high building density with high rise buildings, as in Fig. 1. This urban context is made by buildings with different height and shapes, streets with different dimensions and outdoor spaces. These features of the selected area are able to highlight and emphasize solar access conditions and provide obvious differences in the simulations made by different tools. According to the purpose of this study, there is not the will to assess the solar efficiency or the environmental quality of the specific urban context but to evaluate and to compare the selected simulation tools.

IV. Simulations

According to the purpose of this study, models of the case study and simulations have been performed with the selected tools, exploring and testing functions and types of results. In relation to the different capabilities and features of each tool, it has been necessary to model the case study with different CAD techniques. In order to evaluate and to compare differences among these tools, the overall simulation process has been considered, starting from the modelling process, with the import facilities, the creation of objects and the model management, until to the interpretation of the results.

For every tool, steps and actions have been annotated to obtain reliable remarks about usability, defining three main evaluation categories: modelling, simulations and results.

A. Ecotect Simulations

Ecotect Analysis tool can import geometric models from other CAD tools, both 3D model and 2D model. In the specific case, a 2D DXF drawing of the urban case study is imported and a 3D Model, made of single planes, is traced over it. The editor commands of Ecotect with the modelling toolbar and the editing toolbar provide simple commands to create and to modify objects in the 3D editor menu, in similar way to the most diffuse CAD tools. The climate data can be managed directly, while weather data can be only imported through the Weather tool plug-in from other source tools. Ecotect Analysis provides a large variety of analyses and simulations about solar potential and sun conditions. Starting from a very simple model, such as the case study, it is possible to obtain qualitative representations of shading conditions, shadow range and shading masks for every surface. In any time, it is possible to view the sun path diagram across the model. Ecotect Analysis provides a specific calculation for the Solar Access Analysis as in Fig. 2. This simulation refers to the availability of incident solar radiation on the model surfaces. The solar radiation calculations use hourly data from the weather file. Shading calculations need only the geometries of the buildings. With climate and weather data checked, it is possible to run different types of simulations: the incident solar radiation simulations that calculates total, direct and diffuse solar radiation falling on every object; the sky factor simulation that shows the total solar radiation and the percentage of visible sky; the shading, the overshading and the sunlight hours that show shading percentage, visible sky and total sunlight hours. In addition, these types of simulations can be performed for different conditions, choosing specific periods and days and choosing type of returned values (cumulative values, average values or peak values).

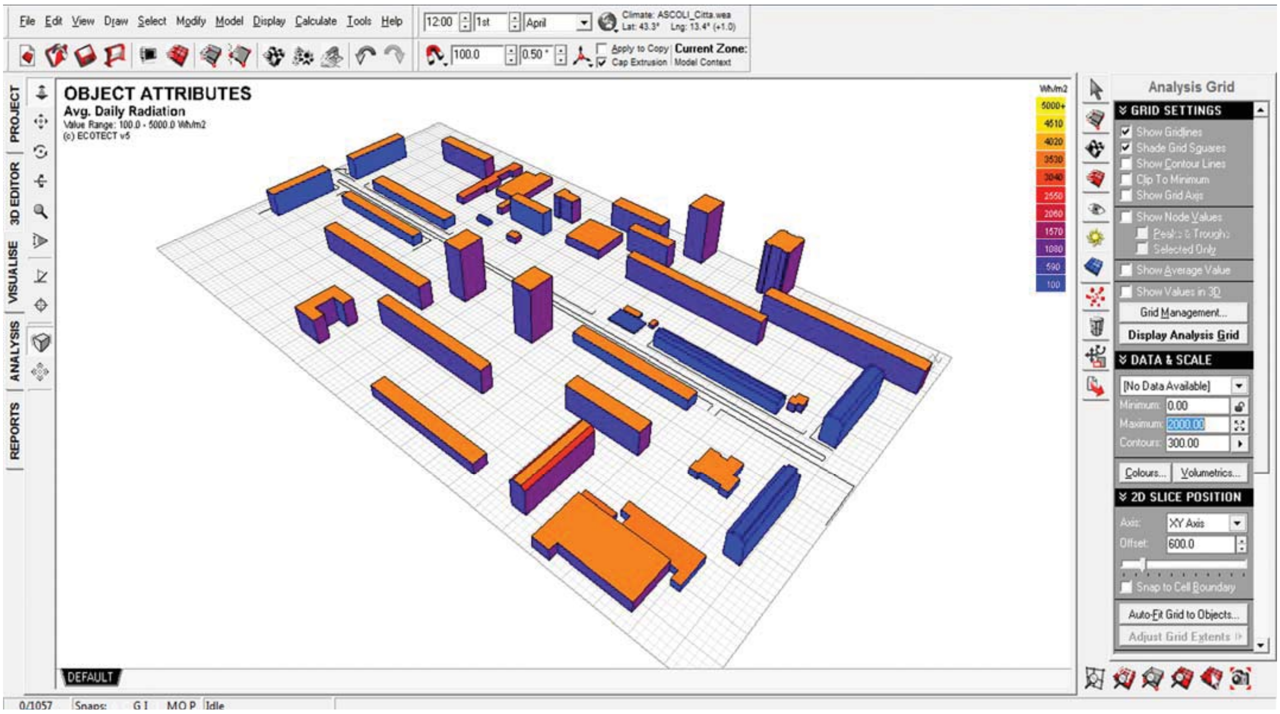

Fig. 2 Solar access analysis; Ecotect screenshot: Result of the average incident daily radiation (Wh/m^2) on model surfaces

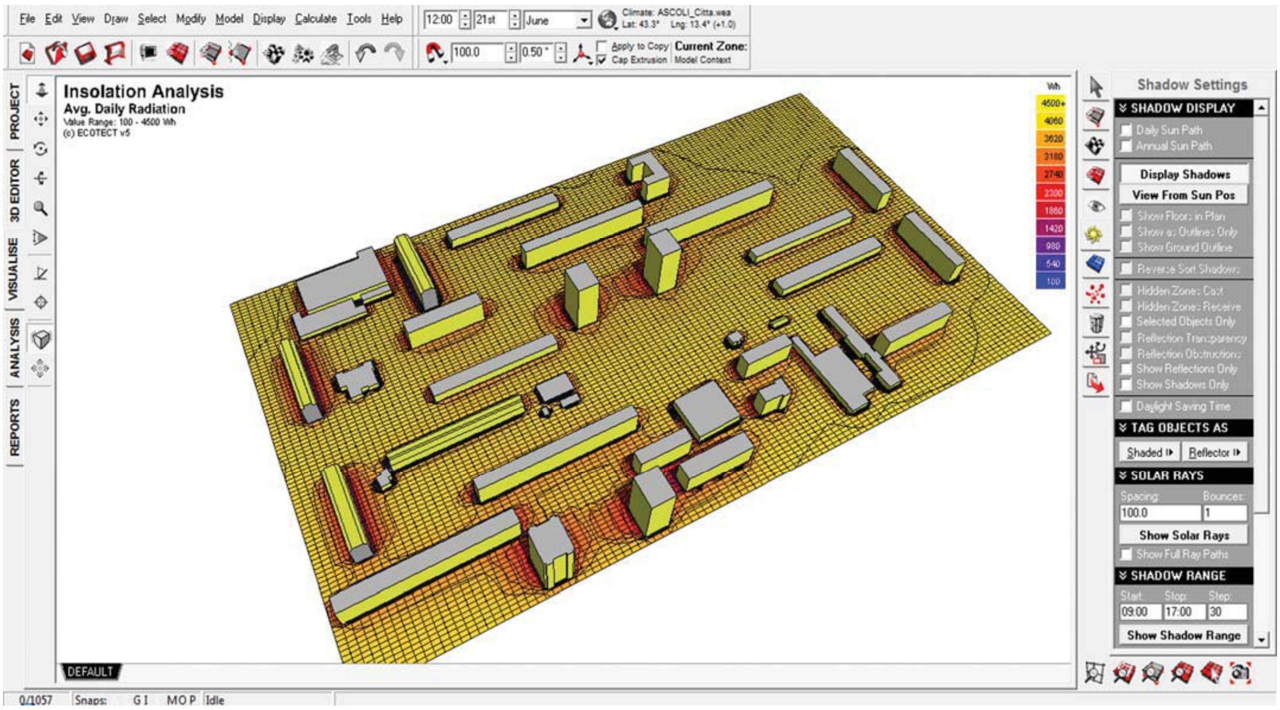

Fig. 3 Solar radiation analysis; Ecotect screenshot: Result of the average total daily radiation (Wh), using the Grid Analysis, with shadows

Ecotect can provide with the same model and without other data implementations another useful solar potential analysis: The Solar Exposure Analysis. This simulation can calculate the detailed amount of incident solar radiation on any surface in the model. This can be displayed with instantaneous hourly values or with daily and monthly total values. Using hourly climate data and geometric data, the degree of solar exposure for any object and for any shape in the model can be calculated. The Solar Exposure Analysis can show immediately, for one or more selected surfaces, diagrams and quantitative values of incident solar radiation in different formats. A similar simulation can be provided using the Grid Analysis with which it is possible to calculate solar radiation, with a very high level of detail as in Fig. 3. All the results of simulations are displayed with visual outputs, such as diagrams, representations with false colours and in some cases also with tabular data. Further simulations and analyses can be performed with Ecotect Analysis about right to light, daylighting levels or photovoltaic array size, but they need more detailed models and advanced information, only achievable in a detailed design stage.

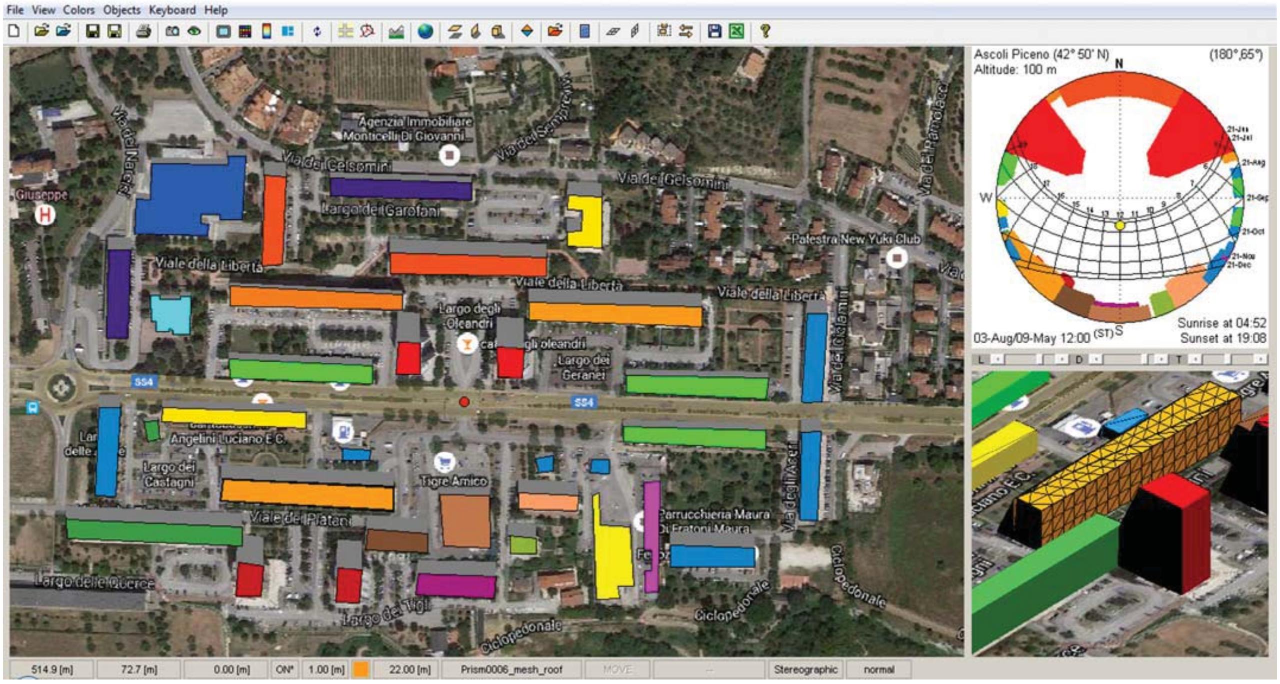

Fig. 4 Shadow analysis; Heliodon screenshot: Visualization of shadows in 2D and 3D views with shadow mask

B. Heliodon Simulations

Heliodon is a tool dedicated to the preliminary study of the available daylight and solar energy without the requirement of very detailed models. Thanks to Heliodon, it is possible to import 3D models in STL format and at the same time it is possible to create a model with the tool itself, also with the support of an imported background image as reference. An advanced function allows to import and to manage Digital Elevation Models for terrain modelling. For the case study of Monticelli district, the model has been produced importing an aerial image and creating building volumes directly on the 2D view space. The climate data are managed in a very simple way, without importing weather data, but only creating in the town database a new specific item with few information (latitude, longitude, altitude and time zone). Heliodon uses a simplified method to calculate solar radiation, useful to reduce calculation time and to give quickly and preliminary but not really accurate assessments. The model with the building volumes and the checked climate data is considered complete to run every simulation provided by this tool. The tool provides in every moment the display of sun path diagram in stereographic projection with obstructions of the buildings profiles and the display of shadows, giving qualitative analysis about the relationship between the apparent motion of the sun and urban context as in Fig. 4.

In order to perform simulations about sunlight time and incident solar radiation, surfaces of the models need to be convert in mesh surfaces. Managing the proprieties of a selected mesh surface, it is possible to run simulations and visualize results as colored maps in a stereographic diagram representation or on the corresponding building face. It is possible to obtain results about incident solar radiation (kW), lighted surface ratio (%) and cumulative solar energy (kWh) of a selected surface with a single simulation command. These simulations are provided for a single day or for a custom period or for the entire year. Results of simulations are diagrams as in Fig. 5, colored maps, and tabular data.

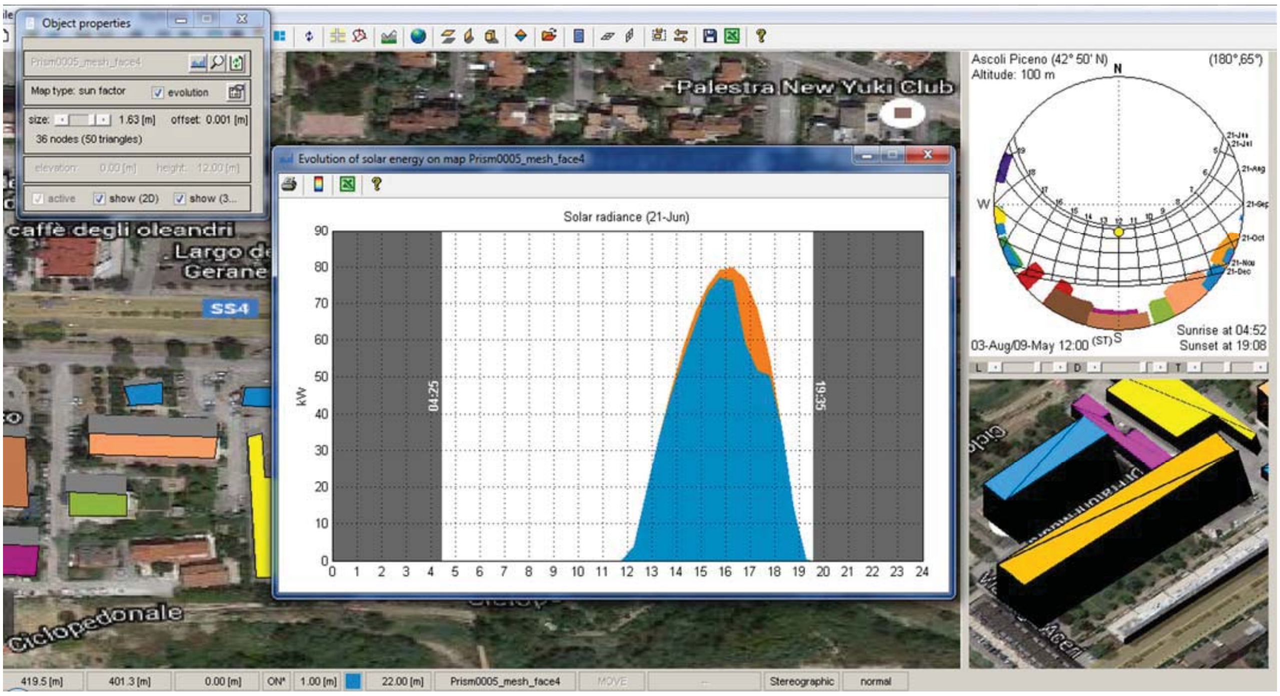

Fig. 5 Solar radiation analysis; Heliodon screenshot: Diagram of the energy (Kw) received by a single selected surface, for a single day (21 June). In blue the real incident solar radiation, in orange the theoretical solar radiation without obstructions

C. Townscope Simulations

With Townscope tool, it is possible to import geometry from other CAD tools. The main CAD formats are supported such as DXF format, 3ds format and OBJ format. Townscope does not provide the capability to create objects and models; it needs to import reference models from other sources. Using Townscope to simulate the urban case study, a 3ds model is imported. Climate and weather data are manageable by the solar access setting box. Townscope uses monthly weather data which can be imported only in xml format. Alternately, it is possible to edit directly each weather value, day by day. The monthly data used in townscope to calculate direct and diffuse solar radiation and sky conditions are: Humidity, Turbidity, Edhcs/Ethcs and Clouding rate. Other monthly values are used for thermal comfort simulations. This tool uses three analysis elements: point, polyline and zone with which is possible to generate simulations. In this sense, it is possible to consider that the only objects which can be simulated are the above elements while the geometric model only represents a context that effects simulations. The surfaces that define the building volumes of the models can be customizated using the surface proprieties window with which it is possible to apply detailed thermal properties: Opacity as the amount of direct radiation energy stopped by the surface, diffusion as the amount of direct radiation energy transformed into diffused energy and transmitted through the surface and reflection as the coefficient of solar energy reflected by the surface. For the case study, two specific points, two polylines and three zones have been created. When the above analysis elements are created and checked, it is possible to perform simulations. The available analyses are as follows. The solar access: This analysis calculates direct solar radiation, sky diffused energy, reflected energy from the surrounding surfaces and sunshine duration. The comfort evaluation: This analysis provides four values describing the human thermal comfort in an urban open space (sweat rate, sweat evaporation rate, skin wetness and sensation temperature). The sky opening: This analysis uses a spherical projection, named isoaire view that looks like a fisheye view, to evaluate the ratio of the visible sky area to the total area of the reference half sphere centered at the view point as observer as in Fig. 6. The visibility: Using the spherical projection, named isoaire view, this analysis computes on each point the visible portion of selected surfaces in the scene and the result values are the ratio of area of visible portions of the selected surface to their total area and the ratio of area of visible portions of the selected surfaces to total area of all visible surfaces. Results of simulations are displayed in two outputs, in relation to the type of simulation with colored maps and labels or with tabular data. Results displayed with colored maps, such as the solar access analysis, as in Fig. 7, and the comfort evaluation can be managed with different styles, colors and value range, to provide more effective representations.

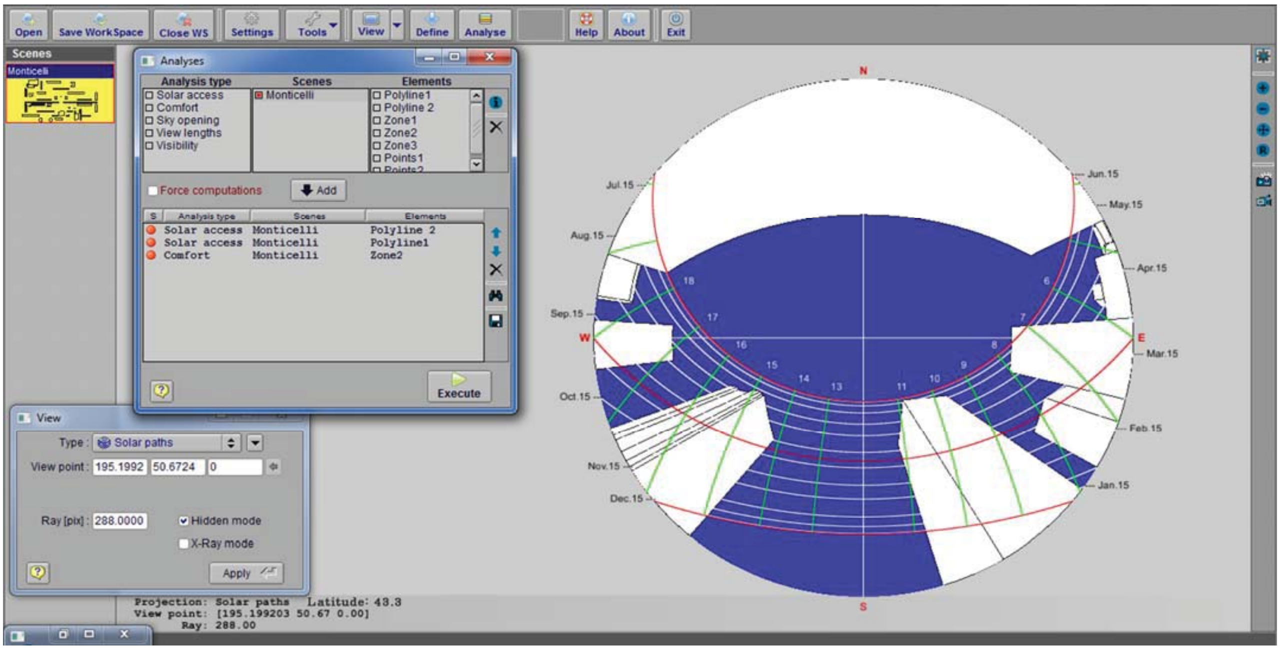

Fig. 6 Shadow mask: Townscope screenshot; Isoaire view, with Sun path diagram, of sky obstructed by buildings envelopes

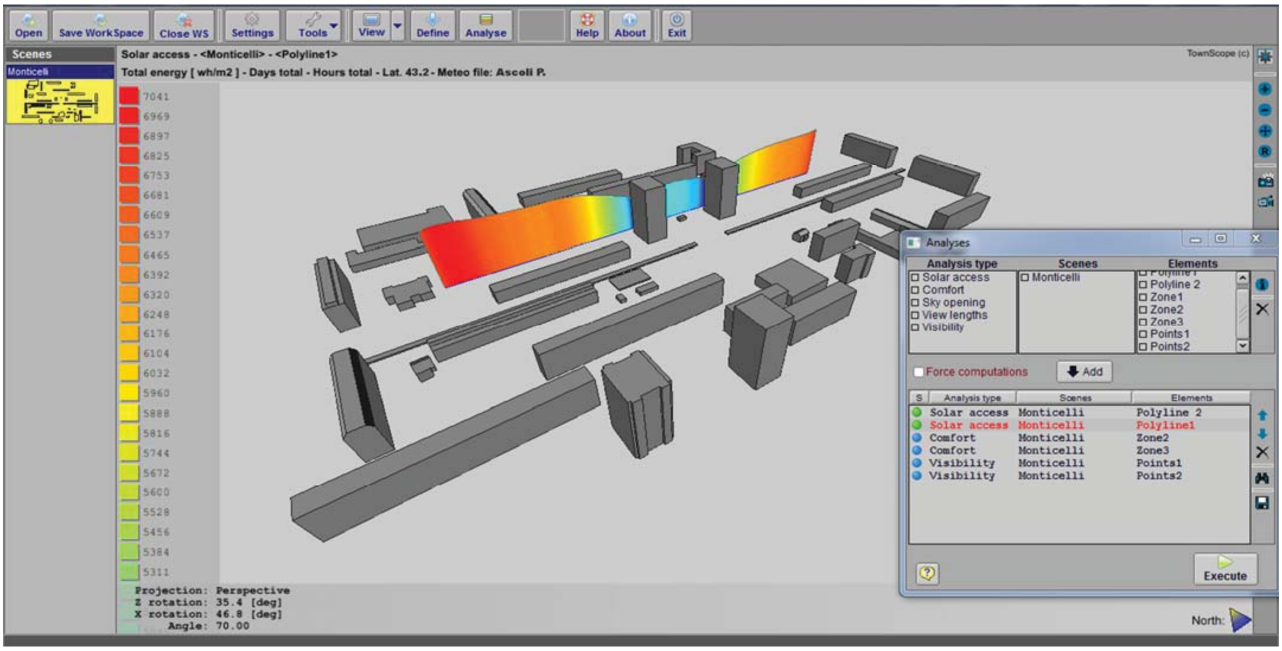

Fig. 7 Solar access analysis; Townscope screenshot: Result of total incident solar radiation (Wh/m^2) on a polyline element

V. Results

Three of the most effective energy simulation tools about sun and solar radiation analysis are evaluated from the point of view of users, for preliminary urban design.

The most of all simulations and analyses, related to the Solar Access Analysis, have been performed to test and to explore functions and capabilities of these tools. Performing the simulations, it has been possible to detect and to highlight several aspects, features, limits and requirements of each tool.

To provide a useful evaluation for users, the assessments about these three tools take into account the overall processes required to achieve output results from simulations. It is also important to consider that some assumptions have been made, considering and admitting that the simulation techniques and the calculation formulas, used by tools are reliable and proper. In this sense, this study is not focused on the evaluation of the quality of informatics and of physical criteria of these tools. The most prominent result of this study is a punctual and comparable list of functions and features of the tools. For each tool is provided an overall scenario, as preliminary result, giving information about operations, requirements, types of simulations and output results, required to perform analyses or simulations about solar access. Next, taking care to remark and to verify similarities and differences among the tools, functions and features of each tool have been matched, using coordinate topics and general fields of application. The description and the comparison of functions and capabilities of these tools are divided in three main fields of application: Modelling, Simulations and Results. For each field of application, every tool is evaluated with related sub-topics, as in Table I.

TABLE I
FRAMEWORK OF THE EVALUATION OF THE TOOLS

		ECOTECT ANALYS	HELIODON	TOWNSCOPE 3.2
MODELLING	Model and Data Import	– Import geometric models from several CAD formats – Import data from other energy simulation tools – Import climate/weather data through the Weather Tool plug-in	– Import geometric models only in STL format – Import terrain model in DEM format – Import image as background reference	– Import geometric models from several CAD formats – Import weather data in XLM format
	Objects Modelling	– Objects, as surfaces, creation – Objects modifications by several modes and commands	– Objects, as surfaces, creation – Objects movements	– Climate/weather data editing
	Proprieties and Management	– Building element type defining – Thermal Zones defining – Thermal and visual proprieties assignment to model surfaces using the Material Library	– Elements visualization by colors defining – Surfaces converting in mesh surfaces – Color Maps management	– Analysis elements editor (point/polyline/zone) – Thermal and visual proprieties assignment to model surfaces using the Surfaces Proprieties Window
SIMULATIONS	Shadows and Sun Analysis	– Instant shadows display – Instant sun path display – Shadow Masks – Shadow Range – Sky Factor	– Instant shadows display – Instant sun path display – Shadow Masks – Sky Factor	– Shadows display – Sun path display – Shadow Masks
	Energy Analysis	– Incident solar radiation (cumulative values/ average daily values/average hourly values/peak values) – Absorbed/Transmitted solar radiation – Solar Exposure – Solar Insolation analysis using the Grid Analysis	– Incident solar radiation – Maximum solar radiance – Loss of solar radiance – Cumulated solar energy – View Factor	– Incident solar radiation (direct/diffuse/reflected) – Outdoor thermal comfort
	Lighting Analysis	– Sunlight Hours analysis – Right to Light analysis – Site Visibility analysis	– Sunlight Time analysis	– Sky opening – Visibility – View Lengths
RESULTS	Qualitative Outputs	– 2D/3D Visualization with several graphic settings – Colored maps with scale and unit – Interactive mode to overlap results and to change visualization style	– 2D/3D Visualization with hidden mode and shading mode – Isoaire visualization – Colored maps with scale and unit – Interactive mode to change visualization style, parameters and conditions	– 3D Visualization with hidden mode and shading mode – Colored maps with scale and unit and different visualization styles (gradient/levels/ratios)
	Quantitative Outputs	– Tabular data – Diagrams with scale, unit and legend editable – Interactive mode to change parameters or conditions	– Matched colormap in stereographic projection – Tabular data	– Tabular data

Brief descriptions about functions and capabilities of each tool are provided in relation to three fields of application (Modelling, Simulations and Results) and sub-topics.

The modelling features and capabilities have been analyzed according to three sub-topics:

- Model and data import, considering how and what types of information can be imported, such as climate data or geometric data;
- Object modelling, considering functions and commands provided by tools to create and to modify the model;
- Proprieties and management, considering functions, commands and level of detail to assign useful proprieties to the model to perform proper simulations;

The simulations' features and capabilities have been analyzed according to three sub-topics:

- Shadows and Sun analysis, considering the types of simulations that give specifically information about apparent motion of the sun, sun path diagrams and shadows analysis;
- Energy analysis, considering the types of simulations that give information about energy solar potential;
- Lighting analysis, considering the types of simulations that give information about light conditions, spatial visibility and access to sunlight;

The results features and capabilities have been analyzed according to two sub-topics:

- Qualitative outputs, considering results of simulations which provide only visual outputs and graphical representations without the possibility to share results in other formats or to analyze detailed values;

- Quantitative outputs, considering results of simulations which provide objective data with units, scales, and values or indices, which cannot be estimated;

A framework able to describe and to list the features of each tool, with the opportunity to make comparisons, is produced, as in Table I. In the table, it is possible to identify the main aspects, as discussed previously, and to highlight differences. For each topic, a brief description of the fundamental features is provided about every tool.

TABLE II
RANKING OF TOOLS IN RELATION TO THE EASE-TO-USE

	ECOTECT ANALYSIS	HELIODON	TOWNSCOPE
Climate/Weather data management	★★	★★★	★
Level detail of weather data	★★★	★	★★
Import geometry	★★★	★	★★
Object editing and proprieties	★★	★★★	★
Specifications and other requirement	★	★★	★★★
Number and types of simulations	★★★	★★	★
Clearness of results	★★★	★	★★
Interactivity with results	★★	★	★★★

In the left column, the evaluated aspects. In the other columns, the relative evaluation of each tool, where three stars correspond to the best score

Looking at the framework it is possible to evaluate the three tools. These tools use different techniques, they require different levels of expertise and they provide different types of results. In this sense, it is possible to try to give an evaluation about the ease-to use of these tools, based on the case study experience. A sort of ranking of evaluation is provided, considering skills and abilities required by user to manage these tools and to produce simulations. According to the features and capabilities, previously detected, the three tools are evaluated among them in reference to some relevant aspects, as shown in Table II. For each aspect, the tools are ranked from the best, with three stars, to the worst, with one star, without giving an absolute or overall assessment. The framework gives the opportunity to understand and to evaluate levels of skillful required by tools and to appreciate their capabilities.

VI. Discussion and Conclusion

The experimental evaluation of the analyzed tools allows to present some considerations. The evaluation of the selected tools is conducted, considering single aspects without the purpose to express a comprehensive judgment. The evaluation of the ease-to-use of these tools is limited to the study of solar access or related analyses. In this sense, any other requirement or capability of the tools has not been taken into account, if it is not useful to the above analyses. At the same time, considerations and remarks, based on objective criteria as much as possible, are relative, referring to each simulation tool, and not absolute. Other simulation tools, not tested in this study, could provide better or worst performances.

Testing the ease-to-use of these tools to produce an urban model, as the case study, and to perform simulations on it, is possible to assume that Ecotect is a very effective tool, able to produce and manage data and geometric models, using several and detailed information. It is provided with high calculation capability, several options and parameters, an operative interface and powerful graphic solutions. About simulations, Ecotect can perform a very large number of simulations that offer, in some cases, multiple results. Results of simulations appear very effective and easy to be interpreted. On the other side, Ecotect, as a whole energy building design tool able to simulate many physical aspects, needs an expertise level to manage complex functions and model requirements to perform reliable simulations.

Heliodon is a tool dedicated to study solar energy especially at the urban scale. It is a very efficient tool in relation to the production of preliminary analyses. The management of models is very simple, such as the climate data, but too limited and many assumptions are required. It is possible to perform different types of simulations and different types of representations of results, only with a good confidence level and the accuracy of some data and of some simulations appear to be not detailed. Outputs of results are not more interactive than other tools.

Townscope is a tool designed specifically for sun and solar analyses without the purpose to develop very detailed simulations. It is possible to consider this tool very simple but not really easy-to-use. It requires few data and few commands to run simulations but the management of geometric models and of other data is limited. It is provided with a very simple interface and with a very limited possibility to make errors. There are not many types of simulations but results with graphical outputs or tabular data are useful and effective. However, it is also necessary to highlight that the evaluation of the ease-to-use of tools is not always completely sensible and impartial, because the friendly use of a tool is affected by the level of knowledge about energy, physics and building science aspects and by the familiarity with similar tools. Moreover, the ranking of evaluation, provided in Table II, is based on the specific case study, using a simple model. In this sense, the evaluations about the tools could change or could be updated in relation to a more detailed level of the model. Whereas, the framework, shown in Table I, provides only summary information without detailed data that could validate the differences among the tools, in a more substantial way.

This experimental study, about the ease-to-use of some energy building design tools, can be considered as a method that can be reproduced on further aspects. It is possible to assume that this study represents a contribution for simulation tools developers, to improve their products and for users, to support them identifying suitable tools, according to the relative needs. Starting from this contribution, a future research is planned with the purpose to compare reliability of simulations, and calculation details of these tools and others.

At the end, it should be also highlighted that all of three analyzed tools are not very new, produced years ago, in particular Ecotect is a tool no more developed with the last release at 2011, but nowadays they still represent some of the most diffuse and efficient energy simulation tools.

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