INDICATE: TOWARDS THE DEVELOPMENT OF A VIRTUAL CITY MODEL, USING A 3D MODEL OF DUNDALK CITY

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ABSTRACT

According to the United Nations, the World’s population currently stands at 7.2 billion people and it is estimated to grow to 9 billion by 2050; as a result appropriate urban development in our cities will become more important. Smart technologies are seen as an important technological step forward with respect to tackling the challenges and improving the efficiency and effectiveness of urban systems, and as a result can have a major contribution to the sustainability of the city and its occupants. The definition of the word ‘smart’ means that innovative and new approaches are required for urban design, city planning, energy and buildings, low energy & zones for residential, industrial and commercial use, optimal building density etc. Under the EU FP7 INDICATE smart cities project, a decision support masterplanning tool will be developed, which will; plan, integrate and optimize the following sub-systems of the overall city system: buildings, energy efficiency technologies, renewable technologies and the electricity grid. The INDICATE tool will achieve this through the integration of real data from a city with the dynamic simulation software, the IES <Virtual Environment>, 3D Urban CAD modelling tools, the ESRI CityEngine package, and Sustainable Urban Indicators, to create a Virtual City Model. This will provide a 3D model of the city, its networks and its buildings, ready for urban simulation. This paper will discuss the early stage analysis of the 3D dynamic simulation urban model of one of the test sites for the project; Dundalk in Ireland. The model will analyse the impact of refurbishment for a select number of buildings in Dundalk, with metered data available. The aim will be to understand their energy use and optimise their efficiency at building and district level. Indicators developed through the INDICATE project will then be applied to understand the effects of the changes to the individual buildings, the district and also within the overall urban context.

Keywords: masterplanning, sustainable urban indicators, virtual city model, LiDAR, <Virtual Environment>, energy use intensity

INTRODUCTION

Given the challenges and complexity of urban energy systems, and the related challenges for the decision making, the planning and optimisation of the sub-systems of a city, requires appropriate urban modelling and simulation calculation methods to address these following key issues [1]; First, the variety of the building data available and the level of detail in a city area. Second, data pre-processing stage which must take into account a flexible data set which must be always adapted for the district/city-scale to allow for customisable comparison for modelling and simulation calculations. Third, a set of modelling and simulation calculation metrics which allow for good comparison between results [2].

Widely used building simulation tools are only suitable for high-level detailed design analysis of single buildings, or small groups of buildings [3]. A detailed dynamic thermal building simulation for an urban district, over a long period, with a large amount of different modelling input parameters (multiple model objects, solar and thermal inter-relation, shading, HVAC systems, internal gains etc.), often puts strain on simulation tools that are currently available. Because of the complexity of these systems, the smallest changes in their parameters can induce high consequences in the systems’ efficiency.

To address these challenges, a Virtual City Model (VCM) will be developed. This will illustrate a city and store the processed output from a dynamic simulation model, created with the <Virtual Environment> (<VE>) software. Results from sustainable urban indicators relating to the city, are also applied to the VCM. This is so that it can be passed to a user interface to inform decision making and determine which is the optimal way of retrofitting the building. Different factors such as; the use of the building, smart technologies, integration into the city and its systems, and the geographic location of the building, would further aid this process.

METHOD

A key element of the VCM, is the development of a 3D model ready for simulation. This model has been created with the use of a masterplanning tool that has been developed by IES. This tool works as a plug-in in conjunction with the popular 3D drawing package SketchUp by Trimble. This allows for rapid extrusion of buildings within a model and also assignment of data to the model.

In the case of the Dundalk model, ordinance survey mapping was provided by Ordinance Survey Ireland (OSI), through the local authority for Dundalk; Louth County Council (LCC). This mapping acted as a base-layer in the model, and ensured that all buildings in the town were accurate in terms of their location relative to each other. Coupled with this base mapping, LiDAR information was also provided, which helped to ensure that all buildings in the SketchUp model were accurate with regard to their height.

Steps in the Modelling Process

The following are the steps used in the modelling process:

1. Importing the OSI mapping

The OSI mapping in AutoCAD .dwg format file was imported into a SketchUp model.

2. Creating and Extruding the Polygons

Once the OSI maps were imported, the boundaries of each building had to be marked in order to activate a polygon around the site of the buildings, which could then in turn be extruded. This was done by using a drawing tool in the SketchUp plugin. Once polygons were drawn around each building, the faces of these polygons could then be selected and extruded.

3. Importing The Lidar Data

The LiDAR data was imported into the SketchUp model using a custom build, with functions that allow us to enter a series of set command codes typed in, using the GDAL (Geospatial Data Abstraction Library) format. The command codes were then created and typed in, to allow the model to read the LiDAR files and obtain the height data for identified object (buildings) in the correct geo-located positions. The model buildings were created inside the polygon area which was modelled with a default height of 2.5m before the LiDAR data height was applied. The command codes were entered into a ruby console and set the building heights to selected objects (model buildings) identified in the SketchUp model, in which resulted in the object heights changing with the respect to the new data available.

Due to unavailability of LiDAR data for some areas in Dundalk, missing areas were applied with a default height of 2.5m per floor of each building. It is expected the model will be updated again when more data is available. It is noted some objects in the model have more than one floor, in which the LiDAR height data was applied and divided equally on the identified objects with more than one floors. Without information on glazing size in the identified model, most objects were modelled with a general assumption of between 15-30%. All objects are modelled with flat roof and are the same size as the footprint of the building. The following figure shows the result of 3D modelling for a section of Dundalk.

Figure 1: 3D model of Dundalk (Map data: Google)

Some additional building information can be accessed from the model without data assignment to generate the metrics. Examples of these are: footprint of building; building compactness indicators; building height; floor area; number of buildings; density factors Dsurf and Dvol; urban form ratio; urban compactness ratio; elongation ratio.

Information on building typologies in Dundalk was obtained from the Planning Section of Louth County Council (LCC). This allowed us to apply the different building typologies to the identified model buildings. The following figure shows the range of different building typologies in the centre of Dundalk, with each colour representing a different typology. In this case, the main categories were; yellow for residentail, brown for retail, and dark brown for commercial.

Figure 2: Building typologies mapped in Dundalk (Map data: Google)

Building energy rating metrics were built as custom attributes in the model, which allowed us to highlight the energy rating of each building, where information was supplied by LCC.

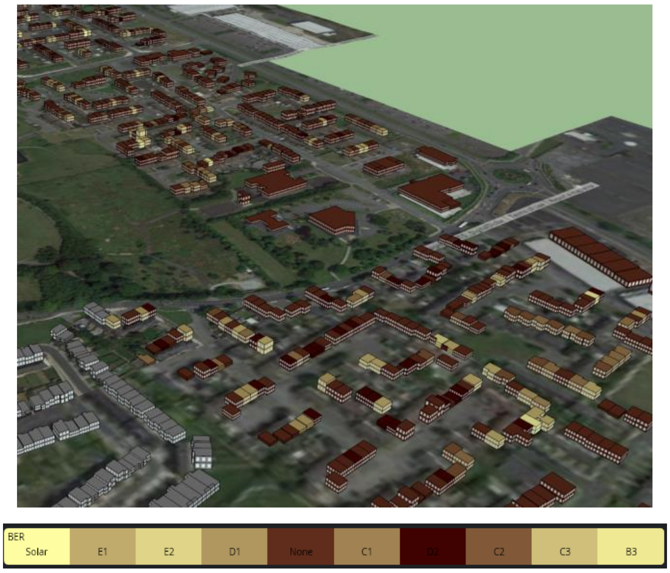

Figure 3: Building Energy Rating mapping of buildings in the Muirhevnamor area (Map data: Google)

THE DYNAMIC SIMULATION MODEL

The SketchUp model of Dundalk was imported into the IES <VE> software. This allowed us to carry out solar and wind analyses of the buildings in the town. The following figure shows the wind analysis result on the centre of Dundalk using MicroFlo; the computational fluid dynamics (CFD) analysis tool within the IES <VE> software. The following figure show the wind speed surrounding the buildings in Dundalk town are in the range between 2 – 5 m/s, where the darker the blue, the higher the wind speed. This was taken at a point in time to provide an indication of what is possible with regard to CFD analysis. Colour is required for a clearer understanding.

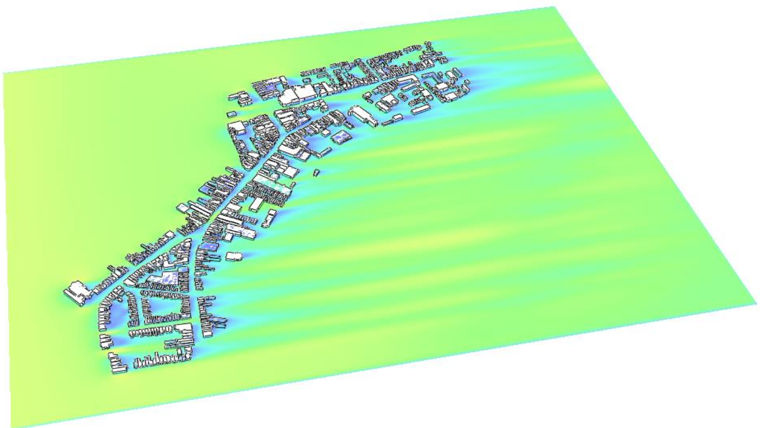

Figure 4: Wind Analysis of Dundalk Town

The following figure shows the solar analysis result on the Vincent Avenue area in the centre of Dundalk, which included solar radiation striking the external walls and roof surface areas of the buildings. The annual number of hours of solar radiation striking the surface of the buildings in Dundalk was calculated and is displayed in the following figure (colour is required for a true understanding). It is noted that an historical weather file was used in the analysis, so the solar incidence information will be different to the actual values. Nevertheless the solar radiation results generated are encouraging and clearly show the potential use of renewable energy technologies such of PV or solar thermal panels on buildings in Dundalk, with the majority of roof areas receiving over 12 kWh/m^2 of solar irradiance.

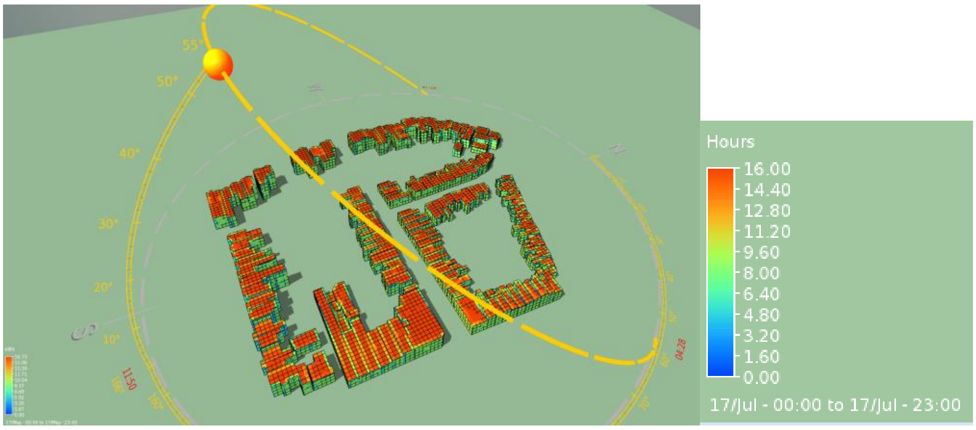

Figure 5: Solar analysis on partial area of Dundalk Town

IMPACT OF RETROFIT ON A SELECT NUMBER OF BUILDINGS IN DUNDALK

The buildings identified in the Muirhevenamor (MM) area which had building energy rating data were selected for a range of building simulation analysis within the IES <VE>. Detailed data input parameters (e.g. construction, internal gain, HVAC systems etc.) was applied to each identified building model in the MM area. The following figures illustrate the energy use intensity (EUI) result from a dynamic simulation run in the <VE> through the SketchUp plug-in, with the darker colours on the right hand side highlighting an improved EUI. This was used to consider the impact on energy with and without the potential retrofit / refurbishment options.

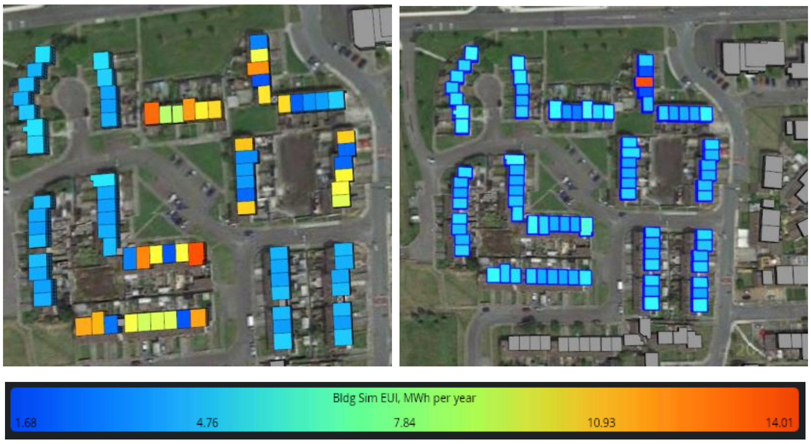

Figure 6: Energy Use Intensity (EUI) on buildings in Muirhevenamor area before and after retrofit implemented (Map data: Google)

The simulation result shows the average EUI on selected building in the area, with different retrofits implemented, is 39.74 kWh / m² per year compared to 55.77 kWh / m² per year without retrofits implemented. The simulation result shows the 28.74% decrease in energy performance between the buildings with the respect to the construction and district heating retrofit implemented. It is important to note that the urban configuration of Dundalk can facilitate or hinder the viability of different retrofit technology to be implemented.

The variety of the buildings available, and the level of detail in the building information available must be taken into account. Some input data was modelled based on information obtained through a library of building typology templates which IES have already compiled.

CONCLUSION

This paper has highlighted a number of modelling and simulation methods available through the IES masterplanning plug-in and <VE> software. The results clearly show the huge potential impact on energy consumption within the buildings modelled in Dundalk along with implemented retrofits.

The visualisation capability and its results from the masterplanning tool have highlighted the numerous potential solutions which can be utilised in tackling the challenges, and improving the efficiency and effectiveness of urban systems. This includes a set of metrics that it can be constructed within the tool and should prove useful for urban design, city planning, and energy planning and general construction.

Through the use of the tool, it clearly shows how it is easy to compare the renewable energy potential across individual buildings or groups of buildings in a city. This paper has highlighted the method shown to be an effective way of modelling and simulating at the early stage of analysis, and can have a positive impact on areas like Dundalk.

It is one of objectives of the INDICATE project is that the indicators (metrics) should be easily scalable and developed through the project, which will be then applied to demonstrate the effect of the changes within buildings, districts and within the overall urban context. The report has highlighted the key areas of the modelling approach in which will be similar, with the respect to the capabilities to be developed as the project progresses, along with the <VE> software and ESRI CityEngine software.

ACKOWLEDGEMENT

This work was conducted as part of the INDICATE project under the European Union's 7th Framework Programme for research under grant number 608775.

REFERENCES

1. Page, J., Basciotti, D., Pol, O., Nuno Fidalgo, J., Couto, M., Aron, R., Chiche, A., & Fournie, L. (2013). A multi-energy modelling, simulation, and optimisation environment for urban energy infrastructure planning. In: *13th conference of international building performance simulation association, 26-28 August 2013 Chambéry, France.*

2. Nouvel, R., Schulte, C., Eicker, U., Pietruschka, D., & Coors, V. (2013). CityGML-based 3D city model for energy diagnostics and urban energy policy support. In: *13th conference of international building performance simulation association, 26-28 August 2013 Chambéry, France.*

3. Huber, J., & Nytsch-Geusen, C., (2011). Development of modelling and simulation strategies for large-scale urban districts. In: *12th conference of international buildings performances simulation association, 14-16 November 2011, Sydney, Australia.*