Welcome to an overview of 3D city models with AccuCities.

What we will look at today is a direct comparison of 5 different 3D city models. We have overlaid a render of each so we can compare and contrast the accuracy and level of detail for each.

In the second part, we will look at real-world case studies of their use, especially in the context of Sustainable architecture and construction. We will consider the suitability of each type of city model and highlight applications where free or inexpensive models might be sufficient.

To quantify the findings of this comparison, we will score models on a number of variables.

But first, let me introduce who we are. AccuCities is a specialist 3D city modelling agency. From today's examples we capture photogrammetric 3D city models, both in CAD solid and Textured formats. We capture and manage a library of 3D city models for our customers, mostly architects and building consultants. We also capture small and medium-size 3D models to order, mostly for planning. To date, we have delivered over 2,300 (twenty-three hundred) projects to more than 230 customers.

Last but not least is Plan.City our urban planning application. Powered by Unreal Engine 4, the app is capable of displaying the entire city dataset, overlaying with third party data and examining with a number of custom built-in tools.

We are based in London, a city with a rich historical record of itself in maps and ortho drawings. Mapping London in 3D is therefore nothing new and we are proud to continue this mapping tradition in the digital age.

To achieve the level of accuracy and quality required by our customers, we use an old-fashioned, tried and tested manual stereo photogrammetry. That means that every point and every line in our city models has been captured by one of our technicians working on a state-of-the-art stereo photogrammetry work stations. Our technology, skilled team and multiple stages of quality control means that 8/10 customers buy from us more than once and our complaint rate is below 0.3%.

Our customers require accurate, detailed and up-to-date city models. This means the model has to be constantly updated and upgraded. This example of a 500 by 500 meters tile of London illustrates the amount of change there is from the 2016 to 2020. As we also capture Future Skyline layer, how the skyline will look like in 2027.

Future Skyline layer buildings are either 3D modelled by us from planning applications or sent to us by architects or developers. All of these proposals already have planning permission and although there might be further additions, this is how the London city skyline will look like in 2027. Where available, we make the Future Skyline layer part of our 3D models as a standard.

Customers can choose a level of detail model and license to fit their needs. We supply our 3D models in CAD solid, Sketchup or FBX formats as standard. Large sample models of an area of every city in our library are available, including a 1km2 sample of our latest 2021 Textured 3D London model.

The term “3D model” is an overarching term covering everything from simple extruded map polygons models all the way to custom-made millimeter-accuracy 3D scans. The 3D models vary greatly in terms of their accuracy, level of detail, recency and usability, as well as in terms of their costs, delivery time and its file format.

It is necessary for architects to understand the spatial context of a development. Architects usually take advantage of existing 3D city models or commission or even create their own 3D model of the surrounding area. RIBA plan of work has been updated in 2020. it is a task of Stage 1 to source Site information and Site Survey and 3D models of the as-built environment are often already used in stage 0 for the initial Site Appraisal.

Although architects are rarely involved in Stage 0, the project might inherit the 3D models sourced for the Site appraisal task and use this information in subsequent stages. Depending on the nature and location of the site, the site appraisal 3D model might be already a premium 3D model that can be used in subsequent stages. To avoid the use of low-quality site models, Stage 1 instructs project managers to “Source Site information including Site Survey”.

This seminar will compare these 5 types of 3D city models:

- Extruded Buildings footprint Polygons 3D map - this is easy to obtain and possibly the simplest form of a 3D city model. It’s excellent for background models and wide area city visualisations on a budget.
- Airborne Lidar model - a much more accurate and detailed model, however it’s quite a messy and unseparated Digital Surface model dataset.
- Aerial photogrammetry - made with clean geometry with a high level of detail, up to 15 cm accurate. This does come at a cost.
- Textured photogrammetry model - textures applied onto clean geometry, an accurate city model with high visual fidelity. Might be cost prohibitive and currently only available for London
- Game-ready model - not made for architecture or urban planning but very affordable with a surprising level of detail on landmark buildings.

For this discussion the first example of a 3D city model is an Extruded Polygon 3D map. The model is basically created by extruding building footprint polygons to a given height. This is usually an average height of a building given in a map or, more crudely, a set height to simulate a 3D environment.

This kind of 3D model is easy and cheap to obtain. It has separated, lightweight geometry, ideal for large city models visualised on a budget. Excellent for background models and wide area city visualisations where accuracy and level of detail are not important.

The model offers some third dimension to a map, but that is pretty much it and its level of detail is almost not existent. It is therefore a bit unfair to compare an extruded polygon of a London landmark to other types of 3D city model. But it also shows the limits of this type of model.

This is Tower Bridge in all five models. When compared to the Extruded Polygon 3D map, the Lidar model clearly offers much more detail and accuracy. However, as the laser “only” picks features from top and in a uniform grid pattern, there is clearly a limit to how pretty the model will look, but overall, not bad.

A managed Photogrammetry city model would have landmark buildings upgraded as a matter of making the model as realistic as possible. However, some basic detail is lacking. The dataset is accurate and separated into layers. A Commercial licence is needed to use this type of model.

Not that well illustrated by this render, textures can add to the overall recognisability of the environment. Here they are on the Textured photogrammetry model as well as on the non-geo referenced model for games. On the recognisability alone, the Non G.I.S team in purple has it.

Londoner’s must have already noticed there is something missing south of the river. As the buildings are only extruded to a set height, skyscrapers tend to disappear. The Shard surprisingly, considering its angled glass facades, is not a problem for a lidar scanner. The model has the building at accurate height and dimensions. But look at what happened on the News Building! Either under construction or some weird refraction caused this feature to be visually clearly incorrect.

The Photogrammetric city model has the building with clean geometry and upgraded facades. The textured model realistically shows the detailing on all the buildings from London Bridge Station, The Shard, The News Building and The Place. The gaming model, however, has The Shard in a fairly high level of detail but somehow inaccurate from this distance.

The Airborne lidar model is created by a plane collecting laser scans. Inherently a much more accurate and detailed model, great not just for backgrounds but also to measure from and even run some basic studies and simulations. Free datasets are available. When converted the Lidar does create quite messy geometry and the resultant Digital Surface model isn’t separated.

Let’s look at an area of the Tower of London. The lidar model starts to show it’s limits with messy geometry. These residuals are very difficult to remove as the unseparated Digital Surface model dataset is best used “as-is”, rather than trying to modify it.

The Extruded Footprint polygon model has once again the least amount of detail and no accuracy to speak of. However, note that features are separated on the ground. Much like on the right here with the photogrammetry model where the ground is separated into different land uses and includes a tree layer. Really showing the difference money can buy.

What doesn’t illustrate the difference money can buy, is the comparison of the textured model and the gaming model. Can you tell which one is cheap and all over the internet and which one is a premium 3D city model dataset?

The worst offence of this dataset is how out of date it is. It is the destiny of lidar 3D models to stay as young as when they were captured. It must be said that all the other datasets had the new London Bridge station modelled in. The reason behind the exaggerated way the heights look on the extruded building polygons model is because raised railway tracks do not have a footprint polygon on a map. And so the entire features such as railway tracks are missing from this type of city model.

An Aerial photogrammetry model has clean geometry, high detail and up to 15 cm accuracy. Every point and every line in these 3D city models is manually captured using stereo photogrammetry. A model like this comes at a cost; outside of small sample areas these models are only available with a commercial licence.

Thanks to a mature business environment respecting intellectual property rights, all of the established UK suppliers of photogrammetric 3D context models should be able to offer a full commercial licence.

For comparison let's focus on the area around 22 Fenchurch street. Extruded footprint polygons are not even trying. The Gaming model once again has a nice 3D model of the landmark building itself, but very little accuracy or detail in surrounding areas. The Lidar model, once again, shows lots of irregular geometry.

The Textured photogrammetry model includes textures applied onto clean geometry. It's an accurate city model with high visual fidelity. The cost of this premium dataset might be prohibitive for non-commercial projects and the model is currently only available for London.

Focusing once again on the London Bridge station area, this slide compares all 5 models.

And lastly, an inexpensive game-ready model. Not made for architecture or urban planning but very affordable with a surprising level of detail on landmark buildings.

A late entrant to this comparison, yet surprising close contender. 3D city models for videogames were historically only rarely used in architecture; simply until very recently they were only vaguely based on actual cities. But it would be unfair to omit them as for projects in some cities, game-ready models do offer an attractive and affordable option for many applications that require recognisability rather than high accuracy. High detail landmark buildings make this city model suitable for at least some applications such as CGIs or data visualisations on a budget.

We have already looked at landmarks, let's look at a residential area in the model. The Gaming models shortcomings are most visible here where the model is made out of hap-hazard geometry of uneven accuracy. Extruded footprint polygons don't fair much better and it's difficult to say which one is worse. The Lidar model is much better in terms of both accuracy and level of detail; note that previous models didn't include the raised railway tracks. The Photogrammetry and textured photogrammetry models are once again in a different league; but that quality comes at a cost.

If you opt to use a non-gis game model, be weary of different 3D city models used in games. You don't even have to be an architect or be restricted by a budget for a wrong choice of city model to invite ridicule and lessen a project value. A good example of this is the 3D London model used in MS Flight simulator a few years back. Even though the model was intended to be viewed from a plane and using procedural textures made sense for this purpose, using procedural textures across the city resulted in Buckingham palace looking like a council estate and the Queen Victorias memorial as a bungalow.

Just for the record, the London model in the MS Flight simulator has now been upgraded and looks great.

We would always recommend using premium 3D models for at least the immediate surroundings of

the site; using out of date, simplified or inaccurate context models for applications where accuracy is important can result in loss of credibility when questioned or, even worse, in design mistakes caused by an inaccurate context model.

Examples of Use

We have discussed the advantages and shortfalls of Extruded Footprint Polygons models. Illustrated here on the example of two 3D models of Cardiff, it is crucial for users to understand the limitations of this dataset.

However, they are often used as a background model to illustrate the wide-area context. Here they are used as a background model, supplementing the Photogrammetric model in Plan.City (pronounced as Plan City) app. Viewed from shallow angles, the line between 2 models is all but invisible. Can you spot where the photogrammetric model ends and Extruded buildings polygons model begins?

Used in GIS applications, the Extruded Polygons 3D maps can offer an inexpensive way to visualise the city environment. Using for example Cesium, users can visualise the urban landscape but also quantify its features such as buildings use, density or heights.

However, it is not recommended to rely on these datasets for an immediate site context. They might be released but not further managed by non-profit organizations such as OpenStreetMap or by local authorities such as New York City through its OpenData portal. As we can see here, there are significant differences in these datasets. These are usually down to the different understanding of buildings levels, different underlying mapping data as well as differences in what constitutes a building or a feature that should be displayed as a 3D object.

3D models from Lidar are often created from the Environmental agency 1m grid Lidar surveys. This data usually needs to be further processed to be used in various applications. For example, there is a source code on Github for a little program to convert LIDAR scans into 3D-printable STL tiles for 3D printing.

Because Lidar 3D models are not usually separated into terrain and buildings, they are referred to as Digital Surface Models. That means that they can be used directly in applications such as Wind Load and Pedestrian Wind Comfort Modelling without much post-processing. A study conducted using Lidar model will generate more accurate results than using Extruded Footprint Polygons model. But because of the messy geometry of the Lidar model, the study might take longer to process.

Lidars' accurate height readings over a large area are often utilized to assign better height values and even correct roof shapes to Extruded polygons 3D maps. The results of these mapping processes are very much dependent on the quality of both the datasets and algorithms used in the process. The workflow design for this process is constantly changing and improving with continuous research.

Another way to use Lidar 3D models is to run simulations on this data to generate new 2D mapping data. A good example of this 2D mapping data generated from Lidar height maps is the OS Flood map.

The photogrammetry 3D models are the most commonly used premium dataset. 3D models of major UK cities are usually already created and sites outside of these city centers are very well covered by existing aerial surveys. As a result, photogrammetry 3D models can be sourced from existing libraries or produced to order in a very short amount of time for pretty much any site in the United Kingdom.

Similar coverage exists for sites in Ireland. Whilst elsewhere in the world it might be more difficult to source these 3D models, it is almost always possible to commission a custom 3D model.

The photogrammetric 3D models are usually sourced by a planning consultant or the architect. This can be done at either stage 0, 1 or 2 of the RIBA Plan of Work 2020. It is recommended - but not always possible - to source these models early on as the maximum building envelope, facades shapes and even building orientation can be significantly amended during the pre-planning and planning stages.

Building envelope constraints stemming from local planning regulations or from acquired rights such as rights to light can have a significant impact on the building design.

Visual Sky Component calculations assess the daylight impact of different massing options. This type of study is usually conducted by an architect or a planning consultant during the pre-planning phase and results in a generation of a maximum building envelope constraining the final architectural design.

Compliance with local planning regulations such as the London View Management Framework or 'St Paul's Heights' maximum heights grid represents further constraints on the maximum size of the proposed building.

Photogrammetric models are georeferenced to OS map, can be overlaid with third party data and easily updated and upgraded. They are therefore ideal to be be used in many stages of the design and development process. Used here in digital public consultation process by 3D repo, the 3D model has been used to take a stakeholder through possible issues with a proposed design, with the possibility of viewing changes from their windows or balconies.

Weston Williamson Architects used photogrammetry 3D models for Public consultation boards, as well as to generate 2D maps from geo-referenced 3D model data.

To comply with the City of London Wind Microclimate Guidelines requires wind modeling studies to be carried out. Exceeding the recommended values might result in amendments to the architectural design. More and more local authorities require these studies to be conducted for planning purposes.

Further studies might be required by local authorities during the planning process. Solar Glare Assessments might be required for developments near railways and Accurate Visual Representations renders will be very likely required in the planning process of tall and significant buildings to inform the effect of a proposal on the as-built environment.

Compliance with a wide variety of regulations often creates back and forth between the architect, planning consultant, and the investor. Using the same 3D model for all assessments from early on can help to identify and communicate possible issues and significantly reduce the time required to

produce an architectural design compliant with all local planning restrictions.

Well thought-out access design and temporary site structures positioning are important considerations on every site. Working on a development in a busy city centre can increase the pressure and complexity of the operation multifold. BAM Construction used a photogrammetry 3D context model as part of a competitive tender process to design and communicate the size and appearance of the scaffolding, locations of the in/out site access, cranes positioning and even turning circles checks. For simple sites, even extruded building footprints may be sufficient. Premium 3D models are recommended for sites in urban areas, sites with complex terrain height changes or where the initial assessment identifies issues.

The last example of using 3D city models for designing more livable cities is an innovative project by Ioana Man. She explored how architecture can collaborate with biology to create a more sustainable built environment. She conducted microbes DNA sequencing and identification and used a photogrammetry 3D city model to take into account the existing urban density & land use. The use of accurate context model will also be pivotal in the effort to quantify and extrapolate her findings to other parts of London or other cities.

Textured photogrammetry models are not necessarily required to conduct most architectural or planning studies. They can, however, be employed to create recognizable visualizations for planning and public consultations.

Because the textures are applied onto a separated high detail photogrammetry model, users can turn textures on and off on buildings, terrain or on any other features. Pixel stretchings and imperfections, occurring mostly in urban cannoyons, can be rectified on focus buildings by upgrading a UV map from custom photographs.

Textured photogrammetry models can also be 3D printed, as illustrated on this 500x500 meters tile 3D printed in 15 x 15 cm by Hobs 3D.

Textured photogrammetry 3D models will also give architects a new way to visualise their designs in the existing environment. For example, it is now possible to visualise the reflection of the neighboring environment on the facade of a proposed development.

The greatest advantage of using the textured photogrammetry 3D models is in the ability of the investor to use the same 3D context model all the way to marketing and sales. Good example of this is this real-time simulation of views from a proposed restaurant created in Unreal Engine 4.

Scoring the compared 3D city models

We have never meant for this overview to have a winner. But as a fun experiment, we have attempted to score the city models on their Usability, Cost, Delivery time, Accuracy, Level of Detail, How up to date it is, and on their File Size and Polygon count.

The extruded footprint polygons 3D model scored 38 out of 100. This is the highest score of the non-premium city models and is most suitable if your main considerations are the cost, delivery time and file size.

The airborne lidar 3D model scored 36 out of 100. It might have scored higher if the compared 3D

model would be more up-to-date. It is most suitable if your main considerations are cost, delivery time and accuracy. The 3D model is limited by its large file size end low usability.

The photogrammetry 3D city model has scored the highest. Suitable for applications requiring high accuracy, level of detail and recency. The model offers best overall balance of factors but scores lower on its cost, delivery time, and file size.

The textured photogrammetry 3D city model, despite being an upgrade of a photogrammetry model, has scored only second highest. Suitable for more applications than a non-textured photogrammetry model, the model lost points on its cost, delivery time, and file size.

The game-ready model has only achieved 32 our of 100, but that was kind of expected. It is a non-standard solution for architecture. It has very low accuracy and level of detail, but if delivery time and file size is what matters, it might suit your needs.

We certainly hope that you have found this 3D cities models overview interesting and informative. Visit accucities.com/cpd to read more case studies, download samples, images, and the transcript of this presentation.