Scanning Cities: Point Cloud Data and Reality Capture Within Architectural Process

Code AB7001
Speakers: Rebecca De Cicco & Matt McCarter

Class Description

The class will focus on the uptake and rise of laser scanning workflows in the architecture, engineering, and construction industry in the United Kingdom. We will discuss a variety of workflow options of scan data into Autodesk software. The class will also delve into typical and best-practice workflows when it comes to using the scan data effectively on large-scale projects, as well as understanding how the use of the data can begin to replace traditional visualisation methods when communicating ideas to clients and consultants through differing stages of projects. The class will enable you to realistically help your staff to utilise the scan data and effectively manipulate it to produce typical architectural diagrams and drawings.

The speakers will also update the audience on current UK developments in the development of BIM in the UK based on the Government incentive leading to 2016. Laser scanning and utilising scan data on all stages of projects has become of paramount importance on BIM enabled projects. The handout will also discuss how 3D scanning technology integrates with Building Information Modelling and supports the broader objectives of the UK BIM Task Group.

Learning Objectives - at the end of this class, you will be able to:
Learn how to more accurately document existing buildings using scan data.

Learn how to utilise large-scale scans and effective divide and manipulate the information for use on projects.

The workflow and manipulation of scan data into Autodesk Recap and linked into the Revit Environment.

Discover differing versions of visualisation techniques from point cloud data and into varying Autodesk Software.
About the Speakers

Rebecca De Cicco - Director, Digital Node.

Rebecca is a digital design specialist who completed her honours in Architecture in 2001. Her keen interest in digital technologies and how they can evolve and ultimately change the construction industry has always been at the forefront of her thinking. After a series of successful senior roles in varied architectural organisations, Rebecca now manages her own consultancy, Digital Node, providing advice and insight to construction professionals on advanced digital solutions on projects. Rebecca is one of the team leaders for the UK Construction Industry Council BIM 2050 Group, which is a team of young professionals aiming to steer the industry and its government drivers toward a Digital Built Britain. She sits on the User Group for Building Smart UK, and she is the founder of the Women in BIM (Building Information Modelling) incentive. Rebecca is an Autodesk University speaker and an Autodesk Feedback Community attendee and Gunslinger.

Matthew McCarter - Laser Scanning Sales Manager, Topcon Positioning - Great Britain & Ireland.

Matthew recently joined Topcon as Laser Scanning Sales Manager GB. He has been working with laser scanners and point cloud data since 2000. He has spent over 5 years at London Underground in the Land Survey Team where he was instrumental in the adoption of Laser Scanning across the organisation. During this time he put in place the processes, hardware and associated software needed to manage a large amount of scan data.

He has a keen interest in BIM, especially where laser scanning can bring greater benefits to the overall construction industry drawing upon his time spent at London Underground gaining and understanding of a client’s requirements. Matthew was a key member of the working group that produced the UK Government BIM Task Group Client’s guide to Laser Scanning. He also sits on the Survey4BIM committee for the BIM Task Group as well as the advisory board for the SPAR Europe 2014 laser scanning conference and is on the Technical Committee for the GeoBusiness 2015 conference.
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Introduction - What is Reality Capture?

There is much debate about what it is to capture reality, physical reality? Virtual Reality? Sound, touch and smell. What is it we need to realise is that digital solutions to capture reality, capture this reality at a static moment in time. For this reason is it fair to necessarily assume that the static objects we capture at that time is a sense of reality?

Autodesk state that photographic captures of the real world with a laser scanning device captures the 3D physical nature of that entity, be it an object, a space or a building.

Scan data or point clouds are captured using 3D scanners and devices to capture that state. In most cases this occurs from a survey company who provide a correctly positioned (geographically) static object within a scan in its native scan format, dependent on the device used to capture that information.

The aim for this process is to bridge the divide between the physical and the digital world in order to allow for contextual design information. This is becoming increasingly more important for Architects and designers as it allows us to understand and capture a space or building without the need to revisit it or have to return to a site time and time again.

The real world objects are captured, there is no need for any counting of bricks, photography and time taken to assess a site. This process can now be eliminated and we can allow for accuracy and precision of design proposals at very early stages either with the use of photogrammetry or laser scanning.
Overview - Laser Scanning

The application of 3D laser scanning technology offers a myriad of solutions to the Construction Industry and building projects. The process is most often used to capture survey data for existing building projects and utilise this information for review of existing site conditions. It is also an intelligent process to capture information for clients and contractors and utilise the information to evaluate construction progress, as built conditions and also manage large asset portfolios as necessary. The equipment and cost of laser scanning continues to decrease and therefore is becoming more tangible for all parties involved in Construction and Building.

Scanning technology and its related processes are becoming a critical element within BIM projects and it is already providing clear value to clients utilising this technology on their projects.

Currently we are seeing an upsurge of the below processes.

1. 3D Laser Scanner for creation of Point Cloud
2. Photogrammetry to Models data.

To understand how scanning technologies and processes can be applied to a BIM workflow it is important to understand what the definition of laser scanning is and what its basic functions intend to serve. Scanners are generally used to send out a high density of laser beams for the purpose of positional measurement. Laser beams project from the scanning hardware and are measured as they move and then return to the source scanner. The hardware measures the return time of the laser and knows how far away a physical element actually is. The scanning technology then has the ability to send out thousands of beams per second, resulting in a point cloud.

The point cloud measurement values are represented within the file format which contains the position, intensity and colour of the point cloud. The point cloud data can then be extracted in a number of file formats directly from a scanner, including:

- ASCII
- PTS
- LAS - aerial data
- E57
There are several hardware and software vendors that have proprietary point cloud formats that can be readily converted and translated prior to submission of the point cloud.

These include:
- CL3
- CLR
- FLS
- FWS
- POD
- PTG
- PTS
- PTX
- ISPROJ
- ZFS
- ZFPRJ

To remain non hardware or software specific it is important to request the non proprietary XYZ or E57 Format.

Upon commencement of a scan the requirements, deliverables and summary of what the data will be used for should be clearly outlined by the party involved in procuring the scan from a surveyor or otherwise.

Once the above is outlined the following information requirements should also be established. This will outlined the format requirements and how the data will be used on the project.

Deliverables may include the following:

The scan data captured will also generally be accompanied by a web based viewing platform to access, view and analyse the point cloud data. Access to this information generally exists through the cloud or a secured client server as necessary. In addition to this a variety of markup tools currently exist to be able to communicate varying elements of existing data to all
parties involved on building projects. This therefore intends to negate the need for site visits, physical viewing of site conditions and numerous visits to and from areas that may need to be captured.

Reference: Client Guide to 3D Scanning and Data Capture, 2013
UK BIM Standards & Relevance

The Construction Industry in the UK is currently undergoing an industry shift. HM Government released a report in 2011 stating that our industry required radical change and progress. It determined that in Construction in the UK our sector performs poorly and Construction projects lead to waste and inefficiency. The report concluded that the use of Building Information Modelling would be mandated on all Government funded projects by 2016 in order to:

1. Ensure alternative design proposals can be evaluated with ease by all parties involved;
2. Projects are to be modelled in three dimensions avoiding errors in coordination and to allow for 3D aggregation of discipline model data;
3. Design data should be fed directly into machinery tools for DFMA (Design for Manufacture an Assembly);
4. Data can be use downstream for asset management using information expelled from design and construction model data.

The above was born from the fact we spent a high amount of time on design and construction changes along all stages of projects as well as there being no strategy toward coordination both digitally and on site which resulted in poor building processes and no valuable outcome. As a result, BIM and Digitally integrated design and construction were placed as a high priority for all projects procured through HM Government. The aim was to enable a process and adoption of BIM by 2016. The BIM Task Group was formed from this incentive and driven by the government to enable this change in industry and help those involved in Building Projects to build their knowledge and capability in a BIM capacity. It established a set of clear guidelines for industry to work through regarding the information that was required by 2016 on these projects.

A level definition was therefore established to guide and enable this process while outlining a staged process toward mandating BIM. These levels help industry understand a staged approach to development and how we’ve transitioned and will continue to move into a more digitally integrated process in building construction. It was necessary to outline which standards were in line with these levels and the process toward doing so which was also enabled by the standards as per below.

The industry required guidance in terms of where we needed to be regarding BIM development in the UK and information and a process guiding those involved on BIM enabled projects.
This level definition can be seen in the diagram above and at present industry is aiming to
deliver projects to hit Level 2 as outlined above. Level 2 projects can be summarised to
include:

1. A full coordinated design model
3. 2D Drawings in PDF format

Reference: PAS1192.2 Specification for Information management for the capital delivery
phase of construction projects using Building Information Modelling.

The BIM Task Groups aim was to create a network of key individuals and groups who would
support this incentive and create a portal for information for all suppliers involved in
Construction. Not only did this drive adoption for the pre construction processes but also
enabled the creation of a series of BIM 4 groups which aimed to develop key areas and help
our industry move ahead.

The Construction Industry in the UK was therefore hit with an important task - to ensure our
built projects were not only using a digital process but also to train and create opportunities for
all parties involved on these types of projects. Those involved in Government projects
therefore rapidly aimed to ensure their processes and procedures changed to adapt to these
challenges. With this, the UK saw a huge uptake of private clients requesting BIM as a process
on their projects and embed an asset solution very early so as to use this information to help
manage their assets. This incentive has progressed incrementally from 2011 to today and is
continuing to do so leading to 2016. What we are seeing currently is that more and more
clients regardless of if their projects are Government funded are requesting BIM related
process.

Surveying processes and adequately documenting building projects not only involved internal
processes. The above also created an opportunity for all design consultants and trade
contractors to change they way they worked. The processes that were put in place to ensure
existing information was delivered to clients also had to undergo a shift. This shift involved
utilising current technologies to deliver both traditional survey information as well as scan data.
A series of documents were issued incrementally to industry over the past few years not only
captured what the governments aim for BIM projects involved but also how to utilise scanning
processes and point cloud data on projects. The Client Guide to 3D scanning and laser
capture was therefore released to industry via the BIM Task Group in 2013 and involved those parties who formed part of the Survey4BIM Group. The documents aim was to dissect the technical processes involved in laser scanning as well as ensure clients understood why they would need to use scanning processes on their projects. It was a critical document issued to ensure those clients driven by BIM related processes as well as those involved on Government projects would understand how to capture existing asset information and building projects in a BIM environment using scan data.

The below diagram indicates the BIM Task Group Strategic groups that have helped drive the above. Not only were BIM for groups established but also a network of ‘regional’ BIM hubs which were created to support and train industry and create a networking opportunity for those who had implemented BIM to share their knowledge and expertise to those beginning their journey. These key groups have supported and grown a strong community in BIM in the UK and many of the below groups are interlinked and have strong ties internationally.
UK Surveying Industry in Context

As a result of the BIM Task Group and HM government incentive the UK Surveying industry is also undergoing a critical shift. This shift is driven by BIM related processes and government mandate but also by technological changes that fuel these ideas. These changes in technology are affecting how we capture existing information and work with survey data, how to accurately deliver this information and subsequent model data to clients and consultants accurately and also to how to ensure those utilising scanning processes do so accurately and effectively based on the equipment, technical workflow and processes available.

In the UK there are no special licensing requirements for performing 3D scanning services to industry. A number of surveyors are currently undertaking this work but there are many organisations stating their capabilities and that have the finance to purchase the equipment without any prior knowledge of laser scanning. This is therefore a risk item when it comes to procuring scanning services and currently large clients and contractors are assessing their supply chain in order to ensure the knowledge is there to deliver this accurately.

There are a number of processes that involve using scan data on building projects. The handout will document those processes in context to real life projects and from a Surveyor and Architects point of view.

The processes covered in this handout will include:

• Step by Step process of capturing scan data and delivering to clients for use (on varying stages of projects).

• Design using Scan data for Visualisation and Image capture as well as animation.

• Utilising point clouds data in Revit at Detail Design Stages.

• Moving from design to fabrication data using point clouds.

• Progress scanning on new build projects through Construction.

• Refurbished projects and using Scan data to build existing model data.

• When to use only Scan data in lieu of a full model.

This document will cover the processes above using Autodesk Recap, Recap Pro, Revit and Navisworks. The handout will also provide feedback on Autodesk Point Layout tool which was recently released, and is able to capture point data on site and link this with applications such as Autodesk Field using the A360 web based tools that are currently accessible to Autodesk customers.
**Current Scan Capture Process**

The 3D scanning process is one in which all parties involved must have clear and concise deliverables outlined prior to any work being undertaken. This is an area which requires thorough planning. The UK Surveying Industry is currently processing this for many BIM related projects and there are a number of companies who are delivering a ‘Scan to BIM’ service in line with the Governments push for BIM leading to 2016. The process of scanning and delivering information for Surveying consists of the following deliverables.

1. Commission for Scan data only - e.g., Registered Point cloud.
2. Existing Building Information Model from Scan data.
3. Traditional 2D Survey and 3D Scan.

It is imperative that the process and capture process is clearly defined as indicated in the diagram below.

![Diagram of scanning process](image)

*Size indicates relative level of effort at each stage*

**Reference: Client Guide to 3D Scanning and Data Capture, 2013**

Surveyors will traditionally be commissioned to deliver one of the above and this service is becoming more common in Construction in the UK and abroad. It is important to note that there are a variety of external consultants and AEC professionals that are also utilising this process in industry. Those adequately modelling and using scan data on projects must have the relevant experience and knowledge to avoid error downstream. This will become less important as point to point registration becomes more common place in industry to avoid manually 'stitching' scan data together.

The Indexing process and registration should be performed by a registered Surveyor and delivered accurately as survey data. Should the scan be used as background information it is
imperative those using this information are aware of the processes toward stitching this data together. Many consultants are now acquiring scan data and are not using it accurately.

**Commission of Scan Data**

At the point of a commission of a scan either via a Surveyor or external consultant it is imperative to ensure the following queries are addressed by the client or necessary party prior to any work being undertaken.

1. What is it I require from the scan? What do I need to use it for?
2. Will the scan be delivered in its raw format? What file format will be required?
3. Is the scan registered? How is the scan registered, e.g., either manually via targets or using point to point registration with the scanner software used.
4. What is the level of coverage, e.g., What is it I need to see in the scan? This will ultimately affect the cost and site work involved.
5. What type of scan do I require. Internal or external?
6. Reflectivity of Scan data - Will this be an issue?
7. Cleaning scan data prior to delivery (e.g., removing people, vehicles or any furniture etc).
8. Does the scan need to relate to a grid?

Once the above has been defined it is the responsibility of the Surveyor to ensure the information is delivered accurately. Surveyors have the relevant insurances to ensure information is delivered according to their relevant professional service (in the UK case via RICS - the Royal Institute of Chartered Surveyors).

At times there is an industry perception that information delivered via a laser scan is not accurate. The information is only as accurate as the company providing the service. Laser scanning does not replace the technical knowledge and expertise of a Surveyor and therefore it is necessary that this is known and communicated at early stages of projects. Many contractors and large organisations have the capability of internal scanning teams. Should they have this process set then it is possible to rely on using the information relevant to the stages of the project or project deliverables.
There are a number of key benefits for laser scanning in Construction. These include the following:

**KEY 3D SCANNING BENEFITS FOR CLIENTS**

- Capturing existing conditions with high resolution
- Identifying errors with 2D as-built documentation
- Reducing client risk for renovation/rehabilitation projects
- Reducing need for physical site visits and inspection
- Assessing structural integrity of assets
- Monitoring and recording construction progress
- Recording cultural and historical facilities and artifacts
- Facilitating better information management on projects

Indexing and Registration

Once the deliverables are agreed and the commission is established it is imperative that the data be indexed and registered by the relevant Surveyor. Should the scan data be registered and indexed the following must be undertaken.

The following example software solutions for registering scan data include:

- Topcon: ScanMaster
- Faro: Scene

Indexing and registration therefore occurs prior to import into Recap. Some surveying companies are using Recap Pro to index and register prior to delivering the information. Recap Pro and Real view for Recap 360 enable the use of the 360 offering to view and share the scan data relevant to the project.

The only differences between Recap and Recap Pro are the indexing and registration process. In lieu of using hardware specific software platforms, Autodesk have made it easy for construction professionals to register and manipulate the information themselves.

Many consultants are now registering and capturing scan data independently. This is becoming increasingly more popular with the scan facility becoming cheaper and more accessible. The process of working with this scan data for this process involves:

1. Scan data delivered by a surveyor or consultant with the relevant equipment.
2. The scan data is imported, indexed and saved as a Recap project.
3. The Recap file or files are then directly linked to Revit.
Registration of multiple laser scans

Laser scanners can only measure what is visible from their location. As such, it is standard practice to have multiple laser scans from different locations around a site in order to measure a site comprehensively enough for the purpose of a project.

Until some form of co-ordination is applied to the multiple scans, they will not form a coherent data set to represent the area that has been measured. Co-ordinating/stitching scans together is known as registration.

Registration can be achieved in a number of different ways, primarily dependent on the hardware and software used by the surveyor.

1. **Target Based**

   The original method that was used to co-ordinate scans. Special flat targets are placed around the area to be scanned such that 3 or more are visible from multiple scan set ups.

   These targets can be identified in adjacent scans and used as the common points to link them together. These targets may additionally be co-ordinated to a site grid or recognised grid such as a state plane or in the UK the “Ordnance Survey National Grid”

2. **Sphere Based**

   Similar to target based. Spheres are placed around the area being scanned such that they are visible from multiple locations. The use of spheres offers the advantage of being automatically identifiable in the registration software.

3. **Resection**

4. **Scanning from known locations.**

   The tried and tested method of surveyors since the pre-digital era of setting up over a known survey marker such as a peg or nail in the ground. These survey stations can be co-ordinated in advance, at the same time as the scanning or after the scanning has been completed. As well as the scanner being set up over a known point, it will also need to measure to another known survey station in order to establish an orientation. This is known as a back sight.

   This method means that the scans are co-ordinated in relation to each other on the scanner and no registration is necessary. It may still be desired to tighten up the registration by using….

5. **Cloud to Cloud**
This method of registration can be used as the sole method for registration, or in addition to any of the others to further improve initial results. It is however more important than other methods to ensure there is a good overlap of measured points between adjacent scans.

Cloud to cloud does not require any targets to be placed around the scene in order to register the scans together. The software will look at individual laser scans and check the measured points in it against other scans to find areas of overlap and common geometry. This common geometry is then used to link the scans together.

2014 has seen a great shift towards automatic cloud to cloud registration from many vendors. This can essentially mean one button registration if the site work has been carried out with due consideration.

It should be noted that with targets and spheres, not only is it critical that 3 or more of them are visible in adjacent scans, they should also be geometrically spread evenly around the scene in both plan and height. I.e. Having them all along the bottom of one straight wall would be poor geometry and hugely increases the risk of a mis-matched registration. Thus rendering the data not fit for detail design.

Creating strong geometry such as this is intrinsic in surveyors minds and second nature to them, but is worth highlighting if scanning is going to be undertaken by non-surveyors.
Recap Photo at Early Design Stages

At stages of projects where scan data may not be available (or a survey has not been undertaken) and it is necessary to capture existing conditions of a site or building facade it is necessary to take alternative measures which superseded traditional analogue processes. This may occur during design competition work, refurbished facade options and streetscapes or even object data for design.

This is where the Recap Photo workflow becomes of paramount importance to capture site data without the need to continually revisit the site. Gone are the days were we needed to visit our site and count bricks to measure and document existing facade or site conditions.

Recap photo is a tool that allows integration of photographic data into a web based platform to create a mesh based on a series of photographs. The photographs must capture all dimensions and spread of the allocated site and this will ensure Recap Photo is able to produce a relevant mesh necessary. Recap Photo allows now for an export to .rcs which allows for direct linking into Recap. The mesh can then be manipulated and altered and then inserted into Revit. The below dialogue will allow for early stages of concept design iterations.

What is critical in this process is the accuracy of the photography. If photographs do not capture the coverage then Recap photo will not create a closed mesh. The photography is incredibly important and can affect exactly how the mesh is created so it is relevant to ensure
you are consistent and accurate with this. The better way you handle the camera and use it the better the mesh.

There are a number of things to remember when taking photos in terms of accuracy. Obviously when using Recap photo for buildings this becomes very important as it is crucial that all elements of the area or building facade are captured. The key is to ensure photos are clear, they capture every angle (Autodesk recommend 5 degrees minimum) and are continually overlapping. It is recommended to also retain the same settings regarding exposure and zoom control when taking these pictures.

It is also important to avoid direct sunlight and shadows (e.g. dark areas). If there is too much sunlight the shadows will cause inconsistencies of the mesh creation and will need rework. Blurry photos and moving objects will also cause inaccuracies, as will anything shiny. Remember to always capture what is necessary to the scan information you are trying to create.

There are three choices for mesh quality in Recap Photo. Preview mode: You can use this mode to a quite result and to see if the stitching has been successful. High and Ultra settings allows a much high quality mesh model and can be exported to various file formats. Recap photo can be exported in the file formats as above. The resulting mesh can be manipulated if required in Project moment which is free on Autodesk Labs and allows for high quality mesh objects to be simplified and used downstream. This allows for file size to be reduced and the complexity of the mesh to be simplified prior to use or insertion in the Revit Environment.

Project Memento is still an Autodesk Labs product yet it is useful for the following reasons:

1. Manipulation of mesh
2. Simplification of mesh

Should the mesh be too complex or high in density Memento allows for the manipulation and simplifies it accordingly. This can then be used inside of Recap as necessary. It is also possible to insert mesh elements from other means (eg if a mesh is created in Autodesk or fusion). There are a number of ways to quickly decipher if your photos will have enough coverage and once you select the photos you can create a quick ‘draft’ mesh to review.

There are also some advanced features that exist in Recap photo. The advanced features allow for either further photographic data to be embedded or registration to occur. This will therefore aid in setting an accurate geographic location and also will help to add more information to the point cloud in Recap Photo as necessary. This process is useful when the scan data via a point cloud is not accessible and should there be a commissioned point cloud
later the information can be used relevant to that stage of the project. It is important to remember that information will only be available relevant to the project. The project will need to address how to use the scanning data (regardless if its something created by Architects themselves with photos or via a scan).

Do not forget to ensure you have an Autodesk account as this is a web based solution and you'll need to access the mesh once its created via the Autodesk 360 websites.
Recap Basics

Recap is available free on subscription to view, measure and manipulate Point cloud data. It is part of the subscription tools on suites and therefore can be used on projects relevant to their processes. Recap allows for grouped scan data (regions) to be manipulated and controlled prior to insertion into Revit. It is for this reason that Construction professionals are utilising the service to create information relevant to projects.

Once the scan data has been inserted into Recap it should be cleaned and manipulated according to project needs and requirements. The offering of Recap Pro however (at a cost) allows scan data can be automatically registered using scan positions in Recap. Recap 360 however offers a web based viewing platform to view scan data relevant to projects.

It is important to note that ReCap 360 comes with 25GB of Autodesk 360 storage and 50 cloud credits for ReCap 360 projects, which can be used to cut processing time. This should be managed via the discipline model manager or relevant BIM manager within the practice.

*Rule of thumb is to undertake the following prior to linking in Autodesk Revit regardless of the stage of the project:*

1. Save raw scan data locally and ensure users are not manipulating the original data.
2. Duplicate this data for manipulation and insert into Recap.
3. Review and refine the scan - e.g., remove unnecessary point data including moving objects, entourage, furniture, etc.

In most cases the scan data is delivered by a survey company who will correctly orient and deliver the scan data in the native scan format of the manufacturer. Recap enables insertion of the following file formats as shown here.

Scan data can be used to generate the following:

1. 3D Model creation from Point Cloud.
2. Surface Modelling from scan (using third party software).
3. Point Cloud into Clash review Software to check against other discipline model data.
4. Capturing Asset Data.
5. Progress on site - Review Design intent vs Built.
Recap Workflow

The Recap Project screen is where most of the work is undertaken and is divided into several areas. The interface is easy to use, very simplistic and allows a strong visual tool for those using scan data on projects. The below shows the typical User Interface for Recap.

![Recap Interface Image]

Depending on the information required the first stage of the process within the Recap environment is to directly import all the native scans and save the project to a relevant project location. Once these are linked (and as long as these are indexed prior to insertion with the necessary scanner software (or Recap Pro should you have access) the Recap file will become one ‘total’ scan project. This project can then be manipulated as necessary and used as a reference for further project work downstream.

The project tools are available as per the diagram below and consist of a Home button, Display tools, limit box (scope box for those understanding Revit terminology) and a Project Navigator. These tools are straightforward and are simply visual tools to help to view and navigate the scan data dependent on its requirement.

As you hover over each tool it is easily able to understand the relevance of each. Should the scan be delivered with RGB as you can see above the scan information can be viewed with a variety of display options.
Prior to import of the scan data it is also possible to adjust settings.

The various settings you are able to adjust include;

1. Noise Filter: This allows you to determine how to address stray points or movement points from a scan. It is possible to either remove none of these points (and do this manually) or allow Recap to preserve most of the points in the standard option or aggressively remove points that aren't part of a surface.

2. Distance Range: Maximum or minimum distance from the scanner at which points should be included.

3. Intensity Range: Intensity to allow for included points.

4. Decimation Grid: This allows a user to specify the number of points applicable to be entered which improves the end quality of the point cloud.

5. Coordinate System: Allows the point cloud to be aligned to a particular coordinate system.

Once all the scan data is inserted into Recap and registered the process of capturing regions in order to separate the zoning or portions of the site will allow individual RCS files to be
exported and then linked into Revit as required. The clipping tools at the bottom of the Recap window allow a clipping either inside or outside the scope box and also allow grouping or isolation of points within the Recap file. These may be different to the individual scans and therefore it is important to capture these regions and name them accordingly.

A point cloud typically contains information from multiple scan files. After the imported scan files have been indexed, it is the aggregate scene, not the individual scan files, that are important. For example, scan regions, which are used to organise and filter the content of the point cloud, often extend across the boundaries of the original scan files.

A point cloud file (RCS) is a single scan file that has been indexed. During the import process, RCS files are automatically saved in your designated Output folder. When you open an RCS file in Autodesk ReCap, you do not need to index it again.

A point cloud project file (RCP) is a relatively small file that references the point cloud files, but does not contain them. In order to use a project file, the RCS files must be located relevant to the Recap file.

As part of a planned deliverable or access to certain information it is possible to export the files as hardware neutral file formats. You can also export the files in the project as a single RCG, E57, or PTS file.
Moving into Revit from Recap

At the point of handover of the scan data it is imperative that the information delivered is also shared with a true view application to be able to view the data and imagery on a web based platform. This platform will either be via the independent Surveying companies TruView software or via Recap 360. Recap 360 is an independent area and not linked to the A360 interface. Therefore we must upload and use it according to best practice standards.

As Architects we require existing information early so as to assess the realistic nature of design optioning on site. Should an existing scan be delivered, either of a site or an existing building the information can be used during design stages in the following ways:

1. Process and stitch all scan data into Recap as above.
2. Save this as a RCP file and link this file directly into a new Revit Project. *(Note: Should Work-sharing be enabled it is recommended to set up an independent workset for the Recap file, this way it is easily managed in terms of visibility and in turn will not affect model performance). It is also imperative that the raw scan files are stored relative to the RCS file to avoid any loss of linking to the scan data.*
3. Create Revit model according to project requirements and export as a Navisworks (.nwc) at stages or create separate Revit files for design options to avoid issues with performance.

Once the Recap file is linked to the project it is possible to use Recap to view and measure from external to the Revit modelling environment and use it as a visualisation tool for clients to share and view the information. This capability is also available via the Recap Pro 360 service which allows for direct viewing of scan data in the cloud should Recap Pro be used to index and register the data.

Once the scan data is registered, manipulated and grouped according to zone or portion of building requirement the Recap Project can either be exported based on 'regions' set up as individual RCS files or linked into Revit as a Recap Project file.

Dependent on the nature of the project the above will need to be determined as early as possible and within relevant stages of projects.

Many companies chose to set up View Templates within their Revit model environment settings. The view templates for Point clouds will allow the point cloud to be viewed according to the setting assigned in the Visibility and Graphics dialogue. This allows a variation of colour modes. These colour modes can aid in the visual graphics of the view using the scan data and also allow users to extract images using both model geometry and scan data.
The two settings recommended for image extraction either via a saved image per view or print to pdf or dwf are either RGB or one colour.

Shown here is an example of an image extracted from a view in Revit following the linked RCP file being inserted into Revit. As you can see it allows for a quite pleasing visual graphic. Note: It is recommended that any image saved from a view in Revit be removed from the Project Browser immediately after it has been exported from the project.
Common Processes with Scan Data & Revit

The Construction industry is currently grappling with how to utilise scan data at varying stages of building projects. Currently there are a number of processes that are gaining traction in the UK and they are listed and explained in more detail below. It is important to note that these are recommended workflow processes that the UK BIM community is beginning to encourage and adopt across all stages of projects and therefore in order to utilise these processes a series of guidance documents need to be put in place to aid and support this. As explained above, using scan and photographic information on building projects is important at early stages but as we move into a BIM enabled construction landscape it is also important to support further and more advanced processes that will aid in a more productive and efficient workflow.

These include:

1. Creation of geometry from Scan data using third party plugins.

2. Validation of design model from construction progress scans at key stages of projects.

3. Existing buildings and Scan to BIM offerings.

Point Clouds inserted into Revit either via .rcp or .rcs are easily used to create site information and set up the extent of a building project. The site extents should be set up immediately upon insertion of the cloud data. This will ensure the site data is communicated and formed as early as possible within multi user projects e.g. levels, grids etc. Once the site is set up it is recommended that the point cloud be linked and placed on its own independent workset. All BIM processes on projects should be managed and monitored so as to allow for optimum model performance and use of heavy scan data.

It is also recommended to use the following tools when using Point cloud data inside of Revit.
1. Section Box: Ensure all views are only clipped to enable use of the scan data relevant to the view. This will also increase performance capability as point clouds are heavy and do become complex if not managed.

2. Create separate Workset for any Revit Links. It is recommended to include all linked .dwgs or linked Revit files on separate worksets as well as Point clouds on their own.

3. Select Links. In some cases it is worthwhile turning off the select links button in Revit. This will ensure all users do not move or manipulate the scan location in Revit and hovering over to view will not be an issue.

Revit modelling from a point cloud is now a very simplistic process. Coordination of both project and true north, integration of model geometry and use and also snapping allows for accurate Revit modelling from Scan data.

1. **Automating Geometry using third party plugins**

   There are a series of tools available that allow for direct creation of geometry from Point Clouds to allow a seamless transition from points to building elements.

   These include:

   1. ImagineIT Scan to BIM Tool.

      ![ImagineIT Scan to BIM Tool Image]

      This tool allows for the following to be undertaken and is a useful process when needing to quickly build Revit elements from a point cloud. As much as this is a third party software add-in for Revit it is widely used for the creation of geometry in Architecture. The tool allows for integration and assisting in building walls, columns and mechanical pipe work as well as construction geometry relevant to the building documented. This tool is useful should a Revit model need to be created quickly and
delivered to a client. The only reason this is not used more commonly is due to its price and it is an extra $599 per install. This would be

2. Edgewise Building. Secondary software that allows for building elements in their toolset from point cloud data. Edgewise allows for direct integration more seamlessly in their own software. This can then be exported into Revit. The edgewise Revit plugin allows Revit to read edgewise files. The walls come into Revit as wall objects and come in to the best fit of the points as per its extraction from the original point cloud.

An example of a project from Edgewise Building.

The above tools allow for direct point cloud integration and creation of geometry from the scan data. Currently industry is adopting their own ways of manipulating scan data and generally are using scanning hardware to process the scan prior to submission. Once this has been registered the scan data is delivered to clients using their BIM Authoring platform and model data built accordingly. It is therefore important that we ensure we are using the tools available to deliver information accurately from a point cloud and using the point cloud in its correct geographic location.

Currently only Autodesk Revit and Bentley AecoSIM allow for direct manipulation into their authoring software from either Pointools or Recap.

It is important to note that should the scan data set be too hard to manage directly into Revit. Recap allows for ‘portioning’ of the point cloud. It is possible to create slices that
can be used as floor plans via the region tool as mentioned previously. The section box will allow the point cloud to be positioned and clipped according to what is required to be seen and then once this process has been achieved, individual RCS files are easily exported out and can be used in a variety of differing ways.

Infrastructure projects and large scale sites with more than one building will almost definitely require this process. It is important to plan this division of data prior to any modelling work being undertaken.

2. Validation of design model from Construction Progress Scans

As architects regain their roles as lead consultants it is becoming more common place in industry on BIM projects that we are commissioned to update and deliver an as built model at the completion of the project. This is not different to delivering our as built drawings but industry speculates at how this is possible without the use of accurately captured data from a delivered project. At present we are therefore looking at alternative solutions to capture this information and there are leading industry professionals discussing a process that enables progress scan capture at regular stages across projects. Scanning at regular intervals during construction allows the as-built model data to be accurately updated and checked for all discipline data inside a Building Information Model.

Progress scanning should be undertaken in the software specified at the early stages of the project and noted in the BIM Execution plan. This should be included as an extra service and can be included as part of an Architects deliverables at early stages.

3. Refurbished Projects or Existing Building Models

Existing building information is rarely documented in a cohesive BIM Environment. For this reason it is necessary to communicate to clients and consultants regarding capturing current geometry and information data on projects.

As explained above the process for building an existing structure in Revit not only includes ‘seen’ and visual information but also asset data which can be delivered within the BIM. This process should include a series of laser scans of the existing site both within the internal and external areas of the project.
In terms of building this information it is recommended that the following be undertaken:

1. Scanned information delivered in relevant format

2. Recap use for manipulation of scan, including sectioned elements of the project to insert into Revit.

3. Data Information can be delivered and captured in a COBie spreadsheet or similar.

At times scan data may be used as a visual tool for projects that already contain existing asset information in the way of Owner manuals and drawings. Should this be the case, the scan data can only be used to view and review the existing asset should this be a requirement of the project. Some scanning software allows point data to be linked to a data management solution yet this is only relevant points included in a point cloud rather than a group of points.
**Point Clouds and Navisworks**

Point Clouds and scan data can also be used in Navisworks for the validation of model data, visualisation and review of existing information as well as analysis and clash detection. Should scan data be needed to create visualities

Currently common workflow within Navisworks for Architecture includes Clash detection and coordination. As these processes become more common place it is imperative to use the tools at our disposal relevant to the processes and stages of our projects.

The below diagram is an example of the format and extension files for insertion into Autodesk Navisworks. As you can see from the below, the solutions for file format versions primarily link to the scanning hardware format as below (e.g. Leica, Faro) yet the non proprietary formats can be linked directly. Recap files however can be appended to Navisworks directly.

<table>
<thead>
<tr>
<th>Format</th>
<th>Extension</th>
<th>File format version</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autodesk ReCaptcha</td>
<td>*.rcs, *.rcp</td>
<td></td>
</tr>
<tr>
<td>ASCII Laser File</td>
<td>.asc, .txt</td>
<td>n/a</td>
</tr>
<tr>
<td>Faro</td>
<td>.fis, .fws, .iQscan, .iQmod, .iQwsp</td>
<td>FARO SDK 5.1</td>
</tr>
<tr>
<td>Leica</td>
<td>.pts, .ptx</td>
<td>n/a</td>
</tr>
<tr>
<td>Riegl</td>
<td>.3dd</td>
<td>Version 3.5 or higher</td>
</tr>
<tr>
<td>Trimble</td>
<td>Native file NOT supported. Convert to ASCII laser file</td>
<td>Same as ASCII laser file</td>
</tr>
<tr>
<td>Z+F</td>
<td>.zfc, .zfs</td>
<td>SDK version 2.2.1.0</td>
</tr>
</tbody>
</table>
As you can see below it is useful to be able to capture imagery from the point cloud in Navisworks as Revit does not Render the point cloud. Revit enables extraction of images yet the Recap file in Navisworks goes beyond this and can export high quality images for use on presentations, Planning applications and design options on projects. As you can see from the quality below image extraction from Navisworks it is possible to view beautifully composed elements from a scan. This goes further with animation in Navisworks. The animation tools and point clouds work seamlessly together and again provide strong tools for Architects and designers to use to communicate design ideas in context as well as refurbished projects to their supply chain and client bodies.

The image above is a direct export from Navisworks. The image was simply exported as a jpg with a gradient background. This is exported simply and easily in Navisworks.
Recap Pro Features

Recap Pro is not available as part of the suite products yet can be used instead of Hardware specific software to register, index and create relevant RCS or RCP files for integration with Revit. Targets registration, data quality analysis tools for accuracy and verification and a full range of point cloud editing capabilities for integration with Revit allows Surveyors and or designers to use the product to create relevant.

Dramatically improve the quality and efficiency of laser scanning projects with target-less registration for onsite scan processing, data quality analysis tools for accuracy verification, a full range of point cloud editing capabilities for data preparation, integrated workflows for point cloud support in Autodesk design and creation products, and collaboration capabilities in the cloud with Autodesk ReCap 360.

Recap Pro Features include:

• Process 3D data on the job site with an intuitive user interface designed for a Windows based laptop or tablet
• Do more work in less time by registering scans in the field without the need to install targets
• Improve data quality by validating registered scan data while at the job location
• Accelerate project communication using visualisation tools to navigate and interact with fully immersive panoramic scan views
• Validate the accuracy of point cloud data and tie into site coordinates when you add survey control into registered scan data
• Choose the best reality capture technology for each job by mixing scans from different scanner file formats in the same project
• Move directly into modelling and design from a scanning job with seamless support of the ReCap file in Autodesk AutoCAD, Navisworks, Revit, Inventor, Infraworks, Civil 3D, Map 3D and Plant 3D products.
• Publish laser scans to the cloud to collaborate online with Real View on Autodesk ReCap 360, enabling your team to review scans in a web browser, take accurate measurements and add tags to features.

Once you start the import process, ReCap Pro begins indexing the files. This indexing process, which converts the point cloud files to Autodesk’s proprietary Reality Capture Scan (RCS) file format, can take anywhere from a few seconds to hours, depending on the number
and size of the files imported. The Import Settings dialog box displays the status of the import process. When the indexing process is done, you can save an aggregated scene of the project to a single Reality Capture Project (RCP) file that links to the processed data.

Recap Pro enables the integration of the following file formats:
Fabrication & Scan Data

BIM fabrication software solutions help extend BIM workflows to Trade contractor and fabrication processes. Contractors and consultants can more quickly and easily convert 2D and 3D design-intent models into constructible, 3D detail models populated with real-world, purchasable components that can be used to accurately estimate project costs without wasting valuable time and resources on redrawing designs or recapturing lost data. Existing fabrication information can also be integrated from point cloud data.

Traditionally, detailers/fabricators receive MEP design-intent drawings in one or more 2D formats, including DWG, DXF, PDF, JPEG, and in many cases, simply hard copy paper drawings. To convert these types of 2D drawings to a format useful for cost estimation and fabrication, contractors using traditional tools are forced to manually redraw the designs by hand—an approach that is time-consuming, often results in data loss, and ultimately produces a detailed, but still a flat, 2D design that is difficult for other disciplines to interpret properly.

The creation of model information suitable for fabrication is therefore crucial in the BIM process for design for manufacture and assembly. In order to be able to create digital information for fabrication it is imperative that the process be managed and created accordingly. As the process from design to manufacture becomes more widespread, the technical details and workflow associated to these processes must be clearly outlined. As well as the creation of fabrication ready components, these digital files will also be used to send information to machinery for the use downstream within a CNC machine and be fabricated and assembled prior to delivery on site.

Utilising the design model is merely the first step in this process. The digital fabrication details required vary with the specifics of the process and machine planned for use in fabrication. It is important that the responsibility of the fabrication data be managed and built according to the requirements outlined in this chapter.

Moving data between software tools often introduces compatibility issues and errors that must be avoided. It is also important to plan and test the complete chain and flow of data between all of the software tools in the planned production process, and then prototype and test to find and resolve any unanticipated issues.
Autodesk retain a link within the entire suite of products to be able to work together as a suite. Therefore should the Autodesk Revit < Inventor workflow be utilised it is easily able to link the .rvt and or .dwg files directly to Revit.