Reality Capture for Construction and Engineering Projects

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A drive towards digitalization

The construction industry is experiencing digital transformation, but for some industry professionals the adoption is slow. Yet, forward thinking Architecture, Engineering and Construction (AEC) companies are embracing new approaches, tools, digital workflows and data centric strategies to improve project and business outcomes.

Digital ways of working can improve productivity, reduce costs and minimize risk in construction. The road to digitalization requires a connected, data driven 'digital first' approach. Data can be captured from multiple sources and shared with everyone involved in the project to boost efficiency, improve build quality and deliver the project on time.

A data revolution

In today's 'data economy,' it can be argued that data, due to the insight and knowledge that can be extracted from it, is potentially more valuable than oil.

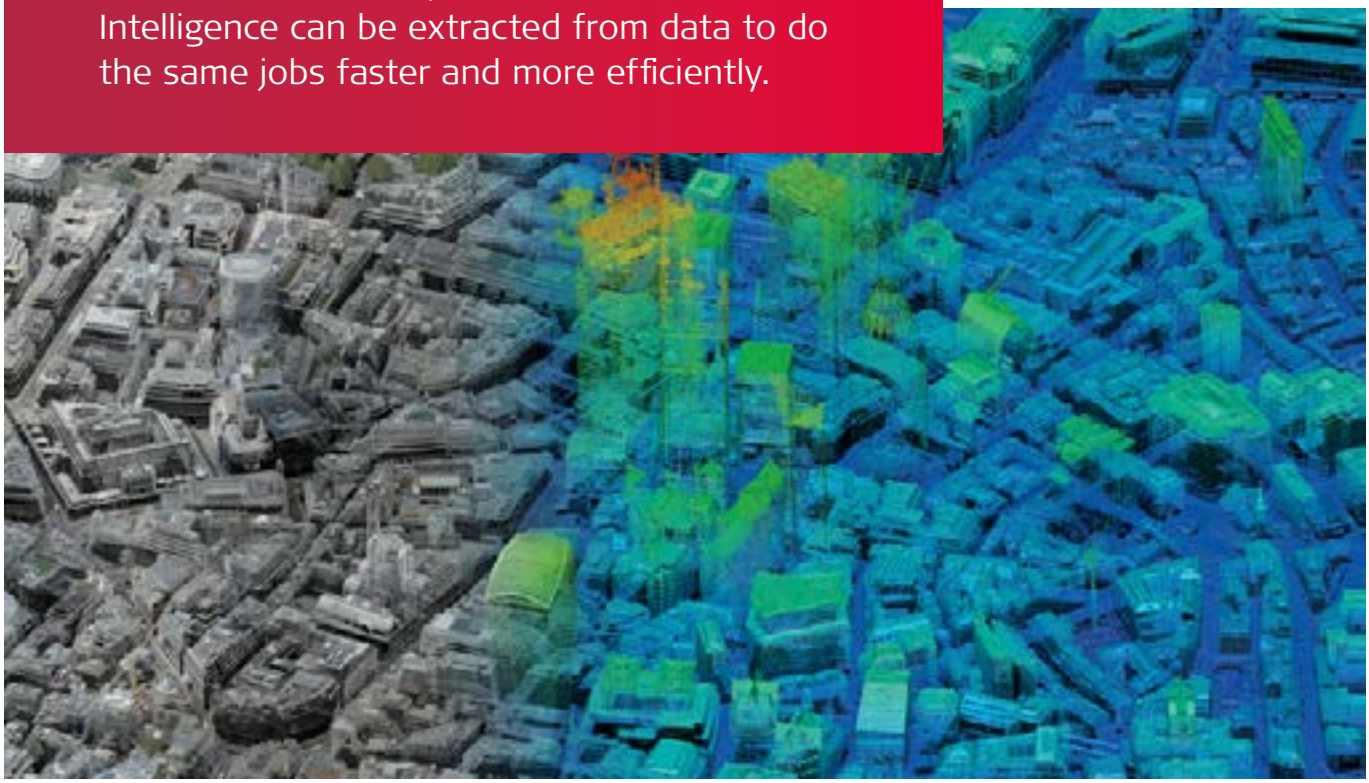
Data plays a huge role in many aspects of everyday life, and over recent years has become even more critical in improving the way we are entertained, how we travel, how we work, and how we build. Domo's latest "Data Never Sleeps" [1] report states that per minute 4,497,420 Google searches are conducted, 9,772 Uber rides are taken, 511,200 Tweets are posted, and 188,000,000 emails are sent.

A data revolution in construction

The construction industry is already collecting data through sensors and reality capture technologies which are used to design, construct and manage assets in a better way. This increases in value as companies gain data from multiple projects and are able to analyze and identify trends and patterns. These insights foster a culture of continuous improvement and allow operational outcomes to be predicted with greater certainty, therefore resulting in more efficient buildings and infrastructure as well as better results for stakeholders.

This e-book explores the need for digitalization and the role that reality capture can play throughout the entire construction process. By bringing in accurate data that fuses the real world with a digital world, projects can benefit from better planning, design and execution.

Information generated from data can be used to transform the way industries work. Intelligence can be extracted from data to do the same jobs faster and more efficiently.



Understanding reality capture

Building Information Modeling (BIM) is one of the forces driving digitalization across the construction industry, generating demand for accurate up-to-date information, improved workflows, and greater collaboration. Access to information allows AEC professionals to make smarter decisions and gain a full understanding of a project, comparing what exists in reality versus what is planned.

Accurate data is needed to apply BIM. But in order to capture this data, the right reality capture tools for your environment/project are required. Understanding reality capture and how you can turn data into information is a key step towards digitalization.

What is reality capture?

Reality capture is the process of digitizing the physical world through the use of different measurement technologies that enable accurate 3D data to be utilized in a variety of different software applications and workflows. An accurate 3D design model of the environment is produced from the extracted data. By capturing an object, building or site, the images and point clouds represent the closest portrayal of reality, or 'digital reality'. This brings accurate real-world information based on time, into a project, ensuring that decisions are founded on the true situation, and not on out-dated plans and assumptions.

The 3D design model, in the most basic form, can provide value by identifying discrepancies or potential problems early on in the project – for example, a new air conditioning system has been designed, but does it fit into the existing building?

Integrated into the BIM process, the 3D design model connects all parties and improves the outcome of the project. Furthermore, the model can be used as the basis of a 'digital twin' (an exact replica of the environment) and allows digital simulations to be undertaken to:

- Improve project efficiencies by making decisions based on facts (real world data) rather than assumptions
- Aid construction by continuously monitoring progress of the physical asset against the design
- Increase the speed of project completion by eliminating errors
- Assist in the management of the asset once construction is complete

Why use reality capture?

Collaborate: Improve communication and understanding throughout a project

Analysis: Quick analysis of existing and as-built conditions

Improve: Reduce guess work and minimize errors

Reduce risks: Identify and address challenges early in the project

Turning data into information

Once data is captured, how can this be managed, processed and acted upon?

3D data-sets such as point clouds and meshes can often be large in size – depending on how much data is collected – usually in the realms of gigabytes, if not terabytes, requiring suitable computing and specialized software to view, manipulate, build geometric models and manage the size of the data.

Technicalities aside, the application and benefits of 3D data are vast. The data gained provides valuable information and allows all parties involved in the project to make informed, timely decisions that minimize errors, reduce costs and improve the build quality.

The next section of the e-book explores the role of reality capture and digital twins throughout the construction process, and shares how 3D data is applied within various projects – from new building construction to the construction of roads/bridges, and rail/tunnels.

Digital design based on real-world conditions can be integrated into the BIM process, connecting all parties involved – ultimately, improving the way we construct by continuously monitoring progress of the physical asset against a digital representation.

Data gained provides valuable information and allows all parties involved in the project to make informed decisions

Reality capture for design and architecture

Reality capture facilitates greater design accuracy by gaining a precise and clear understanding of site restrictions and challenges. This allows for efficient workflows, less site visits and an improved client experience.

In the initial survey stages of a construction or renovation project, reality capture technologies can be used to capture a complete and accurate data set of the situation or landscape in the form of actionable 3D data.

This enables architects and design teams to connect this data to the design process and produce a detailed digital design of a client's concept, to easily identify possibilities and limitations. A 3D visualization, or model, of the proposed asset is then produced and can be shared with the client and all stakeholders pre-construction. Any design changes can be quickly communicated and shared, keeping the project on track. The end goal is to create an as-built digital twin that incorporates the digital design with all the revisions that have been made.

Why use reality capture in design and architecture?

- Obtain accurate dimensions where there may be a lack of as-built plans
- Generate accurate visualization of a design based on the reality of the existing environment to help meet the client's architectural aspirations
- Generate, simulate and test 3D models to ensure reality matches design
- Ensure complete collaboration of design and progress with all stakeholders throughout the project

Architects and design teams connect data to the design process

Reality capture for construction and engineering projects

Reality capture empowers construction and engineering professionals to manage projects more efficiently by being better prepared to respond to problems at the early stages of the project. Delays and costly rework can therefore be avoided and projects can be completed on time, on budget and to specification.

Data sets of the site can be captured before, during and on completion of projects to improve visibility and control at all stages of construction. The data obtained can be fed directly into the BIM model to make sure that what exists in reality conforms to design plans, verifying the accuracy and validity of the on-going construction process. As work begins and the model is shared with stakeholders, progress can be documented and digitally signed-off in accordance with the design. At all stages of the project, the model is used to identify any discrepancies, make better decisions and communicate changes, avoiding costly implications to the build schedule.

Why use reality capture in construction and engineering?

- Start a project with accurate data for early identification of problems
- Avoid costly delays and rework through collaborative sharing of up-to-date digital data based on reality
- Save time and costs with a reduced number of site visits
- Continuously monitor progress and maintain visibility of potential issues
- Digitally record progress and validate work against the design to ensure the project stays to the planned budget
- Collaborate throughout the project with up-to-date 3D models of as-built and design plans
- Share progress with all parties involved

Verifying the accuracy and validity of the construction process

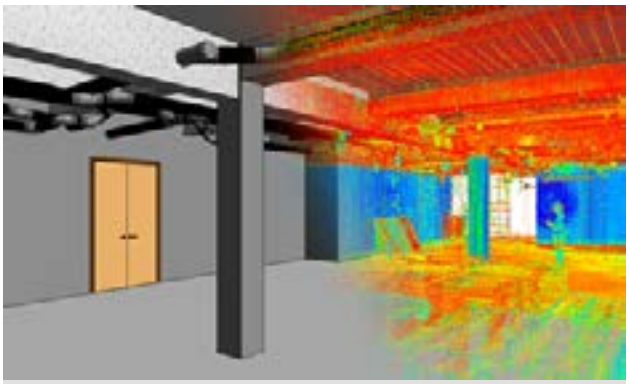
Applications of reality capture: new building construction

Throughout the phases of a new building construction project, BIM helps to convey design intent from the office to the field, reducing change orders and field coordination problems. Reality capture enables works to be verified and deviations or problems to be identified early for on the spot resolution. A digital twin provides intelligence to manage each phase of the works with full visibility and control. A record of works can be created after the build is complete to manage operations and maintenance.

During a new building project, smart digital reality best practice can be applied in the following ways:

As-Built modeling (scan to CAD/BIM)

In situations where existing plans are outdated or inaccurate, reality capture data is used to create a new 3D design model. This provides a true reflection of reality and reduces the risk of potential costly errors downstream when conducting renovations and repairs.



As-Built modeling (scan to CAD/BIM)

Site awareness and visualization

The progress of a project can continue without having to constantly visit the site. Utilizing a viewing solution gives users a comprehensive 3D picture of the asset from the comfort of the office. Visual checks and digital measurements can be extracted and used to make informed decisions, and the data is shared and easily viewed by the project team.

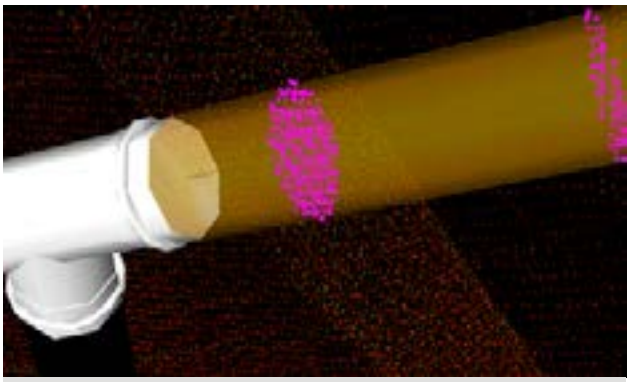
Example: A design team in London want to understand the size and shape of the building located in Dubai without visiting the site.

Site awareness and visualization - remotely checking the size and shape of a building

Clash detection

A common occurrence in new-build or renovation projects is components not fitting into the intended location. This could be through errors in the design process or oversights where someone has strayed from the plan. Actionable 3D data can be used inside coordination software to clash against design models - this is an automated process which indicates potential conflicts. This information is used to either make alterations to the design model or to highlight required changes.

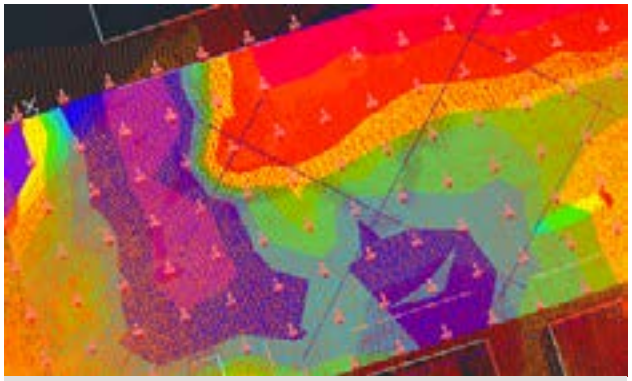
Example: the new air-conditioning system has been designed, but does it fit into the existing building?



Clash detection - enabling accurate fit of components

Deviation reporting

Meeting specification and constructing to design is possible by validating and checking the position accuracy of work as it happens, to either make corrections or to inform others that changes may be required to address any unwanted deviations. This is a common method for tasks like validating the flatness of concrete slabs through a heat map, where positive and negative variations are displayed according to color. Calculated decisions can then be made to avoid costly changes.



Deviation reporting - validating concrete

Construction verification

During construction, it is not unusual that time, effort and money are lost due to errors and rework. This could be due to components being installed incorrectly and creating differences between planned and actual construction. The consequences of these differences are the inevitable rework created downstream as components installed in the future will not fit.

Utilizing reality capture technologies to record actual site conditions on a continuous basis creates a view of the digital reality over time– snapshots in time that can be compared and contrasted against the design model. Any irregularities can be spotted, assessed and corrective action taken before costly rework is required.

Example: Does the structural steel frame match design? If not, what effect does this have on the rest of the project?

Construction verification - spotting irregularities to the structural steel frame

Applications of reality capture: infrastructure projects

200,000 people a day are migrating to urban areas around the world[2], increasing the need for sustainable infrastructure. Furthermore, countries from across the globe are experiencing aging infrastructure. In the UK, 70% of transportation infrastructure is over 100 years old[3], while in Germany, 15% of municipal road bridges need to be completely re-built[4]. Applying a smart digital reality approach can simplify and improve the way infrastructure projects are planned, executed and maintained.

At the start of an infrastructure project, reality capture tools enable large areas of land to be digitally recorded and modeled simply and quickly – saving huge amounts of surveying time. The range of tools, from unmanned aerial vehicles (UAVs) to mobile mapping and wearable devices, means that all types of terrain, including restricted and hard to reach areas, can be accessed to create a digital twin. This provides a digitalized working environment that helps to identify possibilities, limitations and challenges.

There are further benefits to the earthworks process, which enables efficient cost management of materials by understanding the quantities and location of stockpiles. Data captured in the initial reality capture stages provides informed insight of the location of underground utility assets. This data can be seamlessly shared between the various stakeholders and used when laying or replacing utilities. The data is easily exchanged onto machines, such as excavators, to specify where and how deep to dig, thus preventing devastating and costly utility strikes. An updated record of utility works can be digitally recorded, documented, shared and stored in line with BIM process.

Why use reality capture for infrastructure projects?

- Survey huge areas of land quickly
- Gain a full, accurate understanding of existing site conditions
- Prevent devastating utility strikes
- Automatically detect landscape features
- Generate terrain models
- Determine schedule progress through earthwork quantities and movement
- Quickly validate large areas of infrastructure

Applications of reality capture: road and bridge

Cost management, reduced downtime, and health and safety all need to be considered for road and bridge projects. However, other factors such as minimizing disruption to the surrounding environment, and the need for traffic management should also be taken into account.

For road projects, large areas of land need to be mapped. Mobile mapping technologies enable users to capture data of the environment in a fraction of the time, reducing disruption. During construction, deviations of the positioning and flatness of roads can be quickly identified and resolved, and inspections can be carried out to guarantee work is completed in line with design, ensuring an efficient, quality project.

Accurate information is essential for every part of bridge construction. Data from reality capture technologies provides analysis and reports explaining dimensional control and the quality of pillars and supports prior to assembly to make sure that all elements of the bridge are constructed exactly to design. Documentation of progress can be quickly carried out with the use of reality capture technologies, providing an efficient method of capturing what has been achieved on a daily basis.

The need for a digital twin extends into the maintenance of projects. The data captured can be used to carry out regular checks and reports on the deviation of slopes, and on the general condition of the constructed assets. Any required maintenance work is quickly identified, confirming structural safety.

Application of reality capture - mobile mapping of existing road

Applications of reality capture: rail and tunnel

Laying new rail tracks and building new tunnels, or the maintenance of both, exposes workers to dangerous work environments. Furthermore, the intricacy of the works required at every stage of these projects is essential to ensuring the works are structurally safe when completed. Reality capture data ensures efficient construction workflows, safer operations and more manageable maintenance and monitoring.

As with the road projects, there is a need to capture data over long distances whilst mapping both underground and overhead utilities. A combination of reality capture technologies – including mobile mapping, UAV and laser scanning – provide an efficient way to generate accurate digital data of the real-world environment. This reduces time pressures and prevents track closures or interruption to service.

By bringing the track environment into the digital world, the infrastructure can be analyzed, managed and optimized without the need for costly and regular on-site deployment of resources. A digital representation of a rail network enables field work to be brought to the office, reducing foot traffic on the tracks and increasing safety.

Maintenance checks can also be carried out to ensure the condition of constructed assets are in good working order. Clearance inspections can be completed with the highest level of accuracy, and by capturing surrounding features and track geometry data, accurate calculations can be quickly made for track alignment.

Efficiencies of tunnel construction can be vastly improved with reality capture technology. Measurements of how much has been excavated can be captured and visualized to identify areas where more rock needs breaking out. Tunnel alignment can be swiftly inspected in the field, and areas where more tunnel lining needs applying can be identified and actioned without the need to return to the office.

Investment in reality capture technologies helps to ensure that rail construction projects can be built quickly and safely by fusing the real world with the digital world to create a digital twin. Reality capture has a role to play beyond just the initial construction process. Operations and maintenance can be improved by quickly and safely capturing data using mobile solutions, providing a predictive analysis of existing rail infrastructure, and helping to prevent costly operational interruptions.

Application of reality capture - capturing existing rail track

Which reality capture technologies? The right tools for the right job

There is an array of reality capture technologies supporting various applications. The key to realizing the benefits is to start by understanding what needs to be achieved, how 3D data generated by the technologies can be used, and how BIM or digital twins can enhance the build process.

Laser scanning technology is commonly used in isolation for some projects requiring reality capture, but it doesn't always provide the insight needed to fully appreciate all the elements and intricacies of a project. Some large-scale or complex projects require a combination of technologies, as well as laser scanning, to work together to form a complete interpretation of a site or environment, as well as visibility of the conditions above and below the ground. The complete view and depth of information is essential at the start of the project. This reduces the risk of pausing a project, having to carry out re-work or, worse, change the design and re-submit plans due to unseen utilities.

The true value of reality capture lies in accessing information that allows informed decisions to be made and, ultimately, keep the project on-time, on budget, and to specification.

Understanding data

The investment in reality capture software enables users to go from data collection to delivery as quickly and efficiently as possible. This involves preparing, modeling, visualizing and sharing data which is converted into information based on real-world conditions.

Data from different sources can be stitched together and georeferenced in the preparation stage. This is then modeled and visualized to evaluate challenges which may impact on design plans and activities without needing to visit the site.

Virtual reality capabilities further improve collaboration with the ability to mark-up measurements, access asset information and share data with the relevant parties.

> *"Laser scanning on its own is not sufficient to provide a complete geometric framework for the survey of a building or structure, or to provide the depth of information required for interpretation and creation of the BIM model.[5] "*
>
> **Plowman Craven**

Types of reality capture: tools and

Dynamic reality capture solutions

- **Small portable 3D laser scanners and devices give access to difficult areas and capture detailed data and images at the touch of a button.**
- UAV's (or drones) are one of the fastest growing reality capture tools. They capture aerial imagery and generate 3D deliverables and are ideal for working in inaccessible, dangerous or restricted areas due to safety limitations.
- Mobile mapping includes mounting 3D laser scanners on people and vehicles, providing an effective solution for capturing data across large areas.

Static reality capture solutions

- Terrestrial scanning allows long range data capture specifically in large scale jobs, or fast assembly of multiple 3D scans for mega projects.

The digital construction

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Digital tools and processes can be applied at every stage of the construction and infrastructure

The future is reality capture

Digitalization and the rapid pace of change continues to increase as the construction industry adopts more digital ways of working, supported by smart technologies. Balfour Beatty[6] predicts that the future of construction will include changes such as exoskeleton wearable technology, an increased use of robots and automation processes. Unmanned Aerial vehicles (UAV's) will be used to capture site data continuously, to inspect work, and predict and solve problems before they arise. Data will be shared with robots and autonomous machines enabling them to carry out work under a supervisor.

For the future, machine-to-machine connection (M2M), machine learning, artificial intelligence (AI), sensor telemetry and predictive analytics bring further improvements in the capacity to leverage digital twins.

The future is closer than we think, with UAV and similar technologies already in existence. Today, reality capture sensors generate huge quantities of data, or 'big data', which can be turned into actionable information. Data and analytics provide a solution for effective information management, which can be used to predict and prevent problems before they arise. Smart artificial intelligence can facilitate more evidence-based decisions and will be used to improve the tracking and management of resources, provide accurate budget and schedule estimations, and lower project risk.

Those embracing change have a competitive advantage when it comes to winning business and delivering to specification. As adoption increases, investment in reality capture technology and digitalization can address skill shortages, construction quality, and health and safety concerns within the industry. The continued rise of new disruptive technologies, underpinned by artificial intelligence, is a game-changer for the industry with the benefit of enhanced efficiencies, reduced risk and cost savings.

The onus is with AEC professionals to shape change, fully embrace digitalization and harness the power of reality capture data to help better plan, design and execute projects.

Digitalization Your Way.

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