CLIENT
Highways England

LEAD CONTRACTOR
Joint Venture of Carillion and Morgan Sindall

DESIGN
AECOM and Sweco (previously Grontmij)

LOCATION
Ireland

SOFTWARE
Autodesk® AutoCAD® Civil 3D
Autodesk® Revit®
Autodesk® BIM 360™ Team (A360)
Autodesk® Navisworks®

AutoCAD Civil 3D, Revit and Navisworks are also included in the **Autodesk Architecture, Engineering and Construction Collection.**

"By implementing model-based BIM workflows using a suite of products from Autodesk, Highways England made huge cost savings on the A1(M) motorway upgrade between Leeming and Barton. Meanwhile, the value derived from helping non-technical stakeholders visualise the project is immeasurable."

– **Rupinder Wilkhu**
Head of BIM
Sweco

The benefits of using BIM on A1(M) Leeming to Barton Road Project:

- 30% improvement in the efficiency of inter-disciplinary checking, saving £300k
- Provides a collaborative medium, eliminating unnecessary service diversions, saving over £300k
- Enables a clash validation process mitigating over £400k of additional costs
- Allows 'virtual' stage 2 road safety audits eliminating £100k of costly re-work prior to road opening

Total savings in excess of £1 million

BIM on the A1(M) Leeming to Barton Road Project

The project team is achieving benefits with the adoption of BIM

A1 Leeming to Barton Improvement

As part of the investment strategy for the Department of Transportation, the North East England and Yorkshire schemes include the A1(M) Leeming to Barton Improvement – one of 4 major corridors in this region. Construction has started on the A1(M) motorway upgrade between Leeming and Barton.

The A1(M) Leeming to Barton scheme is managed by Highways England, constructed by a contractor joint venture of Carillion/ Morgan Sindall and designed by AECOM/ Grontmij. The team is tasked with improving the safety of the A1(M) between Leeming to Barton in North Yorkshire. This is to be achieved by widening the carriageway provision and applying motorway standards throughout.

On this project the team says they are embracing BIM principles not because of the Government's drive for all members of the supply chain to adopt Level 2 BIM by 2016, but because they genuinely believe in the benefits the adoption of BIM can bring. This faith has since been rewarded in the development of more cost efficient construction processes. The team's culture changing vision is now the norm in delivering the physical asset that performs effectively in operation. This change has totally reinvented stakeholder engagement; bringing the client, joint venture, design partners, extended supply chain and customers together; and increased understanding, improved safety, buildability and a better informed customer.

Highlights of the project

Maintaining routes

In order to maintain routes used by non-motorway traffic (such as farm vehicles), the programme utilizes the redundant A1 carriageway integrated and local access routes. This unique approach realized areas of asymmetrical mainline widening with sections of green-field construction and areas where redundant surfacing is not available.

Traffic management

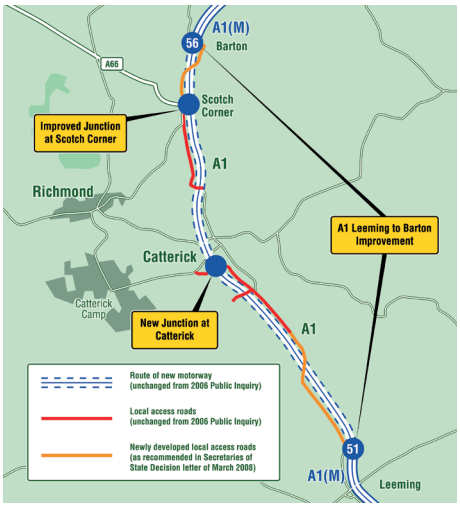
Phasing traffic management is being carried out online i.e. maintaining two lanes of traffic (Northbound/Southbound) in a manner that the public being affected is greatly mitigated.

Re-using Existing Pavement

Parametrically driven assemblies – driven by design rules to define the depth of milling and parametrically linked to the pavement analysis workflow – allowing the team to validate pavement depths for the on-line sections.

Re-using Existing Structures

The team embraced laser scans providing the level of detail to allow highly accurate modelling of existing structures. This is a process that led to mitigating costly issues on site and re-using existing structures where possible. This process is also allowing the team to graphically study construction sequencing and highlight any potential issues in the construction programme.



A1 Leeming to Barton Improvement

Visual Impacts

The bi-weekly federation of the entire scheme and the careful consideration of design improvements is allowing the team to continually assess the visual impact and performance of the design intent; an important design criteria especially in rural North Yorkshire.

Benefits of BIM

Model-based workflows

The project team is already achieving benefits including increased programme surety and savings already in excess of £1m. The team is now engaging with Highways England and their Maintenance Contractor to realise similar benefits for the handover of the asset into operation by the adoption of asset data collection methods.

Early process criteria

The vision from a very early stage in the project was to fully embrace the culture of collaboration. Our early process criteria included a digital 'Process Plan' (an industry first) that supported the early collaboration required, programme changes, level of detail and information, workflows and our innovative model-based design methodologies for all disciplines. The processes are now engrained into the team's design and delivery processes and used as a shared resource for reliable and collaborative decision-making. The early principles we set out also meant that procurement strategy encompassed the requirements of the project.

Bi-weekly federation

Our innovative model-based design methodologies for all disciplines supports the bi-weekly complex federation and clash validation process in Navisworks. This has introduced designers to embrace construction and maintenance practices early in their design process; improving efficiency.

The federation process supports the:

- automated clash validation rules defined early by each discipline which includes design and construction clearance checks.
- bi-weekly self-checking and the IDC (inter-disciplinary coordination) process with clashes tracked and reported in our monthly BIM report.
- early collaboration with temporary works and traffic management.
- Road Safety Audit for the mainline, side and approach roads.
- utilities diversion workshops with suppliers using Ground Penetration Radar (GPR) in complex areas.
- non-motorised-users workshops with the customer.
- MoD workshops to foresee & mitigate accessibility concerns and disruption to planned events.

Fundamentally, the Federated models and our innovative model-based design BIM processes are being used as a shared resource for reliable and collaborative decision-making; by ensuring all members of the team from Project director to site engineers have access to the Navisworks models.

Construction Sequencing

Embracing phasing in the model development is allowing the team to virtually study and mitigate any potential demolition and phasing issues on site.

Digital Machine Control

The project team decided at an early stage to construct the entire project without the use of setting-out pins and utilize digital machine control. The 3D design allowed the use of machine control for the earthworks, slip form concrete works and also the blacktop pavement and this ability strongly influenced our procurement strategy. This resulted in benefits to the project in terms of programme, quality, cost and most importantly health and safety.

Material Testing

With the aim of improving the asset management and handover (6D), we specified that the material testing should be compliant to our BIM strategy; which in turn drove the procurement of the pavement. In particular, providing digital GPS locations of all of the material testing allowing records to be tagged into the model.

Integrated analysis

Our digital design based BIM approach will allow downstream model authors to re-use the populated values and enable them to proactively plan for smarter & more efficient operations in a virtual environment rather than on site or reliance on invalidated paper trail.

Collaboration

The continuous engagement, a common level of understanding and a 'can-do' attitude from all disciplines has allowed an inclusive approach in the speedy implementation of our innovative model-based design methodologies. The project is managing to keep the vision alive with significant benefits realised by allowing new technology and new ways of digital solutions to flourish, even in the high pressured situations.

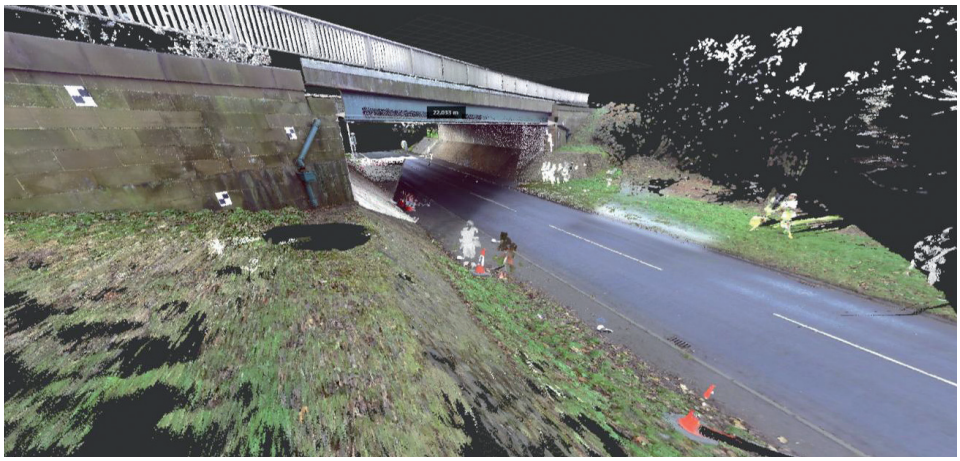
Fundamentally, BIM is being used as a shared resource for reliable and collaborative decision-making, by facilitating ease of access and enabling clear communication of how the digital data is created and accessed; in a common data environment.

Digital Design Based BIM Approach

Our innovative model-based design methodologies is fundamental to our BIM Vision. This enables the intelligent fine-tuning of values in the design models; allowing the team to validate multiple design aspects in the virtual environment for an optimized asset. This innovative approach coupled with our collaborative approach to work with the Client and their asset maintenance team; the asset will realise significant savings in maintenance operations.

Strategies that have been developed to further this aim include:

- Our adoption of the AutoCAD® Civil 3D UKIE Country Kit to ensure all underground utilities are processed with the agreed level of detail to support the IDC, design and construction validation process including



Incorporating & Re-using existing structures – embracing phasing

By implementing model-based BIM workflows Highways England made huge cost savings on the A1(M) motorway upgrade

the ongoing field based validation surveys.

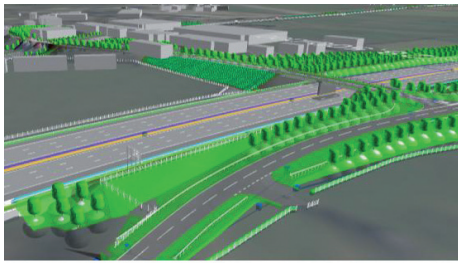
- Our parametrically driven assemblies driven by design rules to define the depth of milling and parametrically linked to the pavement analysis workflow (including data being captured from field).
- Our application of JV Mix material types within the parametric 3D 'information' objects (Revit Structure) to support downstream digital take off during construction.
- Our 'assembly based approach' within Civil 3D & Sub-Assembly Composer for delivering smarter 'design based solutions' for ancillaries; this includes safety barriers and guard rails, noise barriers, boundary fencing and all trenching elements i.e. for communications and traffic signals. The solution allows an increased control over the finished built asset.
- Our Object Enabled Design Approach for Signs and Markings within the AutoCAD API defines the calculations in accordance with the latest TSRGD; enabling the creation and automatic annotation of the road 3D signs and 3D markings. This innovative approach has introduced new levels of flexibility, guidance, accuracy and speed of design to the preparation of spatially accurate traffic sign drawings.

Simulation

The team's willingness to share our innovative solutions and the ongoing work to define the digital handover process with the Maintenance Contractor will provide further effective uses of simulation within the operation stage.

Our innovative model-based design methodologies embraces a simulated design based BIM approach that has allowed for the following uses of BIM to be deployed most effectively:

- Visualisation – already enhanced a greater understanding of the built outcome for all disciplines, stakeholders but most importantly the customer.
- Design Authoring & Analysis – intelligent fine-tuning of the design models are used to validate multiple design aspects for an optimized asset.
- Clash Validation and Prevention – serving as mitigation against future construction delays and cost increases. Potential 15 months delay avoided by having sub-surface utilities within the Federated Models.
- Safety – enhanced safety for future road and non-motorised users, permanent and temporary works.
- Construction Sequencing & Programme Management has increased understanding of construction works at Agricola, Fort and Scotch Corner; resulting in fewer technical queries and potentially avoiding months of delay.
- Phasing Works – the Revit structure models embrace phasing early within the design process that has enhanced communication amongst the team and is allowing the team to graphical study & mitigate any potential demolition and phasing issues in the virtual Autodesk® Navisworks environment rather than on site during construction.
- Information Management & Collaboration – delivering a smarter asset with an increased level of coordination and communication between all disciplines.



Federated Model

Visualization

Simulations of Maintenance Operations

The visualizations from both the native and federated models have proved to be a valuable asset to greatly reduce the language barrier by allowing the team to run virtual simulations of maintenance operations and gauge impacts of proposals post-construction.

Inter-Disciplinary Consultation (IDC) Process

To support the virtual IDC process, validation rules have been defined early in the programme by every discipline within the federation process. To date, the clash validation process includes over 250 design checks and construction clearance checks. This bi-weekly federation of over 330 information models and validation checks are continually being reviewed through self-checking and the virtual IDC process with the aim to reduce the number of new and active clashes. This process has greatly increased coordination and communication between all disciplines to generate better decisions for design, construction and maintenance.

Third Party Briefings

The 'moving' federated models are proving to be a valuable asset for the road safety audits, utilities diversion workshops with suppliers, non-motorised-users workshops and customers like the Ministry of Defence.

The federated models are proving very valuable to foresee and mitigate accessibility concerns and disruption to planned events. A number of issues were able to be identified from the virtual federated models which were not detected from the drawings; issues which could potentially have serious safety implications.

> "We selected the most appropriate packages from the Autodesk suite to construct and share our 3D models providing a more coordinated, efficient, cost-effective and buildable design through an integrated federation process accessible to all via our common data environment."
>
> – **Rupinder Wilkhu**
> **Head of BIM**
> Sweco

Cloud

Our Common Data Environment

The project teams are working in a truly collaborative manner with a 'can-do' attitude from all disciplines.

To date, the team is successfully delivering 330+ 'information' models, 250+ design & construction validation rules (in Navisworks), construction sequence models (Scotch Corner, Fort and Catterick Central), across 19 disciplines and 10 locations; in a common data environment encompassing our complex bi-weekly federation (Navisworks) of the entire scheme.

Embracing Digital Archaeology

Excavation levels from site within the federation process using GPS enabled equipment has allowed the team to append the excavation levels (Civil 3D) from site within the federation process (Navisworks); allowing the team to foresee potential construction issues in the virtual Navisworks environment. As such at Work Section 7, the Agricola drainage tank & its associated network has now been re-located in the virtual environment rather than during construction on site; potentially saving weeks of delay and mistakes.

Material Trial Tagging

Similarly, the field team have adopted material trail tagging into the Navisworks federation process using smart coordinate geometry in Civil 3D and data acquisition. This processes has improved the data validation process between on and off field activities.

Return on Investment

Reduce Costs of Project Delivery

Our common data environment allows the teams to deliver cost effective yet innovative digital solutions by minimising abortive work through uncontrolled change and enhancing inter-disciplinary collaboration.

We implemented the assembly based approach that is allowing all disciplines to virtually review the design and construction depths. By using 3D information models in a federated (Navisworks) environment, we have a process in place which analyses in excess of 250+ design and construction validation rules.

This approach can be further extended into the asset management cycle to run virtual simulations of maintenance operations and gauge impacts of proposals post-construction. The clash validations rules allow the teams to quickly carry out self-checks, discipline checks and, on a bi-weekly basis, allows them to validate their proposed design solutions during the IDC process. This will lead to a huge reduction in Technical Queries and Designers instructions being produced on site; could result in savings of over £500k.

We also created value engineered solutions for certain elements, using 3D models to illustrate the potential advantages and facilitate early acceptance as the impacts and benefits to all parties are easier to comprehend.

Tangible Savings

Many benefits gained from the use of BIM processes are difficult to assess in monetary terms, but the value derived from helping non-technical stakeholders visualise the project is immeasurable. Typical examples include:

- Allowing adjacent landowners to understand how the scheme affects their properties.
- Helping English Heritage assess the impact on local archaeology.
- Assisting NMU groups to engage in discussions regarding provision of footpaths\bridleways etc.
- Engagement with Ministry of Defence.

However, there are many areas where the federated models have produced more tangible savings, such as:

- A 30% improvement in the efficiency of inter-disciplinary checking where it is estimated over £100k has been saved.
- Development of more efficient construction sequences at Fort Bridge, reducing impact on the travelling public.
- Providing a collaborative medium for the identification and design of Statutory Undertaker diversions and eliminating unnecessary service diversions, saving over £300k.
- A powerful visual aid for safety briefings to the workforce which also supports our 'Right First Time' philosophy.
- Importing point cloud surveys of existing structures to ensure compatibility when designing modifications.
- Sophisticated clash validation – Our clash validation process is defined to track design clashes, construction and maintenance tolerances; by their level of significance to provide an increased focus on those critical clashes; saving time and effort during the IDC meetings. 1,800 clashes have been identified within the Federated models. This has mitigated over £400k of additional costs.
- Allowing the Road Safety Auditors, Police etc. to carry out 'virtual' Stage 2 Road Safety Audits before construction, eliminating costly re-work prior to road opening, costing up to £100k and resulting in embarrassing delays.
- Savings in the design process by adopting BIM reflect in below forecast scheme design costs.

Increase Return on Investment (ROI)

We selected the most appropriate packages from the Autodesk suite to construct and share our 3D models providing a more coordinated, efficient, cost-effective and buildable design through an integrated federation process accessible to all via our common data environment.

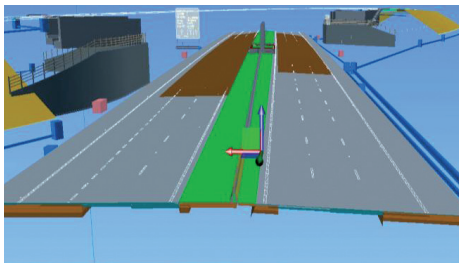
Our Autodesk Design Suite

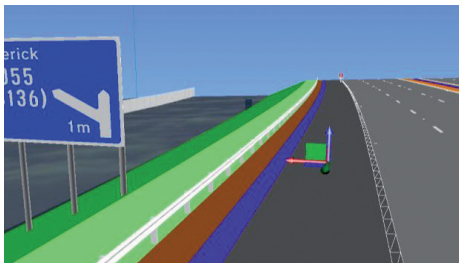
- AutoCAD® Civil 3D
- Sub-Assembly Composer
- Revit® Structure
- Revit® Structure Viewer
- AutoCAD®
- BIM 360™ Team (A360)

Reduce Operation Costs

Our modelling methodologies embraced construction phasing. Early discussions within the team allowed us to tag models to facilitate construction sequencing. The developing designs were then shared via our common data environment to allow them to be linked to the construction programme and study the construction process virtually to highlight difficulties around sequencing, access, temporary works etc.

The point cloud survey of existing structures is an excellent example of the opportunity for re-using existing features afforded by the use of technology and 3D modelling and sharing this information via our common data environment allows for extended use by others to check elements beyond the originally intended purpose.





Level of detail and information requirements – Process Plan

Sustainability

As sustainability is discussed in the Department for Transport Road Investment Strategy: Overview December 2014, we felt it important to also highlight the sustainable components of this project as well.

Reducing impacts on ecosystems and water resources

Protecting Existing Watercourses

Through close collaboration and consultation with the Environment Agency it was agreed, that in order to protect existing watercourses and their associated ecological impacts on the local environment from the effects of development, that all outfalls into Environment Agency assets will be restricted to the rural runoff flow rates.

The natural catchments within the proposed works corridor were assessed to determine how they influence and contribute to the local environment. The proposed works were then designed to ensure that the downstream ecology of watercourses is not adversely affected and the risk of flooding from all sources within the catchment area and adjacent watercourses is maintained at the current level.

Additionally, modelling of watercourses was undertaken to ensure that the provision of any new or amended structures did not result in an increase in upstream flooding.

Ground Water Levels

Similarly the team has studied the impact of climate change in different parts of the scheme; carrying out a consistent assessment of the 3D ground-water levels. This modelling also assessed the impact of how the re-profiled ground and provision of additional drainage was likely to affect the groundwater levels along the route. This was extremely important in a number of areas where an abstraction license had agreed with the Environment Agency.

Sustainable materials in construction

Procurement Strategy
The 3D design allowed the use of machine control for the earthworks, slip form concrete works and also the blacktop pavement and this ability strongly influenced our procurement strategy. This resulted in benefits to the project in terms of programme, quality, cost, sustainability and most importantly health and safety.

Pin-less Construction
The early principles that we set out with respect to BIM meant that procurement strategy encompassed the requirements of the project. The project team decided at an early stage to adopt totally pin-less construction methods through full machine guidance. This decision has resulted the elimination of several thousand steel pins and timber profile boards resulting in substantial carbon savings.

Pre-cast Manhole Units
Square chamber design was chosen rather than the traditional circular shape to allow a reduction in the champers overall size. A square chamber only has to be marginally larger than the pipe it is designed to accommodate because the pipe meets the chamber on a flat surface. This reduction in size is saving on material and transportation costs and by extension lower emissions. A smaller chamber is also less likely to clash with pre-existing or additional structures and services. Chambers were incorporated into the Navisworks federation process together with the design & construction validation checks.

Natural Resources
The vision from a very early stage in the project was to fully embrace a culture of collaboration. As such, the team took an active role during the early design process working with the construction team on what materials would provide a natural resource. The team has used:

- RECO panels to save on the use of substantial reinforced concrete walls, which require natural resources.
- Plastic pipes instead of concrete pipes.
- Modular manholes instead of traditional manholes to save on concrete surround.

Promoting sustainable neighborhood developments

Non-Motorised Users (NMU)
Engagement with NMU groups in discussions regarding provision of footpaths\bridleways etc. The Federated models continue to be used to take NMU groups through the routes highlighting issues specific to them. Issues such as:

- explaining over bridges and embankments are easily demonstrated and greatly appreciated by NMU groups who have been reliant on hard copy plans.
- the federated models also embrace our proposed landscape designs which has enhanced clarity during the demonstration of the proposed NMU route required.
- junction layouts and routes around the dumbells for experienced, confident road cyclists who wish to use the local access roads in lieu of circular leisure routes.

Embracing Digital Archaeology
Through our shared approach, we continue to find innovative value added uses of BIM. With the recent Archaeological finds and the use of GPS machines by our Archaeological Contractor; the team have embraced the digital excavation levels from site within the federation process. This has allowed the team to foresee the potential construction issues.

Engagement with the Ministry of Defence (MoD)
The developing Federated models continue to be presented to the MoD aimed at reviewing possible interruption with the construction; or diversions required for any MoD or public events during construction around the barracks.

Reducing environment consequences of construction and operations

Phasing of Works
Our modelling methodologies embraced construction phasing. Early discussions within the team allowed us to tag models to facilitate construction sequencing. The developing designs continue to be linked to the construction programme and study the construction process virtually to highlight difficulties around sequencing, access, temporary works etc.

This strategy continues to improve the work phasing to avoid double handling of materials as such saving on additional journeys and their consequential emissions. This approach can be further extended into the asset management cycle to run virtual simulations of maintenance operations and gauge impacts of proposals post-construction.

Embracing Tree Survey & Proposed Landscape Features
The team have incorporated the existing tree survey and the proposed landscape features into the Federation Process to further aid the validation process of trees to be removed and/or relocated. These features embrace the potential growth of roots hence virtually foreseeing potential sub-surface complications during the operational phase of the assets.

Realising Quantities Plannings
Use of recycled road plannings from the scheme within embankment fill as well as landscape bunds to avoid the environmental impacts associated with taking the material off site. The template approach helped in validating the quantities plannings to be realized on the scheme and aid in planning areas where these could be utilized.

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Inter-Disciplinary Coordination – Virtual Review process.

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- Provides a collaborative medium for the identification and design of Statutory Undertaker diversions and eliminating unnecessary service diversions, saving over £300k
- Enables a clash validation process defined to track design clashes, construction and maintenance tolerances by their level of significance to provide an increased focus on the most critical clashes. 1,800 clashes have been identified within the federated models, mitigating over £400k of additional costs
- Allows road safety auditors and police to carry out 'virtual' stage 2 road safety audits before construction, eliminating costly re-work prior to road opening, costing up to £100k