Autodesk® Revit® MEP

Using BIM to Design a High-Performing Advanced Learning Center

Building Information Modeling (BIM) is an intelligent model–based process that provides insight for creating and managing building and infrastructure projects faster, more economically, and with less environmental impact.

As the use of BIM in the AEC industry continues to grow, engineering firms are increasingly relying on BIM processes and software to deliver their projects. This paper offers insight into how one firm, Buro Happold, used Autodesk® Revit® MEP software to design a high-performing school and learning center in England.

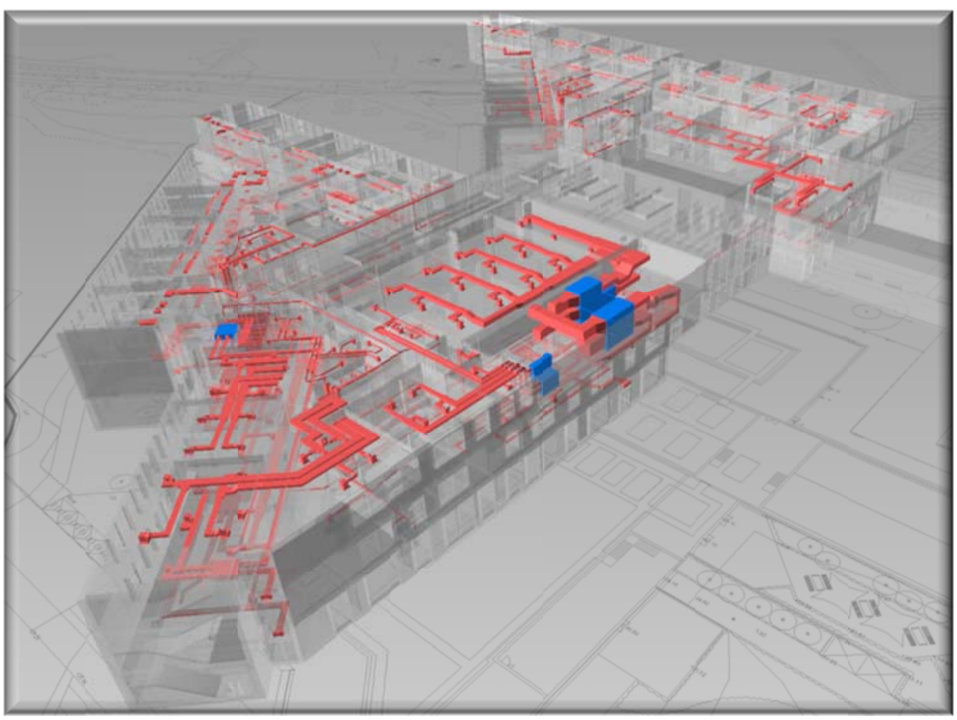

Figure 1. Engineering firm Buro Happold used Autodesk BIM solutions for the MEP and structural design of the new Foulstone-Wombwell Advanced Learning Center.

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Introduction

Mechanical, electrical, and plumbing (MEP) engineers are facing considerable challenges in today's building industry. National and global economic pressures are forging an increasingly competitive environment. Current business models are under pressure as new project delivery approaches are changing the nature of project collaboration and demanding tighter coordination and cooperation across extended teams. These shifting contractual structures and the continuing evolution of business relationships is a challenge MEP firms must embrace to win more work.

Engineering firms are also challenged by the increasing demand for sustainable design and their clients' expectations for green compliance. As more green mandates emerge, engineers are under increased pressure to meet and exceed targets set by project stakeholders. Job site challenges due to lack of skilled labor, increased cost pressure from owners, safety concerns during construction, and demand for pre-fabrication are on the rise as well.

Saddled with intense competition and already-thin profit margins, firms today need key differentiators that can win them new business. They must find ways to cut project costs, and do more with less. In response, many firms are turning to BIM.

BIM Overview

BIM is an intelligent model–based process that provides insight for creating and managing building and infrastructure projects faster, more economically, and with less environmental impact. BIM software is helping the AEC industry facilitate new ways of working and improve control over project outcomes.

Models created using software for BIM are "intelligent" because of the relationships and information that are automatically built into the model. Components within the model know how to act and interact with one another. The model is actually a complex database of elements that contains both geometric information and nongraphic data. Drawings, views, schedules, and so on are "live" views of the underlying building database. If designers change a model element, the BIM software automatically coordinates the change in all views that display that element—including 2D views, such as drawings, and informational views, such as schedules—because they are all views of the same underlying information. Regardless of how many times the model changes, the data remains consistent, coordinated, and more accurate.

Project teams can also use information contained in the models to improve the accuracy of documentation and perform a variety of complementary tasks, including energy and environmental analysis, visualization, and construction simulation.

Cross-functional project teams in the building and infrastructure market segments use these model-based designs as the basis for new, more efficient, collaborative workflows. Early access to the rich information in the models helps everyone on the project team gain more insight into their projects. As a result, the team can make more-informed decisions much earlier in the planning, design, construction, or renovation process—when decisions can have the greatest impact on project cost, schedule, and sustainability.

BIM Adoption

Studies[1] conducted in the U.S. and Western Europe demonstrates that BIM is firmly entrenched in the building industry. For example:

- **Building industry overall**: Nearly half of the U.S. building industry is using BIM, a 75 percent increase since 2007, and 36 percent of the industry in Western Europe has adopted BIM.
- **Architects**: Six out of ten architects in the United States create BIM models, with half of those users also performing analysis on the models. In Western Europe 70 percent of architects that use BIM believe that it leads to better-designed projects.
- **Engineers**: Over the next two years, the use of BIM is expected to double by structural engineers, triple by MEP engineers, and quadruple by civil engineers. In Western Europe, nearly 70 percent of engineers report positive ROI and 62 percent found BIM to be of high or very high value during the construction phase.
- **Contractors**: The use of BIM among U.S. contractors has almost quadrupled in the past two years, with half of all contractors currently using BIM, In Western Europe, 52 percent of contractors found BIM to be of high or very high value during the construction phase.
- **Owners**: Fully 70 percent of the U.S. owners reported a positive ROI from using BIM and in Western Europe, 65 percent of the owners surveyed report asking for BIM.
- **Green BIM Professionals**: The use of BIM on sustainable or "green" projects is poised for great growth, with 78 percent of BIM users who do not currently use it on green projects planning to do so within the next three years.

Case Study – Buro Happold

One example of an engineering firm who is aggressively pursuing the use of BIM is Buro Happold Ltd., a multi-disciplinary consulting firm providing engineering, design, planning, project management, and consulting services for all aspects of building, infrastructure, and environmental projects. The firm has extensive experience in a wide range of project types, particularly education, healthcare, stadiums, and historical. Founded in Bath, England in 1976 by the late Professor Sir 'Ted' Happold, Buro Happold now has over 1,500 employees in offices throughout Europe, North America, the Middle East, and Asia-Pacific.

Recognizing the value that BIM brings to both its internal processes and external project deliverables, Buro Happold has been an industry pioneer in the use of BIM. The firm has relied on Autodesk BIM solutions for many years and has completed over 100 BIM projects in the last decade.

The firm currently uses these Autodesk solutions: Autodesk® Revit® MEP, Autodesk® Revit® Structure, AutoCAD® Architecture, AutoCAD® MEP, AutoCAD® Civil 3D®, and

[1] The U.S. and Western Europe industry statistics referenced in this "BIM Adoption" section are based on these McGraw Hill Construction reports:

- Norbert W. Young, Stephen A. Jones, Harvey M. Bernstein, and John E. Gudgel, *The Business Value of BIM: Getting Building Information Modeling to the Bottom Line*, McGraw Hill Construction, 2009.
- Harvey M. Bernstein, Stephen A. Jones, and John E. Gudgel, *The Business Value of BIM in Europe: Getting Building Information Modeling to the Bottom Line in the United Kingdom, France, and Germany*, McGraw Hill Construction, 2010.
- Harvey M. Bernstein, Stephen A. Jones, and Michele A. Russo, *Green BIM: How Building Information Modeling is Contributing to Green Design and Construction*, McGraw Hill Construction, 2010.

Autodesk® Navisworks® Manage software. One of the firm's recent BIM projects is a new educational facility in South Yorkshire, England.

Project Overview

The Foulstone-Wombwell Advanced Learning Centre (ALC) is a new school being built near the villages of Wombwell and Darfield, in Barnsley County. The ALC will provide over 1,900 students with a modern educational environment that will enable new forms of learning and teaching. The £55M facility will also be used by the community for adult classes as well as leisure, sporting, and cultural activities.

The ALC the will replace two existing schools: Darfield Foulstone School of Creative Arts and Wombwell High School. Built on the site of a former coalmine, the new 14,281 square-meter educational facility will feature state-of-the-art facilities for students, teachers, support staff, and others involved in the teaching and learning environment. The building includes three floors of flexible learning spaces with advanced information and communications technology resources, as well as modern educational resources, social facilities, circulation and social spaces, and sports and leisure facilities.

The project is expected to achieve a 'Very Good' BREEAM® (BRE Environmental Assessment Method) rating for sustainability and environmental performance. Green design aspects include natural ventilation, rainwater harvesting, and the use of a biomass boiler.

The project schedule—from start of design to the school's opening in September 2012—spans just two years. To accommodate this tight schedule, the project features "design for manufacture" construction techniques for the following types of building elements: structure, sub structure, building envelope, MEP services, and electrical services wiring.

The project team includes Buro Happold, architectural firm Aedas, and general contractor Laing O'Rourke. Buro Happold was responsible for structural, MEP, and civil design. To meet the aggressive schedule and help minimize field changes, close collaboration and careful coordination between the various building disciplines and elements were needed. The general contractor, a strong proponent of BIM, required BIM deliverables—preferably based on the Autodesk® Revit® design platform—from all of the subcontractors and used both Revit and Autodesk® Navisworks® software to support project coordination and clash detection.

During construction, the Navisworks project model is available onsite to give the ~20 construction personnel a better understanding the school's design. In addition, the project model can be used in the future for facilities management, operation, and other lifecycle management activities.

BIM Project Goals for MEP Design

An early adopter of BIM, Buro Happold began using Revit Structure in 2007 and Revit MEP in 2008. Prior to this ALC project, the firm completed approximately 15 projects using Revit MEP software. After using Revit MEP for the design of an earlier ALC project, Buro Happold was eager to build on that success and decided to push the boundaries of its use of the software, as well as the BIM capabilities within its MEP department, on the Foulstone-Wombwell ALC project. At the start of the project, the firm made the decision to use Revit MEP not only for modeling and coordination, but also for distribution board scheduling and equipment scheduling. Another goal was to utilize both Revit and

Navisworks Manage software to improve collaboration and coordination between the architecture, structure, and MEP building disciplines.

At the onset of the project, the firm formally defined its BIM project goals and objectives, as it does for all of its BIM projects. This gave the client and design team partners a better understanding the extent of Buro Happold's use of BIM and the Revit design models on the project.

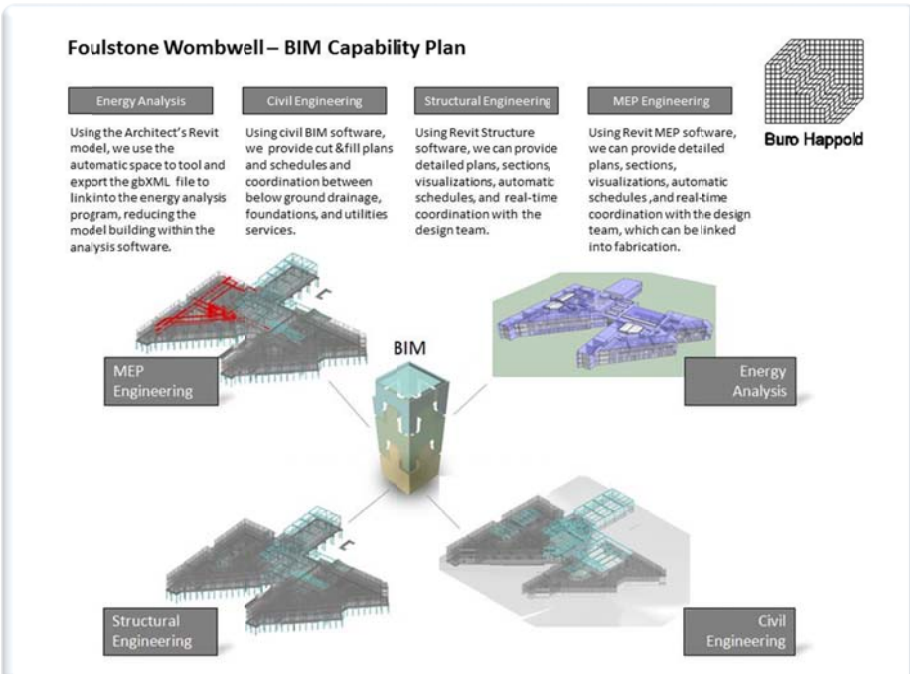


Figure 2. At the onset of the project, Buro Happold created a BIM Capability Plan that formally defined the firm's BIM goals and objectives for the project.

	C	D	E	F1
Chilled Pipework	Model a MEP service zone in Revit mep for Co-ord with Revit Arch and Revit Structure	Model a MEP service zone in Revit mep for Co-ord with Revit Arch and Revit Structure	Model Chilled pipework in Revit mep for Co-ord with Revit Arch and Revit Structure	Model Chilled pipework in Revit mep for Co-ord with Revit Arch and Revit Structure
DWS Pipework	Model a MEP service zone in Revit mep for Co-ord with Revit Arch and Revit Structure	Model a MEP service zone in Revit mep for Co-ord with Revit Arch and Revit Structure	Model a DWS pipework in Distribution areas (i.e Corridors) using Revit mep for Co-ord with Revit Arch and Revit Structure Revit model to terminate @ drops into rooms with schematics being used for final connections	Model a DWS pipework in Distribution areas (i.e Corridors) using Revit mep for Co-ord with Revit Arch and Revit Structure Revit model to terminate @ drops into rooms with schematics being used for final connections
Heating Pipework	Model a MEP service h zone in Revit mep for Co-ord with Revit Arch and Revit Structure	Model a MEP service zone in Revit mep for Co-ord with Revit Arch and Revit Structure	Model a MEP heating system using Revit mep for Co-ord with Revit Arch and Revit Structure	Model a MEP heating system using Revit mep for Co-ord with Revit Arch and Revit Structure
Gas Pipework	Model a MEP service zone in Revit mep for Co-ord with Revit Arch and Revit Structure	Model a MEP service zone in Revit mep for Co-ord with Revit Arch and Revit Structure	Model Gas system Distribution areas (i.e Corridors) using Revit mep for Co-ord with Revit Arch and Revit Structure Produce 2D for non Distribution Areas (i.e Classrooms)	Model Gas system Distribution areas (i.e Corridors) using Revit mep for Co-ord with Revit Arch and Revit Structure Produce 2D for non Distribution Areas (i.e Classrooms)

Figure 3. Buro Happold's BIM Capability Plan included detailed descriptions of system modeling (for various design phases) and the use of Revit design models to support cross-discipline coordination.

Project Challenges

Buro Happold's use of BIM workflows and Revit MEP software on this project varied based on the design phase and engineering task.

Schematic Design

On previous projects, Buro Happold had only used Revit MEP for detailed design and downstream stages. On this ALC project, the firm explored the use of Revit MEP for schematic design. Early stage modeling during the schematic design phase helped the firm gain confidence in its emerging design and helped improve its internal processes.

Traditionally, during schematic design the firm used 2D software to create hatched plans of the building(s) to convey design intent for the project. With Revit MEP, Buro Happold used the software's automatic space and filter tool to more quickly create hatched zoning deliverables for all MEP systems; helping to increase productivity during schematic design by an estimated 30 percent. In addition, the use of bi-directionally linked area schedules allowed the hatch areas to be more quickly changed using simple engineering equations that calculated heat output and lux levels.

Sustainable Design

An important sustainable design feature of the project was the use of solar energy[2]. To help maximize the number of solar panels and therefore the energy savings, the project team modeled all the roof elements—especially the mechanical rooftop plant and associated ductwork—at an early stage. This helped the photovoltaic manufacturer exploit the available roof top area for the placement of the solar panels. In addition, with support from the Revit MEP model in conjunction with sun analysis software Buro Happold designers determined the optimal position and orientation of the solar panels.

One of Buro Happold's BIM goals for this project was to minimize the amount of redundant modeling. Therefore, the firm took advantage of a direct export link between Revit MEP and the energy analysis software used by the project team. The space tool functionality of Revit MEP allowed the team to create a design model that could be directly exported to the energy analysis software using the gbXML format.

A few missteps during this process helped the new Revit MEP users improve their modeling practices, enabling them to create a design model that can also be used for energy modeling. For example, during their initial energy simulations, they realized that some of the rooms from the Revit MEP design model were not enclosed, causing the energy analysis to fail because the spaces could not be correctly defined. The issue was simply resolved by updating the Revit MEP design model to create fully enclosed spaces. In addition, the architectural design includes several curved walls that the team exported to the energy analysis software. They quickly realized that the energy model was too detailed—degrading the performance of the analysis—and updated their design procedures to accommodate model simplification.

[2] Due to site constraints (including defunct mining shafts), the building's orientation and shape were largely fixed, severely affecting the potential of a solar energy solution. At the completion of the design, the client decided to use a wind turbine solution (versus solar energy) based on cost considerations.

Even with this learning curve, the team experienced an estimated 50 percent productivity improvement over their traditional energy modeling/analysis process, helping to improve project efficiency and engineering accuracy.

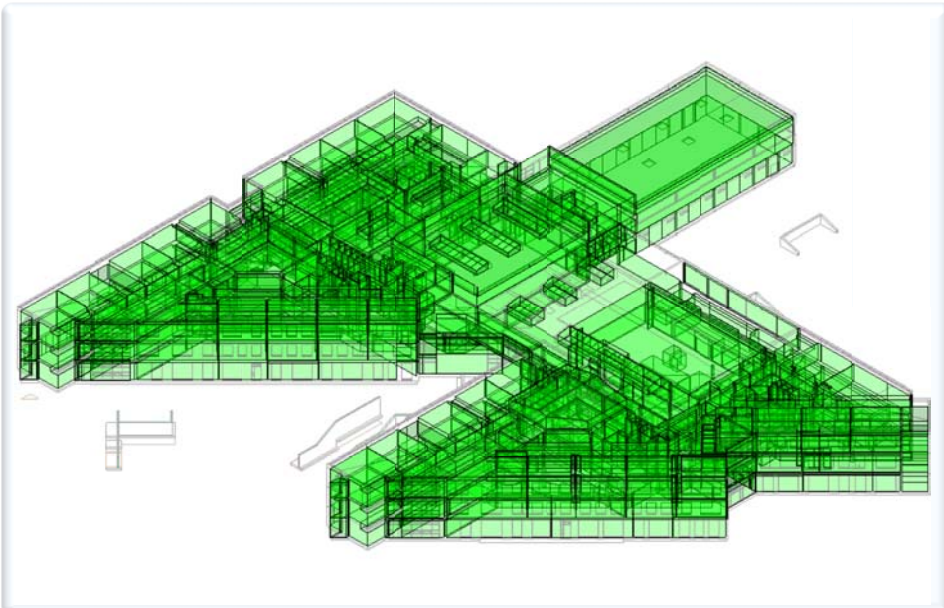


Figure 4. Revit MEP design model with heating and cooling zones highlighted.

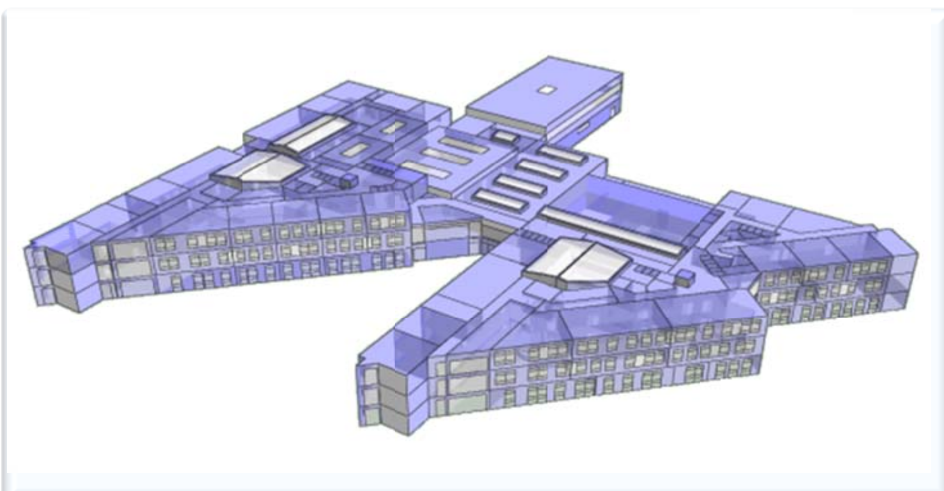


Figure 5. Revit MEP design model exported to energy analysis software.

Roof Top Plant: Design Considerations

The location of the ALC facility is such that the building, particularly the rooftop, can be seen from parts of the surrounding communities. To minimize the visual distraction of the mechanical equipment on the roof, Buro Happold developed several design options for the roof top plant. The model, and resulting design visualizations, helped the team better understand the visual impact of the design iterations and limit the view of the roof top plant from nearby locations.

Electrical Design

Buro Happold used Revit MEP to explore and evaluate a series of early lighting design options. The team provided design visualizations of the options to the client and architect, helping them make more informed project decisions earlier in the design process.

During detailed design, Buro Happold used the Revit MEP panel schedule tool to link the project's panel scheduling and circuiting to the lighting and small power design. This helped Buro Happold to streamline its internal design processes for these areas and enabled them to improve project quality by helping to keep the drawings and schedules coordinated and consistent with the underlying design model.

The bidirectional link between design and documentation allowed Buro Happold to incorporate design changes more quickly. Improved change management also promoted client satisfaction, helping Buro Happold to react quickly to design changes without compromising quality.

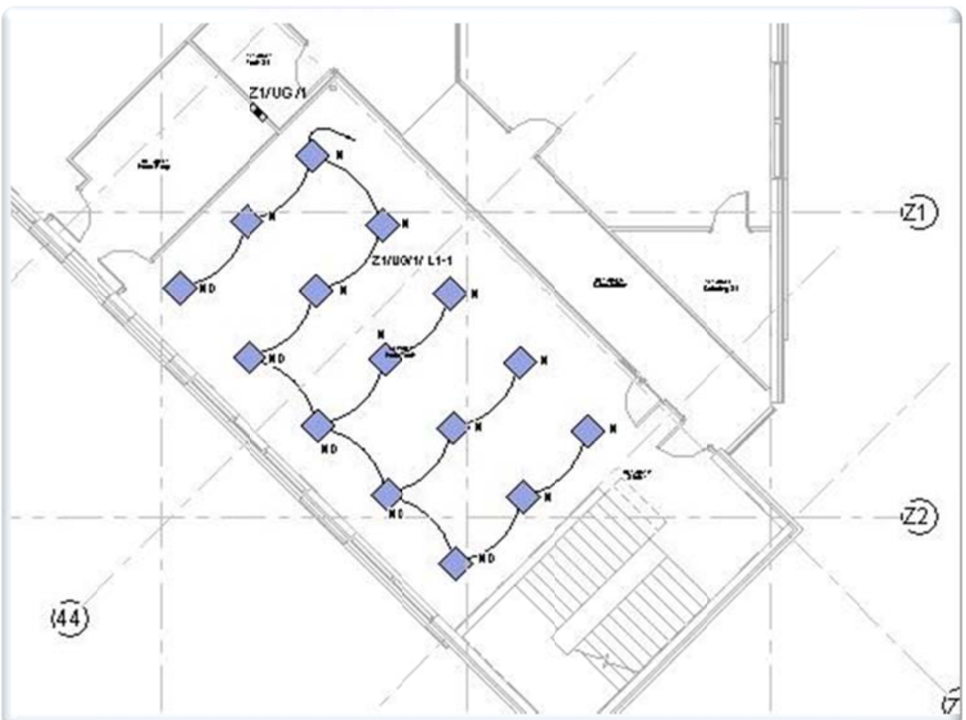
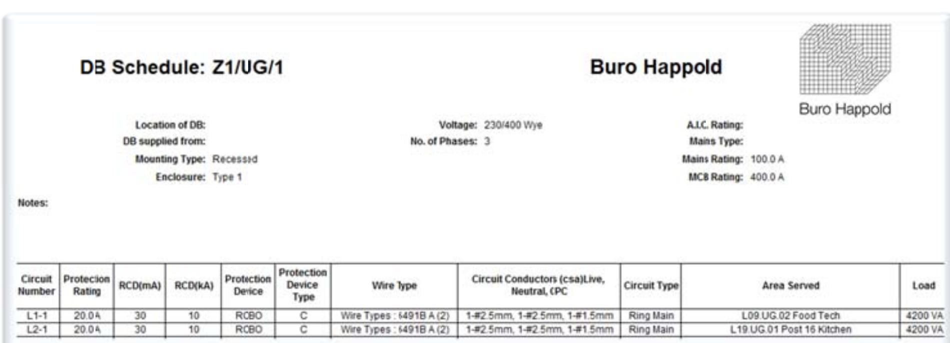


Figure 6. Buro Happold uses Revit MEP to create lighting layouts such as the one shown here.



DB Schedule: Z1/UG/1 **Buro Happold**

Buro Happold

Location of DB:
DB supplied from:
Mounting Type: Recessed
Enclosure: Type 1

Voltage: 230/400 Wye
No. of Phases: 3

A.I.C. Rating:
Mains Type:
Mains Rating: 100.0 A
MCB Rating: 400.0 A

Notes:

Circuit Number	Protecion Rating	RCD(mA)	RCD(kA)	Protection Device	Protection Device Type	Wire Type	Circuit Conductors (csa)Live, Neutral, CPC	Circuit Type	Area Served	Load
L1-1	20.0A	30	10	RCBO	C	Wire Types : 6491B A (2)	1-#2.5mm, 1-#2.5mm, 1-#1.5mm	Ring Main	L09.UG.02 Food Tech	4200 VA
L2-1	20.0A	30	10	RCBO	C	Wire Types : 6491B A (2)	1-#2.5mm, 1-#2.5mm, 1-#1.5mm	Ring Main	L19.UG.01 Post 16 Kitchen	4200 VA

Figure 7. Revit software's bidirectional link between design and documentation helps keep documentation (such as this distribution board schedule) automatically coordinated with the underlying Revit design model.

HVAC Schedules

Similar to the panel schedules approach mentioned earlier, Buro Happold took advantage of the automatic scheduling tools within Revit MEP for its HVAC design. This dynamic interoperability between the design model, drawings, and schedules helped increase team confidence concerning changes made during the design process and improved overall design efficiency.

Project Coordination

One of the largest advantages that Buro Happold gained from the use of Revit software on this project was the improved coordination of all the design disciplines. Throughout the project, the extended design and construction team placed a strong emphasis on the use of a common Revit design platform for cross-discipline project collaboration and coordination.

By sharing discipline-specific design models, the overall project design was more naturally coordinated. In addition, the main contractor used Autodesk Navisworks Manage to aggregate cross-discipline design models and to help perform clash detection in preparation for project design reviews. This helped the team to make quick, on-the-spot decisions and resolve design interferences—minimizing field delays and costly change orders.

In fact, to help improve project coordination on future projects, Buro Happold created a new project position for its future BIM projects: BIM Integrator. The BIM Integrator will define and manage the sharing of project models, and use Navisworks Manage software to help perform routine clash detection on models for overall project coordination.

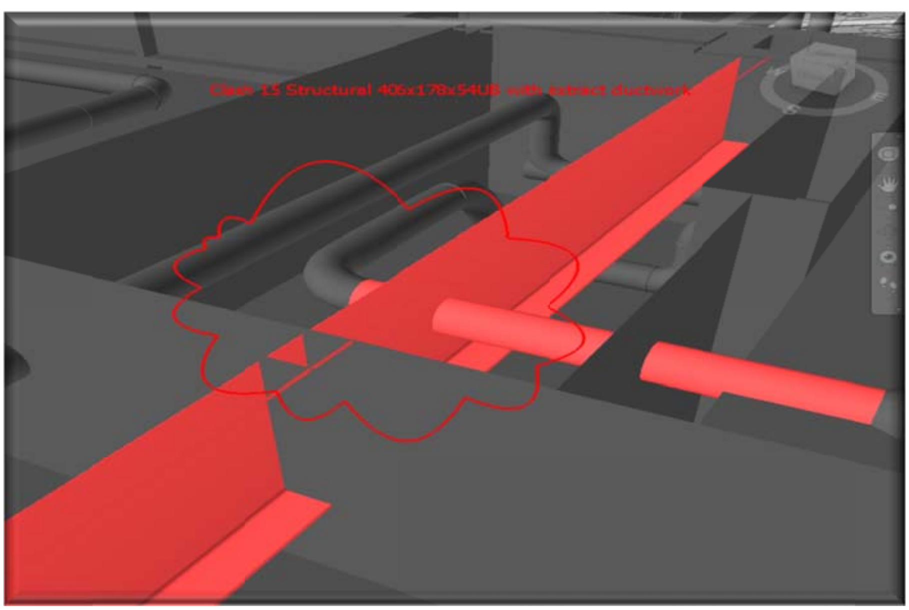


Figure 8. Buro Happold uses Autodesk Navisworks Manage (shown here) and Autodesk Revit software products to help conduct clash detection.

Prefabrication and Construction

The project's general contractor prefers to self-perform critical portions of its construction projects. As a result, the offsite manufacturing of precast concrete building elements and MEP modules was a requirement on this ALC project.

The use of the Revit MEP design model helped the Buro Happold team design, model, and coordinate the building services to fulfill the contractor's requirement for the offsite construction of the building envelope. This included the coordination of the building's substructure ground beam with the below ground building services. The use of a digital design model streamlined Buro Happold's design-to-fabrication workflow and helped preserve and communicate the design intent during manufacturing.

Project Outcome and Conclusion

When Buro Happold began the Foulstone-Wombwell ALC project, it set very high goals for its use of BIM for MEP design. Being one of the first significant Revit MEP projects for the firm, Buro Happold wanted to push the capabilities of the software and discover its potential to improve and streamline the fragmented design approach of traditional CAD-based projects.

In the process, the firm experienced successes as well as some setbacks—deriving important lessons-learned for the use of BIM and Revit MEP on future projects. Overall, the use of the Revit software platform helped the project team make informed decisions early in the process and uncover issues that, on a traditional project, might not have surfaced until construction.

For the client, the use of BIM on this project resulted in substantial cost and schedule savings. For Buro Happold, the use of Revit MEP facilitated cost savings by improving its efficiency and helping to minimize costly construction change orders. In addition, the software's automatic change management features helped the design team improve documentation efficiency and accuracy. Based on the Foulstone-Wombwell ALC project, Buro Happold is looking forward to the use of Revit MEP on its future projects.