The buildingSMART openBIM Awards Yearbook 2021

Extraordinary projects from the 2021 buildingSMART International openBIM Awards Program

buildingSMART International

About buildingSMART

buildingSMART is the worldwide industry body driving the digital transformation of the built asset industry, committed to delivering improvement by the creation and adoption of open, international standards and solutions for infrastructure and buildings. buildingSMART is the community for visionaries working to transform the design, construction, operation and maintenance of built assets and is an open, neutral and international not-for-profit organization.

The buildingSMART Awards program was established in order to recognize exemplary projects that have used buildingSMART standards and solutions to effectively overcome interoperability challenges. The first awards were presented in Toronto in October 2014, and the program continues to grow year on year.

The 2021 Awards saw projects compete in 8 categories, with 1 additional Award being presented at the discretion of the buildingSMART management team, resulting in 9 project winners.

2021 Highlights

Categories

The program was divided into four broad categories: Project Delivery, Operations, Research and Technology. Each category has its own sub-categories, providing the basis for the Awards program.

Jurors

This Awards program was supported by 154 jurors across 23 chapters. The primary role of the juror is grading project submissions against a strict criteria, designed to ensure the highest quality of submissions. This year there was once again a triage team to help reduce the amount of work on all jurors.
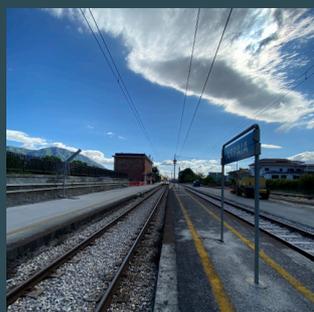
Submissions

There were a record 133 submissions across all the categories, 74 of which passed triage. The breakdown for those that passed triage is outlined below:

- Asset Management: 4
- Construction: 17
- Design: 18
- Facilities Management: 2
- Handover: 2
- Professional Research: 10
- Student Research: 3
- Technology: 18

Special Mentions

Due to the high volume of quality submissions, there were a number of projects deemed a high enough standard to warrant a special mention. These projects were scored especially highly by the jury, falling slightly short of the required score to become a finalist. These projects were duly awarded during the Awards Ceremony, alongside all finalists and Award winners.

Contents

WINNER

smartBRIDGE Hamburg - The openBIM-based Digital Twin for Bridge Maintenance

MKP GmbH, Germany

About the Project

smartBRIDGE Hamburg is a pilot project with the aim to optimise the maintenance of the Köhlbrand Bridge in the Port of Hamburg, Germany by harnessing the concept of the "digital twin". The project was initiated by the Hamburg Port Authority (HPA) with a multidisciplinary team consisting of Marx Krontal Partner, customQuake and WTM Engineers was appointed by the sponsor to realise it.

The bridge structure is 3,618 m long and 17.2 m wide and carries four lanes. Around 36,000 vehicles per day cross Germany's second-longest road bridge, with heavy goods traffic dominating.

Core Objectives

This project aims to transform the current analogue and reactive maintenance processes to digitally enhanced and predictive maintenance based on real-time condition information to ensure the functioning and availability of the ageing transport network.

Project Description

smartBRIDGE Hamburg is an innovative project demonstrating the application of digital twins to optimise the maintenance of bridges. The current maintenance process in Germany consists of a periodic manual inspection and an analogue workflow in analysing and documenting the results. This leads to limited

traceability and sustainability of asset condition results and produces a time-discrete condition assessment. In addition, structural damage is currently only detected after it occurs, leading to costly and inconvenient reactive maintenance.

To improve current processes and implement predictive functionalities, this project combined BIM with IoT and other heterogeneous data sources and processed the data with high-level analytics.

A BIM model was created to provide a geometry of the complete Köhlbrand Bridge structure, in line with the Employers Information Requirement (EIR) and the BIM Execution Plan (BEP). The BIM model consisted of a large number of models (terrain, diagnostic, electric, bridge, monitoring, damage) created by different disciplines in their specialised software applications. To enable collaboration, all sub-models were stored as IFC 2x3 in a Common Data Environment (CDE), where the models were managed and versioned.
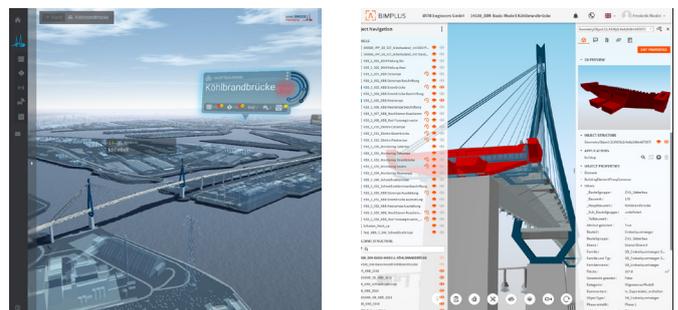
All project partners could access current data and undertake model-based collaboration. Reviews of models were made and delivered via BCF.

In addition to the EIR, the "Bauteilkatalog Brücken" component catalogue was used, as it contains project-independent specifications for the creation of 3D BIM bridge models and enabled interoperability. The different semantic information was embedded in the model as attributes for each IFC object. These standards were extended for the implementation of monitoring systems, damages and diagnostic examination.

Real-time condition measurement data from Köhlbrand Bridge came from continuous structural health monitoring (IoT) sensors, inspection data from traditional periodic manual inspection and other structural diagnostic examinations. The information streams were combined into a single information source, with the BIM model acting as a central data hub that linked real-time conditions.

The collected real-time data was aggregated into easily understandable condition indicators that allowed all stakeholders (owner, operator, maintainer) to have a constant overview of the bridge's condition. A high-level browser-based solution for visualisation of the digital twin called conditionCONTROL was developed to allow approachable and open access for any user, with different navigation views to choose from, depending on the user's needs.

A cloud-based system was developed that enabled the use of machine learning algorithms to predict the bridge's behaviour and trigger maintenance countermeasures when alarm or limit values are exceeded.

Highlights

- Second largest road bridge implemented in BIM

- About 10,000 IFC objects modelled, and 26 different models created

- Over 200 different non-geometric attributes assigned

- Implementation of automatic model checking rules

- Cross-discipline model-based collaboration

- Comparison of as-designed and as-built models based on a LIDAR point-cloud

- Connection of BIM to real-time data from heterogeneous monitoring sources

buildingSMART openBIM Solutions

BCF, IDM, IFC 2x3

Software Used

Autodesk 3Ds Max, Autodesk Revit, BIM Vision, BIM360, BIMplus, Blender, Desite BIM, NavVis Indoorviewer, Nemetschek Allplan, Sofistik Bridge Modeler, Solibri Model Checker, Unity

Result

In this project, the Köhlbrand Bridge was used to demonstrate a transformation in infrastructure maintenance and operation based on BIM methodology. By combining BIM with IoT and other heterogeneous data sources and processing the data with high-level analytics, it becomes possible to optimise the maintenance process and implement predictive functionalities. The result is more precise damage prognoses and thus predictive and sustainable maintenance management.

"The award is a great opportunity to show the world what is already possible with openBIM today. In the future, BIM will be indispensable - in all phases of a bridge's life. As a company, we gain international visibility and prove ourselves as BIM experts. A great programme."

Marc Wenner, MKP GmbH
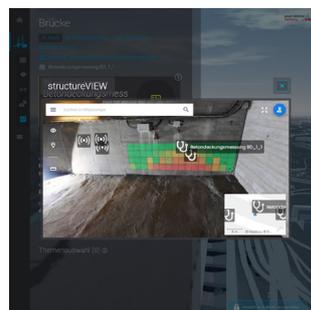
FINALIST

Asset Information Management of an Existing Railway Infrastructure in the openBIM scenario: the Cancello-Benevento Line
University of Naples Federico II, Italy

About the Project

This project tested the application of BIM methodologies to the management of an operating railway infrastructure, the Cancello-Benevento railway line. The project team was made up of collaborators from two Italian railway managing authorities (EAV, RFI), ACCA Software and the Department of Structure for Engineering and Architecture at the University of Naples Federico II.

The railway line was built in Campania at the beginning of the 20th century and completed in 1913. It is made up of 12 stations, 15 bridges, viaducts, and overpasses, and six tunnels along a length of 47 kilometres.

Core Objectives

To test the application of openBIM standards for the digitisation of an existing railway infrastructure for application in its operation and maintenance.

Project Description

This project stemmed from a need to model the existing condition of the Cencello-Benevento railway line for asset management purposes in light of a potential management takeover by Rete Ferroviaria Italiana (RFI) from regional managing authority Ente Autonomo Volturno (EAV). The modelling of the railway line was required to enable the analysis of

the infrastructure gap with respect to RFI company standards, as well as the technical and economic feasibility of future rehabilitation investment. This project offered an opportunity to test the potential of BIM methodologies through fully openBIM standards in a real-life case study.

The University of Naples FEDERICO II was appointed to provide services such as BIM modelling, information management and surveying. The technological solution for the project was provided by ACCA Software and was used for BIM modelling of the railway infrastructure (by means of an authoring environment), management of project information (through a CDE), and information flow between collaborators through the application of openBIM standards (IFC).

The project was formed of two key overarching activities: surveying the existing infrastructure and the digitalisation of the railway line. The surveying activities involved the use of drones
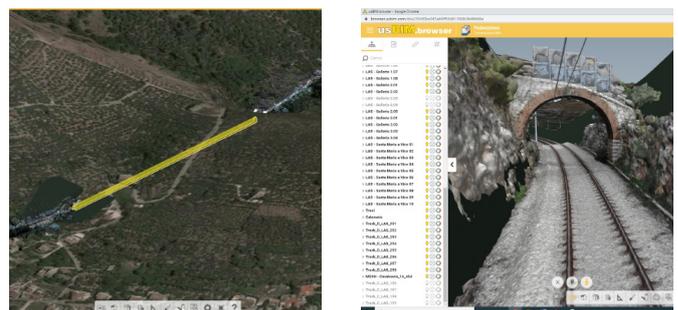
and an autonomous railway truck (equipped with instrumentation such as laser scanners, GPS, railway odometers, and an inertial platform) to collect multiple forms of information (geometry, condition, structural conditions) about the linear railway infrastructure.

As part of the digitalisation of the railway line, a BIM object library was created using Edificius and its integration with other tools such as Blender and SketchUp. This resulted in a series of IFC models with detailed geometry and properties for each object type, as identified in the information requirements (e.g. pole models, sleeper models, rail profile, ballast profile, and so on). After validation, the BIM object library was uploaded on the CDE to be reused for future asset management and operation & maintenance projects.

The BIM object library and the existing track geometrization were used as the input for the modelling of the track. This was done using a specific tool developed for the purpose and produced IFC models using the IfcAlignment concept and the IfcLinearPlacement concept to create the track and position the objects along the track, respectively.

After validation by railway specialists, the models were uploaded on the CDE together with the point clouds, 360˚ photos and all related documentation to form a unique federation of all the available documents and models for use in the maintenance management workflows of the railway.

Highlights

- A model of approximately 47 km of the railway infrastructure was made using openBIM standards

- Use of the IFC 4x2 for the development of IFC objects and models

- Project information management through an IFC-certified BIM Management Platform

- Linear positioning of objects with respect to alignment, as required by IFC standards

- Exchange of information based on IFC files

buildingSMART openBIM Solutions

IDM, IFC 2x3, IFC 4, mvdXML

Software Used

Blender, CloudCompare, Edificius, pix4D, Sketchup, usBIM.browser, usBIM.IFCinfra, usBIM.platform

Result

The use of the openBIM methodology enabled greater reliability, accessibility, and transparency of the exchanged data between project collaborators, considerably reduced the time and resources needed to deliver the project's objectives and facilitated interoperability between the different systems and software.

The use of a digital, federated model offers secure data storage, avoiding dispersion and loss over time, and the objects library in IFC format will have further application as a reference for other projects in asset management, maintenance, and operation.

"As shown by the project outcomes the openBIM offers the opportunity to reassess and reorganize company processes in asset management context, allowing a reduction of time-consuming activities. Information is accessible via a single environment (CDE) to all actors at any time and place. The IFC models can represent an "access key" to information and processes related to other systems (CMMs and ERP) and the client, through the use of IFC certificated platform, can manage, control and validate the required information (objects library and models) in open format (e.g. IFC)."

Angelo Ciccone, University of Naples Federico II
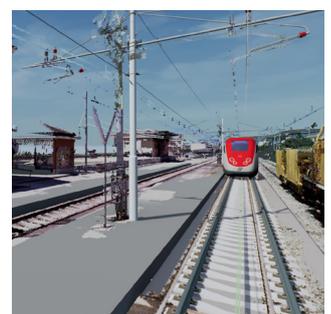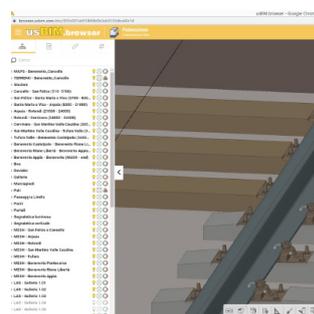
FINALIST

openBIM based Digital Building Twin – Technology Centre II
Siemens, Austria

About the Project

The Technology Centre 2.0 or "tz2" is a commercial building constructed as a sustainable passive house standard and is owned and operated by the Vienna Business Agency. It comprises approximately 5,600 m2 of rentable office space and workshops over five floors and is home to 25 innovative companies and start-ups.

As a project of Aspern Smart City Research (ASCR), one of the largest and most innovative energy and smart building research projects in Europe, the building is a testbed for various R&D use cases.

Core Objectives

This project's scope was to use BIM data to create a digital twin of tz2 that would act as a single source of truth to optimize facility management, energy management and allow predictive maintenance.

Project Description

Aspern Smart City Research was launched in 2013 by Siemens, Wien Energie, Wiener Netze, Wien 3420 and the Vienna Business Agency. ASCR uses real data from the urban development zone of Aspern Seestadt, where tz2 is located, to explore solutions to power future of cities.

To gather building data, tz2 was equipped with a wide range of networked building technology,

including over 1,500 sensors. The state-of-the-art devices found in the fire alarm, access, and building automation systems together formed a powerful building intelligence network that allows data-driven decision-making. All systems were combined in Siemen's Desigo CC Building Management System (BMS), which was used for control, maintenance, localization and documentation of the building technology.

A reliable connection between this live data coming in from the building and the as-built BIM model was essential to creating and maintaining a digital twin.

To establish this connection, the project team first quality-checked the as-built discipline BIM models against 3D scans of the building to ensure the correct spatial placement of all objects. Two model checker applications were used: NavisWorks Manager for clash detection between disciplines with issues reported via BCF and Solibri Model Checker for model conformity and the verification of technical system
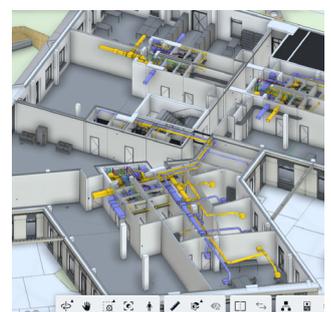
features/compliance with technical guidelines.

Once the data quality was ensured, the BIM models could be matched with the BMS by connecting devices (BIM objects) and data points using a communication protocol for Building Automation and Control (BACNet). Algorithms were employed to facilitate the critical relationship between the individual devices and their multiple sensors, thus enabling the connection between IFC and the BMS.

The integration of IFC models with the BMS resulted in a digital twin of tz2 that is enhanced by live data coming directly from the on-site devices. Through an openBIM approach, the BMS was made more useful in facility management by contextualizing building system data in the constructed model using a BIM viewer.

The integration of the real-time data feed from the building sensors with the building model enables different use cases that improves efficiency and productivity in the operation and maintenance phase. Other use cases include the automatic creation of 2D plans in the BMS, the visualization of live data (e.g. temperature, humidity, occupancy, movement states, or window states) directly in the BIM model, linking asset schematics with the BIM model, and alarm and issue localization in the BIM model. This latter use case is of particular interest in industrial and hospital environments where systems can be highly complex, and reaction to possible issues must be instant.

Highlights

- Integration of the IFC model and a BIM Viewer directly in the Building Management System

- Visualization of real-time building system data to improve facility management planning and decision-making

- New Model View Definition (MVD) adapted to meet the visualization demands of different disciplines

- Clash detection between discipline models reported using BCF

buildingSMART openBIM Solutions

BCF, IFC 2x3

Software Used

BIM360 Build, BIM360 Design, BIMcollab, Navisworks, NavVis IndoorViewer, Revit 2019, Solibri Model Checker

Result

An openBIM approach, as explored by ASCR in this project, provides excellent flexibility, customization and adaptation to customer requirements, while facilitating collaboration. This openBIM method and the use of the IFC standard ensures a future-proofed, manufacturer-independent, and open building data structure that can be maintained over several decades.

As a result of this project, the operation and maintenance team at tz2 will benefit from better building documentation, high efficiency in operations and higher building performance stemming from optimization and improved analysis with real-time opportunities.

"Combining BIM & real-time data is complicated because there are currently no standards existing for this topic. But with the openBIM standard, IFC and its classification system, which includes elements from the building automation domain, we already have the perfect foundation to combine structural BIM data with real-time data standards like BACnet, Modbus, or OPC UA. This combination enables the efficient creation of digital buildings twins, which can further help achieve up to 10% total operating cost reduction and 30% faster fault resolution for the Facility Management."

Kevin Bauer, Siemens
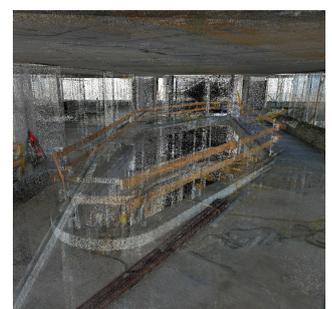
WINNER

Make it Easier with openBIM: Primary School in Warsaw's Wilanów District

Mostostal Warszawa S.A., Poland

About the Project

This project saw the design and build of a modern, sustainable primary school for 750 children in Wilanów, Warsaw. The budget was 59 million Polish złoty (US$14.4 m) and encompassed three buildings (the school, sports hall and parking garage with rooftop playground) with a total area of approximately 13,500 m2. The project had a fixed and immovable deadline—the first day of school.

This project established openBIM practices within Mostostal Warszawa S.A. (General Contractor) and the use of IFC and BCF for the first time.

Core Objectives

The project aimed to develop an openBIM framework that would involve all project participants and could be further scaled to all company projects.

Project Description

The project became the foundation of openBIM strategy development for Mostostal Warszawa S.A., who aspired for all project participants to be able to implement BIM technology in their everyday tasks. The key to achieving this was to highlight the benefits of the openBIM approach at the construction site and train the relevant parties how to use IFC models.

Early in the project, the project team defined the construction needs and decided to use BIM to perform the quantity take-offs, multidisciplinary coordination, earthworks, scheduling and reporting work progress. They implemented a Common Data Environment (CDE), using the Dalux platform, to manage documentation and construction work processes.

During the mobilization phase, a naming convention for project documentation and the rules of information exchange between the stakeholders were established. Software and information exchange platforms were tested, with the openBIM standard enabling quick and easy switching between different software. To ensure a smooth exchange of models, the modelling method and the information required to be contained in the elements were defined. The models were divided into zones, and an additional reference model was created to enable the correct placement of models in space.

During the mobilization and construction phases, Mostostal's staff and the project's designers,
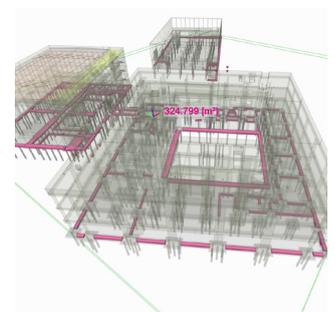
subcontractors and inspectors received extensive training to strengthen their openBIM competencies. The participants learned, among other skills, how to view models (moving in 3D, managing the visibility of elements, sections), search for information about elements, take off quantities directly from the IFC model and communicate through the coordination platform.

Time-effective clash detection and model review using IFC models allowed the effective communication of over 1000 potential clashes to the designers using BCF. This resulted in a better-coordinated execution design, avoided additional project costs at the construction stage, and allowed more time to be spent on quality control at the site.

A 4D schedule was created using IFC structure models, which provided a better understanding of the scope of work and the relationship between subsequent works. This allowed the project team to better plan the work and eliminate inaccuracies and incorrect assumptions early.

Quality control processes on the construction site were facilitated through mobile applications that gave subcontractors access to data, tasks, drawings, documentation and IFC models, reducing the risk of miscommunication and improper interpretation of technical designs.

Highlights

- On time and within budget

- 6,151 documents, 7,215 document revisions with tenfold faster access to documents

- 1,250 BCFs

- Over 120 project participants

- 3 buildings, 16 building models, 35,311 building objects

- 2,927 defects managed, increasing defect resolution by 75%

- Over 20 new company projects now being carried out using the openBIM solutions employed in this project

buildingSMART openBIM Solutions

BCF, IFC 2x3, mvdXML

Software Used

Airtable, Asana, Autodesk AutoCAD,, Autodesk Civil 3D, Autodesk Revit (plugins: Dynamo, Bentley Navigator, BIM Track, BIMcollab, BIMcollab ZOOM, BIMvision (plugins: Advanced Reports, Compare, Dalux BIM Viewer, Dalux Box, Dalux Field, Enscape, Fluid Desk Ventpack (supported by SimpleBM), IFC Comments, Instagantt, Multifile), Navisworks Manage, Object Info, Power BI, RTV Xporter), SharePoint, SYNCHRO Open Viewer, SYNCHRO PRO, Twinmotion

Result

Thanks to openBIM, the school's construction was completed on time and budget, and there was an overall cost reduction of BIM implementation (software, hardware, digital skills, training). The simplicity of using openBIM made it easy for project participants to adapt to using digital BIM tools that employed the IFC and BCF standards.

Using openBIM contributed to better communication and quicker decision making. It reduced the time required to analyze project documentation, perform quantity take-offs, manage issues and accept final work by up to 75%. These time savings and faster information exchanges led to a higher quality project delivery.

"openBIM is not about technology. At its core it is about giving and sharing information which encourages every project participant to be collaborative, transparent and to contribute. That creates more friendly atmosphere and removes the information silos. We want to share our positive experience and exchange ideas with others in order to grow together. buildingSMART Awards Program provides the opportunity to compete on international level with the best."

Dawid Fedko, Mostostal Warszawa S.A.

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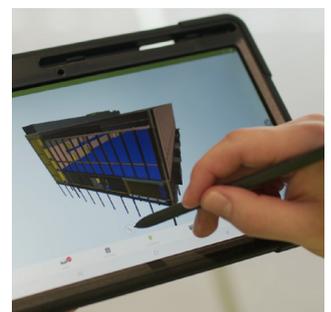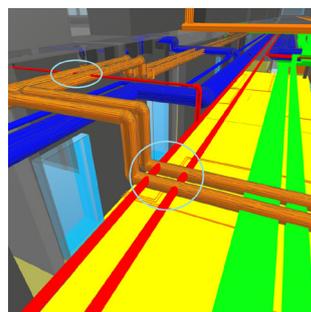
WINNER

openBIM Implemented on Beijing-Zhangjiakou High-Speed Railway

China Academy of Railway Sciences Corporation Ltd, China

About the Project

The new Beijing-Zhangjiakou high-speed railway project has a total length of 174 km, with 10 stations, 66 km of bridges, and 49 km of tunnels along the line. The design speed of the line is 350 km/hour and will ultimately serve the Beijing Winter Olympics in 2022. The total investment in the project was 53.54 billion yuan ($8.32 billion).

In the process of construction, a BIM platform was established with multiple users, enabling the implementation of openBIM for the full lifecycle of the project.

Core Objectives

There were three primary objectives in the construction of the Beijing-Zhangjiakou high-speed railway. Firstly, it will support the Winter Olympics 2022, as well as the coordinated development of the Beijing-Tianjin-Hebei region. Secondly, as the world's first smart high-speed railway, it will serve to create a guidance plan for future smart railway construction and operations. Finally, by adopting an openBIM methodology, the project seeks to establish data transmission channels for different stages of the railway's lifecycle.

Project Description

The project was full of complexity in both the design and construction stages, requiring streamlined collaboration and coordination.

In the design phase of the Beijing-Zhangjiakou high-speed railway project, several software applications were used, including Autodesk, Bentley, and Trimble to build the openBIM model. The IFC format was adopted for model file transmission, and the project team established a Common Data Environment (CDE) in the form of a REMPLAT data center to facilitate a collaborative and open design (and, later, construction) process.

The IFC standard was verified and extended according to the project requirements. Railway elements were mapped to IFC elements, and the lists of information models to be built and the existing IFC models were created. Unified Modeling Language (UML) was used to define new objects. Finally, the extended IFC standard schema files (EXPRESS, XSD) were generated from the conceptual model and deployed in the relevant software.

In the design delivery phase, the Bentley suite was used for the secondary development of ECObjects,

and the IFC standard was integrated into the software and bound with geometric entities to generate the structure objects. To represent the long, linear infrastructure entities, the openBIM model was imported into SuperMap iDesktop, and oblique photography data was superimposed to merge BIM and GIS data.

In the construction phase, the BIM management team created a cross-professional Information Delivery Manual (IDM) and applied IFC files in the data exchange scenario. The ISO-19650 standard was applied in the information management workflow to form a standardized railway asset model and information generation process.

In the operation and maintenance stage, the information exchange templates were formulated using COBie. By establishing the railway infrastructure operation and maintenance information model data standard, a firm foundation was laid for the full life cycle management of the railway.

Highlights

- The first high-speed railway that adopts the concept of openBIM to carry out multi-domain full life cycle management on the whole process in China

- More than 20 software were used in the project, and a new mode of multi-platform collaborative management at all stages was adopted

- Successful adoption of openBIM standards such as IFC 2X3, IDM, mvdXML and COBie in the design phase and construction phase

- The first digital railway project in China that combines openBIM modelling with GIS data

buildingSMART openBIM Solutions

COBie, IDM, IFC 2x3, ifcXML, mvdXML

Software Used

Ansys, Bentley ContextCapture, Integrated Maintenance System (IMS), MicroStation V8i, Model Review Software (MRS), Navisworks, OpenRoads Designer, PowerCivil, ProjectWise, Railway Engineering Management Platform (REMPLAT), Revit,SOLIDWORKS, SuperMap iDesktop, Tekla Structures,Unreal Engine 4,

and a variety of self-developed construction management software

Result

By using openBIM standards, the project team built an ecosystem for multi-party cooperation and information sharing. The application of IFC, mvdXML and other standards greatly improved communication between the project participants, resulting in a time saving of 144 days and an estimated cost saving of $2.36 million.

Employing the COBie standard when transferring data from the construction to the operation and maintenance stage prevented information misalignment due to imperfect information-sharing mechanisms. This reduced the need for the repeated collection of construction data during the operation and maintenance phase, resulting in further time and cost savings and better-quality data.

Feedback from the various project stakeholders reveals that openBIM allowed them to better understand the project's status throughout and improved quality, safety and communication between all parties.

"The bSI Award is a recognition of the development in applying openBIM in railway projects. The project proves that openBIM can help us establish a digital environment that is interoperable and shared throughout the life cycle, creating a more convenient and comprehensive ecosystem for constructing the first intelligent railway in China."

Dashuang Li, China Academy of Railway Sciences Corporation Ltd
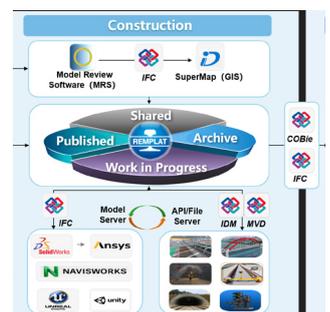
FINALIST

Building a Hospital with openBIM – Haukeland University Hospital

Helse Bergen HF, Norway

About the Project

Helse Bergen HF (Bergen Hospital Trust) is currently building phase 2 of the project "Glasblokkene", due to be completed in 2023. The project is a 50,000 m2 hospital building providing comprehensive specialist health service to women, children and adolescents in Bergen, Norway and the surrounding area. It comprises 10 wards with a total of 160 beds, 60 polyclinic rooms, 12 operation theatres, a radiology department, and maternity and neonatal departments. The total investment into the project is estimated at NOK 3.5 billion.

Core Objectives

The project has employed openBIM methodology to facilitate an efficient flow of information between stakeholders, improve decision-making and transparency, providing seamless communication between different BIM applications and support on-site production.

Project Description

The project is being led by the hospital's own project management team and is being carried out in line with the Norwegian contract standard "NS 8405". For the purpose of this project, the standard was modified and adapted to the openBIM IFC standard, as IFC models have been contractually mandated as deliverables.

The IFC model will be used in all phases of the project. So far, the IFC model has been used in the

processes related to controlling the model during pre-construction and currently acts as a single source of truth to support different processes during construction, such as supervision, making corrective actions and testing.

The project prioritizes lean construction methodologies, digital collaboration, and systematic completion, all of which are supported by the structured data found in the IFC model. To produce this reliable, structured data, Norway's interdisciplinary building part tagging system, "tverrfaglig merkesystem" (TFM), was used to assign a unique TFM tag to almost every building part in the IFC model. dRofus, a room and equipment database, acted as the generator/ owner of the tag system and was essential to structuring the data in the IFC model.

This structured data of the IFC model has enabled the project team to connect various software and automate several operations, including maintenance, parameter updates, IFC model exports, updates and checks in Solibri models,
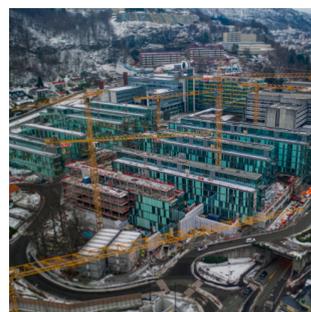
and model "clean-ups" in Revit files to reduce their size. Additionally, the model has facilitated interdisciplinary communication among the design team, contractors, owners, and other stakeholders via BCF, which offers an efficient way of communicating and problem solving.

The software StreamBIM has been implemented to ensure the most up-to-date version of the IFC model is accessible to all stakeholders (owner, design team, contractors, hospital staff) on a phone, tablet, or PC. StreamBIM has facilitated openBIM-based collaboration and information distribution, and it has enabled several workflows supporting different project phases and purposes. Through StreamBIM, users are also able to access non-geometric information supplied by the contractors from the dRofus database, such as product data sheets and other documents necessary for the construction, operation, and maintenance phases of the hospital. Because StreamBIM is accessible via personal electronic devices and can handle many large IFC files, it allowed the transition to a paper-free building site.

The easy accessibility of information to all stakeholders has been an important aspect of the project's transparency and participation. It enabled, for example, the end users of the building - the hospital staff - to participate in digital testing of the building using VR to correct design issues. This data accessibility via the IFC model will continue to play an important role in the completion and handover process and, ultimately, in the operation and maintenance phase of the building.

Highlights

- IFC files contractually mandated as deliverables
- 76 IFC files, approximately 90,000 BCF issues
- Communication between 600 distinct users through the IFC model
- IFC data structured using Norway's interdisciplinary building part tagging standard
- 3D models viewed on devices, leading to a paper-free building site

buildingSMART openBIM Solutions

BCF, IFC 2x3

Software Used

dRofus, IT-base, Novapoint, Power BI, Revit (BIM360), Smartsheet, Solibri, StreamBIM, SYNCHRO Pro, Touchplan, Vrex

Result

Although the project is still in the construction phase, using the IFC standard as a foundation to support all project phases and processes has shown several benefits thus far. These include improved communication between and participation of stakeholders resulting in better problem-solving, greater project transparency, better design leading to improved "buildability" on the construction site and usability in the operation phase, interoperability between different software and the implementation of automation.

"Participating in the Awards Program has been a valuable process and important in terms of evaluating oneself in our quest to contribute, as a building owner, to push the construction industry in our area to adopt to new ways of planning and executing construction projects by working with openBIM; a direction in which we have great faith."

Tord Monsen, Helse Bergen
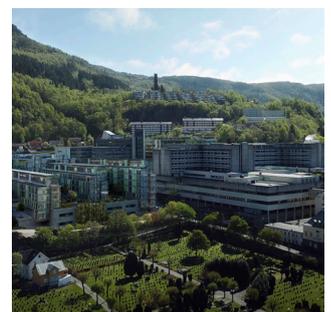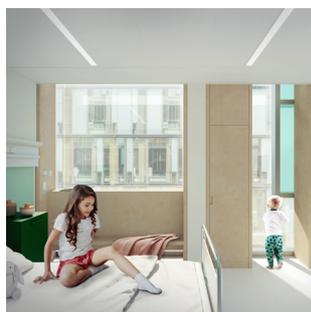
Randselva Bridge – Preparing for the Future

Sweco Norge, Norway

About the Project

The Randselva Bridge is a 634-meter-long free cantilever cast-in-situ concrete bridge and is the world's longest bridge built without the use of any drawings, only BIM models. It contains over 200,000 rebars, 200 pour stages, 250 unique tendons in the pre-stressing system, over 19,000 m3 of concrete, and 18,000 m2 of formwork.

The owner of the project is the Norwegian Public Roads Administration (NPRA) and the project included a multidisciplinary, international team including a design team situated in five different countries (Norway, Finland, Denmark, Poland and Portugal).

Core Objectives

This project was a proof of concept for complex model-based projects and demonstrates that model-driven projects can be more beneficial for site management, site monitoring, clash detection, understanding the scope of work and flexibility in the design.

Project Description

In recent years, the NPRA has gradually extended their demand for how BIM is used in their projects. Initially, they mandated that BIM models should be used for project drawings, which resulted in a significant reduction in change orders thanks to better clash control and an improved understanding of their scopes of work. As a result

of successful BIM use, they proposed that the Randselva bridge should be designed and built based entirely on BIM models.

Engineering consultancy Sweco Norge, who produced designs, calculations, and openBIM models for the Randselva Bridge, had experience in BIM-driven approaches on smaller scale projects in the past. As a result, they recognised the benefits a BIM-based approach would offer to a project of this magnitude, including the ability to detect clashes, implement design changes, and the impact cost and performance early in the project could have. Additionally, while drawings are country-specific, BIM models are international, which allowed Sweco to choose their best engineers from across several countries to work on the bridge's design.

The project involved complex geographic considerations, including an asymmetric river valley geometry and a steep, 80 m2 sandy slope located on the west side of the valley. These key requirements, together with other functional
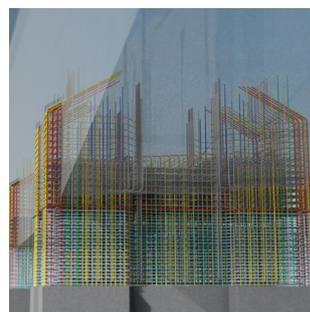
crossing needs related to an existing railway line, the Kistefoss road, a future parking place and a local access road, necessitated the development of a bridge solution that harmonised all these elements.

The whole bridge was modelled in Tekla Structures using both calculations and parametric design and exported as 57 IFC files to the client. To limit model sizes and lessen the information filtering requirement, the model was divided up into several parts when exported into IFC files. The superstructure was divided into three parts with each part made up of one pier/abutment. All objects in the model were fed with 22 user-defined attributes to serve as metadata. In addition, shape codes with additional attributes for bar bending schedules were also included.

Communication between stakeholders, including the contractor, the design team, third-party control, internal quality control and the construction site, was done using IFC and BCF standards. New ways of transferring information through geometry and attributes was enabled by an openBIM approach, with 95 % of the information flow from design team to the construction site transferred through the IFC format.

At the construction site, the IFC model was used for backfilling and excavation, scaffolding systems and coordinates, third-party products helped with reinforcement and material placement. This information was available on-site using tablets or, for some tasks, augmented reality.

Highlights

- World's longest bridge built using only BIM-models
- 95% of the information transferred through IFC format
- Over 250,000 IFC structural objects and over 200,000 rebars modelled
- Collaborative design process across five different countries and multiple software

buildingSMART openBIM Solutions

BCF, IFC 2x3

Software Used

Grasshopper, Rhino, Solibri Model Checker, Tekla Structures, Trimble Connect

Result

Applying openBIM on this project has and will continue to provide numerous benefits throughout the lifecycle of the Randselva Bridge. Using IFC files enabled designers from different countries to use the best suited software for the task at hand, which resulted in significantly fewer change orders, enhanced understanding of the scope of works, and made procurement easier. It also improved communication between stakeholders, and facilitated progress monitoring and supported construction teams with information on-site.

In the future, openBIM models created in this project will have further application as digital twins for the operation and maintenance stage and can act as input data for future design based on reference models.

"Taking part in the buildingSMART Awards Program has encouraged us to define current benefits and future goals of our BIM-workflow. It has also given us publicity to communicate the ever-increasing importance of BIM and the need to democratize it by using openBIM formats."

Øystein Ulvestad, Sweco Norge
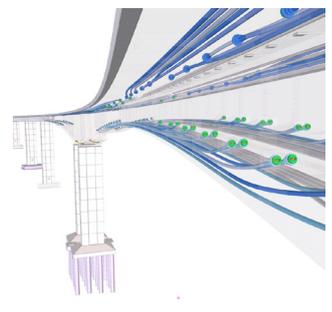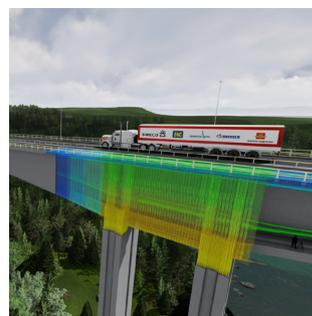
WINNER

Yan-Jiang Expressway G4216 – openBIM Flagship Highway Megaproject in Southwest China

Sichuan Highway Planning, Survey, Design and Research Institute Ltd., China

About the Project

Authorised by the Ministry of Transport of the People's Republic of China in January 2019, the Yan-Jiang Xin-De Expressway is a 136.2-kilometre (84.6-mile) road-bridge-tunnel system consisting of a series of highway structures, including 88 bridges, 39 tunnels, 45 culverts, 4 flyovers and 22 interchanges. It is in a challenging mountain-canyon area and is one of the most expensive highways in Southwest China, with an initial total estimated cost of 40 billion RMB (US$ 6.2 billion).

Core Objectives

In addition to sustainability goals, the project's objective was to enable a design process with reduced time and cost—but improved quality—through adopting openBIM-driven BIM technology and a model-centric information flow.

Project Description

Recognising BIM's ability to enhance collaboration, increase productivity, and thus improve efficiency, the asset owner mandated its use for the entire lifecycle management. Sichuan Highway Planning, Survey, Design and Research Institute Ltd. (SCHDRI), the appointed BIM solution provider, adopted openBIM standards and workflows to enable reliable and transparent information exchange between all project stakeholders.

Three core concepts of openBIM were implemented in SCHDRI's Cloud-based Collaborative Design System (CCDS) platform to define the meaning (bSDD), the process (IDM), and the format (IFC) of the information exchanged between project stakeholders.

bSDD   A BIM standard framework was developed to establish a consensus on standards that suited the project's use cases and requirements. Inherited from the bSDD mapping framework, SCHDRI's Dictionary Release Scheme (DRS) translated and unified the terminology of objects and properties used in the design stage. All technical terms were aligned with both national and regional encoding regulations. Each object was assigned a GUID, which acted as a unique language-independent serial number and ensured information could be extracted and maintained accurately without the risk of terms being mixed up.

IDM/MVD   A customised IDM was developed to define user-specific information
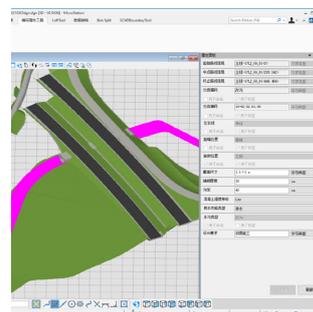
exchange requirements and to specify methods and processes of information exchange. This included, but wasn't limited to, a detailed solution design (i.e., MVD) supporting information exchange in software products and the handover standards for object coding, geometric modelling, attributes, materials, relationships, and information flows.

The IDM served as the basis for communications between domain experts (e.g. road, bridge, tunnel), software experts, and the BIM end-users for project management and software development throughout the project lifecycle.

IFC A wide range of authoring software tools were used for various design tasks in different disciplines. To overcome the lack of interoperability between the different BIM software, a suite of secondary toolkits and plug-ins were developed that used IFC. This allowed the native models to be exchanged, federated, and visualised in the CCDS serving as a Common Data Environment.

An IFC-CSV-BDMP conversion tool was developed to allow users to manipulate IFC data in bulk with CSV spreadsheets without requiring access to a 3D BIM graphical environment. This tool also enabled the IFC data to be transferred to the project's BIM Data Middle Platform (BDMP)—a central data platform housing all lifecycle data. The BDMP enabled IFC models for downstream applications to be exported to other third-party platforms via designated data formats.

The data format of this megaproject follows the IFC 4x2 schema, the national IFC platform specifications, and refers to the Chinese highway industry specifications. Where necessary, IFC extensions were developed for different types of bridges, roads, and tunnels.

Highlights

- Over 357,000 elements modelled and over 4.8 million properties within over 500 IFC files

- 10+ disciplines, with interoperability achieved via IFC

- openBIM-based IFC 4x2 extensions for highway structures were developed

- openBIM-methodology underpinned and streamlined the design work and

the information exchange processes by implementing bSDD, IDM, and IFC

buildingSMART openBIM Solutions

bSDD, IDM, IFC 4

Software Used

Autodesk AutoCAD, Autodesk InfraWorks, Autodesk Revit, Bentley lumenRT, Bentley OpenRoads Designer (ORD), Bentley Reality Modelling Software, Civil 3D, CloudCompare, Dassault CATIA, Faro Scene, including Hintsoft, MicroStation CONNECT (MS), software for processing 3rd party data, SuperMap GIS software

Result

The adoption of IFC models and other openBIM standards and workflows supported collaboration between all participants, increasing the interoperability, transparency, and reliability of data exchange. The time and financial costs of manual data processing were significantly reduced, while information quality was drastically improved.

Leveraging standardised openBIM concepts not only added value to the project lifecycle management, realising cross-platform and cross-phase data flow, it also provided the project team opportunities to harness available technologies and innovate new applications.

> *"the bSI Award helped us reach more international recognition and visibility. Looking forward to staying with openBIM standards and scaling up our innovative processes to really propel our organization and the global highway industry forward."*

Ruodan Lu, Sichuan Highway Planning, Survey, Design and Research Institute Ltd.

FINALIST

openBIM, Essential for Major Infrastructure Project Delivery

CBGU (CPB, BAM, Ghella and UGL) Joint Venture in collaboration with Willow, Australia

About the Project

Cross River Rail (CRR) is a $5.4 billion investment by the Queensland Government to deliver a new 10.2 km rail line through Brisbane, which includes 5.9 km of twin tunnels under central Brisbane, four new underground stations and eight newly rebuilt above-ground stations. Construction works are currently underway, and passenger services are due to commence in 2025. CCR is expected to be the largest transport project ever built in Queensland.

In addition to native file formats, the client, Cross River Rail Delivery Authority (CRRDA), has mandated IFC models as a deliverable, clearly demonstrating their intentions to promote the use of open file formats. The approach was developed to help overcome the inherent challenges that large infrastructure projects face relating to information exchange across a large range of software from various vendors.

Core Objectives

To unlock a transport network bottleneck at the core of the Brisbane transport network while embracing openBIM principles.

Project Description

The CCR project is divided into three major works packages: Tunnels, Stations and Development (TSD), Rail, Integration and Systems (RIS) and the European Train Control

System (ETCS). CBGU D&C JV (CBGU), a joint venture between four partners, was appointed as the principal design and construction contractor for the Tunnel and Stations package.

Although the client mandated the adoption of the IFC standard for CRR, CBGU independently recognised the value in applying the openBIM methodology due to the wide range of different software platforms to be used and their lack of interoperability.

To ensure effective use of the IFC format, CBGU drew on previous experience to identify the challenges in applying the IFC 2x3 version of the schema (as mandated by the client) in infrastructure projects. CBGU emphasised the importance of having the IFC file export correct from the outset as it would ultimately be used as a first source of truth for design collaboration, model data auditing, quantities take-off and costing and site set-out.

CBGU faced two key issues in delivering suitable IFC models:
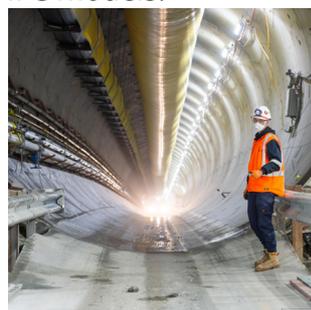
IFC models:

1. Consistency in the metadata of the export – which was overcome by CBGU providing project-specific export settings to all the consultants and an IFC sample file with the

metadata structured in a standardised way.

2. Quality in the 3D modelling practice to match the construction sequencing and processes. While not an openBIM-related issue, the problem was generated in the authoring tool and picked up by the survey team trying to use the IFC files for site set-out.

Once these issues were addressed, usable IFC models were produced that enabled embedded asset information comparison between disciplines and compliance checking using a model auditor Power BI dashboard. Automated processes were established to allow the auditing of embedded asset data from more than 330 IFC models containing more than 650,000 modelled elements across disciplines such as mechanical, electrical and plumbing (MEP), utilities, architecture, civil and structural.

Today, the model auditor is used by all consultants to measure the progress of their asset information requirements per discipline and project phase. It is also used by CBGU's

digital engineering team to ensure the consultant's performance is tracking at an acceptable pace. The same auditor is also used by senior leadership within the project team as a verified and empirical, data-driven metric to assess earned value vs amount invoiced.

Highlights

- IFC file format mandated by the client as a contractual requirement for design, construction, handover and service phases

- More than 330 IFC models containing more than 650,000 modelled elements across multiple disciplines

- Automated processes established to audit embedded asset data in IFC models for progress and performance tracking

buildingSMART openBIM Solutions

IFC 2x3

Software Used

12d, AGACAD Cut Openings, Autodesk Navisworks, Autodesk ReCap, Autodesk Revit, Bentley OpenRail, Bentley ProjectWise, Bentley Rail Track, BIMFlow, Civil 3D, CostX, dRofus, Dynamo, Esri GIS, Feature Manipulation Engine (FME), Grasshopper, iConstruct, Microsoft Office 365 Suite (SharePoint, Power Automate), Power BI, Revizto, Solibri Model Checker, Structured Query Language (SQL), SYCHRO Pro, Teams, Tekla Structures, Trimble Total Stations

Result

Once the right processes were established and implemented, openBIM effectively brought down the barriers of interoperability typically encountered when dealing with various design authoring ecosystems. Coupling this with automated workflows, design teams were able to share and interact with each other's designs in close to real time. This brought many benefits beyond contract compliance, including risk reduction and improved certainty, 3D coordination and validation across more than 650,000 modelled elements, standardised deliverables and information capture, greater transparency around design quality and asset information development, enhanced constructability support and future handover and asset maintenance/management.

"It's clear that the use of openBIM was critical to achieve the extremely stringent information requirements on a project of such magnitude as Cross River Rail TSD and has been essential to collaboratively engage with stakeholders across a broad spectrum of party involvement."

Matthew Boynton, Floth

FINALIST

Santiago Bernabéu Stadium Refurbishment Project – An openBIM Workflow

FCC Construcción Madrid, Spain

About the Project

The 81,000 seat Santiago Bernabéu football stadium, home of Real Madrid F.C., is undergoing a major transformation led by FCC Construcción. The scope includes a new façade, a retractable roof, a 360° video scoreboard, an expansion of the stadium to the west, new leisure offers, a new logistics ring inside, and the improvement of surrounding areas.

The design and build phases of the project will take 40 months and is due to be completed in 2022. It involves over 50 companies and covers 150,000 m2 of stadium space and 25,500 m2 of public space. The estimated project cost is more than EURO 450 million.

Core Objectives

To employ new digital tools, openBIM technology and a collaborative, multi-disciplinary and multi-user workflow to deliver the extensive scope of the stadium's state-of-the-art refurbishment megaproject.

Project Description

Given the extensive scope and size of the stadium refurbishment project, it was essential to its success that all stakeholders were able to work in a coordinated manner with access to the latest information. Therefore, an openBIM methodology was implemented with a view to achieving reliability, interoperability,

collaboration, and flexibility in the project.

At the beginning of the project, exchange information requirements (EIR) were established with a focus on facilities management. As the client, Real Madrid, will use a BIM-friendly computerised maintenance management system (CMMS) that uses IFC in the operation and maintenance phase of the stadium's lifecycle. Additionally, the project team developed a 700-page BIM Execution Plan (divided into design and build) and two accessible Common Data Environments (CDE) also separated into design and build.

Throughout the project, openBIM standards were used for information exchange (IFC) and coordination (BCF) between over 30 different companies and for ten distinct BIM uses. These BIM uses included design authoring and design revision, model coordination, existing conditions modelling, record model, structural, MEP and CFD analysis, digital fabrication, 4D, and 5D.
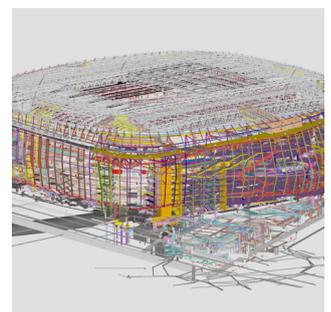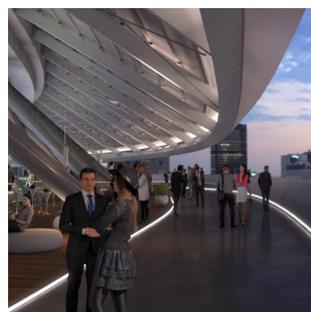
Information exchange

The IFC standard enabled information exchange between the main software used in both the design and construction phases, as they could export and import the models in the format. The most common flows was between Tekla, Revit, and Solidworks, with the federation of models in Navisworks. The information exchange was done using IFC 2x3 and the Coordination View MVD.

Coordination

Effective collaboration was the only way to successfully develop a project of this complexity. Therefore, BCF files were used and managed through BIMcollab collaborative platform for coordination and clash detection. This approach provided all team members with up-to-date information about the status of the project, helped to manage the complex fragmentation of the model's issues, facilitated traceability of issue resolution, improved communication between disciplines, and enabled issues to be solved quickly and efficiently.

Highlights

- Over 150 native models, 70% of which were exported as IFC files
- Over 500,000 structural IFC elements
- BIMcollab used as the main coordination tool, with over 2,500 BCF issues
- 127 versions of the federated model
- Two CDEs (design and build) with over 150 users from over 30 companies
- Two BEPs (design and build)
- Multiple BIM uses by12 disciplines using over 20 different software

buildingSMART openBIM Solutions

BCF, IFC 2x3

Software Used

AutoCAD; Analysis: ETABS, Bexel; 5D: Presto, Bexel; 6D: Verity; 3D Coordination: Navisworks, BIMcollab, Caneco BT, Cost-It, CYPE, CYPE MEP; 4D: Synchro, Design Authoring: Autodesk Revit, Dialux Evo, Fire Dynamic Simulator, Rhino, SAP2000, Solidworks, Tekla

Result

openBIM was identified as the most reliable and secure way to facilitate and optimise information exchange and coordination on a project of this size and complexity. As a result of the implementation of IFC and BCF, the project has benefited from deep coordination, improved communication and compatibility between the disciplines, deadline and cost optimisation, fewer errors in early project stages, and better information requirement compliance.

openBIM provided a solid foundaton with clear project objectives that were established. This helped to avoiding misunderstandings and confusion, and and brought all stakeholders together with a common vision.

"The existing conditions, design and construction information needed updating on daily basis. This was all done with a challenging schedule whilst the stadium was still in operation. I believe this can only be achieved using openBIM and collaborative technology. The broad software ecosystem, with many BIM uses, makes the use of openBIM essential. The importance of working in a coordinated manner and having the latest information available to everyone, enhances the value of the CDE."

Óscar Liébana Carrasco, FCC Construcción Madrid
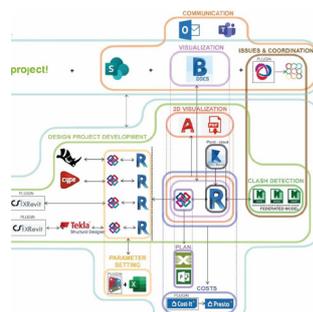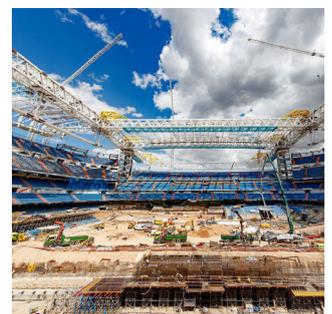
Grosspeter Tower: Performance Gap Analysis with Simulation

Siemens Schweiz AG, Switzerland

About the Project

This project by Siemens implemented an IFC model-based performance gap analysis in the building management system (BMS) of an existing high-rise building, Grosspeter Tower, Basel Switzerland, by comparing the real-time values to the predicted values from a simulation tool that was used during the planning phase of the project. The proof of concept focused on the temperature values as transmitted by temperature sensors on one floor.

Core Objectives

The goal of the project was to enable a client or operator to identify areas where building performance optimisation is required by visualising the gap between the simulated as-designed building performance and the real-time building performance.

Project Description

To identify opportunities for building performance optimisation, target/actual performance comparisons—or so-called gap analyses—could be achieved. This requires real building values on the one hand and simulated or target values on the other to calculate the discrepancy between the two.

In this project, the architectural simulation model and building management models of Grosspeter Tower (in IFC 2x3 format) were integrated into the

BIM viewer (Desigo CC) of the BMS. In alignment with the buildingSMART Use Case Management Service "Auszug Elemente Gebäudeautomation" (Automated Building Element Extraction), the unique system asset ID (AKS) from the planning stage were used to pass information between the simulation tool and the BMS. The ID keys created a link between the real and simulated world and enabled collaboration with other project stakeholders, such as planners, electricians and the facilities management team.

In the common data environment (CDE), each data point was connected to a BIM object, the simulation data, and the live values obtained from temperature sensors, as represented by IfcSensor in the model. The resulting data points were visualised on the BIM Viewer (using IfcSpace) to show the gap value between the live data and the simulation data using a colour gradient in a 3D floor view of the respective rooms.

The IFC (IfcSpace) was parameterised with the
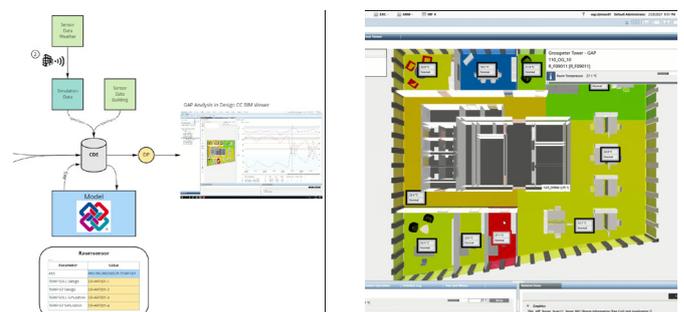
use cases using the CDE and imported into the IDA ICE (Indoor Climate and Energy) simulation environment from the software company Equa via the IFC import interface. The pre and post-processing took place in the authoring software Revit. The quality assurance of the input data was first carried out with the help of Simplebim and then with Solibri. The simulation results were analysed using Python scripts (model-based data analysis), visualised in Python and Revit (model-based data visualisation) and exported from Revit as IFC in Trimble Plancal Nova for building services planning. In the process, both the heating and cooling capacity required for dimensioning and the expected indoor climate were passed on.

Integrating the simulation tool into the building management platform environment allowed live data from linked systems to be fed back into the simulation. This enables continuous improvement of the simulation and even enables operational improvement opportunities to be predicted. As the building can be optimised by the simulation, and the simulation can, in turn, be improved by data from the building. This results in a symbiosis between the two systems with the digital twin in the BIM viewer at the centre.

Highlights

- openBIM methods and the IFC 2x3 format were used in the design and integration of the simulated and actual 3D model data

- Target and actual building energy efficiency performance values were compared to conduct a gap analysis

- IfcSensor used as a transfer medium between the simulation and actual values

buildingSMART openBIM Solutions

IFC 2x3

Software Used

BIM 360, Equa IDA ICE, Plancal Nova, Revit 2019.2, Siemens Desigo CC, Simplebim, Solibri

Result

The processes explored in this project brings the simulated (as designed) world together with the real world in one digital medium that allows the

operator to identify and inform their operational decisions using the IFC model.

The standardised and open IFC schema meant that it was possible to translate and represent the designed, simulated, and real worlds in one consistent digital form within the IFC structure to provide the operator with a clear visualisation of Grosspeter Tower's relative performance.

Further, the use of IFC models during the planning stage added value to the project through better and faster data availability regarding simulation boundary conditions and related simulation results, more transparent communication of decision-making for building use and internal loads, and business savings through optimisation and automation of the planning process. This has led to a holistic increase in quality and accuracy of the expected building behaviour and lower error costs in planning.

*"Model-based performance gap analysis brings the simulated, designed world together with reality in one digital medium that allows the operator to identify and inform his decisions u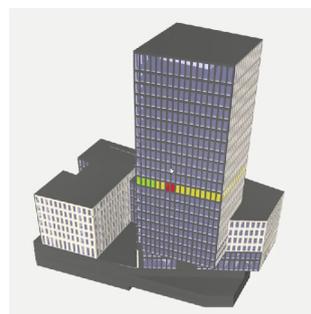sing the IFC model. The main added value in planning phases using IFC models was the better and faster data availability regarding simulation boundary conditions and related simulation results."*

Werner Fehlmann, Siemens Schweiz AG

2013
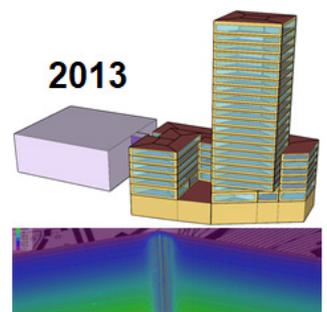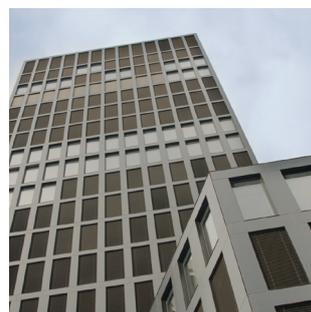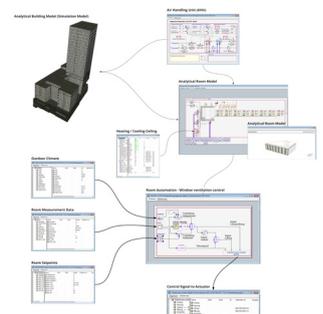
FINALIST

An Ecosystem of Digital Twins - Kampusareena

Granlund Oy, Finland

About the Project

Kampusareena is a multifunctional building serving all faculties of the Tampere University of Technology in Finland, as well as companies and research institutions operating on campus. In addition to the university campus library, student services and restaurant services that operate on site, there are meeting, working, and teaching facilities in the building. The facility has a total area of 13,706 m2 distributed over eight floors.

To improve the facility management of Kampusareena, Granlund Oy used the building as a pilot project for their BIMLIFE platform, an ecosystem of digital twins built on openBIM standards.

Core Objectives

The BIMLIFE project aims to develop a world-class BIM-based digital platform for the lifecycle information management of building assets.

Project Description

Managing and operating facilities is a complex process and involves many different stakeholders with very different sets of goals and objectives. To help overcome these complexities, Granlund developed their BIMLIFE platform using openBIM standards and digital twins. The platform enables different tools employed by various users in the operations and management of buildings to exchange information seamlessly from design to operations.

Kampusareena was selected as a pilot project to test the BIMLIFE platform. It was agreed with the client to integrate the existing automation and maintenance management systems with openBIM, focussing on maintenance and indoor air quality (IAQ) use cases.

Important in the development of BIMLIFE was the understanding of the different levels involved in managing building assets, namely strategic, managerial, and operational. With these different management levels in mind, four tools were developed to make up the BIMLIFE platform:

Portfolio benchmarking tool

This tool is a strategic decision support system for property managers that is flexible to changes that arise over the course of a building's life cycle and provides an interactive and dynamic user interface. The scope of the solution includes two common financial instruments used in the strategy level of building management: OPEX and CAPEX. In this
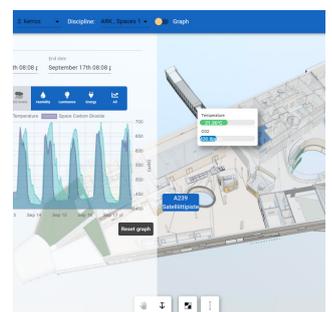
case study, the strategic goal was to reduce the operation and maintenance costs for one of the buildings in the portfolio.

Digital twin for building maintenance

At the managerial level, the digital twin was used to improve both the efficiency of the teams' performing operations and maintenance work and the efficiency of the technical systems. The tool has an integrated interface for accessing information about the technical systems, like heating, cooling, ventilation, water, gas, fire, and safety. These systems are represented digitally in BIM, integrated using IFC, and coupled with static and dynamic data about the building. Having all the maintenance data in single repository enables better planning of maintenance activities and identifying the root causes of maintenance issues.

Digital twin for indoor air quality

A second managerial tool uses the digital twin for improving and tracking the indoor conditions using real-time sensor data (temperature, CO2, humidity, lux levels) and feedback inputted by end users about the conditions (indoor air quality, noise, light, odour, ambience, design, quality of the furniture) within the building.

A colour-coded heat map quickly shows whether rooms are within, below or above predetermined targets, allowing building users to select the area where conditions are most suitable for their workday. The tool can also monitor room, floor, and occupancy levels, which can help to understand space usage and plan post-COVID return-to-work measures.

Augmented reality for facilities management (AR4FM)

This operational tool was developed to help field maintenance engineers plan efficient reactive and preventive maintenance routines. The tool's main feature is to visualise and provide static and dynamic information about the technical systems and equipment that are commonly not visible. It can be launched using mobile devices such as tablets and smartphones.

Highlights

- An openBIM-based platform enables seamless information exchange in the operation and management of building assets

- openBIM standards, such as IFC, were the primary information sources for developing the platform tools

- Digital twins used for maintenance and indoor air quality use cases

- Maintenance monitoring systems integrated with openBIM

buildingSMART openBIM Solutions

IFC 2x3

Software Used

AR4FM, ArchiCAD, Granlund Designer, Granlund Manager, Revit, SimpleBIM, Solibri Model Checker, Tridify, Unity

Result

openBIM was an essential aspect of the development of the BIMLIFE platform. IFC enabled the project team to exchange information between different tools, integrate with the building automation systems, develop the facility management use cases, and exchange and synchronise information.

Through the application of these openBIM tools, building maintenance teams will be able to improve the value and sustainability of real estate assets while increasing the satisfaction, health, and wellbeing of building users.

"An ecosystem of Digital Twins is a good approach to create value with the use of openBIM, and satisfy the needs of the different stakeholders in building operations."

Francisco Forns-Samso, Granlund Oy

WINNER

Foodstuffs North Island Headquarters and Distribution Centre at Auckland Airport
Auckland International Airport Ltd, New Zealand

About the Project

The Foodstuffs facility at Auckland Airport's The Landing Business Park is a new, purpose-built facility to serve as both the company's corporate headquarters and a distribution centre (80,000 m2 of floor area) for over 100 supermarkets. An adjacent and architecturally award-winning office building (8,500 m2 of floor area) was designed to accommodate approximately 1,000 Foodstuffs employees, along with a flexible ground floor design for conference, catering, and presentation areas.

Core Objectives

The main objective was to deliver a new, architecturally significant, and sustainable head office for Foodstuffs, adjacent to the new distribution centre, using BIM technology and processes throughout all project phases to promote efficient project delivery.

Project Description

The two projects, the distribution centre, and the office, were delivered by separate teams, with a BIM consultant coordinating the information exchange on behalf of the client, Auckland Airport. This role was critical to ensuring that all 22 discipline models aligned, and attribute fields were correctly structured.

A BIM execution plan was developed at the start of the project and clearly set out the goals of the project. One of these goals was an accurate and verified as-built model handover with asset attribute information requirements, as set out by the client for their eventual use in Asset Management/Facility Maintenance (AM/FM) in the building operations phase. Auckland Airport required these delivered models to be in IFC format alongside the native authoring files, rather than indicate a specific BIM authoring software for the disciplines to use.

Throughout the design and construction phases, delivery teams collaborated via regular model exchange using Revizto and updated models to reflect the as-built situation as the buildings were constructed. All native files were set up to align to a common survey control network, which ensured that each IFC discipline model output would correctly align without the need to translate models to the correct location in a model federation tool.

IFC files were delivered to the client via Aconex to
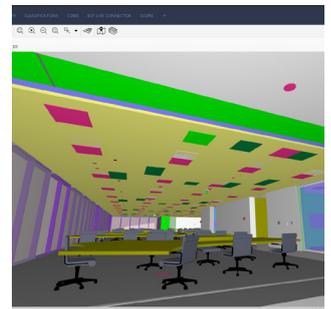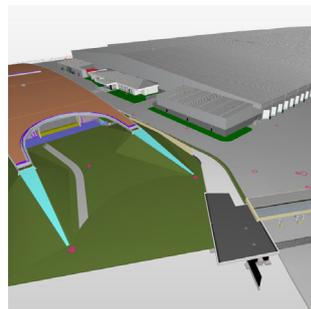
keep them informed of progress. Aconex enabled the models to be viewed via a web browser without needing desktop installations.

At project close-out, both the contractors and independent information managers meticulously reviewed the as-built models against what was constructed and went to great effort in ensuring models were updated accordingly. During this stage, 965 as-built issues were resolved in the BIM models.

The final models from the separate disciplines were geolocated to a national coordinate system and subsequently dropped into the correct location within the airport campus GIS model with minimal effort.

Highlights

- 22 different design disciplines across the two buildings and one significant land development package, with two construction contractors on site simultaneously

- Client mandated IFC deliverable in their Asset Information Delivery Manual

- Both projects were delivered ahead of schedule and under budget

- All disciplines produced BIM models, leading to a full as-built model deliverable

- Regular model coordination via a Project CDE and delivered to the client Project Document Management System (PDMS), Aconex

- On-site validation using mobile devices of models against the as-built construction

- First time using IFC as an information exchange format for most of the delivery team

- All parties were able to model in their preferred software ecosystem and contribute to a successful handover

buildingSMART openBIM Solutions

BCF, IFC 2x3, IFC 4

Software Used

Aconex, Autodesk AutoCAD, Autodesk Inventor, Autodesk Navisworks, Autodesk Revit, Bentley Prosteel, BIMcollab Zoom, Graphisoft Archicad, iConstruct, Revizto, Solibri Office

Result

openBIM brought value to the project as it enabled the project team selection to be based on the quality of their holistic tender proposal rather than the BIM software they used. It also enabled smaller firms, who are relatively new to BIM, to participate in the process using their existing toolset, eliminating the need for them to invest in new software and training.

In addition, the use of IFC enabled the relevant handover data to be consolidated to one custom property set with consistent attribute fields regardless of the modelling software used. This was the first time that an Auckland Airport project had mapped data to a common IFC property set for all model disciplines and resulted in a streamlined process for reviewing models.

By mandating IFC models as deliverables for this project, the Foodstuffs will eventually be able to choose whichever AF/FM system that best suits their specific user requirements rather than be beholden to using a system that works with native handover models.

"From the outset, the project teams worked towards achieving the requirements set out in our Asset Information Delivery Manual, which facilitates an openBIM approach and includes a full IFC based deliverable requirement. There was a great level of collaboration and innovation throughout all project stages, which led to a highly successful delivery of the physical assets and ultimately led to a trustworthy and detailed digital record of the built assets. This can now be used in the operations of the building with confidence that the data is well structured."

Karl Fitzpatrick, Auckland International Airport Ltd
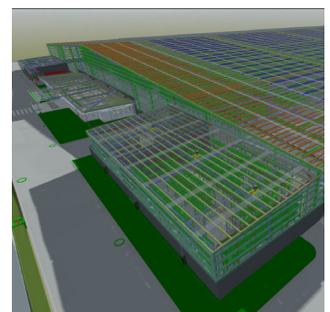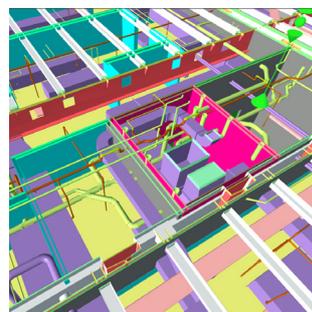
WINNER

openBIM: Opening the Gate for BIM and Blockchain Integration (OBBi)

The University of Hong Kong, Hong Kong

About the Project

There is great enthusiasm within the AEC industry for the potential for blockchain and BIM integration to overcome challenges arising from multiple parties working concurrently on collaborative BIM programs (e.g. cybersecurity risks, lack of single source of truth), as well as the information redundancy and massive data volume that result from file-based data exchange.

However, the integration of BIM and blockchain faces challenges such as lack of interoperability, information redundancy, and resemblance and swiftness of retrieving data. The project team, from the University of Hong Kong, harnessed openBIM to solve the interoperability issue and applied their Semantic Differential Transaction (SDT) method to solve the information redundancy problem.

Core Objectives

This research project aimed to take advantage of BIM and blockchain integration to solve challenges in building projects, such as communication, provenance and quality assurance, installation, traceability, lifecycle management and more.

Project Description

A prototype system integrating BIM and blockchain (called OBBi, openBIM and Blockchain Integration) was developed for managing AEC processes in a real-life building project in Hong Kong called the WCH project. In particular, it looked to manage

design changes, offshore production, cross-border logistics and supply chain, and on-site assembly.

This research adopted a threefold approach. Firstly, the in-house research team developed the OBBi system architecture, its major components, and interlinks. Secondly, the system was contextualized in bSI's openBIM ecosystem for implementation, with the core input-output format being IFC. Lastly, the prototype was tested and validated in the WCH project.

The OBBi system was designed to meet the demands of BIM users for the WCH project. Four vital layers were designed:

(1) Commercial BIM as the base model designed in Revit

(2) Web openBIM interface for the visualization of nD BIM in IFC;

(3) openBIM semantics-based server back-end for minimization of changed BIM components as SDT records; and
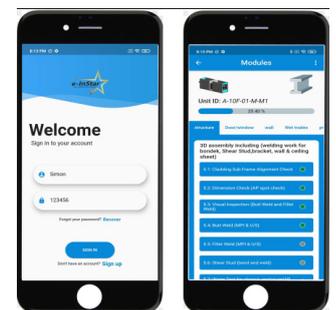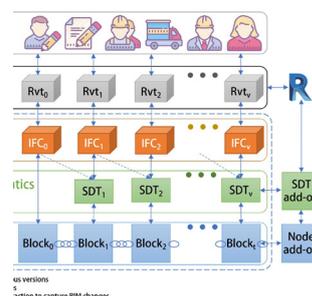
(4) Blockchain-based BIM data storage for the authenticity of BIM versions and changes on the blockchain.

The web-based openBIM interface displayed the up-to-date and historical BIM models during the WCH project. On the interface, a user could upload the latest BIM model, retrieve the recorded historical BIM at any timestamp, and contrast the changes between versions.

The BIM semantics back-end minimized the massive IFC files as incremental changes for blockchaining. Particularly, the Semantic Differential Transaction (SDT) model developed by the research team could differentiate the chronological changes and eliminate the information redundancy between IFC models. First, an IFC file was loaded as a hierarchy of openBIM semantics. Then, the "global IDs" of IFC components generated by Revit were de-randomized to compare their semantic contents. The resultant SDT records filtered out the unchanged IFC components and relationships.

A permissioned Blockchain 2.0 stored the initial version of the project BIM and all the incremental changes over time. A smart contract formatted the SDT records as encoded transactions documents. A permissioned blockchain channel shared the on-chain SDT records to the WCH project users via on-demand requests from the web-based interface. Alternatively, a permissioned user could also synchronize the SDT records via two Revit node add-ons that supported access to the OBBi system through the Revit environment and APIs.

With the three layers of openBIM blockchain and two Revit add-ons, the OBBi system can resolve the information authenticity and redundancy at the same time.

Highlights

- One of the first studies to employ IFC for blockchain and BIM integration

- Invented an innovative methodology to blockchain only the changes in the model to minimize data volume

- Developed a novel approach to retrieve information from the blockchain and restore it to BIM without time delay or information loss

buildingSMART openBIM Solutions

IFC 2x3, IfcJSON

Software Used

Autodesk Navisworks, Autodesk Revit, BIMVision, e-InstalStar, e-Instar, e-TranStar, Hyperledger, Solibri

Result

The project led to three significant and unique contributions: the tidying up the IFC for BIM and blockchain integration, the invention of an innovative methodology to blockchain BIM changes only and the development of a new approach to retrieve information from blockchain and restore it to BIM without time delay or information loss.

As a result, the key outcomes of the implementation were a high IFC compression ratio on chain—largely reducing information redundancy, lossless IFC encoding and quick restoration of IFC from the blockchain.

This is one of the first few studies that has truly harnessed the benefits of openBIM and IFC to integrate BIM and blockchain to enable various value-added uses of these technologies.

"The buildingSMART International Awards Program is a competitive but friendly program. I first experienced the ceremony in Beijing and decided that we should participate in it. I found it is particularly inspiring to combine the real-life AEC challenges with cutting-edge research findings, to connect practitioners with researchers, and to promote the value of openBIM in real world AEC applications."

Professor Wilson W.S. Lu, The University of Hong Kong

FINALIST

1 Information unit

2 Concept → IFC element

3 Concept-based MVD generation algorithm (Lee 2009)

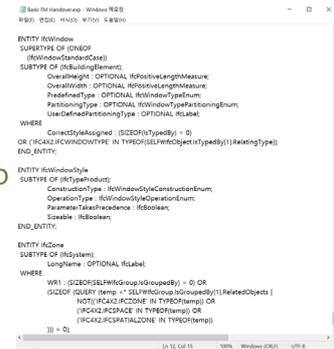IDM (ISO 29481-1, ISO 29481-3) bSDD (ISO 12006-3) MVD (IFC ISO 16739-1)

window window → ifcWindow

SCHEMA BasicFM;
ENTITY IfcRoot
END ENTITY
...
ENTITY IfcWindow
...
END ENTITY
END SCHEMA

```
ENTITY IfcWindow
  SUPERTYPE OF (ONEOF
    (IfcWindowStandardCase))
  SUBTYPE OF (IfcBuildingElement);
    OverallHeight : OPTIONAL IfcPositiveLengthMeasure;
    OverallWidth : OPTIONAL IfcPositiveLengthMeasure;
    PredefinedType : OPTIONAL IfcWindowTypeEnum;
    PartitioningType : OPTIONAL IfcWindowTypePartitioningEnum;
    UserDefinedPartitioningType : OPTIONAL IfcLabel;
  WHERE
    CorrectStyleAssigned : (SIZEOF(IsTypedBy) = 0)
OR ('IFC4X2.IFCWINDOWTYPE' IN TYPEOF(SELF\IfcObject.IsTypedBy[1].RelatingType));
END_ENTITY;

ENTITY IfcWindowStyle
  SUBTYPE OF (IfcTypeProduct);
    ConstructionType : IfcWindowStyleConstructionEnum;
    OperationType : IfcWindowStyleOperationEnum;
    ParameterTakesPrecedence : IfcBoolean;
    Sizeable : IfcBoolean;
END_ENTITY;

ENTITY IfcZone
  SUBTYPE OF (IfcSystem);
    LongName : OPTIONAL IfcLabel;
  WHERE
    WR1 : (SIZEOF(SELF\IfcGroup.IsGroupedBy) = 0) OR
    (SIZEOF (QUERY (temp <* SELF\IfcGroup.IsGroupedBy[1].RelatedObjects |
      NOT(('IFC4X2.IFCZONE' IN TYPEOF(temp)) OR
      ('IFC4X2.IFCSPACE' IN TYPEOF(temp)) OR
      ('IFC4X2.IFCSPATIALZONE' IN TYPEOF(temp)))
    ))) = 0;
```

Automated Generation of a MVD by Linking IDM and bSDD
Yonsei University, South Korea

About the Project

A team made up of researchers from the Building Informatics Group at Yonsei University, Cospec Innolab and BIM Peers created a machine-interpretable link between an Information Delivery Manual (IDM) and a Model View Definition (MVD) to avoid the need for manual mapping between IDM and MVD elements.

The new solution, xPPM-neo, employed idmXML and the buildingSMART Data Dictionary (bSDD) Application Programming Interface (API) to automatically generate an MVD from an IDM document.

Core Objectives

To improve and facilitate the IDM and MVD development process to make clear what information should be generated, managed, and submitted at each phase of a BIM construction project and how it can be used throughout the project's lifecycle.

Project Description

This study proposed a mechanism to directly link IDM and MVD through bSDD and address the absence of a proper data schema that makes an IDM document machine-readable. To do this, the team employed the newly developed IDM data schema (idmXML schema definition or idmXSD), which enables users to store, search, share, and exchange IDM documents and their contents.

Recently, this IDM schema was proposed as ISO 29481-3 and is currently in the Draft International Standard (DIS) phase.

The proposed solution was validated through the development of xPPM-neo, a new IDM configuration (authoring) tool, that allows a user to generate an MVD from an IDM document using idmXML and the bSDD API.

xPPM-neo consists of three components to support the use case, the business context map (including the process map and the interaction map), and the exchange requirements (ER) of the IDM, as specified in ISO 29481-1.

To automatically generate an MVD and validate the xPPM-neo solution using the exchange requirement (ER) section of IDM, the following steps were taken:

1. Specification of information units

The first step was to specify information units required to conduct the target tasks. In the ER section, the user can specify the information units
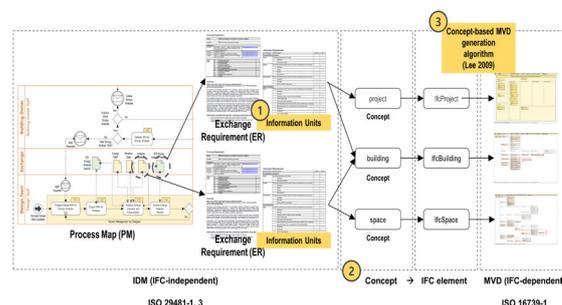
that they want. In the IDM data schema, the information unit includes name, data type, definition, external element, and example.

2. Linking ER and bSDD

The second step was to use the bSDD API to search for the IFC element (entity or property) that corresponded to the specified information unit. An advantage of using bSDD as a search engine was that bSDD could also find the IFC elements with synonyms in addition to the IFC elements with exact-matching terms. For example, if a user typed in "floor" to mean a concrete slab, bSDD will return "IfcSlab" as one of the candidates IFC elements for "floor".

3. Derivation of a full valid MVD from individual elements

The final step was to collect all the IFC elements matching the specified information units and automatically generate an MVD. Even if all the IFC elements that match specified information units were found, the collection of IFC elements were still far from a fully valid MVD because, for example, IFC requires supertypes and mandatory properties to be included in a valid MVD. To create a full valid MVD from the collection IFC elements, the concept based MVD generation algorithm previously developed by one of the project contributors (Lee) was used.

Highlights

- A new IDM authoring tool, xPPM-neo, was developed to recreate IDM documents in a machine-readable format, idmXML

- xPPM-neo linked the IDM and MVD through the bSDD API

- The solution helps to resolve the current slow and error prone MVD development process

buildingSMART openBIM Solutions

bSDD, bSDD API, IDM, idmXSD, IFC, MVD

Software Used

xPPM-neo (a newly developed IDM configuration tool)

Result

This study demonstrated the validity of the IDM

data schema as a linking mechanism between IDM, IFC and bSDD. Further, this study opened the possibility of linking IDM not only to IFC and bSDD, but also other standard data schemas including cityGML, gbXML, and openGIS by converting IDM documents into a standardized, machine applicable, readable, and transferrable (SMART) format through idmXSD. By automating MVD generation, the solution helps to resolve the current slow and error prone MVD development process.

"This study proposed Automated generation of an MVD by linking IDM and bSDD through IDM schema – idmXSD. Machine-readable IDM includes a mechanism to link information units in IDM and IFC elements in bSDD. Using Concept-based MVD generation algorithm, a generated MVD includes all specified IFC elements, supertypes, and mandatory properties. This study contributes to demonstrating the validity of the IDM data schema as a linking mechanism among ISO 29481-1 (IDM), ISO 16739-1 (IFC), and ISO 12006-3 (bSDD). Furthermore, the proposed study contributes to the open possibility of linking IDM to other standard data schemas through ISO 29481-3 (idmXSD)."

Seungwoo Son, Yonsei University

<ISO 29481-3 idmXSD>

.NET Framework 4.6.1
C#.NET

HBIM–SHM

BIM-based Structural Health Monitoring Platform for Historic Timber Buildings

Xi'an University of Architecture and Technology, China

buildingSMART Tools

IFC 4.1

Microsoft

SQL server

About the Project

Students from the Xi'an University of Architecture and Technology developed an automated BIM-based Structural Health Monitoring (BIM-SHM) platform to monitor the status of historic timber structures in real-time and to identify and eliminate damage risk factors. The BIM-SHM platform linked IFC models with real-time monitoring data from IoT sensors for further analysis to aid in conservation decision-making.

The project captured the relationship of historic timber building elements, damaged elements, and craft elements through ontological analysis and established a rule expression framework for historic building attributes through the Semantic Web Rule Language (SWRL).

Core Objectives

This study seeks to solve the lack of digital representation and digital preservation of the remnants of historic Chinese timber buildings.

Project Description

Chinese historic buildings are dominated by timber structures, and the extensive use of wood has become a weak point in their longevity. Adverse factors such as material degradation, long-term loading, biological erosion, and human activities leads to damage that threatens the safety and stability of these structures. Current conservation techniques are primarily post-event protection,

that is, repaired after destruction.

The combination of BIM technology and Structural Health Monitoring (SHM) can serve to unify the management of multi-source monitoring information and update BIM models of these historic timber structures with real-time monitoring data. This enables repairs to be made in response to damage monitoring thresholds being reached rather than in response to severe damage observed after it occurs.

In developing a solution to bring together BIM and SHM, the team initially analysed the logical relationship between different concepts and divided the ontology into knowledge in the field of historical buildings into three parts: entity, craft and damage. They then used Protégé software to establish ontology models for them.

Second, the team used SWRL to express historic building construction rules and damage rules. In accordance with the ontology model and the SWRL expression mechanism, the IFC standard was
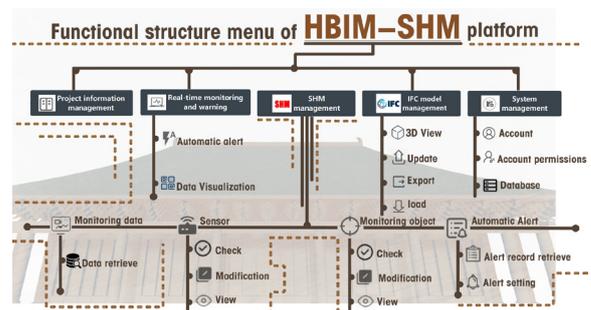
extended to accurately express the information related to entities and damage of historic timber structures.

In the third stage of research, C# programming, SQL Server, IoT monitoring technology and a comprehensive evaluation method for the overall health of historic buildings were combined with the IFC historic building entities and damage expressions to create an automatic health monitoring and early warning platform. This platform, named "BIM-SHM platform", was developed using the xBIM NuGet package and provides several functions, including management of the monitoring system, visualisation of the monitoring data, real-time sensor monitoring and automatic alarm triggering, automatic updating of the IFC model with monitoring data and importing/exporting the IFC model.

Using the ChengHuang Temple in Xi'an as a case study, a BIM model was created in Revit from the point cloud captured by a laser scanner. Then, the IFC file exported by Revit was transmitted to the BIM-SHM platform. The platform outputted the IFC model with the monitoring information, as stored in SQL Server, which was collected from environmental and pressure IoT sensors already installed in the ChengHuang Temple.

The BIM model with monitoring information was imported into Abaqus and Ansys Fluent to analyse the environmental and mechanical data for use by the historic building repair, maintenance, and management personnel.

Highlights

- The development of a BIM-SHM platform offers a new solution for ancient building inspection

- Creation of an SWRL language and ontology model of ancient building processes, restoration and damage

- Established a framework for representing the damaged elements of historic buildings under the IFC standard.

- Created a traceable repair process for ancient buildings by loading the monitoring data into BIM models

buildingSMART openBIM Solutions

IFC 2x3, IFC 4.1

Software Used

BIM-SHM (developed by the project team), IfcCheckingTool, Protégé, Revit, SPARQL, SQL Server, Visual Studio, Xplorer

Result

The application of the openBIM methodology in the development of the automated BIM-SHM platform has led to a powerful, intelligent system for the operation and maintenance of historic timber structures. Compared with the existing non-destructive damage detection methods, the BIM-SHM platform can monitor the health of historic buildings in real time with a greatly reduced human workload and material resource requirement.

"This project got three highlights of openBIM. In the early stages of the project. By the establishment of an ontological framework for the damaged and restored elements of historic buildings, the foundation for the subsequent establishment of IFCOWL was prepared. In the middle stages of the project. By the addition of degradation elements of historic buildings in the framework of the IFC, the gap in the sector has been filled. In the later stages of the project. The completion of the HBIM-SHM platform has not only changed the time-consuming and laborious situation of traditional inspection work, but also greatly improved work efficiency."

Kevin Hu, Xi'an University of Architecture and Technology

The IfcInfraToolKit

The Technical University of Munich (TUM), Germany
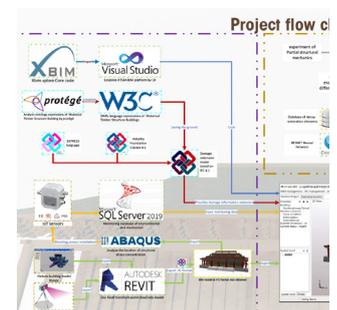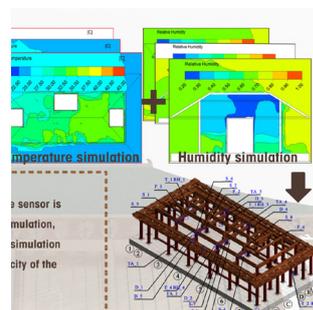
About the Project

This project takes existing authoring tools to develop IFC models using Visual Programming Languages (VPL) and tests the new IFC schema release, IFC 4.3, on real-world projects. The models were used to test and validate initiatives of the buildingSMART International InfraRoom Infrastructure Extensions Deployment project as a community benefit.

Core Objectives

To generate sample models covering new IFC entities and new schema versions recently introduced by IFC schema extension projects. Specifically, the project seeks to enable rapid and user-friendly validation of IFC models for storylines formulated in the IfcInfraDeployment project (buildingSMART International InfraRoom).

Project Description

Extension projects, such as the IFC 4.3 Infra Extension Deployment project, require the creation of prototypes and unit tests to verify the concepts proposed using a platform-specific conceptual model. A conceptual model formulates the collected end users' requirements and maps them to the IFC-based data specification. Thus, the conceptual model helps to identify which use cases can be already covered by extending existing entities. Furthermore, it helps the technical experts define new entities and properties to ensure that

the schema extension proposal ultimately matches the needs of end-users.

During any development and validation phase of a standard, it is crucial to get feedback from future end users and test newly developed entities with sample scenarios from the targeting domains. Such testing tools should enable the user to unlock the full power of the schema extension proposal and have few limitations in their configuration sections. At the same time, the testing suite should remain usable, without the need to know how to program or compile processes for source code.

To this end, this project from the Technical University of Munich (in collaboration with Autodesk) identified the application of visual programming languages (VPL) as a means to dynamically compose information stored and exchanged in an IFC-based BIM model. This use of VPL enabled users to create complex procedures without compiling source code or running development environments on their machines but instead assemble visual components (nodes and
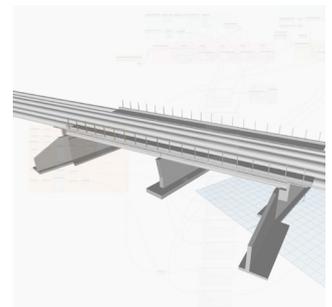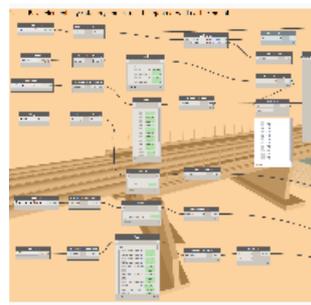
edges) on a canvas. To do so, the user specifies the information exported into the resulting model by dragging nodes. Each node covers a specific concept of the IFC data specification, such as creating new components or attaching specific geometric representations to elements.

The project authors adopted the VPL application Autodesk Dynamo and implemented a VPL-based toolkit, which helped to compose IFC 4.3 models using the latest extensions. The Dynamo library exposed a set of nodes that could interactively compose IFC models and modify the model content without touching source code.

The prototype toolkit was applied to several storylines (i.e., real-world sample test sets) formulated within the InfraDeployment project. This included the creation of IFC 4.3-compliant sample models for bridge storylines from infrastructure design firm HNTB as a comprehensive coverage test.

At the beginning of the testing phase, relatively small scenarios were tested, such as creating simple spatial structures or a single IfcBuiltElement. Once basic functionalities, like constructing a model skeleton with all mandatory items, worked properly (unit assignments, instantiating appropriate geometric contexts, etc.), advanced situations were implemented, and more comprehensive datasets were processed.

The resulting models, developed using the VPL-based toolkit, will assist other implementers in exploring and understanding IFC 4.3 concepts, support the definition of new concept templates, and showcase new entities and geometric representations of real-world scenarios.

Highlights

- A VPL-based toolkit was developed to modularize the assembly IFC 4.3 models using existing authoring tools

- Combines new schema development with user-friendly validation prototyping

- Allows interactive composition and modification of IFC models without touching source code

- The composition of IFC-based concepts in an interactive design environment was found to be flexible and easy to understand

buildingSMART openBIM Solutions

IFC 4.3

Software Used

Autodesk Dynamo for Civil 3D, Autodesk Dynamo for Revit, Autodesk Dynamo Sandbox, BIM Vision, GeometryGymIFC: NuGet package for. NET frameworks, Visual Studio 2019 with .NET Framework environments

Result

This project's prototypical implementation has showcased the application of Visual Programming Languages (VPL) for composing IFC-based domain models. The approach has been implemented and validated as a successful and promising methodology. The ability to compose IFC-based concepts in an interactive design environment was found to be flexible and easy to understand, particularly for unit and coverage test and provided valuable feedback for the IFC 4.3 project.

"The buildingSMART awards program allowed us to present and discuss our recent discoveries in our research activities with a diverse audience of industry experts, practitioners, end-users, and software developers. Therefore, it is a great platform to present and discuss our shared goals: to provide the AEC industry with better collaboration and data exchange."

Sebastian Esser, The Technical University of Munich
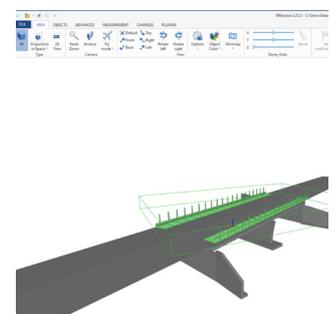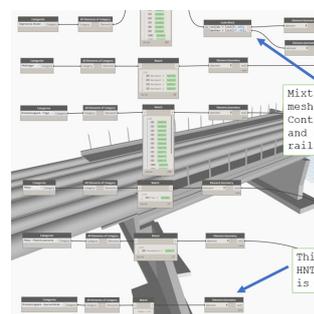
FINALIST

Innovative Building Management System Through Dynamic Digital Twin
The University of Rome, Italy

About the Project

This master's thesis project from the Faculty of Civil and Industrial Engineering at the University of Rome "La Sapienza" developed a new Building Management System (BMS) solution that brings together the dynamic data from smart devices and the static data of a digital twin.

The author used the IFC format as a vehicle to merge data gathered from monitoring devices to BIM objects via a cloud platform.

Core Objectives

To improve the user experience of Building Management Systems by visually contextualizing data from monitoring devices in a building's digital twin.

Project Description

The monitoring of data from different functions within a building, such as security, energy consumption, state of the systems (mechanical, electrical, etc.), often requires different systems and software. The data derived from these BMS's are typically displayed on dashboards that show both the status of the devices and the commands for their control. However, this data is rarely contextualized in a building model, making it hard for building managers to locate the monitoring devices.

This project proposed to connect the digital monitoring data to the digital twins of buildings to create "Dynamic Digital Twins". Using a digital twin as the basis for dynamic data visualization helps to overcome data contextualization by linking BIM objects to real-world devices and extends the life of the otherwise static digital twin into the operation and maintenance phase of the building.

The researcher applied the concept of a Dynamic Digital Twin to the DIAEE (Department of Astronautical, Electrical and Energy Engineering) building at the University of Rome "La Sapienza", with data collection focused on the monitoring and metering of electrical systems of the LAMBDA laboratory.

The complete implementation of the system required a four-step process. The first step was the generation of a digital twin of the building's electrical system using ACCA's Edificius' MEP function. The resulting virtual replica of the building was exported in IFC and then imported into usBIM.viewer+, which allowed editing of object properties and the addition of "dynamic
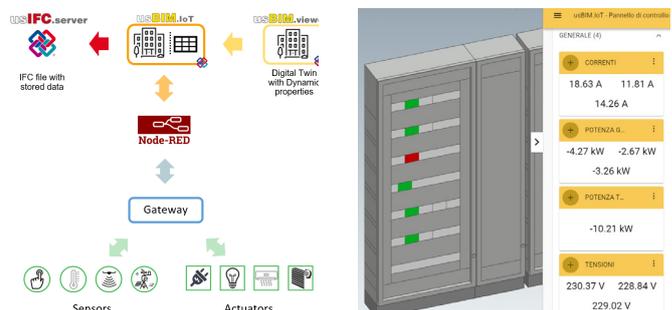
properties". The research team created dynamic properties to describe the smart characteristics of the devices, and their configuration depended on the communication protocol used by the device.

The second step was the communication system configuration between the real-world devices and the BIM objects in the digital twin. The configuration phase built on the communication parameters set in the design phase and used the open-source visual programming tool Node-RED to configure communication with the devices.

The third step was the operational phase, in which Node-RED gathered data from devices and sent them to the cloud-based platform usBIM.IoT, which provided a human-machine interface between users and devices.

In the fourth and final step, the gathered data in the usBIM.IoT cloud platform was stored inside properties of the objects in a new IFC file created by the usIFC.server on user demand. This new IFC file was based on the model created in the design phase but with the addition of the values and the information sent by devices.

Highlights

- A new Building Management System solution using a building's digital twin and smart devices
- The IFC schema used to link real-world monitoring data with BIM objects
- Improved user experience and monitoring data contextualisation in the management stage of a building's life cycle
- Royalty-free communication system based on an open-source programming tool

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IFC

Software Used

Edificius by ACCA Software S.p.A. (BIM design), Node-RED by OpenJS Foundation (data acquisition from the real-world devices), usBIM.IoT by ACCA Software S.p.A. (user interface and IFC reader), usBIM.viewer+ by ACCA Software S.p.A. (properties definition), usIFC.server by ACCA Software S.p.A. (background technology for IFC cloud editing)

Result

In this project, the openBIM IFC standard became the epicentre of data exchange for a series of building management and maintenance processes by enabling the contextualisation of building management data in a digital twin. The improved data contextualisation will allow managers or maintainers to operate a building more simply, leading to time and cost savings.

By applying the openBIM methodology, the solution developed in this project will support continuity between the design and management phases of a building's life cycle by using the digital twin output (in IFC) from the design phase without the need to build brand new model for a BMS.

"Data can be stored inside an IFC model creating a three-dimensional photograph of the building status at a certain moment. It is clear that openBIM, through IFC format, manages to connect design and management creating a continuity between the two phases. Besides, being the centre of the whole management system, IFC model becomes a unique landmark during the entire lifecycle of the building."

Luca Ciurluini, Master of Electrical Engineering Candidate
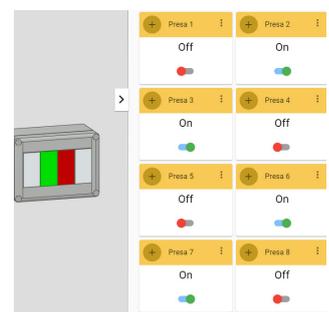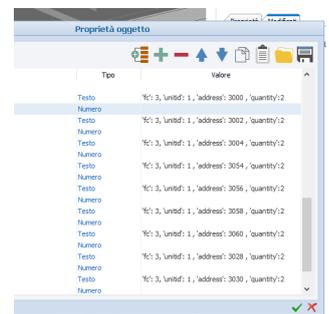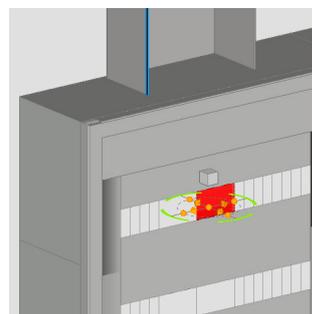
From Pixel to Pset: The Digital Structural Inspection
VCE Vienna Consulting Engineers ZT GmbH, Austria

About the Project

Through a collaborative effort between the corporate start-up STRUCINSPECT (Palfinger Structural Inspection GmbH) and VCE Vienna Consulting Engineers ZT GmbH, a technological solution was developed for the fully automated digital structural inspection of concrete structures.

The solution combines innovative technologies to automate the detection of structural damages (such as cracks, spalling, exposed reinforcement, corrosion etc.) and a novel approach to recording and presenting the results using IFC and BCF.

Core Objectives

This work aims to facilitate the digital structural inspection and maintenance management of concrete structures while promoting the wide-scale industry adoption of an openBIM based structural inspection process.

Project Description

The STRUCINSPECT platform (app.strucinspect. com) enables civil engineers overseeing structural inspections to manage the entire life-cycle process. As part of its advanced inspection services, the platform provides the user with a textured 3D mesh model of existing concrete structures by using photogrammetry to extract 3D information from photographs.

STRUCINSPECT uses neural networks with deep learning optimisation to analyse individual pixels of the high-resolution input images, a highly sophisticated method that produces very detailed outputs. Segmented pixels were produced from this AI damage detection process, in which the identified defects were identified, analysed, marked and documented. Defects were also classified according to the respective level of severity, dimensions, type and any other attributes required to describe the damage.

In addition to the segmented image, the output of the AI pattern recognition process comes in the form of two ASCII raw data text files: one containing the geo-referenced 3D points defining the contour polyline of the damage, and the other containing the damage attribute metadata.

Using the Python IfcOpenShell, these two raw data sources are transformed into a highly detailed, information rich IFC 4 model (with all associated attribute information stored on the appropriate Pset).
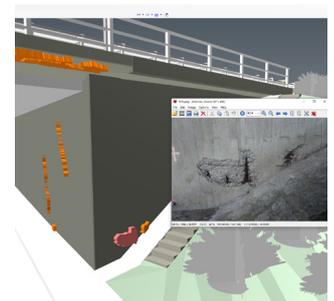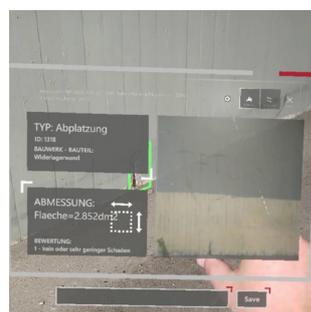
Each IFC model depicts the structural condition of the object at that moment in time. When the IFC structural inspection models are superimposed over the 3D geometry (3D mesh model, BIM model or point cloud), the user is provided with an instant understanding of the damages and the structural condition of the object.

In a parallel process, the raw data is converted to BCF, and the solution automatically generates a BCF damages catalogue using a custom Python tool.

This allows comments and damage updates observed in the field during interim inspections by an engineer to be entered into a tablet-based BIM model and transfer the inspection update back to the BIM model/STRUCINSPECT platform through BCF synchronisation.

The solution is now fully operational and has already been implemented successfully with several large clients, including public infrastructure operators, structural engineering consultants and asset management service providers.

Highlights

- Fully automated digital inspection and analysis of damage to concrete structures using photographs and AI technology

- Solution returns output in the form of an IFC 4 BIM model and an accompanying BCF report

- Fully operational and is already implemented successfully with several large clients

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BCF, IFC

Software Used

BIMcollab Zoom, DESITE, Metashape, Python IfcOpenShell, Revit, Solibri Model Checker

Result

The STRUCINSPECT solution is ground-breaking on multiple fronts. It offers a new and innovative automated approach to structural inspections based solely on photographs. It provides a revolutionary alternative to a 2D structural inspection report in the form of an IFC BIM model, and it enables the "round-trip" of site-based inspection input from minor interim inspections

using BCF.

By using drones or telescopic lenses for conducting digital structure inspection, the solution can reduce labour costs, eliminate risk to engineers, avoid disruption to traffic caused by closing motorways, and improve damage recognition rates (as compared to visual inspection).

The choice of IFC as a BIM format is a software-independent, robust and sustainable format appropriate to the long lifespan of an infrastructure project. Widespread uptake of the STRUCINSPECT platform-based technology would provide the openBIM movement with a powerful new use case, a rapidly growing market and help consolidate its position as the most viable solution for BIM-based asset management.

"The openBIM formats, IFC and BCF, play key roles in our technology solution, as only they provide the accessibility and longevity guaranteed to outlast the lifespan of the structure itself. Our decision to integrate openBIM methodologies has enabled us to create an environment where all parties involved can take control over their data and workflows and retain sovereignty over their internal software solution."

Peter O'Brien, VCE Vienna Consulting Engineers ZT GmbH
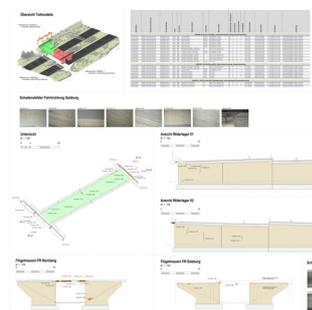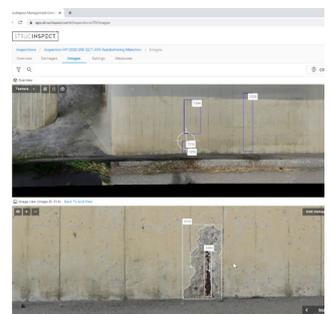
FINALIST

Collaborative Development of openBIM Technologies
Open Design Alliance, USA

About the Project

Open Design Alliance (ODA) is a not-for-profit technology consortium that develops interoperability solutions for the CAD and BIM industries. Through its unique non-profit business model, ODA has put forth a valuable new offering to the BIM industry: collaborative development of openBIM solutions.

ODA has developed a suite of openBIM technologies that allow companies to efficiently achieve high-quality compatibility with the latest IFC specifications.

Core Objectives

ODA's mission is complete interoperability for the engineering software industry through the collaborative development of high-quality, affordable programming toolkits.

Project Description

Historically, software vendors have implemented their own in-house IFC support in response to each new IFC version release. Doing so necessitates hiring and training developers, which consumes valuable development resources, as each IFC implementation must be independently tested and verified. Companies separately developing IFC support for their products in this way can lead to new IFC releases being supported at different times for different software packages due to varying internal resource availability, as well as differences and incompatibilities in their respective implementations.

In 2018 ODA initiated work on a more efficient solution for openBIM development in response to a member survey, in which 60% of ODA's 1,200 members expressed interest in IFC. Through ODA's collaborative model, member companies funded the development of a set of high-quality openBIM technologies, developed by full-time professionals, which could then be shared by all ODA members.

From this development, three openBIM technology components were produced. ODA IFC SDK, the primary openBIM component by ODA, is a cross-platform programmer's toolkit for software developers that can be quickly integrated into any application on all major platforms to achieve high-quality support for IFC import, export, and visualization. ODA Visualize SDK is a 3D visualization technology tightly integrated with IFC that can be integrated into any desktop, mobile or cloud application to provide fast visualization of large IFC models on any device.
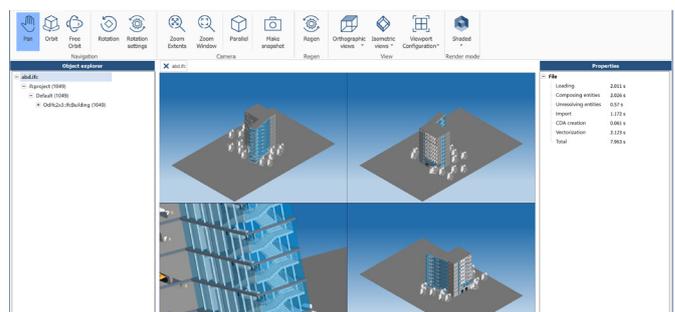
Open IFC Viewer is a free, stand-alone viewer that can be used to independently visualize and verify IFC models of any version and to quickly work with new IFC specifications as they are published by bSI.

The ODA approach to implementing openBIM is far less expensive for member companies than the cost of in-house IFC support development, and by using a shared solution, each member company benefits from the testing and verification done by all other companies. In addition, using the same underlying technology for IFC results in fewer errors and fewer incompatibilities between openBIM data created by different vendors.

The ODA model fosters faster adoption of new IFC versions by providing complete, professional implementations of new IFC versions in real time as soon as the specifications are published. The process of creating a new version of IFC is complex and involves a large number of participants from a wide range of companies and organizations, all working together to verify and refine the specification to ensure it meets industry needs. Fast availability of ODA implementations for new IFC release candidates allows interested parties to quickly integrate new IFC versions into their products, leading to faster verification of the new specifications, and a shorter development cycle for new IFC versions.

In this way, by the time a new IFC version is officially published, it will have been more thoroughly used and tested by more parties than in the past, and users of ODA technology will have a short, convenient, and well-defined process for upgrading to the new version.

Highlights

- Provides a complete and affordable solution for professional BIM interoperability
- Enables quick integration of new IFC releases into software products
- Full access to all data in IFC 2x3, IFC 4 and IFC 4.3
- Fully self-contained solution with no dependencies on third party components

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All IFC versions, BCF

Software Used

All software used in the project was developed by ODA

Result

Applying ODA's collaborative development model to openBIM has yielded a high-quality, low-cost technology solution that has been widely adopted by major industry vendors. This approach has benefitted the industry by enabling a shorter IFC development cycle, promoting faster adoption of new IFC versions by vendors, improving compatibility between vendors, creating higher quality IFC files and making the entire openBIM ecosystem more efficient and user-friendly.

"Partnering with the Open Design Alliance allows Autodesk to fast-track support for international data exchange standards like IFC. ODA allows the industry to share a joint kernel for openBIM workflows, providing a common language and understanding of data to improve interoperability."

Angel Velez, Autodesk
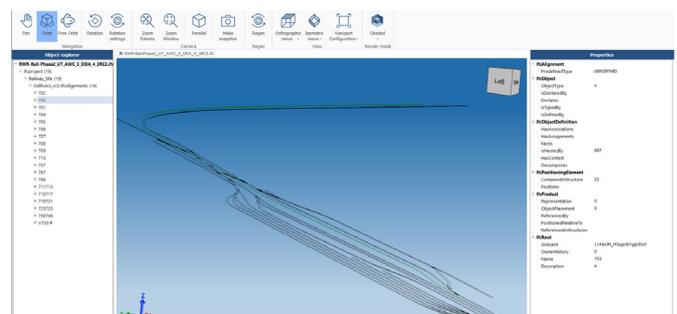
usBIM.ids

ACCA Software, Italy

About the Project

Italian software company ACCA developed the usBIM.ids, a solution that revolutionizes how information requirements from clients and owners are managed in the BIM process. This improves data workflows for many stakeholders and further enriches IFC models.

The solution is based on buildingSMART International's Information Delivery Specification (IDS) standard designed to better understand and implement requirements from clients.

Core Objectives

usBIM.ids was developed to solve a critical issue in the BIM process: the request and delivery of information in the IFC format for clients.

Project Description

buildingSMART International's (bSI) Information Delivery Specification (IDS) is a new open standard that will be used for the creation of a computer-interpretable document that defines the exchange requirements of model-based workflows. This document defines how objects, classifications, properties and even values and units must be delivered and exchanged. In effect, it expresses the Level of Information Needed (LOIN) by a specific IFC model.

As an active participant in the bSI IDS standard working group, ACCA developed their usBIM.

ids solution to support various stakeholders in using the IDS open format in software. usBIM.ids is entirely based on open formats, cloud technologies, and ACCA's own technology, usBIM. The solution consists of three modules that can work together or independently: creator, modeler, and validator.

usBIM.ids (creator) helps to create an IDS file based on the requirements defined by the client. To create the IDS file, exchange requirement data is entered into the creator module by the operator and/or imported from other formats like CSV or XLS. usBIM.ids can also access bSDD and take advantage of all its available features to enrich the model. Once the creation phase is completed, the IDS file is generated and delivered to the modeler via a Common Data Environment (CDE).

usBIM.ids (modeler) receives the IFC geometric model created by the modeler with their authoring software of choice and one or more IDS file(s) as inputs. When appropriately configured with the machine-readable IDS file, usBIM.ids (modeler)

THREE FUNCTIONS: creator, modeler, validator

shows all the property sets, IFC classes, and properties required for each IFC element. The operator uses the modelling feature of usBIM.ids to fill in the required data in compliance with the information requirements defined by the client. For each property, the user can enter only a permitted value as defined in the IDS, e.g. from a list of values or a value in a data range. Once the data modelling is completed, a new IFC file is produced containing all the information requested by the client in addition to the geometric data.

usBIM.ids (validator) receives both the complete IFC file of the model (geometry and data) delivered by the modeler and the created IDS files as inputs. The validator quickly checks the information quality of the IFC file. Any issues found are displayed on the dashboard of the platform and color-coded for easy analysis. usBIM.ids also produces appropriate reports or files in BCF, XLSX or CSV format for further use.

All the output produced by usBIM.ids (IDS files, IFC models) can be registered on blockchain to guarantee document authenticity and immutability over time.

The usBIM.ids solution has been tested in several projects by ANAS, which is part of Ferrovie dello Stato, the Italian Public Railways Group. Prior to the development of usBIM.ids, ANAS used to define the exchange requirements using Excel files but lacked a software tool to verify the correctness and completeness of the models produced by the contractors. It was also impossible to perform manual checking and validation given the large size of the IFC models provided by the contractors. usBIM.ids solves all these problems by enabling ANAS to validate IFC models in a matter of seconds rather than several days, transforming the way they work.

Highlights

- Solution based entirely on openBIM standards (IFC, IDS, bSDD, BCF) and cloud based
- First solution that supports stakeholders in using bSI's proposed Information Delivery Specification (IDS) standard
- Captures and configures exchange requirements in a machine-readable format for modelling and validating IFC models

buildingSMART openBIM Solutions

BCF, bSDD, IDS, IFC

Software Used

usBIM, usBIM.blockchain, usBIM.browser, usBIM.ids, usBIM.platform, usIFC.server

Result

usBIM.ids enables clients and stakeholders to clearly express their exchange requirements, something that was previously a cumbersome and error-prone process. It allows the level of information needs to be defined, enables predictable and reliable data exchange workflows, and makes it possible to automatically validate IFC models against client requirements.

"One of the most important aspects for the correct setup of a BIM tender is the need for clients to have a model governance that is smooth and in line with the objectives for which they are requested. With usBIM.ids, which implements the new buildingSMART standard (Information Delivery Specification -IDS), you can correctly define your Level Of Information Need (LOIN) within the Employer Information Requirement (EIR) and the BIM Execution Plan (BEP)."

Michelangelo Cianciulli, ACCA Software