Anaheim Regional Transportation Intermodal Center (ARTIC)

2014 AIA TAP / BIM Awards
ANAHEIM REGIONAL TRANSPORATION INTERMODAL CENTER
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The Anaheim Regional Transportation Intermodal Center (ARTIC) combines the heritage and civic importance of the grand 19th Century rail stations of the past with the size, scale and complexity of today’s modern airport terminals. ARTIC will be a world class transportation gateway to Orange County, California, the 5th most densely populated county in the United States. Each year, Orange County attracts more than 40 million visitors, Anaheim alone attracts more than 20 million visitors annually. ARTIC will link freeways, major arterial roadways, bus, taxi and rail systems, as well as bike and pedestrian pathways in one central location.

ARTIC will serve the transportation needs of a population of more than three million people in 34 cities. The project will include retail spaces, restaurants, ticketing and waiting areas, and will serve as a grand hall for community uses. It will anchor the Anaheim Rapid Connection (ARC), a high-capacity, fixed-guideway transit system. ARTIC will be the southern terminus of the California High Speed Rail which will link the State’s southern and northern urban centers. This mixed-use location will support four million square feet of office, commercial and institutional development and 520 residential units. Future development opportunities include revenue generation that repays local grant funds, Public/Private Partnership (P3) opportunities, economic benefits such as employment and sales tax revenue, and Transit Oriented Development (TOD) and mixed land use development.

ARTIC by the Numbers
• Size of terminal - 67,880 square feet
• Size of site - 16 acres
• Parking spaces - 1,082
• Expected daily boardings - 10,330
• Number of transportation modes - 10
• Annual Metrolink riders - 540,000
• Annual Orange County Visitors - 40 million
• Number of jobs created - 5,000
• ETFE square feet - 200,000
• Projected Cost - $188 million (US dollar)
The Anaheim Regional Transportation Intermodal Center (ARTIC) is a world-class, iconic gateway for Orange County’s transportation systems, including auto, bus and rail systems as well as future street car and high-speed trains.

ARTIC presents itself to the region in a dramatic fashion with its signature sculptural shape. The structural simplicity of local airship hangars, and the great halls of historic rail stations like Grand Central Station, inspired the design of this catenary-shaped station. High-tech translucent ETFE polymer pillows infuse the grand hall with a lightness and transparency.

The use of BIM was crucial in clearly communicating this iconic design to the clients, the public, and assisting the project team in developing the complex form, geometry and function into reality.

Utilizing Revit, Rhino and CATIA as the primary software along with Navisworks for pre-construction clash detection, the project team was able to produce 3D-printed study models, analyze pedestrian and vehicular traffic to ensure safe path of travel, confirm sustainable strategies to achieve LEED platinum certification, as well as delivering coordinated documents in a compressed timeline and maintaining design intent well into construction. The greatest benefit of BIM utilization on the ARTIC project is the coordination efficiency achieved during design and construction.
The BIM model was very significant to the general contractor and our sub-contracting community. The different styles and requirements of design could not be built without the BIM analysis and model.

Due to the complexities of the project utilizing GeoGrid dimensions, it would be impossible to coordinate locations without a model. The fabrication of the structural steel was designed with complex compound curves and the only means to fabricate this material is by the use of a model. Once fabricated the only means to erect with the tolerances was by using the geopoints. The as-built model is the only way to accomplish this task.

Interior of the building had to be managed and coordinated as we typically do with a model. The main difference is working with the exterior perimeter of the building where we move from GeoGrid to standard dimensions. This could not be accomplished without a model.
Using Building Information Modeling (BIM) for ARTIC, a first for the City, allows the City to have detailed facility information as never before. ARTIC serves as baseline for future benchmarking.

During design, the integrated approach using BIM allowed the design team to share more information and produce an iconic design for a memorable and sophisticated structure, designed to tight tolerances and employing advanced materials and systems. The detailed design information fed the cost estimate; bids came in well within budget tolerances.

Although not all traditional construction documents were produced using BIM, the experience will inform future projects in recording design criteria and standards, feeding future specifications, quantity/cost estimates, and sequencing/scheduling. The model’s information is useful for visual presentation purposes as well. The construction team employed Virtual Design and Construction with BIM for construction sequencing, just-in-time ordering and delivery, and other scheduling matters.

When the project is complete, the City and those directly involved with the facility, such as contracted property operators and managers, will have access to the integrated data for ongoing use in operations, maintenance/repairs, and overall asset management.
BIM Responsibilities

Architect: authors design model for coordination
Structural Engineer: authors design model; reviews coordination model
MEP Engineer: authors design model; reviews coordination model
Enclosure Engineer: authors design model and geometry model; reviews coordination model
Construction Manager: manages BIM coordination; performs model-based estimating
Plumbing Subcontractor: authors coordination and fabrication model
HVAC Subcontractor: authors coordination and fabrication model
Electrical Subcontractor: authors coordination and fabrication model
Steel Subcontractor: authors coordination and fabrication model
Curtain Wall and Metal Panels Subcontractor: authors coordination and fabrication model
Concrete Subcontractor: authors coordination and fabrication model

BIM USES
Design Authoring
Design Review
Design Coordination
Energy Analysis
CFD Environmental Simulation
Structural Analysis
Lighting Analysis
Cost Estimation
Programming
Clash Detection
Space Planning
Construction Sequencing
Data Exchange Diagram

INFORMATION EXCHANGES

DESIGN TEAM
- INTENS
- SMARTFORM
- ROBOT
- RADIANCE
- CUSTOM SCRIPTS VBA
- GRASSHOPPER
- ANSYS
- EXCEL
- CATIA

CONSTRUCTION TEAM
- REVIT ARCHITECTURE
- RHINO
- ACAD
- SAP 2000
- NAVIS WORKS 0C
- REVIT STRUCTURES
- REVIT ENVIRONMENT
- REVIT MEP
- REVIT PLUMBING
- REVIT HVAC
- REVIT ELECTRICAL
- REVIT CONCRETE
- CATIA ACAD ETE
- TEKLA STEEL
- ACAD CURTAINWALL
- ACAD CONCRETE
- NAVIS WORKS 0C
- EXCEL
- GEOGRID

ROLES

OWNER

DESIGN TEAM
- ARCHITECT
- MEP ENGINEER
- STRUCTURAL ENGINEER
- ENCLOSURE CONSULTANT
- GEOMETRY CONSULTANT
- SUSTAINABILITY CONSULTANT

CONSTRUCTION TEAM
- PLUMBING
- HVAC
- ELECTRICAL
- STEEL
- CURTAIN WALL & METAL PANELS
- LIGHTING CONSULTANT
- GC AND FRAMING
- CONCRETE
- ETFE
Design Visualization

In this project, the complexity and scale of the design and execution required a very diverse skill set. Achieving the project goals within budget was the feat of a large group of designers and technical experts.
Design Visualization

BIM models and animations were used to convey performance features to the design team and owner. 3D printing was exploited for physical verification of concepts.
Programming

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Structural Engineering

The ARTIC shell structure consists of diagonal grid of steel arches forming a complex diagrid building envelope. The geometry of the Shell, which affects both the structural efficiency of the building and its aesthetics, was developed jointly by the architect and structural engineers.
Diagrid Development

Design of the Shell 3D geometry were defined by formulas in Excel, then translated into CAD to form a 2D catenary profile that was used to generate a torus. The torus was trimmed to shape a building envelope as established by the architect. To form a diagonal grid pattern of the Shell, the envelope was cut by a series of planes.

\[
Y = A \left( \cosh \frac{X}{L} - 1 \right) \\
X = \frac{C}{L} \left( \cosh^{-1} \left( 1 + \frac{Y}{A} \right) \right)
\]

Where, 
\[
A = \frac{f}{\sqrt{2} - 1} = 68.7672 \\
C = \cosh^{-1} \left( \frac{Q}{Q_0} \right) = 3.0022
\]

\[
f = \text{Max. Ht. of Centroid} = 62.5925 \\
Q_0 = \text{Max. X-Sec. @ Arch Base} = 1262.6651 \\
Q = \text{Min. X-Sec. @ Arch Top} = 1255.1406 \\
L = \text{Half of Centroid @ Arch Base} = 299.2239
\]
A structural analysis model in SAP2000 was used to analyze the structural system to predict its responses and to determine internal forces, stresses, and deformations. Non-linear buckling analyses were performed to verify buckling stability of the structure as a whole.
Custom Interoperability Tools

The enclosure/geometry consultant used proprietary tools to generate geometry in multiple formats suitable for their purpose.
Custom Scripting for Automated Modeling

Due to the volume of components in the enclosure system, custom scripts were written to automate modeling. A “Geometric DNA” was defined and coded, this allowed multiple design iterations in minutes which traditionally would have taken weeks to model manually.
The enclosure team used many analytical tools to study the various components and element types, often employing proprietary tools to quickly parse, visualize and study large quantities of simulation data. Entire systems were modeled to ensure holistic fidelity with integrated systems.
Lighting Simulation

Multiple scientific lighting simulations were performed using BIM models to study performance and to mitigate possible glare issues.

Results: Lightwild Lumenpower Plus 2.1 Proposed design

**Inner Layer:**
- Clear, 10% Translucency, 100% Gloss.

**Outer Layer:**
- 80% Area of Silver printed material (Mat), 70% Translucency, 20% Glossy, Medium size lift.
- 20% Area of Clear material, 10% Translucency, 100% Gloss.

In the shell model used in this simulation the mid layer has been modelled as one piece across the whole area of the shell. The outer and inner surfaces are modelled as individual cushions.
Lighting Simulation

OVERALL RELATIVE SIGHT

10 Degree fixture angle

25 Degree fixture angle

509 508
1804 1796
327 329
1623 1614

3.94
4.96
Environmental Simulation

Analytical BIM models were employed for performance simulations of; wind, ventilation, comfort, energy, temperature, daylighting, shade.
Structural Detailing

Connection detail at Shell ridge

Connection detail at End wall column base
Complex Structure
CNC Fabrication

The North and south wall geometry data defines points for the front of glass, armature connection, column location, and secondary steel arcs.
Rationalization and Digital Fabrication

The side walls are defined by a translated polyline surface which defines planar segments. Key points that define geometry for the curtain wall are defined in the geometry data.
Erection Sequencing
Erection Sequencing

Stage 1
- MAT Foundation

Stage 2
- Half arch sections assembly
- Erect second arch

Stage 3
- Two half arch sections field welded together at ridge
- Temporary Shoring

Stage 4
Erection Sequencing

- **Stage 5**: Fill in the intermediate arch pieces
- **Stage 6**: Erect South wall arch with columns
- **Stage 7**: Fill in the intermediate arch pieces
- **Stage 8**:
Erection Sequencing

Stage 9

Stage 10

Erect North wall arch with columns

Stage 11

Stage 12
Erection Sequencing

Final Stage
Autodesk told the design team that it was problematic to model this project in Revit.
Geometry Coordination
Geometry Coordination

For design control and interoperability all components associated with the complex shell form were coded into what has become known as the "GEOGRID" by the build team. The 3d design was reduced to the simplest geometric elements, points and arcs, to convey exact design dimension to all stakeholders while remaining software agnostic. The approach was carried through to confirm as built survey.

| 400145 | DIAGRID ARCH POINT | GPT_A12_E_4 | -1259.565905 | 6911.951569 | 645.3308451 |
| 400146 | DIAGRID ARCH POINT | GPT_A12_E_5 | -1162.394745 | 6839.752198 | 432 |
| 400147 | DIAGRID ARCH POINT | GPT_A12_W_0 | -2051.0625 | 10138.46905 | 1314.63261 |
| 400148 | DIAGRID ARCH POINT | GPT_A12_W_1 | -2308.20355 | 10117.96766 | 1254.056789 |
| 400149 | DIAGRID ARCH POINT | GPT_A12_W_2 | -2521.492753 | 10066.8386 | 1102.982784 |
| 400150 | DIAGRID ARCH POINT | GPT_A12_W_3 | -2713.236848 | 9997.866315 | 866.6495434 |
| 400151 | DIAGRID ARCH POINT | GPT_A12_W_4 | -2842.559095 | 9911.951569 | 645.3308451 |
| 400152 | DIAGRID ARCH POINT | GPT_A12_W_5 | -2939.830255 | 9839.752198 | 432 |
| 400153 | DIAGRID ARCH POINT | GPT_A13_E_0 | -2051.0625 | 9955.872511 | 1285.233134 |
| 400154 | DIAGRID ARCH POINT | GPT_A13_E_1 | -1798.941387 | 9935.200498 | 1226.230288 |
| 400155 | DIAGRID ARCH POINT | GPT_A13_E_2 | -1889.563991 | 9883.652091 | 1079.994062 |
| 400156 | DIAGRID ARCH POINT | GPT_A13_E_3 | -1401.675537 | 9804.383009 | 852.6263733 |
| 400157 | DIAGRID ARCH POINT | GPT_A13_E_4 | -1273.28092 | 9728.61219 | 636.2462948 |
| 400158 | DIAGRID ARCH POINT | GPT_A13_E_5 | -1186.633777 | 9667.088807 | 432 |
| 400159 | DIAGRID ARCH POINT | GPT_A13_W_0 | -2051.0625 | 9955.872511 | 1285.233134 |
| 400160 | DIAGRID ARCH POINT | GPT_A13_W_1 | -2303.183622 | 9935.200498 | 1226.230288 |
| 400161 | DIAGRID ARCH POINT | GPT_A13_W_2 | -2512.561009 | 9883.652091 | 1079.994062 |
| 400162 | DIAGRID ARCH POINT | GPT_A13_W_3 | -2700.449683 | 9804.383009 | 852.6263733 |
| 400163 | DIAGRID ARCH POINT | GPT_A13_W_4 | -2826.84408 | 9728.61219 | 636.2462948 |
Construction
Construction

The build team is using BIM in their Virtual Design and Construction process. BIM is used for 3D coordination, visualization, cost estimation, fabrication, clash detection, construction sequencing, field coordination, procurement, and as built documentation.
Construction
BIM Standards were developed for the design phase through a BIM planning process. The primary models were divided into site, bridge, architecture, structure, MEP, enclosure, and geometry. Each team appointed a BIM coordinator to manage the process for their discipline. The design team designated a 3D process for construction quality assurance.
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