WHITEPAPER

Study Validates Use of Digital Twin Technology for Cell Tower Maintenance Workflows

Cell tower professionals with over 60 years of experience validate the use of OpenTower® iQ to generate accurate and actionable engineering data for cell tower owners and carriers

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INTRODUCTION

Digital twin technology delivers highly realistic 3D models of physical structures. However, the use of this technology has been limited to visualization and manual measurements. But what is less known is that digital twins are highly accurate and can be used to provide powerful operational and engineering workflow advantages for cell tower owners, operators, and carriers. In addition to updating equipment inventory and performing visual inspections, a digital twin can significantly reduce the time and cost by generating accurate data required for engineering automation.

This white paper explores the validation process used to confirm the accuracy of the data generated by a digital twin using OpenTower iQ, a purpose-built digital twin solution for telecom towers.

BENTLEY OPENTOWER IQ

OpenTower iQ uses the power of artificial intelligence (AI), machine learning (ML), and photogrammetry to produce a highly accurate digital twin model of an existing cell tower for planning, visualization, and inspection.

With it, cell tower owners, operators, and carriers have a single source of engineering truth that can be easily edited over time to maintain an accurate representation of the tower and its equipment.

OPENTOWER IQ ACCURACY VALIDATION

Bentley, in partnership with Consilience Analytics, sponsored a recent study where independent professionals actively sought to validate that OpenTower iQ delivered data of sufficient accuracy and precision to be used in cell tower engineering workflows. The independent engineers' previous roles included vice president of engineering, director of operations, director of deployment, and network engineering manager. The study leveraged a major U.S. carrier's recent installations on existing towers and mimicked the post-construction audit using the Consilience platform powered by OpenTower iQ. The automated output generated by OpenTower iQ was then compared against the best-available, pre-existing data of those towers. At the end of the study, the output of OpenTower iQ was confirmed to have acceptable levels of accuracy required to perform cell tower engineering and operational tasks. This white paper reviews the study and its outcomes, emphasizing data validation.

CONSILIENCE ANALYTICS

The Consilience Analytics (CA) "Flight to Insights" platform transforms physical assets into actionable data.

Since 2019, the CA has processed over 35,000 digital twins to support network deployments, engineering, and asset management.

The CA platform manages and automates the drone capture, digital twin rendering and the production of engineering-grade exhibits

VALIDATION METHODOLOGY

The study used cell tower assets belonging to two major tower owners in the U.S. To validate the data generated by OpenTower iQ, the study's participants randomly selected four out of a group of 50 towers with available structural data and known structural measurements. Next, the engineers gathered all existing data for those towers, including known manufacturer specifications, structural analysis results, RF design spreadsheets (RFDS), and engineering notes. The age of the data ranged from less than a year old to several years old. For this white paper, those pre-existing datasets will be referred to as "best-existing data." The best existing data was then set aside to use as the validation dataset.

To deploy the digital twin solution, standard drone-captured 3D imagery was used. Then, photogrammetry capabilities within the Consilience platform powered by OpenTower iQ were used to recreate the same set of towers as 3D digital twin models. Next, the engineers ran an inspection and analysis within OpenTower iQ to generate a series of reports with corresponding asset data. Over the next two days, the engineers matched the OpenTower iQ data against the best-existing data for each cell tower to verify the accuracy of the reports generated by OpenTower iQ against the best-existing datasets, or to verify they were within acceptable engineering accuracy tolerances of those datasets.

One of the most important parameters of the study was to test the drone-agnostic nature of the software. So, drone flight path and methods were not controlled, nor any special instructions were provided to the drone pilots. Rather, the study tested the "scaling" feature of OpenTower iQ.

VALIDATION RESULTS

To determine if the data from OpenTower iQ contain a level of accuracy acceptable for common cell tower management tasks, the engineers compared and validated the following aspects: scaling, equipment inventory, as-built drawing, mount analysis, and approval capabilities. The detailed results are listed below.

- ### SCALING THE MODEL

  As the input data was uncontrolled and didn't use any correction techniques like ground control points (GCP) or real-time kinematic (RTK), it was necessary to true up the model by using the scaling feature of OpenTower iQ. The program automatically creates equipment clusters and then compares those against known data to compute several translational and rotational scaling factors. Those factors are then applied to the 3D model to generate reports.

- ### CELL TOWER HEIGHT

  Scaling Accuracy

  Tower height was validated by correlating the best-existing data with the height output generated by OpenTower iQ. To begin the process, the engineers referred to the best-existing data, such as 2D CAD elevation drawings showing the height of the tower along with the elevations of RAD centers. Once this was noted, the engineers then generated similar reports, including 2D CAD elevation drawings from OpenTower iQ. Those drawings were then compared side-by-side against the best-existing reference data. The engineers were able to validate that OpenTower iQ could accurately scale the model within acceptable engineering tolerance.

  Study Example

  During the study, one specific tower had existing design documents that described it as 73 feet high at the top of the existing monopole (Figure 1). Using the data from aerial image capture, OpenTower iQ created a digital twin and used scaling to determine that the cell tower was 72 feet 3 inches tall at the same point (Figure 2). The net difference of approximately 9 inches between the best-existing data and OpenTower iQ data is considered a tolerable difference in most cell tower engineering workflows. Also, the difference (0.8%) was considered within the margin of error of the best-existing data.

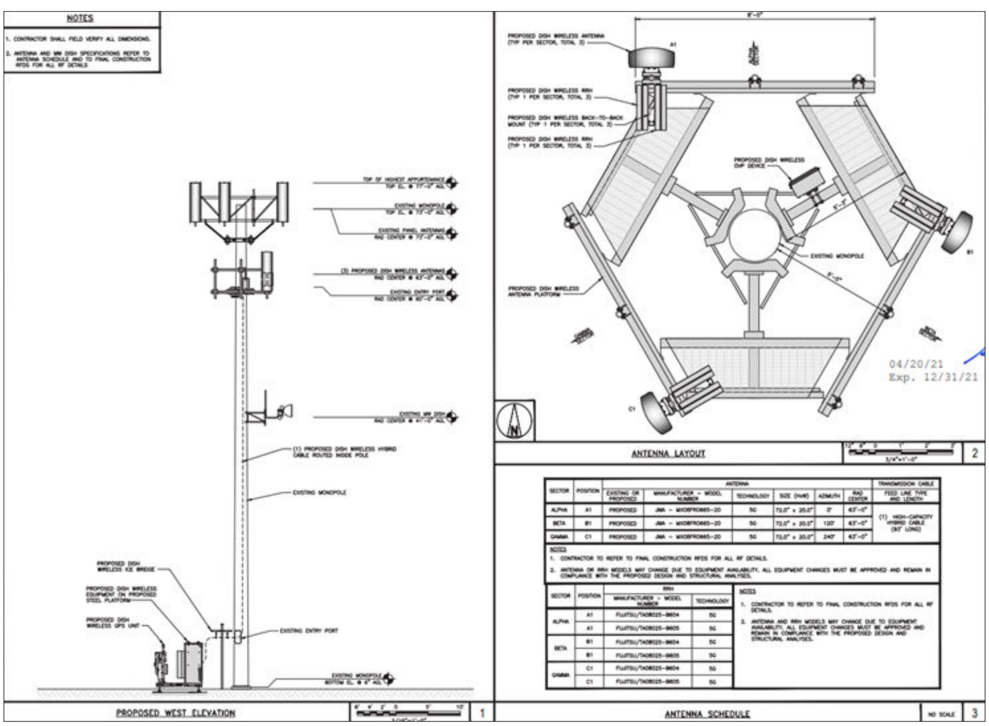
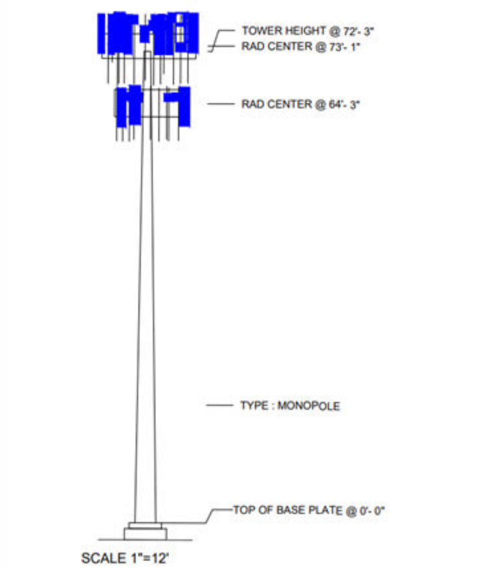
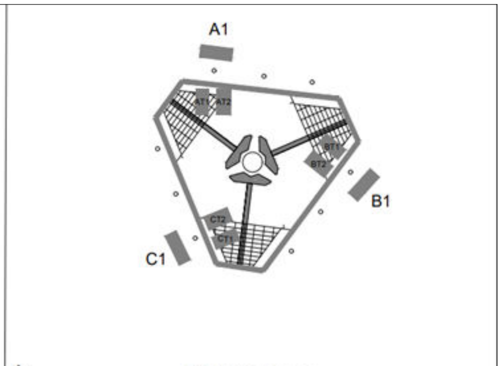


Figure 1 – Best-existing data from existing documentation.





ELEVATION @ 64'-3" SCALE 1/4"=1'

NAME	SECTOR	MANUFACTURER - MODEL	EXISTING/ PROPOSED	AZIMUTH	SIZE (W X H X D)
A1	ALPHA	JMA - MX08FRO665-21	EXISTING	7	20.08" X 72.05" X 7.87"
AT1	ALPHA	FUJITSU - TA08025-B604	EXISTING	271.5	15.75" X 14.96" X 7.87"
AT2	ALPHA	FUJITSU - TA08025-B605	EXISTING	90.5	15.75" X 14.96" X 9.06"
B1	BETA	JMA - MX08FRO665-21	EXISTING	132	20.08" X 72.05" X 7.87"
BT1	BETA	FUJITSU - TA08025-B604	EXISTING	39.5	15.75" X 14.96" X 7.87"
BT2	BETA	FUJITSU - TA08025-B605	EXISTING	218.5	15.75" X 14.96" X 9.06"
C1	GAMMA	JMA - MX08FRO665-21	EXISTING	243.5	20.08" X 72.05" X 7.87"
CT1	GAMMA	FUJITSU - TA08025-B604	EXISTING	158.5	15.75" X 14.96" X 7.87"
CT2	GAMMA	FUJITSU - TA08025-B605	EXISTING	338	15.75" X 14.96" X 9.06"

Figure 2 – One of the many reports available from OpenTower iQ.

CELL TOWER EQUIPMENT LOADING

RAD Centers

One of the deliverables from a tower inspection is the elevations of the RAD centers along the height of the tower. The engineers examined the best-existing data to identify the pre-existing reference points for the cell towers' center of radiation (RAD center). Multiple RAD centers were noted in each tower. Building on the validation of tower height analysis, the engineers then compared this data with the RAD centers generated by OpenTower iQ. Once all the datasets were compared, the engineers could confirm the accuracy of existing RAD centers within acceptable limits of accuracy.

The study example (Figure 3) shows the accuracy of existing RAD centers within a few inches, and the difference is within the margin of error of the best-existing data. The study also shows the difference in elevation of the proposed RAD center at 180 feet. This post-construction inspection helps the carrier and the tower owner to update their inventory database.

Level	Status	Elevation – best-known data	Elevation – OpenTower iQ
1	Existing	190′	190′ 2″
2	Proposed	180′	175′
3	Existing	150′	149′ 7″

Figure 3 – Study example.

Space Availability Reports

For space availability, the engineers reviewed the digital twin model to visually identify and then measure the available spaces. For example, at a given RAD center, engineers identified a number of vertical mount pipes along with the associated equipment on each face. Also, they measured the clear distances between the equipment and between RAD centers.

Next, the engineers turned to the space availability report automatically generated by OpenTower iQ. When the engineers compared the numbers generated by the program with their measured distances, they found that the OpenTower iQ data matched within an acceptable amount of variance for engineering and revenue purposes.

Equipment Positions

One important parameter that is often overlooked during the inspection is the actual positions of the equipment. It's not just the azimuth and tilt, but also the position with respect to the mounting face or leg. The incorrect position of equipment will result in erroneous structural analysis results. The engineers gathered the available lateral, vertical, and horizontal offsets from the best-existing data, including gathering information from older structural analyses and then compared those data with the equipment inventory report automatically generated by OpenTower iQ (Figure 4). They reviewed the equipment's lateral, standoff, and vertical offsets in that report, created using the same scaling techniques previously discussed. When compared against the best-existing offset data, the engineers determined that the offset data created by OpenTower iQ was accurate for engineering workflows.

Tilt and Azimuth Accuracy

Using best-available data, like a radio frequency data sheet (RFDS), the engineers could document the tilt and azimuth of various equipment pieces on the subject towers. Once that was established, the engineers turned to the report data created by OpenTower iQ. After comparing the two datasets, the engineers could validate that the tilt and azimuth data from OpenTower iQ was accurate within a 5% error margin, deemed acceptable for engineering purposes.

Name	Elevation (feet)	Type	Face	Height (inches)	Width (inches)	Depth (inches)	Azimuth	Tilt	Lateral Offset (feet)	Standoff Distance (feet)	Vertical Offset (feet)	Manufacturer	Model
Antenna_52	174.3	PANEL	LegB	72.05	20.08	7.87	106.5	-0.8	-2.91	1.38	1.78	JMA	MX08FRO665-21
Antenna_53	174.3	PANEL	LegA	72.05	20.08	7.87	355.5	1	-2.69	1.43	1.98	JMA	MX08FRO665-21
Antenna_54	174.3	PANEL	LegC	72.05	20.08	7.87	239	-1.1	-2.61	1.27	1.45	JMA	MX08FRO665-21
RRU_73	174.3	TME	LegB	14.96	15.75	9.84	207.5	-2	-2.36	-0.76	2.04	Fujitsu	TA08025-B605
RRU_74	174.3	TME	LegB	14.96	15.75	8.27	27.5	1.5	-3.52	-0.6	2.07	Fujitsu	TA08025-B605
RRU_75	174.3	TME	LegA	14.96	15.75	9.84	84	-0.5	-2.22	-0.72	3.11	Fujitsu	TA08025-B605
RRU_76	174.3	TME	LegA	14.96	15.75	8.27	264.5	0	-3.39	-0.67	3.11	Fujitsu	TA08025-B605
RRU_77	174.3	TME	LegC	14.96	15.75	9.84	327.5	0	-2.17	-0.8	2.57	Fujitsu	TA08025-B605
RRU_78	174.3	TME	LegC	14.96	15.75	8.27	147.5	0	-3.35	-0.74	2.59	Fujitsu	TA08025-B605

Figure 4 – A subset of OpenTower iQ report data that shows equipment data.

Variance Reports

OpenTower iQ generates a variance report comparing the existing RFDS for a given RAD center. The engineers verified the report and were able to confirm that OpenTower iQ was able to create accurate variance reports when the azimuth or tilt differed from what was defined in the RFDS.

Appurtenance Tables

The engineers examined the best-available data, including existing appurtenance tables, to develop a baseline listing of cell tower accessories and equipment. For the validation process, the engineers used the appurtenance tables generated by OpenTower iQ (Figure 5). These tables were auto-generated by OpenTower iQ, which applied AI and ML to the digital twin model to auto-identify tower equipment specifications.

When compared against the best-available data sets, the engineers found that the OpenTower iQ equipment detection and dimension measurements were 95% accurate. This was deemed acceptable for engineering functions.

Table 1 - Proposed Equipment Configuration

Mounting Level (ft)	Center Line Elevation (ft)	Number of Antennas	Antenna Manufacturer	Antenna Model	Number of Feed Lines	Feed Line Size (in)
63.0	63.0	3	fujitsu	TA08025-B604	1	1-3/8
		3	fujitsu	TA08025-B605		
		3	jma wireless	MX08FRO665-20 w/ Mount Pipe		
		1	raycap	RDIDC-9181-PF-48		
		1	tower mounts	Valmont SNP8HR-396		

Table 2 - Other Considered Equipment

Mounting Level (ft)	Center Line Elevation (ft)	Number of Antennas	Antenna Manufacturer	Antenna Model	Number of Feed Lines	Feed Line Size (in)
73.0	74.0	3	andrew	SBNHH-1D65B w/ Mount Pipe	6 6 2 2	7/8 5/8 3/8 Conduit
		6	commscope	NNHH-65B-R4 w/ Mount Pipe		
		3	ericsson	RRUS 32 B30		
		3	ericsson	RRUS 4449 B5/B12		
		3	ericsson	RRUS 4478 B14_CCIV2		
		3	ericsson	RRUS 8843 B2/B66A		
		1	raycap	DC6-48-60-18-8C		
		2	raycap	DC6-48-60-18-8F		
	73.0	3	-	Diagonal Bracing		
		3	-	Horizontal Support Bracing		
		1	tower mounts	Platform Mount [LP 1001-1_KCKR]		
41.0	42.0	1	north star	STARBEAM-4 w/ Mount Pipe	4	1/2

Figure 5 – An OpenTower iQ appurtenance table.

Drawings

The engineers extracted drawing pages from the available construction documents, including the site plan and composite drawings, consisting of tower elevation and the RAD plan view. Those drawings were then compared against the auto-generated drawings by OpenTower iQ. As those were placed side by side, engineers could verify the accuracy of the drawings generated by OpenTower iQ.

The objective was to determine whether sufficient information was available in each of the three categories and whether that information was accurate for engineering purposes. The results are listed in Figure 6.

Category	Validation Outcome
Elevation	OpenTower iQ creates accurate elevation plan drawings.
Mount RAD Plan	OpenTower iQ produces accurate mount RAD plans.
Site Plan	OpenTower iQ creates accurate site plan drawings.

Figure 6: OpenTower iQ Drawing Validation Outcome Table

Revenue Assurance

Square Inch Analysis

One of the important use-cases is to determine the exact amount of area currently being used by a carrier. For tower owners, this is to make sure carriers aren't over-using the contracted space, and carriers want to make sure that they are using the space efficiently.

The OpenTower iQ automatic square inch calculation was then verified by hand calculation using the dataset extracted for the verification of the space availability report. At the end of the comparison, the engineers confirmed that OpenTower iQ delivered accurate sq in data for engineering and revenue purposes.

Stakeholder Stamp

At the end of the study, the engineers looked at the total accuracy of all data and information provided by the OpenTower iQ solution compared to the best-available datasets for the subject cell towers. The goal was to determine if the reports provided by OpenTower iQ could be professionally stamped by engineers as conforming to all requirements of the applicable standards and codes related to the datasets. After evaluating the data and the reports, the experienced engineers verified that the reports and data generated by OpenTower iQ were of sufficient accuracy and legitimacy that professional engineers could stamp them.

OPENTOWER IQ DATA IS VALIDATED

In this study, cell tower engineers with over 30 years of experience validated that Bentley's OpenTower iQ could create an accurate digital twin of a cell tower and its equipment. The engineers further validated that OpenTower iQ could faithfully analyze the digital twin and create actionable engineering data and reports for cell tower owners and carriers. The result is confirmation that the data and information provided by the OpenTower iQ digital twin contain similar or sufficient levels of accuracy needed to perform most engineering and operational tasks.

SAVING TIME AND MONEY WITH OPENTOWER IQ

With the validation of data accuracy, owners, operators, and carriers can use a drone or aerial inspection along with OpenTower iQ to save the time and cost of the manual inspections that support traditional operations and maintenance. These processes usually cost owners and carriers about USD 5,700 per tower.

But with OpenTower iQ, operational and maintenance costs drop to an average of USD 2,200 per tower inspection. That's a cost savings of USD 3,500 per tower per year. This scales to an annual cost savings of more than USD 1.7 million per year for owners and carriers who service 500 towers and over USD 35 million for 10,000 towers.

Additionally, the engineers found that the ability of OpenTower iQ to effectively analyze its highly accurate digital twin and produce a variety of reports and datasets based on that analysis saved considerable time and cost. A selection of the standard OpenTower iQ reports is identified in Figure 6. When evaluated against traditional tower reporting processes, it is estimated that OpenTower iQ can deliver 50% time savings using intelligent automation and reporting capabilities.

Collectively, the creation, analysis, and use of accurate data within OpenTower iQ deliver an estimated 15% annual reduction in total operational costs for each cell tower and an estimated 42% total cost of ownership per tower over the course of a decade.

Finally, with OpenTower iQ, M&A transactions and the entire leasing process are 33% and 95% faster, respectively.

ADDITIONAL BENEFITS

With the Consilience platform powered by OpenTower iQ, owners and operators can confidently and easily ensure compliance with their lease agreements. Revenue optimization analysis becomes an "on-demand" activity. Placement and dimensions verification of equipment can happen within minutes, and space utilization can be analyzed multiple times per year. Carriers can verify that OpenTower iQ measures their equipment's correct placement, tilt, and azimuth, along with many other measurements.

Further, automating key manual engineering tasks within Consilience platform, powered by OpenTower iQ, optimizes engineering time overall. It allows engineers to spend their time on the most vital engineering tasks. OpenTower iQ reduces time out of the office on visits. And, with digital twins, engineers can gain more insights before heading to the site. Finally, onsite, the ability to run numerous virtual simulations and calculations on digital twins speeds up engineering site visits by reducing the need for onsite calculations.

The validation processes assure owners and carriers that the engineers working on their towers are utilizing their hours more efficiently and effectively. Rather than spending most of their time on data consolidation and validation, engineers can instead focus on making better, faster, and more insightful decisions on installation and implementation.

About the Author

Apurba Tribedi is a senior director at Bentley Systems, currently leading a distributed multinational team to create and market new software and services for the telecom industry. After graduating as a civil engineer in 1994, he joined Research Engineers as a software analyst and soon became a lead engineer-programmer for the world's leading structural analysis software, STAAD®. For over 20 years, Apurba has been managing, engineering, architecting, and developing engineering software and services. He has traveled around the world to train and market Bentley's software products and services to its users. Apurba's vision was instrumental to the development of several Bentley product lines, including STAAD and OpenTower.