Optimizing End-to-End Project Cycle Through Advanced Asset Digitization

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Abstract

The exponential growth in wireless data demand necessitated optimizing network expansion processes burdened by long project cycles, multiple physical site visits, and data inaccuracies. This project utilized the DMAIC framework to address these systemic issues, implementing advanced asset digitization using drones, 360-degree cameras, and Artificial Intelligence (AI) to create digital twin (DT) assets and verification tools. The initiative delivered total net savings and cost avoidance of $8,633,200, achieving a unit cost percentage reduction of approximately 5.31%. Operational efficiency improved dramatically, reducing the overall project cycle time by 1.5 months, meeting the target of 1 to 2 months, and improving documentation accuracy by 30%, tripling the 10% goal. Sustained improvements are ensured via the control phase, which mandates digitized deliverables as the new standard and utilizes Application Programming Interface (API) integration for automated data flow, enabling continuous improvement for future network expansion.

Introduction

A major inefficiency in cell site construction was the reliance on multiple firms and vendors for physical site visits to produce designs and estimates, which made coordination difficult and increased unit costs. Another critical issue was the inaccuracy and integrity of asset documentation, compromised by continuous changes in Customer Management Resource (CMR) tools, document loss during database migrations, and the potential manipulation of manual measurements.

To resolve these systemic issues, the project proposed leveraging advanced asset digitization, integrating drones, 360-degree cameras, and AI.

The core objectives were to:

- Reduce the average unit cost per cell site by 1% to 3%.
- Decrease the end-to-end project cycle time by 1 to 2 months.
- Improve cell site asset documentation accuracy by 10%.

Ultimately, the initiative sought to enable faster, more cost-effective network expansion while significantly improving asset documentation and inventory integrity.

Foundation For Asset Digitization

The integration of advanced technologies like drones, DTs, and augmented reality (AR) is crucial for transforming engineering processes and operational management in complex fields such as telecommunications [1-2]. In the context of telecommunications, Network Digital Twins (NDTs) provided high-fidelity virtual replicas of computer networks used for analysis, monitoring, testing, and optimizing network operations and traffic engineering [3]. NDTs are positioned as superior to traditional simulation tools due to their high accuracy, speed, and scalability, facilitated by key enablers like AI, machine learning, big data, and the internet of things (IoT). A specific DT use case applied to telecommunications transport networks utilizes AI for failure root cause analysis by creating a topological match between physical and digital connections [4]. Asset digitization relies on tools like drones and photogrammetry. Drones capture images used to build 3D models with overlaid textures, a methodology that directly relates to the project's approach to creating digital representations of cell sites [5]. Photogrammetry, which reconstructs 3D models from images, is a common method for collecting real-world spatial data. It has been evaluated as effective for the meticulous reconstruction of real spaces, such as architectural interiors like shelters and cabinets, into high-precision 3D models [6]. The project utilizes drones for data capture and maintaining up-to-date asset documentation. Studies investigating the use of drones for updating 3D DT environments detail simulations where multiple drones provide live video streams for reconstruction or updating dynamic regions [7]. An AR-based mobile application was detailed for exploring telecommunications tower sites and interacting with a Building Information Modeling (BIM) database [8]. The objective of such applications was to create tools for maintaining physical assets and ensuring up-to-date models through bidirectional communication [8], which is directly applicable to improving cell site asset documentation accuracy.

DMAIC Framework Implementation

This project employed the DMAIC framework to optimize the end-to-end project cycle by systematically addressing inefficiencies tied to manual processes. The Define Phase addressed the core problem of multi-firm site visits and manual measurements, which caused increased costs, coordination challenges, and data inaccuracies. The scope focused on initial design, real estate, and post-construction as-built verification. A pilot ran in selected markets (TX, OK, LA, Midwest), excluding complex sites like rooftops, power lines or no-flight zones. The Measure Phase established baseline metrics using the pilot program targeting 1,300 assets. The baseline end-to-end project cycle time was measured at 7.5 months, and the unit cost was $120,000. This phase quantified error rates by comparing documentation against precise measurements. Figure 1 shows that over 45.47% of existing antenna azimuths fell outside acceptable tolerance levels of ±3°. Figure 2 show an example of deviations found leveraging the Asset Digitization Process.

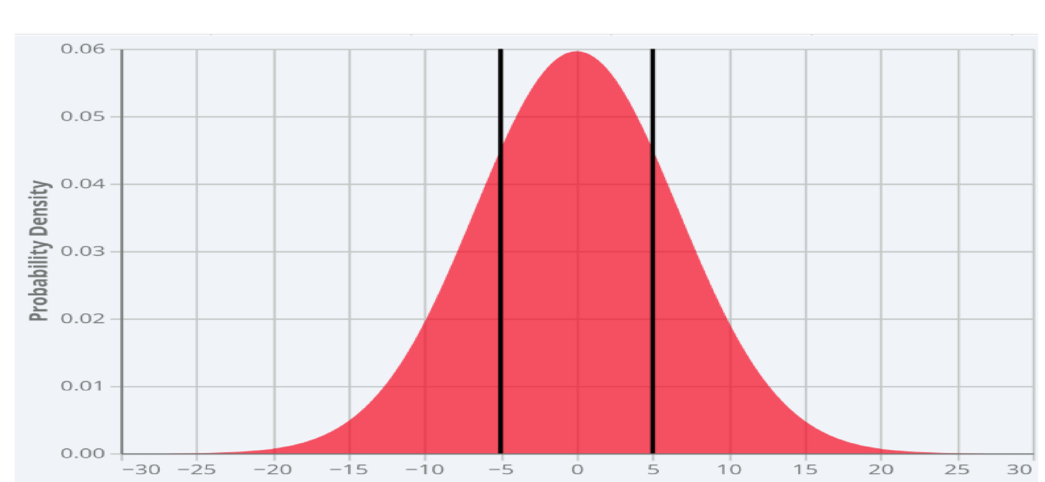

Figure 1
Baseline Distribution of Antenna Azimuth Deviations

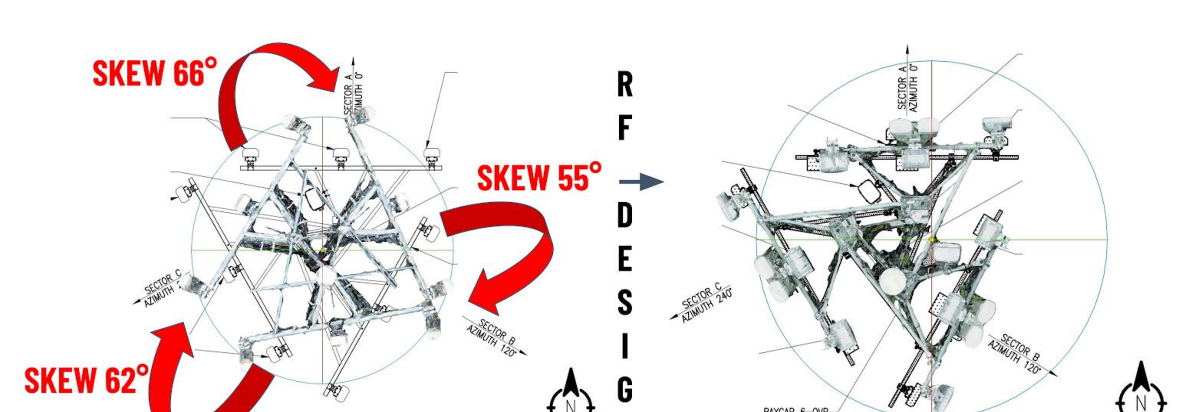

Figure 2
Example of Antenna Azimuth Deviation

The Analyze Phase used process mapping and statistical analysis to confirm root causes, identifying bottlenecks and inaccuracy sources. Analysis showed physical site walks added 3 weeks and data inaccuracy caused 2 weeks of communication delay. This effort produced a prioritized list of improvement areas. The Improve Phase implemented advanced asset digitization using drones, 360-degree cameras, and AI. The strategy involved initial manual data uploads, followed by API integration with the Fuze database. This solution was validated by comparing digitized data against manual measurements in the pilot program. Figure 3 illustrates the overall Asset Digitization process, from data acquisition to digital product delivery.

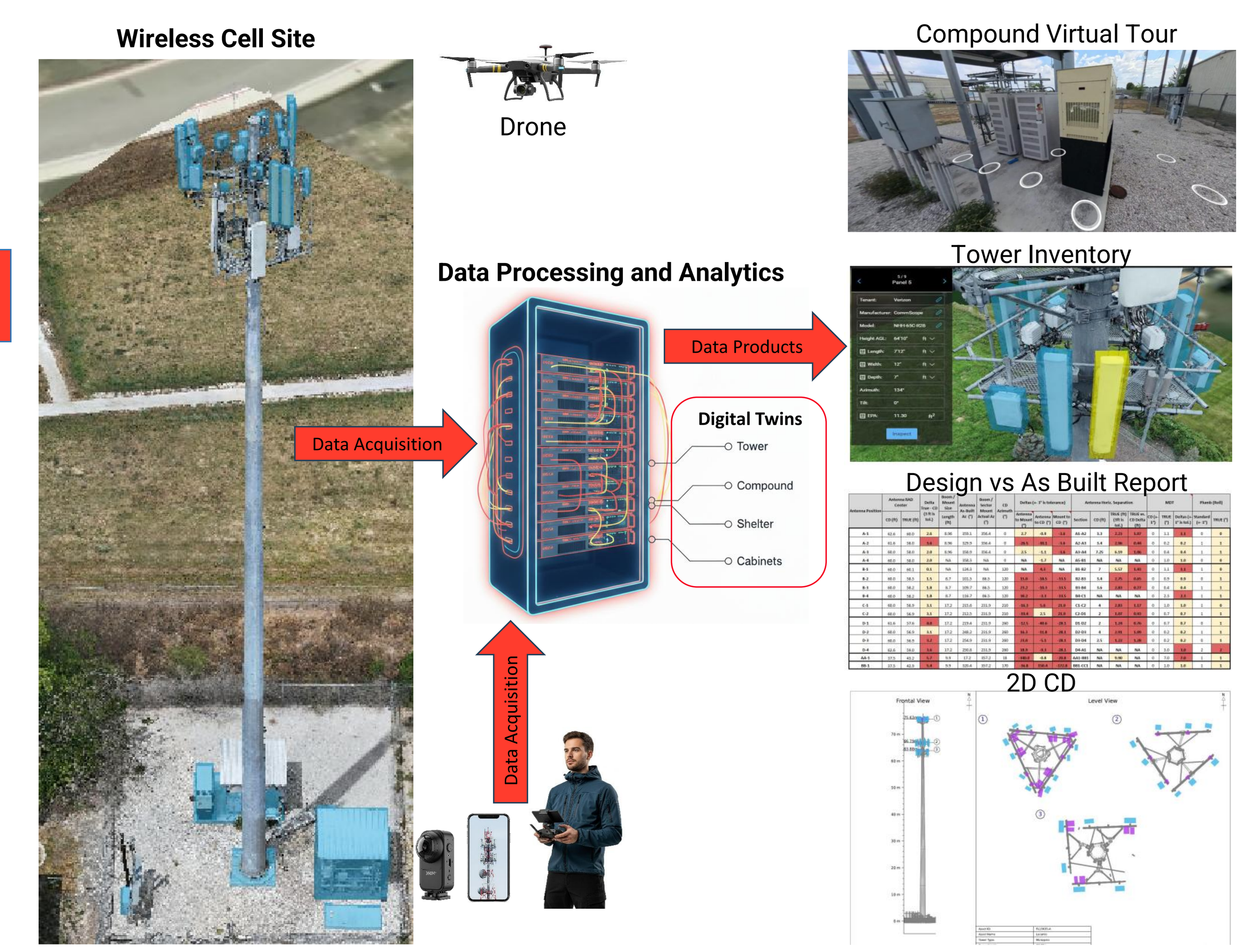

Figure 3
High Level Asset Digitization Process

The Control phase ensured that improvements were sustained through national training and the implementation of new Standard Operating Procedures (SOPs). Digitized deliverables, such as DTs and as built comparisons, were established as the new documentation standard. Automation was critical, once APIs were active, critical data was automatically pushed to the database with built-in tolerance checks. Performance and costs will be monitored through annual reviews and centralized oversight, ensuring continuous adherence, capturing long-term benefits, and providing a feedback loop for continuous improvement.

Results

The advanced digitization delivered $8,633,200 in net savings and cost avoidance, achieving a 5.31% unit cost reduction per project. This financial impact is shown in Table 1.

Table 1
Cost Savings & Avoidance

Metric	Improvement	Financial Impact
Site Walk & CD	$2,200 saved per project	$2,860,000
Antenna Re-trips	591 instances avoided	$1,182,000
Rent Increases	78 projects avoided	$8,424,000
Overall Impact		
Net Savings	After digitization costs	$8,633,200
Unit Cost Reduction	5.31% per project	$6,640.92

Project cycle efficiency improved by 1.5 months, and data accuracy increased by 30%. Sustainment is ensured via new SOPs and API data flow.

Conclusions

The project successfully achieved its objective of optimizing the end-to-end project cycle by utilizing advanced asset digitization, drones, 360-degree cameras, and AI. This approach addressed previous inefficiencies related to manual measurements and physical site visits. The implementation yielded results that significantly surpassed initial targets.

Key accomplishments include:

- Total net savings and cost avoidance reached $8,633,200.
- The unit cost percentage reduction was approximately 5.31%.
- The overall project cycle time was reduced by 1.5 months.
- Documentation accuracy saw a substantial 30% improvement, successfully tripling the 10% objective.

Sustained adherence is ensured via the Control phase mechanisms, which establish digitized deliverables (DTs and as-built comparisons) as the new documentation standard. Completed API development guarantees automated data flow, enabling continuous improvement and supporting faster, more cost-effective network expansion.

References

[1] Afif, M. F., & Sarhan, A. A. D. (2025). Computer-aided process planning, digital twin, and smart manufacturing: interconnections and integration in CNC machining processes. International Journal of Production Research. https://doi.org/10.1080/00207543.2025.2521717

[2] Cetinsaya, B., Neumann, C., Bruder, G., Reiners, D., & Cruz-Neira, C. (n.d.). Assessing the effects of drone control interfaces on situational awareness and digital twin environment updates.

[3] Do, T. L. P., Sanhae, K., Hwang, L., & Lee, S. (2024). Real-Time Spatial Mapping in Architectural Visualization: A Comparison among Mixed Reality Devices. Sensors, 24(14), 4727. https://doi.org/10.3390/s24144727

[4] Mercimek, I. F., Polat, K., & Yazar, M. D. (2025). Digital Twin Use Case in Telecommunications Transport Network.

[5] Palma, V., Spallone, R., Cicone, G., Lops, G., & Rinauro, R. (n.d.). SCALABLE AR FOR BIM ON TELECOMMUNICATION NETWORK SITES.

[6] Pavlik, J. V. (2020). Drones, Augmented Reality and Virtual Reality Journalism: Mapping Their Role in Immersive News Content. Media and Communication, 8(3), 137–146. https://doi.org/10.17645/mac.v8i3.3031

[7] Poorzare, R., Kanellopoulos, D. N., Sharma, V. K., Dalapati, P., & Waldhorst, O. P. (2025). Network Digital Twin Toward Networking, Telecommunications, and Traffic Engineering: A Survey. IEEE Access. https://doi.org/10.1109/ACCESS.2025.3531947

[8] Zhang, Y. (2024). Digital Twin: Architectures, Networks, and Applications. Springer. https://doi.org/10.1007/978-3-031-51819-5