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TRUSTED IOT ALLIANCE – SMART CONSTRUCTION CHALLENGE

October 2019

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EXECUTIVE SUMMARY

The Smart Construction Challenge is a competition run by the Trusted IoT Alliance (TIoTA), the open-software consortium created in 2018 to support the creation of a secure, scalable, interoperable, and trusted Internet of Things (IoT) ecosystem. TIoTA's members are engaged with this ecosystem -- a group of organizations involved with IoT devices, hardware, platforms, applications, and various DLT and blockchain trust services.

The objective of the Smart Construction Challenge is to advance the smart construction industry by enabling new smart sensor technologies, trust systems, decentralized data exchanges, and other IT innovations in smart construction solutions. By connecting start-ups with major industry organizations, the challenge will create the next generation, smart construction ecosystem of digital solutions.

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As co-sponsors of the challenge, TIoTA, with MachNation and construction industry partners that participated in the Challenge evaluated a total of 10 challenge submissions from start-ups and solution providers. There were a wide range of submissions including drone-based aerial surveys of construction sites, noise dampening headsets for construction workers, new IT innovations for Building Information Model (BIM) systems, 3D construction site mapping, and others. Figure 1 below lists the challenge participants.

FIGURE 1 2019 Smart Construction Challenge Participants

BLOCKS Wearables	COMAN	Contilio
CORRUX	EAVE	FAIR FLEET
HOLO BUILDER	HUM-ID	MOECO

Based on the scoring of challenge proposals, judges chose the team comprised of Contilio, HoloBuilder, HUM-ID, and Moeco as the winning solution. This solution, a combination of four technology and business offerings, is aimed at providing full monitoring and visibility of a construction site using 3D imaging, machine learning, AI-infused analytics, and re-usable, low-touch sensors. The business goal of the solution is to lower

FIGURE 2 Winning Solution Description

Technologies Proposed	Business Objective
• 3D imaging • Machine learning • AI-infused analytics • Reusable, low-touch sensors	• Lower construction-related risks • Increase worker safety • Lower site operating expenses

construction-related risks associated with moisture accumulation, increase worker safety, and lower site operating expenses. Each winning company will be building out its proof-of-concept (PoC) over the subsequent month. See Figure 2.

Figure 4 shows the relative strengths of the winning companies' submissions based on the three high-level criteria used to judge submissions. The three criteria used by the judges were business, technology, and community contribution. Participants' submissions were judged on these criteria and how well judges believed that the participating teams could convert their submissions into POCs.

Each of the four winning teams split a total award of EUR25,000 and will have the opportunity to refine each of their proposals to develop POCs with TUV SUD.

THE CHALLENGE: AN OVERVIEW

The challenge began in 1Q 2019, judging took place in 2Q 2019, and the winners were presented with their award in May, 2019, at Bosch Connected World in Berlin.

Overall, the challenge consists of four key stakeholders:

Organizers. TIoTA and the Industrial Internet Consortium are the organizers of the challenge. MachNation, a global independent IoT research and testing firm is both an organizer and co-producing the challenge. Organizers are responsible for the overall management of the challenge, including partner-acquisition, marketing, and event coordination.

Construction industry partners. The role of Construction Industry Partners is to provide the requirements and use case definitions for the challenge. Additionally they work with challenge participants to test proof-of-concept (POC) solutions and provide real-world data and feedback. Following the awards, they will work with the challenge winners to implement their solutions into pilot programs.

Technology Partners. Technology partners provide relevant technology components to assist start-ups and solution providers in the creation of their POCs if chosen for further development. Technology partners also provide overall technology guidance and support to the challenge stakeholders.

Start-ups and solution providers. Start-ups and solution providers submit their proposals, in accordance to technical and business model requirements, to the challenge judges. Proposals are evaluated against the challenge criteria and relevance to the construction industry partners' pre-selected use-cases. If selected as challenge winners, start-ups and

FIGURE 3 2019 Smart Construction Challenge Sponsors

solution providers will further develop their proposals and POCs.

Participants were asked to develop technology solutions to address specific smart construction use cases. The goal of each submitted entry was to address the central topic of the use case while operating under a set of assumptions. The full list of use case assumptions and constraints can be found in the challenge description on the TIoTA Smart Construction Challenge page.

The Construction Industry Partners identified 3 use cases for the Smart Construction Challenge:

Use Case 1: Construction Assurance

Construction assurance is the process of managing, ensuring, and validating the quality of a construction effort. For example, one of the main concerns of construction acceptance and assurance is preventing and monitoring water damage, as well as the resulting consequences, such as mold. This includes water entry through the roof, basement or any other entry point. A use case in this smart construction category provides IoT-related tools to offer construction assurance.

Use Case 2: Track and Trace for Onsite Logistics

A track and trace use case for onsite logistics concerns the efficiency of managing the flow of materials and equipment onsite, for both indoor and outdoor tracking. Particularly, it should ensure that required materials and equipment are made available at the appropriate location at the appropriate time, with methods for tracking and delivery verification.

Use Case 3: Smart Worker Equipment

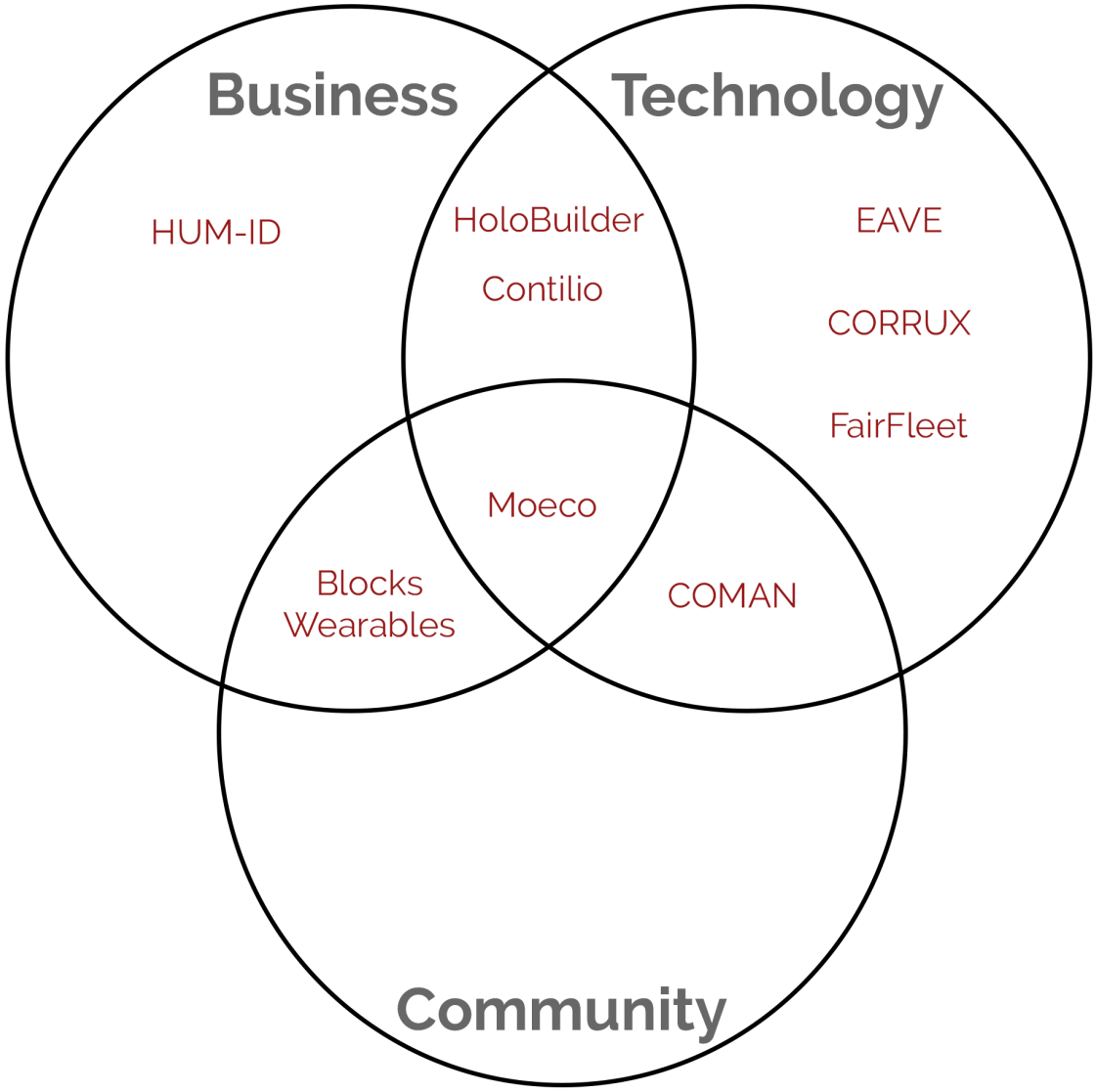
A smart worker equipment use case combines existing innovations in worker equipment and tools to ensure high quality production and onsite safety. Examples include wearables for enhanced safety, advanced communication methods or integration with worker equipment into a central management system for monitoring and security.

Challenge participants were allowed to submit one or more proposals for these three use cases, although most participants submitted only one proposal that fit within one or more use cases.

METHODOLOGY

Challenge participants submitted their proposals to TIoTA as a PowerPoint-style

FIGURE 4 Relative Submission Strengths by Challenge Criterion



> For a best in class IoT solution to operate efficiently within the existing smart construction eco-system, it should fit well within the data structures and systems of the existing BIM.

file. Participants were also allowed to submit supplementary materials including architecture diagrams and online videos to support their proposals.

The Challenge judges graded each proposal on three high-level criteria:

Business - How well does the proposal support the outlined use cases, provide value add for end-customers, and deliver innovation?

Technology - How well does the proposal describe how it will ensure scalability and realistic rollout in an enterprise environment? POCs are given bonus consideration.

Community Contribution - How well have the proposal contributors supported the Smart Construction Challenge events?

Challenge judges scored each proposal on a three-point scale, with one being low and three being high for each judging criterion. Judges met to discuss the proposals and the scoring. In the end, the sum of these totals was used to select the challenge winners.

Judges included representatives from Zublin, TÜV SÜD, Bosch, and Liebherr. They were supported by representatives from the Industrial Internet Consortium, MachNation, and the TIoTA.

CHARACTERISTICS OF A LEADING IOT SOLUTION FOR THE SMART CONSTRUCTION CHALLENGE

A leading IoT solution for the TIoTA Smart Construction Challenge will focus on the three judging criteria: business, technology and community contribution. Below we will highlight key characteristics within each judging category that comprise a best-in-class IoT solution for smart construction within the context of this challenge.

Business

Interoperability with existing systems. In most large-scale construction projects Building Information Modeling (BIM) is used as the foundation for planning, construction, and operations management throughout the project lifecycle. A BIM is a digital representation of physical and functional characteristics of the building and is comprised of multiple integrated monitoring and data collection systems. Interestingly, the concept of an IoT digital twin -- a digital representation of a physical connected asset -- is quite analogous to a BIM system.

For a best in class IoT solution to operate efficiently within the existing smart construction ecosystem, it should fit well within the data structures and systems of the existing BIM. The IoT solution should be able to contribute

data to and extract data from a BIM, and leverage existing data models. Leading IoT solutions for smart construction will minimize disruption to an existing construction environment and be a value-add to the established BIM system.

Multi-domain applications. A leading smart construction solution must offer applications that are relevant to multiple domains of the construction industry. Construction projects often address multiple building systems with requirements specific to the intended function of the systems. Systems can include HVAC, security/surveillance, lighting, energy, water, elevators/lifts, grounds, and more. In addition, construction of a building for public or commercial use must often meet a set of regulatory requirements different than a building for private use. For instance, a structure that is to be certified as a Leadership in Energy and Environmental Design (LEED) designated building may require certain specifications to meet environmental monitoring and architectural design criteria. In this regard, it is important that a smart construction solution develop its internal capabilities to provide support and add overall value to various systems involved in a construction project.

Technology

Solution scalability. One easily recognizable, yet difficult to address, challenge of an IoT smart construction solution is the ability to evolve with the changing landscape of the construction site. This includes basic infrastructure requirements such as sensor installation, connectivity management, capabilities for handling growing data ingestion, and processing increasingly complex analytic functions as the project progresses. A best in class IoT solution should be able to scale with the complexity and at the pace of the property lifecycle.

Distributed architecture and distributed ledger technology. Leading vendors and service providers deploying a leading smart construction IoT solution will create an IoT solution architecture that takes advantage of the benefits of edge and cloud services, and rely on distributed ledger technology (DLT) where necessary. A smart construction IoT solution will typically be a combination of IoT applications including construction assurance, logistics track and trace, equipment monitoring, security and surveillance, worker safety, and more. Some of these applications are best suited to edge-based architectures while others would benefit from a cloud-centric architecture. A leading IoT solution should support edge, cloud, and hybrid approaches.

As with any large-scale IoT deployment, security is a top concern among smart construction solutions. Construction projects often involve multiple stakeholders requiring varied levels of access to systems or data, therefore the need for tight access controls is needed to ensure operational data security. However, this can also pose a challenge for interoperability, as imposing excessively strict controls in an enterprise IT environment may compromise system integration or data availability. Constructing an IoT solution's data model around DLT is one potential solution for creating a decentralized data lake that is selectively accessible and available across systems. Leading IoT solutions for smart

construction will have flexible data models that can be well integrated and secured in enterprise environments.

Community

Joint solutions. One of the characteristics of a leading smart construction solutions is its interoperability with existing and emerging technologies. The next generation of smart construction solutions will not rely on a single innovation. With this in mind, it is important that a proposed smart construction solution fit within the broader ecosystem of the IoT industry and endeavor to develop joint solutions that leverage the strengths of individual solutions to fit business use cases. By engaging in competitive efforts such as the Smart Construction Challenge, and in cooperation with TIoTA's partners, start-ups have the ability to develop joint go-to-market solutions that will add value to the greater technology and construction communities.

Industry engagement. Potential for collaboration and co-innovation is crucial to building an IoT solution that adds value to the industry and to customers. Proposed technologies will benefit from direct user feedback and field trials with technology partners such as TIoTA. Leading smart construction vendors and service providers will engage with the established community to develop enabling solutions that address the critical needs of customers.

SUBMISSION SUMMARY GOALS

This section highlights the goals of each participant's entry to the challenge. Detailed descriptions of the challenge winners are included in the subsequent section.

Blocks Wearables

Blocks Wearables proposed a progress and safety system designed to maximize construction worker progress through a network of BLE beacons that transmit operational data to the BIM system through strategically placed gateways on the construction site. This solution would be compatible with smartphones and smartwatches.

Coman Software

Coman Software proposed a shared data hub with access controls across key stakeholders in the construction project. Users would be able to visualize and share data with OEMs, operational personnel and other relevant parties to control and monitor KPIs in a joint development ecosystem.

Contilo

Contilo proposed to implement 3D modeling technology to provide a visual comparison to the underlying BIM model. This would enable project supervisors to gain real-time insights on potential risks, compliance issues, development progress, and more.

Corrux

Corrux proposed real-time data analytics and data processing software for industrial equipment. This would provide real-time operational data and AI functionality to distill and processes critical performance information.

EAVE

EAVE proposed smart wearable headset equipment for workers on the construction site. This would utilize machine learning and cloud connectivity to preemptively detect

and prevent hearing damage from construction noise.

FairFleet

FairFleet proposed to deploy a fleet of drones to capture aerial data of construction site progress that would be fed into the customer cloud environment. FairFleet would handle pilot provisioning and the relevant governmental authorizations for operation.

HoloBuilder & Bosch

HoloBuilder and Bosch proposed RefineMySite software for project flow planning, information access, and task management. This would integrate into the 360-degree Reality Capture platform to create a visualized digital twin. Stakeholders would be able to access operational data and collaborate with team members by interacting within a 360-degree UI of the construction site.

HUM-ID

HUM-ID proposed physical RFID sensors for detecting moisture buildup in critical architectural positions across the construction site. This would include a mobile application and hardware for scanning and collecting data.

Moeco (BLE & LR)

Moece proposed two methods for collecting and storing operational data. The Moeco BLE mobile application would leverage BLE connectivity from worker smartphones to collect physical sensor data throughout the construction site. Moeco LR would use LoRaWAN gateways for data collection.

ROUND 1 CHALLENGE WINNERS

Summary

Contilio, founded in May, 2018 and headquartered in London, UK. specializes in construction analytics. Contilio's challenge submission is a solution that uses 3D-modeling technology and a machine learning platform to collect and visualize real-time data on a construction site. Contilio's data acquisition partner uses Lidar 3D technology to capture 360-degree images of a construction site once to twice per week. These images are uploaded to a cloud environment, processed through a machine learning platform to deliver analytics, and then made accessible through the BIM system. The Contilo solution most closely aligns with the Construction Assurance use case. Contilio received special recognition, along with the other winners, for its Construction Warranty use case.

Highlights

Contilio's real-time data, AI-powered analytics reduces construction costs and increases safety. Typical construction site evaluations require weeks to assess progress, address concerns, and plan for future phases. Contilio's AI-powered analytics platform has the potential to proactively identify development issues, monitor mission-critical data, track equipment status, and visualize overall progress. Reductions in the amount of time to complete evaluation and planning phases, along with preventative maintenance capabilities, will provide significant construction cost savings and improved worker safety.

Contilio's platform has an important integration to existing BIM systems. One of the key components for any leading IoT smart construction solution is integration into existing technology and business systems. Contilio's 3D data collection and analytics platform integrates directly with the BIM system via cloud and is made available in real-time. Low-code integration and rapid operationalization are certainly an attractive offering to smart construction projects, where technology knowledge onsite could be limited.

Challenges

Contilio's machine learning platform requires large amounts of data to deliver effective analytics. While an effective AI analytics platform can deliver significant operational advantages, vast quantities of data are required before it can be considered truly operational. As such, it may prove challenging for Contilio to deliver an effective analytics offering in the short-term or for any but very large construction projects.

3D technology for smart construction applications is still in its nascency and the business value of solutions unproven. 3D technology has been around for some time, however its use in smart construction applications is still largely unproven from a business-model perspective. While there is certainly some value as a concept, Contilio may face challenges in garnering enthusiasm from clients and recruiting the top tech talent it will need to deliver the desired outcomes.

Summary

Holo Builder, an American-German construction technology start-up, was founded in 2016 and has become an established player in the smart construction space. Holo Builder uses 360-degree camera technology to help builders and engineers create visual, interactive digital twins of a construction site. Holo Builder submitted a challenge submission called RefineMySite in collaboration with Bosch. RefineMySite integrates Holo Builder's current 360-degree visualization offering with a Bosch-supported project management tool. RefineMySite would allow engineers and project planners to document and track tasks directly within the Holo Builder 360-degree digital twin. Holo Builder and Bosch's submission most closely aligns with Smart Worker Equipment use case, as it is an enablement tool that aims to increase production and reduce inefficiencies.

Highlights

RefineMySite enables easy collaboration between project managers and builders. RefineMySite is a cloud-native application that is accessible via a front-end portal to assigned users. All users with appropriate access privileges are able to track tasks, update operational information, and log issues. RefineMySite has the potential to eliminate operational inefficiencies between project planners and workers, leading to reduced project costs.

RefineMySite supports change logs and event monitoring. In a collaborative environment with many moving parts, it can often be difficult to track when or if a task was completed. With RefineMySite users have the ability to review historical logs for project tasks and events. This can be an especially useful tool when unexpected events occur and project managers need to assess when or how something might have happened.

Challenges

Applications of RefineMySite run separately for each user. While RefineMySite offers a compelling project management tool on top of a 360-degree visualization engine, one potential major drawback to its collaboration effectiveness is the inability for users to run in concurrent instances of the application. In its current form, there is a real potential for miscommunications and project errors should two or more users be modifying the same task in separate instances of the same project portfolio. Of course, this is why change logs are necessary. RefineMySite may face challenges in the form of some user frustration with this functionality, particularly among large collaborations. Holo Builder and Bosch should consider a more modern architecture that allows multiple users to collaboratively modify records and see changes in real time.

Summary

HUM-ID is a German company specializing in manufacturing RFID-enabled sensors for detecting moisture. Property and equipment damage due to moisture is one of the most significant challenges facing the construction industry today. HUM-ID provides low-touch, easy-to-install sensors that can be used to mitigate potential construction damage and project setbacks due to moisture. The HUM-ID solution is most closely aligned with the Construction Assurance use case.

Highlights

HUM-ID's RFID sensors can be easily installed and moved during the construction process. Since construction projects are completed in phases, it may be necessary to monitor moisture of different areas at different times during a project. Since HUM-ID's sensors do not require expert installation, they can be easily repurposed and moved over the lifetime of a construction project, thereby reducing deployment costs.

HUM-ID's early detection capabilities help enterprises avoid complicated remediation or potential litigation due to water damage. Damage due to moisture has the potential to strike a construction project during any phase of development: Often the effects are not seen until long after completion. This has the potential to open up the construction company to liabilities and costly lawsuits. Monitoring, detection, and prompt remediation of moisture and excess water throughout the construction process has tremendous potential cost savings.

Challenges

Active, close proximity scanning of sensors might decrease the quality of data collected and delay analysis. The HUM-ID solution requires close proximity scanning of sensors to accurately gather moisture data from sensors. Actively scanning each individual sensor could pose a challenge for large construction developments with potentially hundreds of moisture-prone locations. HUM-ID might want to consider technology supporting passive scanning or another technology that minimizes the probability of errors during the scanning process.

HUM-ID is only a viable smart construction solution in collaboration with other vendors. While moisture detecting technology is of huge importance to the construction industry, HUM-ID's offering does not stand alone as a leading smart construction solution. While it certainly addresses the Construction Assurance use-case, it is not in of itself a connected solution. It does not integrate into existing systems, lacks any sort of data storage or analysis capabilities, and only possesses a simple monitoring UI for smartphone applications. HUM-ID should continue to endeavor to find partners or integrate relevant services into its existing solution.

MOECO

(MOECO BLE & MOECO LR)

Summary

Moeco, founded in 2017 and based in San Francisco, USA, is a blockchain-enabled, machine-to-machine (M2M) connectivity platform that uses crowdsourcing technology to gather data from sensors and gateways. Moeco's challenge submission offers full construction cycle monitoring with two technology offerings, Moeco BLE using Bluetooth Low Energy (BLE) and Moeco LR using LoRaWAN. Moeco BLE relies on workers' smartphones as passive gateways for collecting proximity-based sensor data using a Moeco SDK installed directly on worker's devices. Moeco LR is based on LoRaWAN technology designed for long-range connectivity. This solution generally requires one gateway per site to collect sensor data. Additionally, Moeco offers a wide range of low-cost or customized sensors for supply chain management, site monitoring, and other applications. Moeco's solution is most closely aligned with the Track and Track for Onsite Logistics use case.

Highlights

Moeco's blockchain-enabled architecture makes it inherently failure tolerant. The Moeco solution uses a blockchain network to capture and share data transactions. Since blockchain is a decentralized technology, relying on a network of client nodes for connectivity, there is no single point of failure in the system. Should one node lose connectivity or become compromised, a distributed architecture provides a layer of added reliability and security for overall network integrity.

Moeco integrates into existing smart construction data analytics platforms. Moeco has made efforts to ensure that collected sensor data sent to the blockchain cloud environment can be easily moved northbound to existing analytics and monitoring platforms within the established smart construction ecosystem. Platforms such as Digital Twin, Corrux, COMAN, and Autodesk Forge can be integrated with the Moeco architecture.

Moeco offers customizable alerts and notifications for some of its sensors. Moeco offers construction monitoring and smart building sensors that can be configured to trigger notifications on custom data thresholds. This is a useful edge-compute feature for monitoring environmental conditions on the job site and equipment power consumption, for example.

Challenges

Blockchain is not without its security challenges. While blockchain's distributed architecture in generally regarded as a more secure form of data transfer than a centralized service, localized IoT deployments are still susceptible to security threats. Among the most common are Fifty-One Percent attacks, where a single source is able to take control of the majority of a network's sensors and alter the ledger; and Distributed Denial of Service (DDoS) attacks, where a network is flooded with spurious data to overload and ultimately crash the network. While these security threats are ultimately a limitation of blockchain technology, and not inherent to Moeco individually, the growing popularization of blockchain IoT architectures also comes with growing security challenges.

Moeco may face challenges scaling its hardware availability to meet the needs of a deployed IoT solution. One of the major benefits of a blockchain-enabled architecture is the ease of scaling the deployment for handling increasing amounts of data. However, Moeco may face challenges meeting the hardware demands necessary to support a rapidly expanding construction project. Manufacturing and delivery time of required sensors could limit the rate at which the solution is able to effectively scale.

MachNation is the only firm exclusively dedicated to testing and researching Internet of Things (IoT) platforms, middleware, and services. MachNation owns and runs MachNation IoT Test Environment (MIT-E), the industry's only independent, hands-on, benchmarking lab for IoT platforms. MachNation specializes in understanding and predicting IoT technologies including their impact on digitization, hardware, communication services, applications, and support tools. MachNation specialists provide guidance to industrial enterprises, the world's leading IT vendors, and communication service providers.

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