



## Use of Immersive Augmented Reality Technology in Public Works: Myth or Reality? – A Case Study on Implementation Challenges

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### Abstract

The State of Qatar witnessed an unprecedented transformation during the past three decades in various sectors, more specifically in public infrastructure. The rapid transformation coupled with urbanization has increased the density of public infrastructure assets both at the surface and sub-surface. Ashghal, the Public Works Authority (PWA) contributes to achieving the goals of Qatar National Vision 2030 (QNV) by leading the transformation of Qatar's public infrastructure delivery and improving operational efficiency. Augmented Reality (AR) Technology that interfaces digital information with the real-world environment both spatially and temporally engenders tangible impact in the area of construction planning, operations, and maintenance of public works and assets. AR Initiative is identified as part of the Geospatial Strategic Master Plan for PWA. AR Technology has proven successful in various industries like entertainment, health, manufacturing, etc., however, it has serious limitations and lacks adopting changes in large-scale implementation in the context of public works. In this paper, the intent, technology selection, and implementation roadmap are discussed through a case study. This case study presents various use cases considered in the public works domain including the use of AR with Geospatial and BIM Technology. This paper further discusses the strategy for deployment, best use, limitation, and factors to be considered for full-scale deployment. This paper summarizes the study outcomes of the current effort undertaken by PWA in deploying AR solutions and discusses the feasibility of AR solutions in public work is a myth or reality.

**Keywords:** Augmented Reality; Innovation; Public works; Geospatial Transformation; 3D Visualization

### 1 Introduction

Since the beginning of this century, the use of digital technology has evolved with multipurpose uses, and become an essential component of everyday digital life. The way users consume business services on handheld devices is gaining importance nowadays. As the new industrial revolution takes up a cognitive form, the use of innovative technologies increased its footprint beyond the private & industrial sectors. We live in the generation of Big Data. With the availability of valuable and variety of data, the velocity at which the data availability, decisions, and actions remain still confined in two-dimensional maps and drawings. This creates a major gap between availability and the best use of data. Emerging technologies such as BIM, IoT, and Virtual Reality (VR) gained importance to use of multi-dimensional information for the decision-making process. Augmented Reality (AR), one of the emerging technologies, promises to minimize the gap and maximize the utilization of enriched information.

In the space of civil engineering, the use of AR is increased during the last five years and the percentage of its application is around 10% in underground and about 45 in construction (Xu & Moreu, 2021). Typically, excavation damages to underground infrastructure cause huge financial losses in public sector organizations (Hansen et.al, 2021). In most cases, this is contributed by human errors with a lack of situational awareness of the underground assets. This indicates considering AR to improve upon traditional paper-based or 2D information-based inspection, planning, or maintenance procedures. Public Works Authority ‘Ashghal’ (PWA) the infrastructure implementation organization delivers the majority of the projects in the civil engineering domain.

In this paper, we summarize and share our industry experience in the implementation of AR initiatives in PWA, covering the business context and strategy. The key aim of this paper is to enable the reader, to understand the potential application areas of AR in the public works domain as well as implementation challenges and limitations.

## **2 Anatomy of Augmented Reality**

Augmented Reality (AR) Technology superimposes computer-generated data on top of a user’s perception of the real world in real time. AR falls closer to the real-life context by supplementing the real world with virtual computer-generated objects that appear to coexist in the same space as the real-world (Juan et.al, 2018). Two diverse types of AR are identified, (i) Location-based AR, the application relies on the spatial position and orientation of the device to select and display location-relevant information, (ii) Image-based AR, and the applications use an image recognition algorithm to trigger the display of relevant content over a recognized physical pattern (Vogt et.al, 2013). The application of AR technology is determined by the two available categories, Marker and Markerless (covers location-based, superimposition, projection, and outlining) based. Understanding the specifics of these categories is crucial before the selection of AR products to be employed for use.

## **3 Business Context**

Ashghal, the Public Works Authority (PWA) contributes to achieving the goals of Qatar National Vision 2030 & delivery mandates for hosting the FIFA World cup 2022 by leading the transformation of Qatar’s road & drainage infrastructure and public buildings to develop the nation into one of the most advanced and smart countries in the world. The objectives in the pillars of sustainable development and high-quality urban lifestyle of QNMP-Qatar National Development Framework 2032 of QNMP highly influence the increase in the urban space and utility densities. The rapid transformation by taking advantage of the enormous opportunities of smart technology in developing more sustainable asset management. The “Smart Qatar” initiative also known as TASMU is one of the key components of QNV 2030. The TASMU emphasizes harnessing the power of innovative technology in the delivery of public infrastructure and improving operational efficiency.

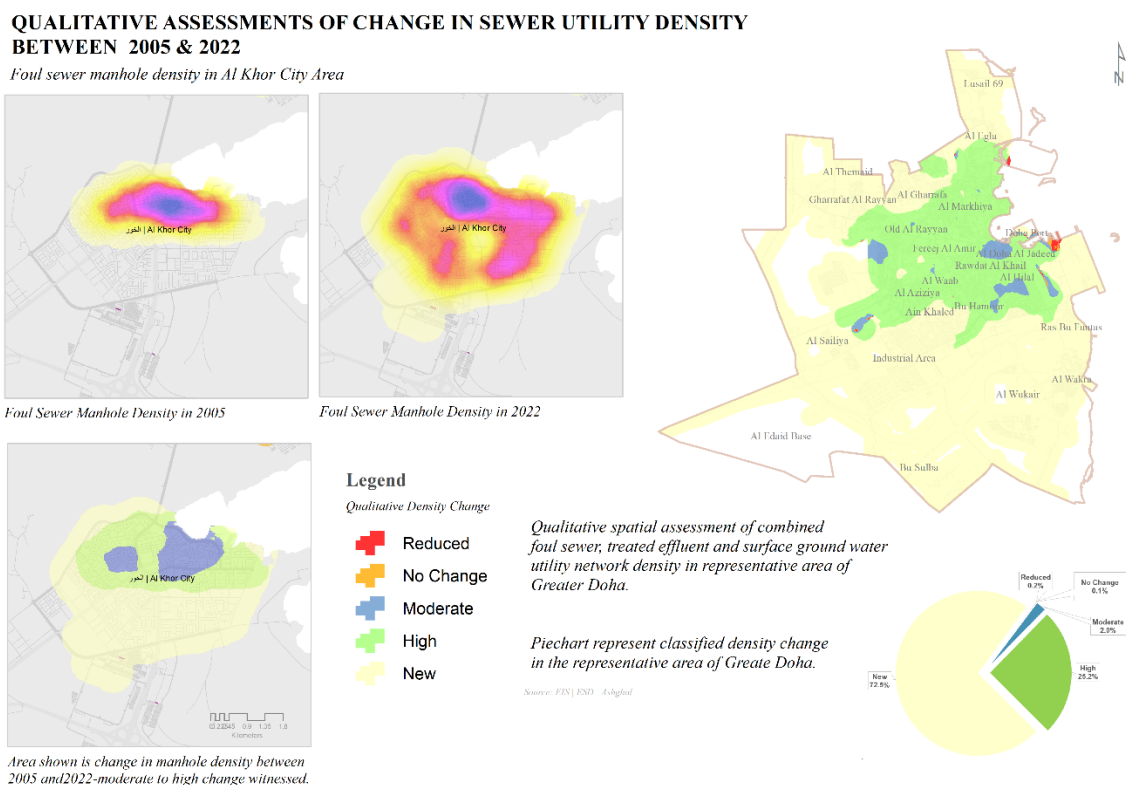
Augmented Reality (AR) Technology interfaces digital information with real-world environments both spatially and temporally. It is considered as one that engenders tangible impact in the areas of operation and maintenance of public works assets. AR Initiative is part of smart city initiatives, identified as part of the Geospatial Strategic Master Plan for PWA. This plan provides a clear road map for geospatial business with PWA for the next five years to meet the strategic objective to achieve operational excellence in geospatial services.

### **3.1 Business Challenges and Needs**

To understand the business case of this initiative, understanding the organization and its core

functions is almost important. Being a construction and asset management organization of critical capital assets, Ashghal depends on Geospatial Information (GIS) for carrying out its various key activities like design, project monitoring, asset operations, and maintenance. Ashghal is the owner of GIS data specifically for roads & highways, and sewers, and the TSE Network and its facilities. The spatial information of the core data acts as the source for key functions and departments' requirements during design, project management, project handover, and asset management. This information is used for various enterprise business applications like EAMS, CRMS, QPRO, QDRS, TDP, etc.

The key constraint in the State of Qatar for the development of road and utility infrastructure is the availability of right of way and it is limited. Thus, the utilities like foul sewer, TSE, ducts for telecommunication, electricity, water network, etc. are placed under the narrow corridor. Any maintenance or inspection activities that would be planned impact the free flow of traffic (Hamidy, 2020). The built environment and high-density underground utilities provide complex challenges to the field crew in locating the service assets. To understand the spatial placement of the underground assets, the density change was analyzed using geospatial information over the past decade and Figure 1 illustrates a qualitative assessment of utility density change in Doha and Al Khor. More than a 25% increase has been witnessed only from sewer density without consideration of other utility assets like electricity, water, telecom, ITS, and metro network assets, etc.



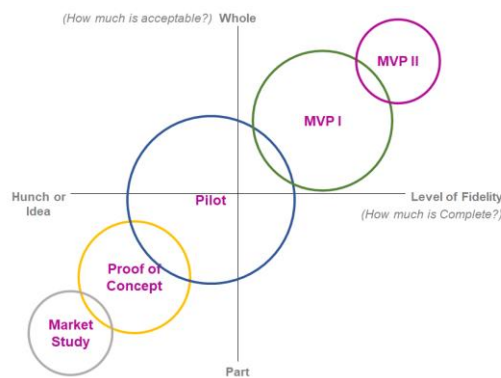
**Fig. 1:** Change in Utility Network Density in Doha and Al Khor Areas

Implementing AR technology would help the PWA field crew in visualizing/identifying any underground/hidden assets. AR implementation is expected to overcome the challenges and optimize any maintenance /inspection activities and design validation. Building Information Modeling (BIM) is being implemented in Ashghal more specifically in design phase of the work. As BIM is playing a critical role in virtual reality space, it creates a vacuum in the design validation in correlation with the real world. This leads to possible design changes based on the field condition during the construction stage. To support the above argument, one of the studies in PWA observed that the root cause for

variation orders and prolongation cost was contributed by the design changes, design clashes, delayed decisions, and unforeseen site conditions. The need for this initiative is expected to realize the following value proportion: (i) reduce the damage of PWA’s assets and 3rd party underground assets and reduce claims (ii) improve the safety of the organizational personnel by eliminating accidentally hitting hazards and sub-surface infrastructure during the work activities and (iii) quick turnaround decisions, (iv) early error detection and design changes.

#### 4 Methodology

A structured approach is being followed from the selection of the product to full-fledged implementation. This approach aims to use public investment to be more efficient and effective by finding out what works and what doesn’t, at the earliest. The approach focuses on agility in implementation to identify challenges and hasten learning. There are two key factors considered to ensure the technology is compatible with the work environment, acceptable to the end users, has business value, and potential to have continuous enhancement. Figure 2 illustrates the context of the methodology adopted for this initiative. It is a modified approach suggested by Bas Leurs & Kelly Duggan (2018).



**Fig. 2:** AR Implementation Roadmap based on MVP Approach

A market study is to explore various commercially available AR products that are used in public works business space. We engaged with the product vendors to understand the capabilities of the product and their roadmap for the next five years. Based on the information available the simplified Technology Acceptance Model (TAM) is used to identify the most preferable product. As this model collects information from five dimensions, it is considered an appropriate framework for product selection. It has perceived usefulness, perceived ease of use, perceived enjoyment, and attitude towards its use (Cabero et.al, 2022).

Proof of Concept (POC) was followed to get real-life confirmation of the product and technology focus. The POC was conducted with three user groups including asset management, engineering information, and positional survey with limited users and dataset. The outcome of the POC helped to fine-tune the drafting of requirements specifications for the next phase and product procurement. Following the POC, the pilot phase is planned and targeted with a full license product of all functionalities, to a wider user base and datasets. This phase is business focused, to place the product in real-life business life cycle activities like inspection, validation, data collection, etc., A longer span pilot period of up to six months to one year is planned, this is typical to collect data from seamless user experience, varying working, and climate and environment, and to realize the product roadmap release from the vendors. Procurement of limited licenses with additional lidar scanner add-ons has been initiated.

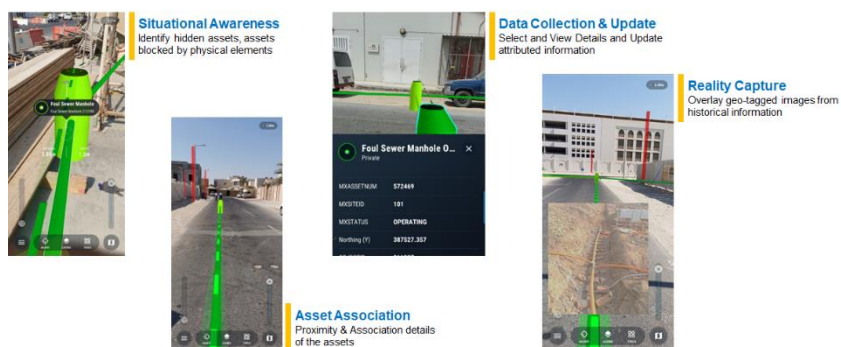
The full-fledged implementation is planned with the Most Viable Product (MVP). The MVP shall provide the core functionality that will continuously adapt to create value in the business operation. The MVP will be rolled out to extended business users including partners and contractors. The implementation landscape will continuously increase and incrementally roll out enhanced versions of the project as MVP II/III etc.

## 5 Case Study Discussions

As PWA is transforming from a project delivery organization to an asset management organization, the case study is specifically designed and addressed to asset management business cases. To support the study, users from the GIS, Asset Management, and Positional Survey engaged to evaluate the technical aspects and position accuracy of the product. The POC case study is handled in two categorical cases (i) Business Cases and (ii) Usability Cases.

### 5.1 Business Cases

The case study used four distinct business cases for field assessment as part of the proof of concept (POC). The *situational awareness* case is to visualize sewer network assets in the real world in three-dimensional space from the handheld device. This task is to have awareness of the underground asset where the visibility of the asset is obstructed by a physical object (like a building, roadside structure) or inaccessible. The business case of *asset association* is to visualize associated assets to show proximity details of the assets like distance to the asset and refurbishment. The *Reality Viewing case* is to overlay geotagged images with real scenes. The case uses photographs taken from past maintenance work, typically captured before the backfill of utility maintenance work of trenches. The task of selecting an asset on the AR tool and being able to view the specific asset information is performed through an *asset information* case. The task is expected to be able to update some of the key attribute information from the field. Figure 3 shows screenshots captured during the POC exercises.



**Fig. 3:** Illustration of the AR Tool screenshot from POC Testing of various use cases

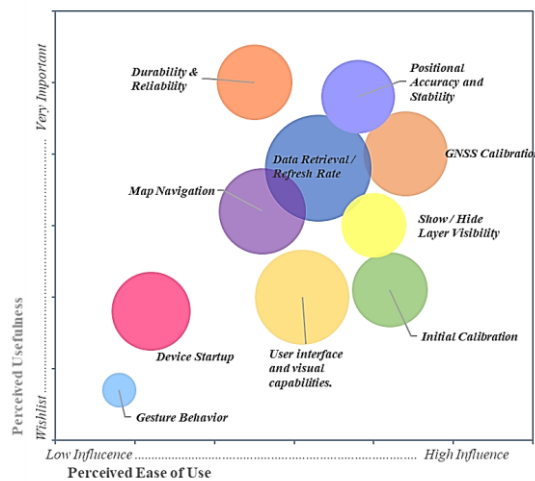
In the Pilot Phase, PWA intends to incorporate the following business cases:

- i. AR indicates a remarkable opportunity as a functional extension of the BIM model during the design and construction phase of the infrastructure development life cycle. The case study scenario is to visualize the BIM model through AR handheld devices from the field and identify clashes with the built environment for design validation.
- ii. Reality capturing, a 3D scanning of assets or works with lidar-enabled mobile devices empower the review of historical works with more accuracy. The case will be used along with work order data on the associated assets or work. This case will be validated to see the practicality of capturing the lidar data as part of the maintenance workflow.

- iii. Using BIM and Reality Capturing to validate construction site inspection for audit and quality checks.
- iv. Display work orders and associated assets with location information for data updates from the field.
- v. Back-office collaboration - able to annotate and provide feedback on the design element remote inspections, review of remote site condition review if there is a conflict with existing assets to optimize response time.
- vi. Image recognition case is to retrieve asset-specific documentation like manual, SOPs, and maintenance history by recognizing the asset captured from the device.

### 5.2 Usability Case

The product was evaluated for its useability in terms of ease of use, usefulness, reliability, and performance. The useability case is very important to achieve technical acceptance of the product and to have an attitude towards using the technology by the end user. Figure 4 below shows ten cases that were evaluated during the POC and its outcome. The size of the bubble represents ease of use for the selected product.



**Fig. 4:** Usability Cases and User Perception from POC

### 5.3 Characteristics of the data and devices

Table 1 below lists eight key data set used for the case study for POC. The nature and profile of the data used for the POC has been discussed with the business users to ensure it has representative data. The dataset was extracted from the geospatial information published as ESRI feature services in WGS84 format.

**Table 1:** Spatial dataset used for POC

No.	Spatial Layer	Characteristics
1	Foul sewer manhole	The point feature represents the location of the manhole used in the foul sewer network. The feature contains z value and invert-level information.
2	Foul sewer network	The data represents the utility network information of the foul sewer. It contains depth information, condition, and pipe material.
3	House connection manhole	This is a point feature and has similar characteristics to a foul sewer manhole. This asset is usually located inside a property boundary and accessibility is a big concern for the field crew.



No.	Spatial Layer	Characteristics
4	House connection network	The dataset connects the land property with the main foul sewer and has similar characteristics to the foul sewers.
5	Work Order	Work order location is mostly represented in point, in some cases, it is also reported as a polygon when there is a road cutting. Able to view historical details where the images are captured.
6	Traffic Signal Pole	Signal Pole was constructed at the road intersection and represented a point feature with height specifications.
7	Street Light Pole	Above ground and represented as a point with the height of the pole. The asset used as a reference for the calibration point for AR Device
8	Images	Images captured before backfilling of underground asset construction/maintenance to use for reality viewing functionalities. These are geotagged images captured from mobile devices.
9	Base Map Layers	A map service contains satellite imagery, road networks, landmarks, etc.,

There were 8 different mobile devices with different form factors & operating systems employed for the POC exercise viz., iPad, iPhone, Samsung Tablets & Phones, Huawei P30 Pro and Trimble R10 GNSS with Bluetooth® and connectivity.

#### 5.4 Case Study Findings

The study concludes with the lesson learned from the POC exercise with the following findings:

- i. The technology demonstrated the best use in situational awareness scenarios (like viewing underground or hidden assets in 3D and augmented with the real scene) for the field crew.
- ii. To have a truly augmented rendering of the depth of information highly depends on the way data is modeled in the database. In the case of unavailability of 3<sup>rd</sup> dimension information, the product is considered a default depth/height value as configured in the tool.
- iii. Able to identify proximity for nearby/hidden assets is displayed with distance measures. This is very handy for the field crew for tracing the hidden/inaccessible assets.
- iv. Able to query the assets and limit the query output through systems configuration. The utilization of the product shall be further explored for asset data updates or reporting of asset defects during the pilot phase.
- v. Losing the positional accuracy as we move. The device location calibration is not reliable and sustained with mobile device internal GPS. However, with the use of external GPS Trimble R10 GNSS, the reliability is considerably improved and consistent. With the use of internal GPS and walking along the dotted line provided in the solution, calibration is required for every 25-30m. For external GNSS it sustains for more than 50m. It is observed that about 1-3cm accuracy was achieved with external GPS using Trimble R10 GNSS and the reliability of calibration is auto-calibrated with GNSS.
- vi. On extreme summer temperatures, it is observed that the AR device is heated up quickly and in turn drains the battery.

#### 6 Myth or Reality

The key barrier to harnessing any innovative technology is the myth around it. The top five myths about AR technology based on user perception are discussed in Table 2.

**Table 2: AR – A Myth or Reality Facts**

No.	Myth	Reality
1	Many users consider AR and VR the same, thus, they dissuade AR initiatives.	Though both technologies are related, with respect to the user experience AR is completely different. VR is an entirely desktop digital experience. VR information can be considered as one of the inputs for AR Technology and a good example is the use of BIM data in AR. AR combines with reality.
2	Too early to use AR Technology in public works areas and impractical to use.	The use of AR in public infrastructure works and civil engineering areas increase over the last five years. In addition to the use cases specified above, there are many use cases like HSE training in treatment plants, that can demand AR.
3	It is presumed that the implementation is more expensive, and deployment is too hard for data and the environment.	With the capability of consumer-level mobile devices and the availability of AR platforms on clouds, it becomes very much reachable on a subscription-based model. With respect to data, the latest AR platform consumes GIS and BIM data seamlessly as services. Thus, harnessing the technology even small organizations are more affordable provided the use cases are demanding.
4	Field calibration of this tool is difficult and time-consuming.	Though the reliability of the device calibration to a certain extent is true, it can be overcome by features like on-the-go calibration.
5	Due to various AR advertisements and exposure to the technology, the user believes that AR required additional expensive gadgets like glasses that are mandatory in order to use the technology.	For public works field activities, consumer-level mobile devices like smartphones, and tablets can provide an ease-of-use experience. In reality, the need for AR glasses, HoloLens depends on the use case. The use of a headset is optional, and the key purpose is to make the hands-free and comfortable for users while operating multiple field devices or tasks.

## 7 Conclusion

This paper considered a proof-of-concept case study, using AR for effective use of situational awareness, reality capture, and asset association for asset management personnel. The study indicates that the proposed AR technology has good potential for inspection and maintenance in the asset management life cycle. Selection of the right AR product eliminates any myth, and the use of TAM establishes user acceptance of the right fit product selection. The authors emphasize that the data needed shall have the right balance with respect to adding value to the business and sustaining its utilization. The implementation of AR technology would enable and encourage PWA to improve the characteristics and value of data to meet further technological needs. Beyond the cognitive limitations, AR technology is a reality and provides opportunities to become even more relevant when organizations incorporate it as an integral part of day-to-day asset management and public works operational areas to improve user experience and process efficiency.

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