Virtual, Augmented, & Mixed Reality in Construction

How, When, & Why to Use Extended Reality to Improve Construction Outcomes

Bringing Construction Plans to Life

As technology evolves, it gives new shape and meaning to reality, offering up new ways of looking at and understanding objects, spaces, and environments. Many different industries and types of businesses are harnessing "reality" technology to improve and expand operations and drive growth.

In the construction industry in particular, reality technology holds significant promise, helping teams increase accuracy and confidence during planning and construction, as well as improve communication and collaboration—both on the work site and in the office. The technologies currently used in construction workflows include virtual reality (VR), augmented reality (AR), and mixed reality (MR). Jointly, they are referred to as extended reality, or XR.

Worldwide spending on augmented and virtual reality is expected to reach $18.8 billion in 2020.

By helping the various stakeholders involved in a project to quickly and easily visualize and explore designs, models, and site conditions, XR is changing the way construction is done

and improving workflows across the building and infrastructure lifecycle. Much more than just the latest tech trend, XR technologies are addressing some of the most challenging and costly problems construction companies face, making these tools a must-have solution to remain competitive.

As XR technologies continue to gain steam in the construction industry, contractors and consultants will need to have a baseline understanding of what the technologies are, how they can be used, and the benefits they provide. This paper explains the benefits of XR in general and details the differences between VR, AR, and MR technologies. It also outlines the uses of these technologies in construction and what to consider when choosing the best technology for specific needs.

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Benefits of Using XR in Construction

XR technology as a whole allows construction professionals to more easily visualize, understand, and communicate information. Each tool helps construction teams "see" digital content in different ways and for different purposes.

For example, XR technology doesn't just make it easier to visualize designs. It can also be used to virtually see behind walls and under floors. These capabilities enable crews to pinpoint the location of underground services, for example, or identify equipment or building maintenance issues. The ability to immerse someone in a virtual environment has other significant implications, such as making it possible to train a worker in hazardous material handling in the context of a safe and controlled environment.

"All immersive technologies extend the reality we experience by either blending the virtual & 'real' worlds or by creating a fully immersive experience."[2]

1 Worldwide Augmented and Virtual Reality Spending Guide. IDC. July 2019

2 Marr, Bernard. "What Is Extended Reality? A Simple Explanation for Anyone." Forbes. Aug. 12, 2019.

Not Just a
WOW Factor

XR is not just about the wow factor or the latest gadget. The use of XR is helping construction companies solve major challenges, enabling them to:

- Foster better stakeholder engagement by improving communication and collaboration
- Achieve greater productivity by accelerating decision making, reducing downtime, and minimizing rework
- Improve safety by facilitating thorough planning and training

Better Stakeholder Engagement

Traditional 2D plans are difficult for many people, both laymen and professionals, to visualize. XR can literally bring those plans to life so internal and external stakeholders can clearly understand how the finished project will be positioned and how it will look and function in the real world.

XR can be used to clearly communicate design intent to external stakeholders, creating greater support for the project and even a competitive advantage for the contractor. By providing stakeholders with a visual representation of the project before construction, challenges can be identified and communicated more easily, ensuring expectations are effectively managed. XR also makes it possible to share work in progress in a safe yet realistic way, a critical capability for those who must manage complex public projects involving multiple stakeholders.

Similarly, XR makes it possible to share design intent with internal stakeholders. Work crews, subcontractors, and others on the jobsite gain a single and consistent visual representation of the finished project. When everyone from owners to public officials to contractors to subs are working from the same understanding, they coordinate and communicate with each other more effectively. XR creates a shared vision for the project that in turn increases the likelihood of success.

Poor communication is estimated to cost the U.S. construction industry $17 billion a year.[3]

3 Thomas, Eric; Bowman, Jay; Schott, Peter; Snyder, Jay; Spare, Natalie. 2018 Industry Report: Construction Disconnected. FMI/PlanGrid. August 2018.

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Improving
Productivity & Safety

Greater Productivity

As the current labor shortage in construction continues, companies are having to do more with the resources they have and make more efficient use of their time. XR tools get everyone on the same page quickly by enabling a common and accurate understanding of the design and site conditions.

> "If construction-sector productivity were to catch up with that of the total economy—and it can—this would boost the sector's value added by an estimated $1.6 trillion, adding about 2 % to the global economy."[4]

By providing a visual representation of the project in context, XR helps project teams estimate, plan, and schedule the work with more confidence and greater precision. Project teams are using XR applications for clash detection, allowing them to uncover potential issues before the build begins and minimize the potential for expensive rework that can erode profits and delay schedules. With fast access to accurate and consistent information, project teams can stream-line construction workflows, stick to timelines, and avoid undue confusion and disruptions.

When XR is used in combination with BIM, teams gain even greater efficiency. They're able to access and share integrated data and in the context of the design. With a clearer understanding of the design intent, they're able to make better and faster decisions informed by reliable and consistent data.

> The reported cost of construction rework is estimated at 5% of the overall contract value.[5] The actual figure could be much higher.[6]

4 Barbosa, Filipe; Woetzel, Jonathan; Mischke, Jan; Ribeirinho, Maria João; Sridhar, Mukund; Parson, Matthew; Bertram, Nick; Brown, Stephanie. "Reinventing construction through a productivity revolution," McKinsey Global Institute. February 2017.

Improved Safety

Construction is one of the most dangerous industries, accounting for one in five workplace fatalities.[7] In fact, it's estimated that two workers per day die in construction accidents in the U.S., and thousands more are injured each year.[8]

The repercussions of fatalities and injuries cost the industry billions of dollars annually. Yet accidents and near misses can be minimized with thorough planning and a clear understanding of the potential risks and threats. XR helps bring the threats to light.

> According to the Common Ground Alliance (CGA),over the past 20 years utility hits have resulted in $1.7 billion in property damage, 1,906 injuries, and 421 deaths.[9]

For example, construction crews can use VR to visualize what's underground before excavation begins. They can use this information to avoid costly utility strikes, as well as know where to divert workers or the public to keep them out of harm's way. XR technologies are also being used with models of real-world sites to reveal safety hazards. These models can then be used for safety training and to inform crews of hazards.

These benefits alone are having significant positive impacts and delivering a sizable return on investment for those who are already using XR technology. While more difficult to measure, the ripple effects of better stakeholder engagement, greater productivity, and increased safety can be expected to produce even more profound shifts and create the momentum to bring about the broader industry transformation that so many acknowledge is needed.

5 Hwang, Bon-Gang; Thomas, Stephen R.; Haas, Carl. "Measuring the Impact of Rework on Construction Cost Performance." ResearchGate. March 2009.

6 Dougherty, Jason M.; Hughes, Nigel; Zack, James G. Jr. The Impact of Rework on Construction & Some Practical Remedies. Navigant Construction Forum. August 2012.

7 Smith, Sandy. "Construction Accidents: The Risks, the Facts and the Repercussions." EHS Today. December 3, 2014.

8 Ibid.

9 "Underground Utility Strikes USA." 1300Locate. May 22, 2019.

Using XR Technology in Construction

While XR has broad application in construction, each individual technology is like any other tool in that it has unique considerations and is best suited to certain applications. Gaining a deeper understanding of how virtual, augmented, and mixed reality work will help clarify which technology to choose for specific situations.

Virtual Reality (VR)

How It Works

Virtual reality got its start in the gaming industry by immersing players in artificial worlds. Wearing special goggles that removed the real world around them and projected a "virtual" reality instead, players became part of the game and were able to interact and respond within it using natural gestures and movements. VR goggles, regardless of their use in gaming or construction, operate using the same principles. Motion sensors in the hardware detect when the wearer turns their head. The digital image the user sees is then updated accordingly to present the new perspective. At the same time, handheld controls allow the user to point, interact with virtual objects, and direct their experience.

VR Applications in Construction

Because VR provides a fully immersive experience, it's an especially effective tool for design teams, contractors, and owners to review and approve plans and understand sites and spaces. The VR application controls the entire environment that the user sees, creating a uniquely detailed and dynamic individual experience.

Some examples of how to use VR:

- Owners can fully immerse themselves in the proposed design of a building that doesn't exist yet and see the concept take shape.
- A team member that may not be located at the jobsite but wants to understand actual site conditions can virtually experience a scanned 3D model of the site in the office and then be able to communicate more effectively with employees in the field.
- Construction contractors can also use VR to train workers on specific tasks in a safe environment, such as how to use heavy equipment or install electrical wiring.

Virtual reality provides a fully immersive experience that allows the user to visualize digital content.

Considerations

VR provides an individual experience rather than a group one, so users won't be able to see or interact with the other people in the room beyond a digital representation of them in the VR environment. Because VR is a fully immersive experience and the user can't see the real world around them, it's also best to use it within controlled indoor spaces so users can safely move around and avoid potential hazards. While VR's applications are limited by this constraint, it's well suited to office demonstrations, presentations, and training.

Augmented Reality (AR)

How It Works

Augmented reality has been in use in a number of industries for decades. AR is the technology behind the field markers that viewers see on TV during football games, for example, but perhaps its most famous application is the popular Pokémon Go game. In construction, AR typically relies on a mobile device, such as a smartphone or tablet. For example, Trimble SiteVision is an AR system that combines a smartphone with a lightweight, handheld integrated positioning system. The system uses GNSS, the Global Navigation Satellite System commonly known as GPS, to pinpoint the user's location, and a rangefinder to allow measurement between remote points and the AR model. Using the smartphone's built-in camera, the user is able to see the 3D model overlaid on the physical surroundings and accurately located in context. This context is important to understand precisely the interaction of the model with the environment. Sensors pick up changes in the user's motion and point of view, then the tool overlays the 3D model on the mobile device screen relative to what the user is seeing.

> Augmented reality combines the physical & digital worlds by overlaying digital information onto the user's actual environment, typically via a mobile device.

AR Applications in Construction

Via a smartphone or tablet, AR projects a "digital window" that superimposes a detailed BIM model, be it a building or a road, onto the user's physical surroundings to help them visualize the placement of entire structures, as well as specific design features, objects, or systems. AR is especially useful in civil engineering and construction and for geospatial activities.

Some examples of how to use AR:

- Crews can use AR to identify and mark utilities or underground services.
- MEP teams can "see" through floors and walls to understand how and where MEP systems and equipment are installed, comparing the reality of the completed work to the documented design and identifying potential clashes.
- Contractors can use AR to do inspections to ensure work has been properly built, installed, or completed.

Considerations

AR is an effective tool for collaboration, allowing multiple people in one area to view the same digital information at the same time on their individual devices or a shared one. Because AR allows the user to remain aware of the surrounding environment, it's ideal and safe for use outdoors and benefits from integration with GNSS for accurate positioning of the models on site.

AR in Action:
Improving Collaboration & Communication During Site Meetings

Augmented reality technology enables any user with a smartphone to bring complex data sets to the field and easily present, share, and view them in a user-friendly format, adding immediate value to workflows and improving communication.

Take a site meeting, for example. Designers, engineers, contractors, investors, owners, and even non-technical community stakeholders can visualize what a project will look like via a 3D model using the AR tool on their own devices. While viewing the model overlaid on the actual site, people can ask and answer questions, raise concerns, and solve problems on the spot.

Instead of crowding around paper plans, users get an instant and comprehensive understanding of the project from their devices—and in much richer detail than they would get with a 2D data set. Users don't need a technical background or years of experience reading or interpreting designs to understand what they're seeing.

With the AR tool, users can also take photos, measurements, and notes onsite. Before the meeting is over, team members can create and assign tasks to other team members to ensure productive follow-up. Updates in the field can be shared and viewed back in the office, further connecting teams, workflows, and data.

>> *Learn how FMT AB, a land excavation and construction company, is using the Trimble SiteVision augmented reality system to improve communication and collaboration between crews and stakeholders.* **Read the interview.**

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Mixed Reality (MR)

How It Works

Mixed reality combines the immersive concept of VR with the interactive concept of AR. In its simplest form, MR is a head-mounted version of AR. A headset device with a lens allows the user to be immersed in the digital content while still being aware of their physical surroundings, including other people. They can interact with both digital and physical objects at the same time. Using cameras and sensors, the headset measures the user's surroundings to determine where the user is located in a room or space and then projects digital content onto that space.

MR Applications in Construction

MR allows the user to merge a BIM model with their surroundings without having to hold a device. The user can continue to conduct tasks as they normally would while being guided by the MR headset, viewing and interacting with the model with accurate, 1:1, surface-to-surface alignment.

Some examples of how to use MR:

- BIM designers can collaborate on creating a 3D model by "touring" a building or structure before it's completed.
- Contractors can use MR to compare and install components on a construction site according to manufacturer guidelines.
- Similar to AR, project teams can identify clashes with installed systems, like electrical or plumbing, and bring them to the attention of a virtual design and construction (VDC) manager to help resolve the issue.

Considerations

MR allows users to naturally interact with other people in the room or space, which also makes it a good collaborative tool. While they can be used in outdoor conditions, currently available MR headsets, like the Trimble XR10 with Hololens 2, work best and are safer when used in indoor environments.

Mixed reality recognizes its surroundings & allows the digital content to interact with the real world in three dimensions.

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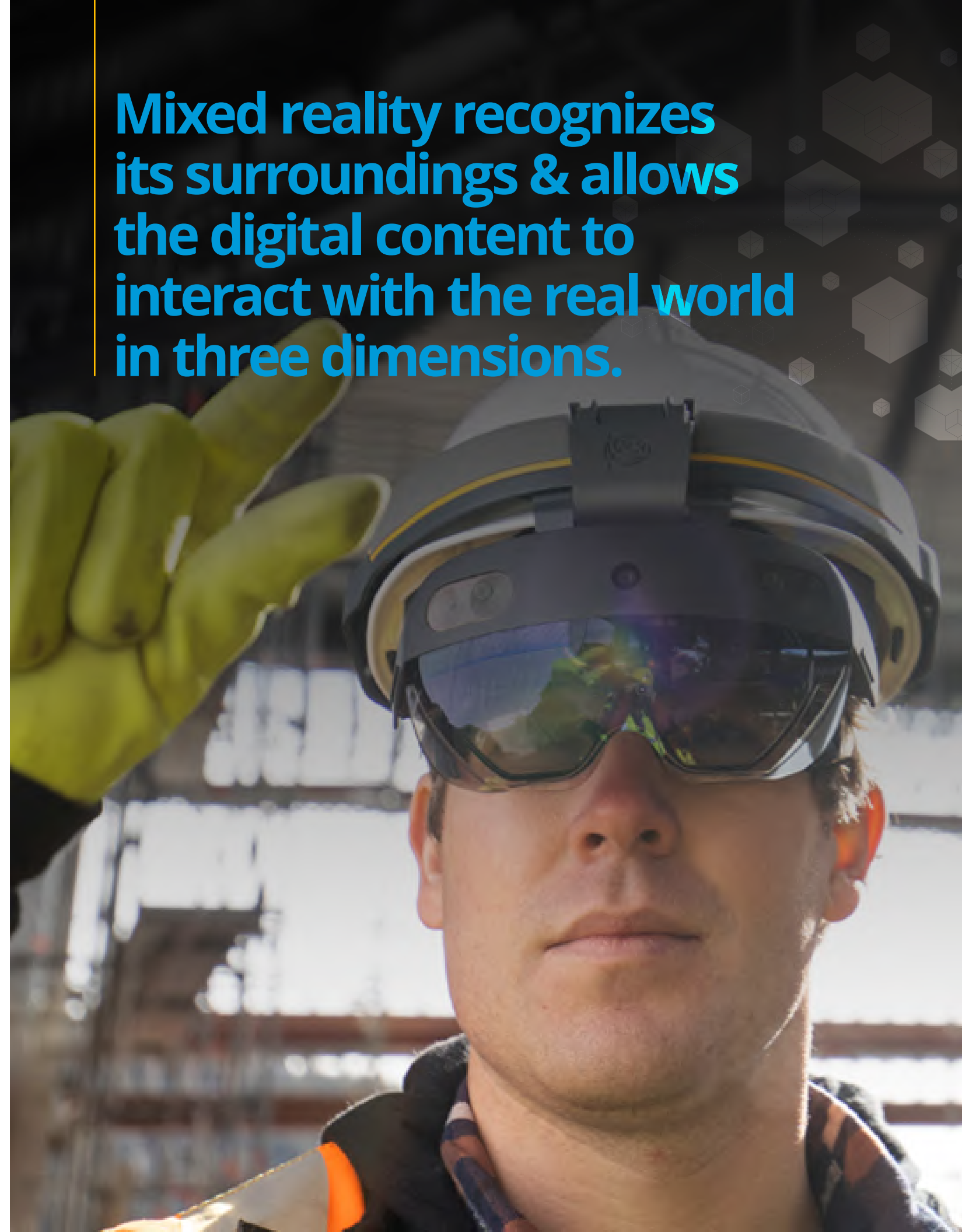
MR in Action:
How Mixed Reality is Transforming Construction

By combining the real world with the virtual world, construction companies are supporting a new way of working with models and increasing collaboration throughout the building lifecycle, providing stakeholders with current and accurate data on their worksites.

New wearable, immersive mixed reality devices are being integrated with software to deliver even more value. Paired with a compliant hard hat, the complete solution can map the physical environment and provide precise alignment of holographic data on the jobsite.

More than simply the ability to look at the model, advanced MR solutions give users access to critical building information modeling (BIM) data embedded within project components. By visualizing and "walking through" their projects in the digital world, teams can route changes and RFIs much more quickly and also accelerate the pre-construction process. They can also identify site issues earlier to reduce downstream rework and prevent chaos during the coordination. This is helping companies shorten project schedules, reduce costs, and support additional workflows like on-site assembly, progress tracking using 4D models, and even asset management.

MR also helps field workers know exactly what task to perform and provides instant feedback to help identify clashes or differences between the model and the as-built environment. When field workers can see their models overlaid in the physical environment, more precise collaboration, project tracking, and project coordination is possible.

Finally, MR solutions are playing a key role in enabling quality assurance coordination and clash detection much earlier in the project lifecycle by coordinating multiple 3D models, which is better than using a 2D screen where it's easy to overlook issues. Contractors can review and approve mission-critical designs by verifying the interaction and constructability of complex systems before they're fabricated and installed. It also saves costs by helping to catch potential issues in the virtual world before something gets built, so companies don't have to tear things out and start over.

As digital transformation continues in the construction industry and beyond, MR will play a bigger role in helping companies integrate and use technology in ways that have yet to be imagined.

Virtual, Augmented, and Mixed Reality at a Glance

	VR	AR	MR
User Expereince	Fully immersive	interactive with the real world	interactive with the world
Flexibility	typically uses hand controllers,often tethered	handheld	hands-free
Number of Users	one device per user	information can be viewed by multiple users simultaneously	one device per user
Working Environment	indoors	indoor/outdoor works great outdoors	outdoor/indoor works best indoors
Field-to-office sharing & Communications	no	yes	yes

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Embrace a New Construction Reality with XR

Extended reality technologies are changing the way construction companies work—for the better. By enhancing physical realities with digital content and making that content readily shareable, project teams can work more accurately and efficiently, make better decisions faster, and collaborate and communicate more effectively.

"If we want to exceed the limits of paper, we need to make the distribution of information easy. Effective communication and collaboration between various groups is a must."

- Pat L'Heureux, Project Engineer, Severino Trucking

VR, AR, and MR systems simplify the complex for any user or stakeholder—bringing data and designs to life and making digital content immediate, understandable, and actionable, whether in the field or in the office.

To learn how an XR system can bring greater accuracy to construction workflows and improve collaboration and communication, visit sitevision.trimble.com.

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