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How AR and VR Will Help Your Construction Firm During COVID-19 and After

Augmented and virtual reality will let you maintain safe distances, but its benefits go far beyond the pandemic.

This research report is sponsored by U.S. CAD.

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HOW CONSTRUCTION HELPED DURING THE COVID-19 PANIC OF 2020

The majority of major industries experienced disruption during the COVID-19 pandemic. Social distancing mandates and the need to meet critical demands in medical care forced construction companies, organizations and their workers to adapt.

Many states designated construction as an essential service at the beginning of the COVID-19 crisis. During the peak of the outbreaks, the construction industry helped expand existing healthcare facilities, converting shipping containers into medical facilities and building temporary hospitals. The Miami Beach Convention Center was converted into a 450-bed field hospital. Citizen Care mobile virus testing centers were set up in adapted shipping containers in Minnesota.

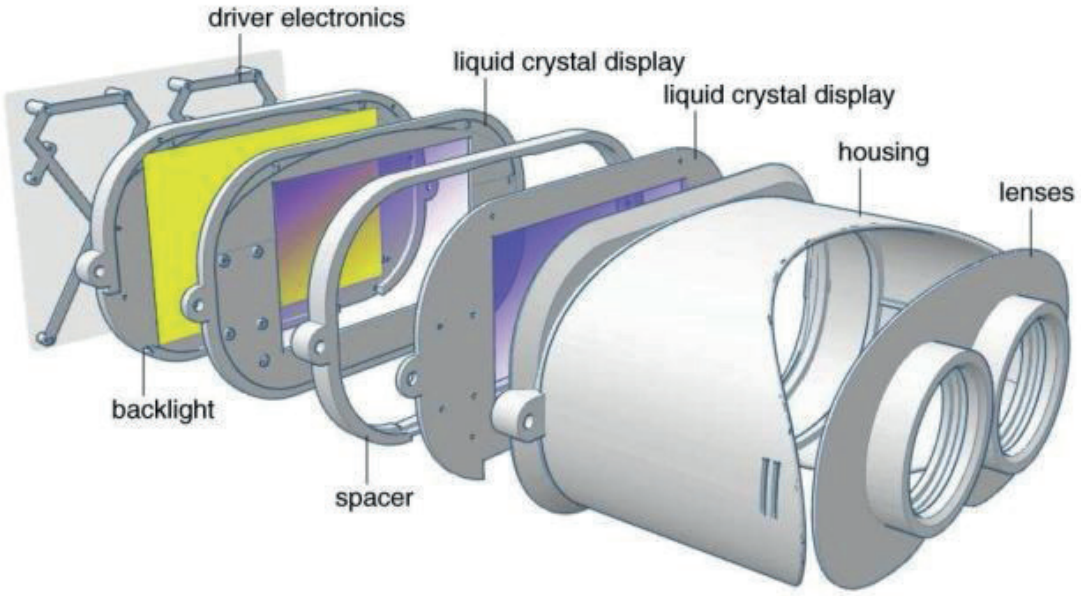
However, after medical facilities all over the world were expanded, built new or adapted to suit the influx of patients infected with COVID-19, many communities halted construction—hurting architecture, engineering and construction (AEC) firms. Limits placed on how many workers can gather at a job site vary from community to community, but the overall dampening effect of distancing regulations can be overcome with powerful software and XR technology.

Meetings can be conducted in a virtual conference room, while virtual reality can transport key people to any job site. More preparation in the initial stages of planning using virtual reality and augmented reality technology is critical to continuing construction. While safe distancing may require fewer people on the physical site, AR and VR technologies will, in effect, open the site up, allowing more people to be on the site virtually—without being subject to travel or unsafe interaction. This can be done today with a combination of the HoloLens 2 and VisualLive along with connectivity supplied by Microsoft Office 365 and Teams meetings.

If you are new to learning about virtual reality and augmented reality, the next two sections will get you up to speed.

GETTING STARTED: WHAT IS VIRTUAL REALITY?

Virtual reality is a technology that allows people simulated access to the digital world as if it were the physical world. Most VR systems use a wearable optical extension of a computerized 2D display of 3D graphics, tailored primarily to sound and vision. The most common form factor currently in use is the virtual reality headset. Virtual reality headsets are a combination of specialized computer electronics and optical hardware that provide the user with simulated access to a 2D screen displaying 3D graphics. Most virtual reality headsets use a nearby computer and software to generate a digital simulation, while the headset hardware completely occludes the user's sight of their physical surroundings.



Architects and engineers benefit immensely from crystal-clear visual communication of CAD designs in a VR environment. For example, you can walk around a CAD drawing as though you were actually there, with nothing physical to manage. You can walk around in the software version of your design, which is particularly beneficial when dealing with large-scale CAD models. A virtual reality headset loaded with a CAD drawing of an existing structure or facility far bigger than a conference room can be navigated naturally.

Now more than ever, it is becoming increasingly important to collaborate visually and immerse decision-makers and clients into designs. Some industries have been using VR for quite some time and others are new to it, but the adoption of the technology will only grow as more impactful applications are created.

Right now, virtual reality is used primarily for immersive visualization and training through simulation. This enables architectural engineers, structural engineers and many other construction industry professionals to understand and examine projects in real-time at a 1:1 scale and in much more detail than with a mouse and a 2D display screen.

If you are new to learning about VR, keep in mind that it supplements existing computer hardware and software such as CAD laptops or workstations. VR does not replace workflows; it extends their three-dimensional character into hardware that allows you and others to see it at full scale.

ADVANTAGES OF VR

VR is a tool that allows MEPs, architectural engineers and architects to make collective and individual decisions about massive virtual models at a 1:1 scale prior to final adoption or pre-construction phases of construction and engineering.

Since traditional CAD applications use WIMP systems (Windows, Icon, Menu, Pointer), exploring VR during the current pandemic is logical. Immersive computing technology will benefit design and engineering teams through remote visualization and extending typical design, engineering and construction projects further into the digital realm—saving time, money and other resources.

WIMP is not wimpy. Trying to design in virtual reality is difficult compared to using WIMP applications to create the intricate details and minutiae of a large-scale CAD design. However, visualizing 3D data using AR/VR and being able to make annotations is more beneficial. The main reason WIMP applications are disadvantageous for visualization is because the 3D models are displayed on a 2D display, creating a dampening effect where a viewer's ability to imagine the CAD data in three dimensions is fundamentally limited compared to VR and AR.

The HTC Vive Pro is one example of a PC-based virtual reality headset.

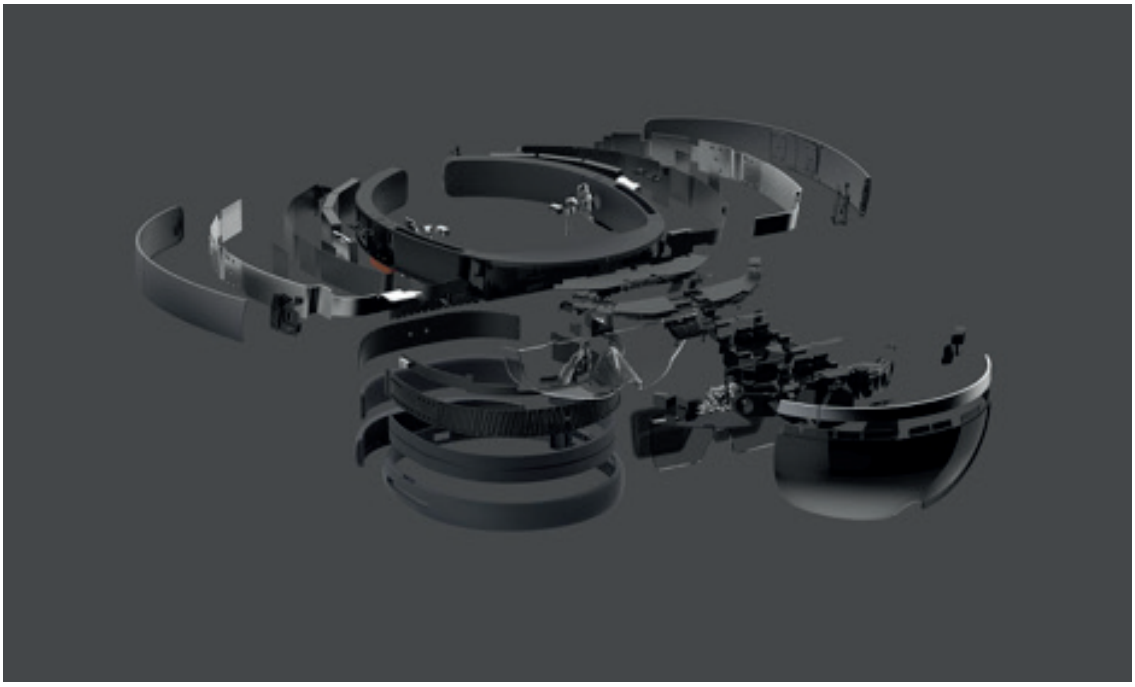
Part of this “lost in translation” effect is due to the varying abilities of individuals involved on a construction project. Translating from a subscale 2D drawing to a 1:1 scale 3D model differs from person-to-person based on their experience, practice and natural inclination. Viewing the drawing through virtual reality gives all team members access to the same translation from 2D to 3D in clear design language. Everyone involved experiences the drawing in 3D as though they were actually there. Even the best imagination cannot readily transfer 2D CAD data into 3D when the structure, building, electrical, plumbing and mechanical drawings reach extremely high levels of complexity and sophistication.

VR is particularly useful to product design teams when they are experimenting and interacting with the product. The ability to surround oneself in a design and interact with a virtual prototype at a 1:1 scale is especially useful if there are no physical prototypes available. Another benefit of virtual prototyping is the ability to simulate real-world context outside of the digital prototype.

For example, a construction company may be interested in having eye-tracking analytics to track people’s focus when shown a completed building design on a VR headset, and then use the data to make design decisions such as which locations to place signage, and where to place emergency exits.

GETTING STARTED: WHAT IS AUGMENTED REALITY?

VR completely blocks out a user's view of physical reality, whereas augmented reality (AR) superimposes digital layers of visual 3D data onto physical reality. For example, AR can show a digital object in context of the physical surroundings. The most common form factors of augmented reality are smartphones, augmented reality tablets or augmented reality headsets.



The Microsoft HoloLens 2 is the company's latest augmented reality headset.

An augmented reality headset uses a unique technology called a virtual retinal display (VRD). The virtual retinal display beams a raster projection directly onto the user's irises. With continued advancements in LED technology, VRD effectively creates a projected display where the user's eyes treat the image as though it were a normal computer display screen positioned directly in front of the eyes. Augmented reality projections have greater contrast in low-light environments, but the technology is sophisticated enough to project clear CAD models onto the user's irises that are visible even in daylight. Most AR headsets use a combination of specialized computer electronics and optical hardware that differs from VR primarily in that it does not occlude physical reality. Instead, AR is a combination of digital information and physical information.

On smartphones and tablets, augmented reality software overlays digital content through a live camera feed, providing the illusion that the digital content is in fact part of the physical environment of the user.

Engineers and architects are taking advantage of the steady technological progress of augmented reality by overlaying digital 3D models directly on 2D plans. Building Information Modeling (BIM) software and other CAD software allow construction industry professionals to present interactive and detailed models of buildings and structures prior to construction. This allows key stakeholders to perform design reviews and preview project outcomes, enabling them to lend their expertise to detect any problems before they occur during physical construction. Changes made during physical construction are much more costly.

BIM, CAD and augmented reality headsets allow AEC professionals to walkthrough with MEP engineers and scrutinize installation and placement of crucial infrastructure to avoid costly mistakes that can occur once construction begins. The more accurate the augmented reality model that is overlaid to the job site, the better a team of professionals can predict what areas of the scheduled construction will result in cost overruns and delays.

ADVANTAGES OF AR

Constructing a building or other structure is a team effort, and collaboration is crucial. Access to augmented reality technology can help all parties stay on the same page in terms of operational and managerial oversight, improving the likelihood of success. Augmented reality is particularly useful in construction because different crews are on site at different stages of the process.

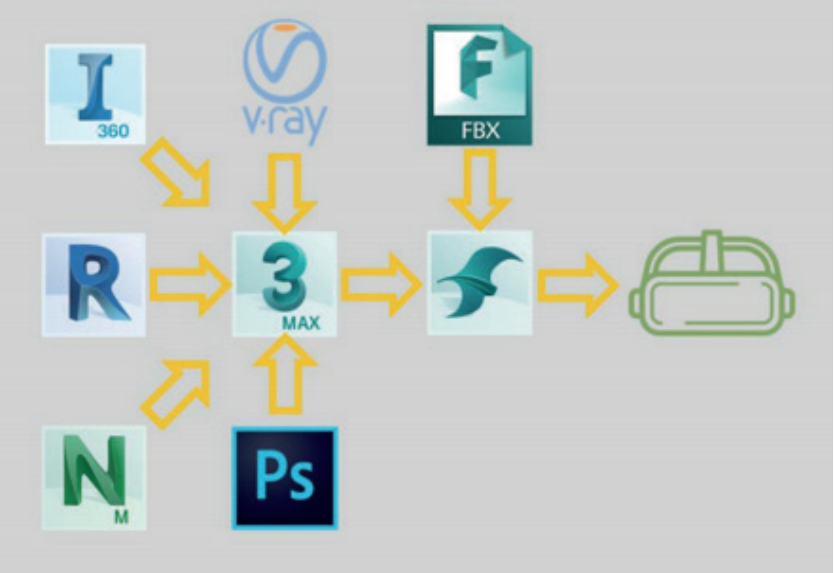
AR platforms can eliminate errors that occur in typical workflows. Carpenters, plumbers, welders and designers do not usually get a chance to assemble and preview blueprints in a manner that optimizes all aspects of a total review, and which allows changes by any involved party. Using a broad access AR platform gives everyone involved the opportunity to question design decisions or pin video reviews with useful notes, even while being part of a distributed team. The professionals involved in constructing a building will likely be in remote locations prior to and during construction. Remote monitoring is enabled by AR platforms that allow each member to consult with each other in real-time, without the need to coordinate transportation to meet at the job site.

Perhaps the main advantage of using AR in architectural engineering, design and construction is having all possible information within reach—and within sight—while at the job site. Mechanical, electrical and plumbing schematics can be accessed and overlaid directly on site in digital layers. Different construction phases in the BIM model can be switched on and off, removing the pressure of translating schematics into accurate visualization. By retrieving digital information, a project can be completely monitored on site according to the exact building plan in every sequential phase. Everything is mapped out and clearly visible, allowing workers to navigate with precision and timeliness through each specific action in each phase of the building plan. Keeping track of each phase and action during construction also allows greater assurance of completing a project on time. Even the timetable of each phase can be overlaid in AR, keeping everyone on track and in check.

An advantage of having the entire project digitally accessible within a professional's field-of-view is the ability to make changes to building models prior to construction, during the course of overlaying the 3D model on site. There are certain geometric issues within BIM and 3D modeling that prevent completely realistic geometry from being drawn out. There are imperfections in geometry on a job site, and the ability to see exactly what the BIM model looks like when superimposed over the physical job site may bring different issues to light. The beauty of AR is that the changes can be made when geometric anomalies are spotted.

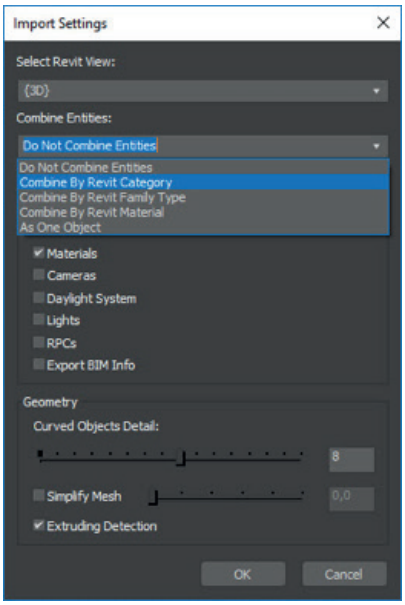
UNDERSTANDING VR: SOFTWARE TO HARDWARE PIPELINE

There are a number of different ways users can port a BIM model created in Autodesk Revit, Navisworks or InfraWorks into VR. The central software that allows this transformation to take place is Autodesk 3ds Max.



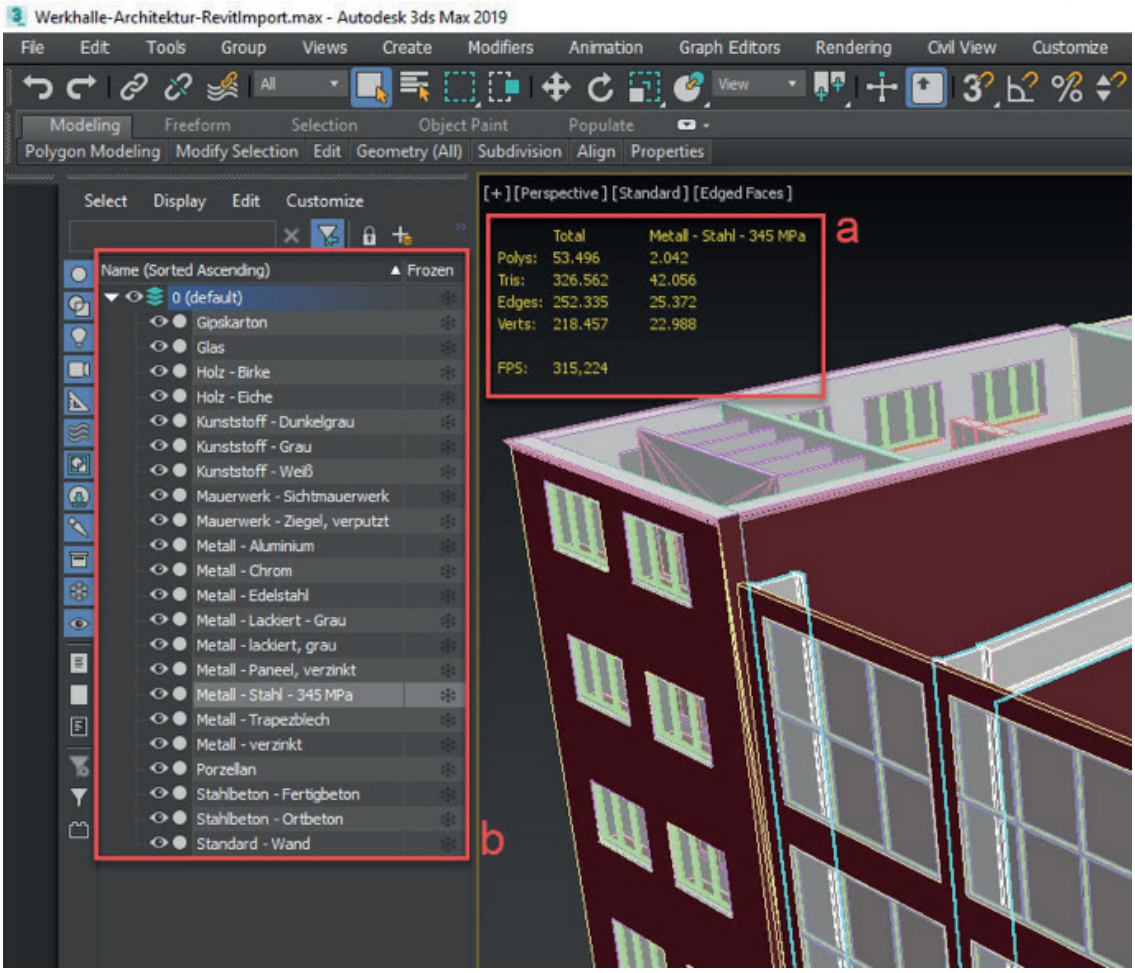
When you are using Revit, you can port your file into 3ds Max using the 3ds Max Import function.

You have to consider how the level of quality will affect the overall experience; generally, more computing power is needed when your file is larger and of a higher density. You can use the Import Settings dialog box to combine entities and ensure a smooth VR scene with little to no latency.



Users can create smaller virtual reality scenes by linking their Revit files to 3ds Max, but this will limit the ability to edit that scene. This is not a good idea for larger VR scenes.

For InfraWorks or another product that saves in an FBX file, export the file and import it to 3ds Max with a level of detail that is minimized for better performance. To do this, optimize the geometry of your model and make sure that your GPU is loading the scene to your computer's RAM, displaying it at a rate between 70 and 90 frames per second. The file's complexity and polygon count should be minimized accordingly.



Simplifying your model in this manner can also be accomplished by attaching similar or connected objects.

To check and reduce polygon count from a 3ds Max viewport, press 7. This will show the scene's statistics, including frames per second (FPS) and polygon count. Users can take advantage of the ProOptimizer Modifier to ensure the model is optimized for VR.

Next, users should export their geometry as an FBX file so it can be read by a gaming engine. This will allow users to view the VR scene on the Oculus, HTC Vive, Valve Index and Pixmax PC-based VR headsets.

CHOOSING THE RIGHT CAD PLUG-IN FOR VR AND AR

Having the right hardware and software configurations help AEC professionals effectively bridge the gap between imagining what a 3D model or BIM model on a 2D display screen will look like at a 1:1 scale in physical reality.

There are many different software products for virtual reality and augmented reality that claim to have great integration for using popular CAD software in different ways on a virtual reality hardware device. However, one plug-in stands out above the rest.

IRISVR PROSPECT

Prospect is perhaps the fastest and most versatile tool for converting Revit and Navisworks models into virtual reality scenes. It converts a wide range of 3D model files into virtual reality scenes including FBX, OBJ, Sketchup and Rhino files for nearly every VR and AR headset on the market today. AEC and MEP professionals can easily view their BIM models in VR with Prospect. Virtual Design and Construction (VDC) teams and other construction professionals can join them in performing design reviews via virtual walkthroughs and performing model coordinations.

CHOOSING THE RIGHT HEADSET MEANS HAVING THE RIGHT COMPUTER HARDWARE

Most VR headsets on the market today require tethering to a laptop or desktop computer. Each headset has slightly different computer hardware requirements, but the variety of compatible options gives professionals more to choose from to suit their particular needs. A higher degree of customization and total compatibility with Prospect makes running pilot programs at companies prior to a larger-scale integration more customizable.

The following AR and VR headsets are compatible with Prospect. Computer hardware system requirements are listed.

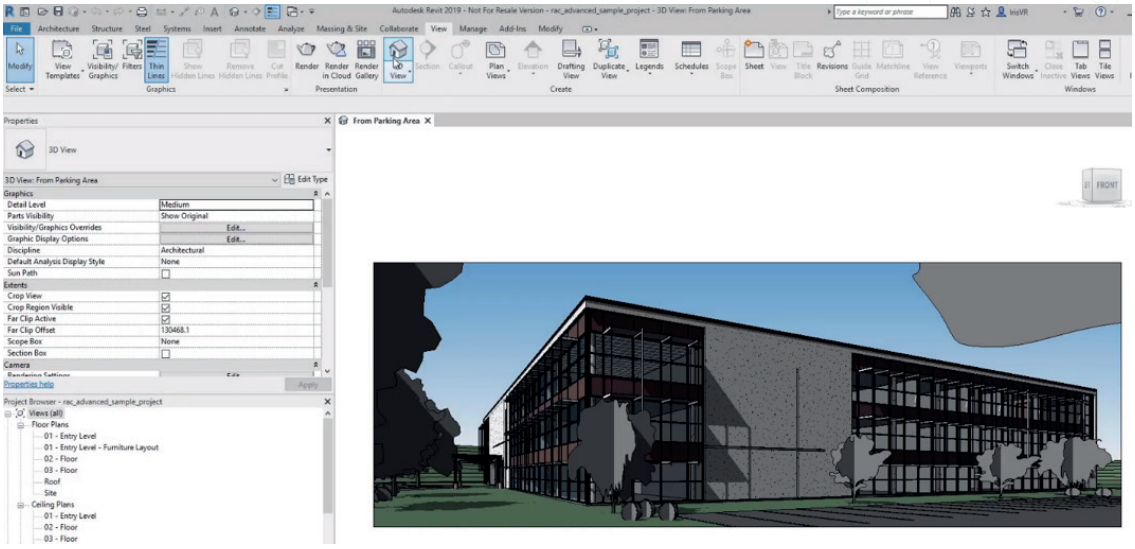
Headset	System Requirements	VR	AR
Oculus Rift 	• NVIDIA GTX 1050 Ti / AMD Radeon RX 470 or better. • Intel Core i3-6100 or better. • 8GB of RAM or more. • HDMI 1.3 output. 1x USB 3.0 port. 2x USB 2.0 ports. Windows 8.1 or newer.	Yes	
Oculus Rift S 	• NVIDIA GTX 1060 / AMD Radeon RX 480 or better. • Intel i5-4590 / AMD Ryzen 5 1500X or better. • 8GB RAM or more.	Yes	
Oculus Quest 	With Oculus Link: • Intel i5-4590/AMD Ryzen 5 1500X or greater. • RAM: 8 GB or more. • Operating System: 64-bit Windows 10. • USB ports: 3x USB 3.0 ports plus 1x USB 2.0 port. • Video Output: Compatible HDMI 1.3 video output.	Yes	
HTC Vive 	• Nvidia GeForce GTX 970 / AMD Radeon R9 290 equivalent or better. • Intel i5-4590, AMD FX 8350 equivalent or better. • 4GB RAM or more. • Video Output: HDMI 1.4, DisplayPort 1.2 or newer. • USB Port: 1x USB 2.0 or better port.	Yes	
HTC Vive Pro 	• Processor: Intel Core i5-4590 or AMD FX 8350, equivalent or better. • Graphics: NVIDIA GeForce GTX 970 or AMD Radeon R9 290, equivalent or better. • 4 GB RAM or more. • DisplayPort 1.2 or newer. 1x USB 3.0 or newer port.	Yes	

Headset	System Requirements	VR	AR
Valve Index 	• Windows 10, SteamOS, Linux. Dual Core CPU with Hyper-Threading. • Memory: 8 GB RAM. • NVIDIA GeForce GTX 970 / AMD RX480, Broadband Internet connection. • DisplayPort Version 1.2 or better and USB 2.0+ Port required.	Yes	
Pixmax 	• Windows 10, 8, 7, Vista. • 1GB Minimum RAM, 4 GB or more recommended. • Screen Resolution: 1152 x 854 minimum, with 16-bit color or higher. • Install Space: 1GB • 4 GB Storage.	Yes	
HP Reverb 	• Intel Core i7 or Xeon E3-1240 v5 CPU. • NVIDIA GTX 1080, Quadro P5200, or Radeon Pro WX 8200 GPU. • 16GB of RAM.		Yes
Dell Visor 	• Windows 10 Fall Creators Update or later. Intel Core i5 7200U/AMD Ryzen 5 1400or better. • 8GB of RAM. • 10GB of storage. • Integrated Intel HD Graphics 620 or greater, NVIDIA MX150, NVIDIA GeForce GTX 1050, GPU NVIDIA 965M or AMD Radeon RX 460/560 or better.		Yes

Headset	System Requirements	VR	AR
Samsung HMD Odyssey/ Odyssey+ 	• Windows 10 Fall Creators Update or later. Intel Core i5 7200U/AMD Ryzen 5 1400or better. • 8 GB of RAM. • 10 GB of storage. • Integrated Intel HD Graphics 620 or greater, NVIDIA MX150, NVIDIA GeForce GTX 1050, GPU NVIDIA 965M or AMD Radeon RX 460/560 or better.		Yes
Acer Windows Mixed Reality Headset 	• Windows 10 Fall Creators Update or later. Intel Core i5 7200U/AMD Ryzen 5 1400or better. • 8 GB of RAM. • 10 GB of storage. • Integrated Intel HD Graphics 620 or greater, NVIDIA MX150, NVIDIA GeForce GTX 1050, GPU NVIDIA 965M or AMD Radeon RX 460/560 or better.		Yes
Lenovo Explorer 	• Windows 10 Fall Creators Update or later. Intel Core i5 7200U/AMD Ryzen 5 1400or better. • 8 GB of RAM. • 10 GB of storage. • Integrated Intel HD Graphics 620 or greater, NVIDIA MX150, NVIDIA GeForce GTX 1050, GPU NVIDIA 965M or AMD Radeon RX 460/560 or better.		Yes
HP Windows Mixed Reality Headset 	• Windows 10 Fall Creators Update or later. Intel Core i5 7200U/AMD Ryzen 5 1400or better. • 8 GB of RAM. • 10 GB of storage. • Integrated Intel HD Graphics 620 or greater, NVIDIA MX150, NVIDIA GeForce GTX 1050, GPU NVIDIA 965M or AMD Radeon RX 460/560 or better.		Yes

HOW IRISVR PROSPECT WORKS

Once users have their chosen headset and hardware-compatible computer, the process begins with BIM or 3D modeling software. In Revit, for example, a user will first open up their model.



An Autodesk Revit BIM model.

Next, the user will activate their 3D view and make a copy, then click on the Project browser and click Duplicate View. After renaming the copy, check the visibility settings with the understanding that the duplicate model will be your exact VR scene.

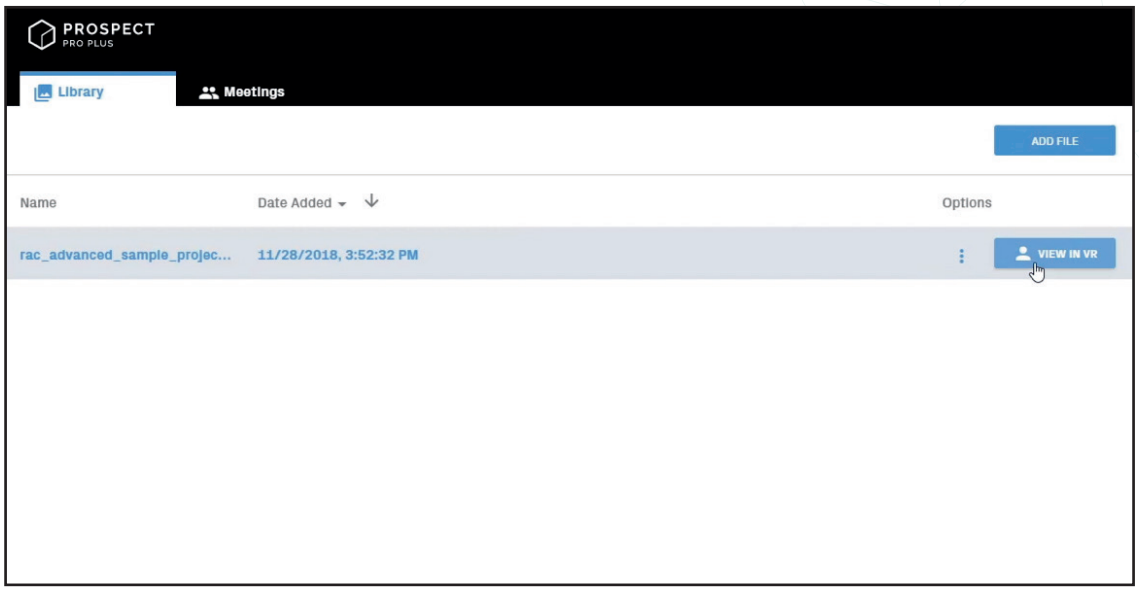
At this point, the user is reviewing visibility settings for a Revit model, and they may face competing priorities; specifically, that the quality of the VR scene may have to be weighed against the functionality of the VR scene.

This means understanding that using a computer with minimum hardware specs for a given VR or AR headset may require a user to lean towards creating a scene with less visual quality in order to achieve better VR functionality. The degree to which a user preparing a VR or AR scene can supersede the minimum computer system requirements made by the AR or VR headset manufacturer, the more freedom they have to convert a VR scene with less attention to visual quality and VR functionality.

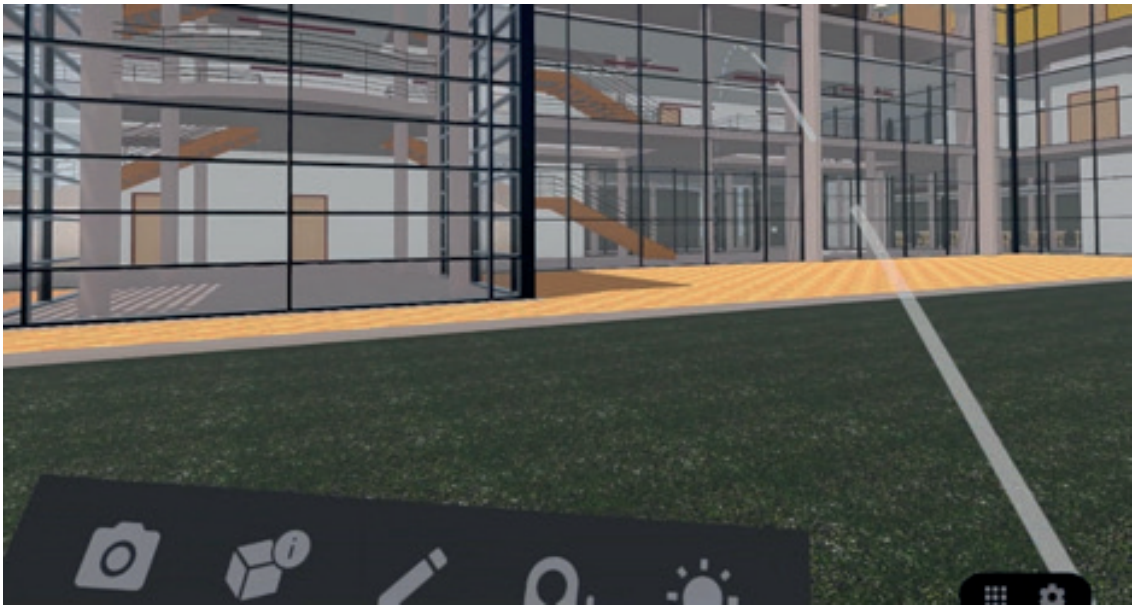
Striking a balance between the two will likely be necessary, and so weighing the opinion of an aesthetic-minded designer versus a functionality-minded engineer could prove challenging if the computer hardware is not powerful enough.

After reviewing geometry and considering form versus function, the user goes to the “Add-Ins” tab, where they can select the IrisVR “View in VR” plug-in and select the view file they renamed from the copy of the original Revit model.

The user will leave the file to process, and Prospect automatically opens when the Revit scene is ready.



In the final step, the user clicks “View in VR” to load the Revit model to the headset. Prospect optimizes the file and preserves the metadata.



Using the controllers that come with the VR headset, the user is free to explore the Revit model at a 1:1 scale in virtual reality.

UNREAL STUDIO PLUGINS FOR CAD SOFTWARE IN VIRTUAL REALITY

The gaming engine known as Unreal Engine, created by Epic Games in the late 1990s, has evolved into a tool called Unreal Studio which allowed enterprise users such as designers, architects and engineers to move 3D data into virtual reality and augmented reality.

Unreal Studio was created from Unreal Engine, which underwent many evolutions from a structure that was designed to be flexible and open to development for gaming. Unreal Engine was initially designed for gaming, and your computer never runs a game from Unreal Engine itself—the main difference between Unreal Studio and Unreal Engine.

Unreal Studio was built for non-gaming enterprise software such as Archviz or CAD applications, and leverages and runs real-time rendering from Unreal Engine, not as a separate .exe file. In Archviz or CAD, 3D data is viewed in VR as a .mov file or a 360-video file format.

Epic Games began focusing on optimizing their real-time rendering engine in Unreal Engine 4, and created Unreal Studio because they discovered that architects were already leveraging Unreal Engine for rendering. One segment targeted by Unreal Studio is construction companies who are experimenting with virtual reality and augmented reality.

Unreal Studio further targets enterprise markets which include architecture, engineering and construction, promising faster iteration time through a more efficient movement of CAD and 3ds Max data into Unreal Engine. In a nutshell, Unreal Studio reduces the barrier to get your 3D data cooking with Unreal Engine's real-time rendering capabilities.

Today, Epic Games has rolled all the features of Unreal Studio directly into Unreal Engine. That includes what was formerly known as Datasmith, a toolkit to help manage the importing of CAD data into Unreal Studio. It supports multiple popular CAD applications.

AUTODESK 3DS MAX (PLUG-IN)

The plugin for 3ds Max can maintain familiar scene hierarchy while translating a scene that includes materials, cameras, geometry and lights. Users can also convert Corona, V-Ray and Mental Ray data into Unreal Engine elements.

AUTODESK INVENTOR

Unreal Engine offers import tools for two supported extensions for Autodesk Inventor users, including .iam (assembly) and .ipt (part) files. Native assembly files can be imported into Unreal Engine, including those with hierarchy data, basic color extraction data and meta data.

CATIA, SIEMENS NX AND CREO

Import tools in Unreal Engine manage file extensions for this group of software including .catpart, .catproduct, .cgr, .asm, .neu and .prt files. Attribute data includes hierarchy data, basic color extraction data and meta data. Unreal Engine allows users to import Creo parts and assemblies into Unreal Engine as well as native NX files.

RHINO 3D

Unreal Engine has an import tool for .3dm files, which means users can import Rhino surface models and scenes into Unreal Engine—though with less attribute data. Only basic color extraction data and meta data are translated over.

The use of Unreal Engine has streamlined the process by which users can begin applying real-time rendering tools to advanced CAD data. A number of customers are now using the software in real world applications.

UNDERSTANDING VR: TRAINING, SUPPORT AND SKILLS

A lot of the value of virtual reality in AEC is derived from viewing CAD designs at a 1:1 scale. This helps bridge the gap between imagining what a 3D model on a 2D display screen would look like at a 1:1 scale in physical reality.

> *Rule of thumb: The less training, support and skills needed for a virtual reality system, the better the system.*

There are a lot of different software products for virtual reality that claim to have great integration for using popular CAD and BIM software in different ways on a virtual reality hardware device.

Understanding the training, support and skills needed for VR implementation is best illustrated by examining companies that have gone through it.

GILBANE BUILDING COMPANY

Providence, Rhode Island-based Gilbane Building Company provides pre-construction planning, general contracting, facility management and integrated consulting among other construction and facility services for clients in diverse markets from 45 different locations around the world. They have been doing so since 1873, when the company was founded.

In search of a solution that would provide a higher level of communication during coordination meetings, Gilbane's research led them to IrisVR's Prospect software. They were attracted to marketing material that promised a quick and painless learning curve with collaborative features and built-out integrations.

A Navisworks scene created by Gilbane.

According to Rawl Sawh, Director of Virtual Design and Construction, “Gilbane wanted a solution where we wouldn’t have to spend two to three days adjusting a model just to have changes made and have to go through that process again. In addition, since most of our workflows go through Navisworks, we wanted a resolution where we would be able to utilize the CAD models we receive from our trade contractors, and Prospect allows us to do that. Prospect has a multi-user function that allows multiple individuals to join a virtual meeting and experience a walkthrough of the same model together. Up to 12 users can join from anywhere in the world, using their own headsets. This multi-user capability is a game-changer, as users experience the space simultaneously. Even if users do not have VR headsets, they can still join in and experience the space on their own, or alongside another user. Within a matter of minutes, you can go from running a Navisworks model, to running a multi-user VR meeting.”

Integrating Prospect was done gradually and with care. They started by introducing the software during weekly project coordination meetings with sub-contractors to help them visualize difficult sections of a project using Navisworks. After this went well, they showed it to design teams who were drawing in 2D, allowing them to enter their own designs at a 1:1 scale to better understand the impact of design decisions they were making in real-time.

Though the integration was gradual, Gilbane is now using Prospect with clients to resolve clashes, improve visualization of 3D models and increase the overall quality of decision making in design and execution of many different projects.

UNDERSTANDING AR: THE SOFTWARE TO HARDWARE WORKFLOW

VisualLive developed three solutions to allow AEC professionals to view and visualize Revit or Navisworks models using augmented reality headsets such as Microsoft HoloLens as well as mobile devices including smartphones and tablets: HoloLive for HoloLens, MobileLive for iOS and Android devices, and Hardhat for HoloLens 2.

HoloLive displaying a Revit model and a field technician examining it with a HoloLens 2 embedded in a hardhat adapter.

Fundamentally, all three products work in the same way for VisualLive's 1,500 customers in AEC and MEP companies around the world. HoloLive for HoloLens works with the first edition of Microsoft HoloLens, while MobileLive works with iOS and Android devices. The latest product, Hardhat for HoloLens 2, features the newest edition of HoloLens integrated into a hardhat adapter for use on job sites.

The HoloLive products include Revit and Navisworks plugins, which allow users to share 3D models with team members with whom they are collaborating on the job site. The plugins radically simplify the process of sharing BIM models, enabling construction team members to both see the 3D file transposed over the real job site and be able to send the latest version of the model to other team members in different locations for remote access. There are markup tools for annotations to the Revit or Navisworks model, labeling tools and communication tools to ensure everyone stays up to date.

The process is straightforward. Users open and view their models in Navisworks or Revit, download Visual Live plugins and place VL markers the vertical or horizontal surface anywhere on their 3D model.

Next, users print out corresponding 2D markers on any 2D printer and place them in the location of the physical job site. Then using a phone, tablet or HoloLens, users scan the marker and the model is instantly placed in the correct location.

After the model is placed through scanning the printed out markers, jobs like field validation, clash detection, BIM coordination and quality analysis and quality control can be performed against the digitally overlaid model, saving time and adding a new 3D perspective to pre-construction and construction phases.

MobileLive for iOS extending a worker's ability to see a model design ahead of time from any location.

The ability to visualize in real time during the design and construction phases allows owners, general contractors, subcontractors, engineers and designers to view the latest version of a Revit or Navisworks model against the actual job site. Reviewing things like clashes at a 1:1 scale has tremendous benefits for reducing differing interpretations when translating a 2D model to scale in the 3D geography of the real job site.

Using the HoloLens with VisualLive also provides benefits outside of the construction site in a manner similar to virtual reality. Users can reduce the scale of the model and place a printed marker directly on a conference room table to verify placement of installed components, allowing a group of professionals to confirm the correct installation of components on the job site. For design reviews, the smaller scale model can be viewed with HoloLens to see the whole project at once.

UNDERSTANDING AR: TRAINING, SUPPORT AND SKILLS

APOLLO MECHANICAL CONTRACTORS

Mechanical construction companies such as Apollo Mechanical Contractors have to provide clients with dynamic visualization of contracting work. 2D visualizations were the standard mode of operation for visualization until two years ago, when the company decided to analyze the possible ROI for implementing a visualization solution in AR or VR. After researching HoloLive, they began to gradually introduce it to their team of project managers, MEPs, sheet detailers and pipe detailers.

Apollo Mechanical Contractors is in the business of providing pre-construction, construction and design building services, so the advertised collaborative features and flexibility of running on mobile devices for model coordination meetings and conferencing were attractive. HoloLive had the right features for using Microsoft HoloLens headsets on job sites to overlay mechanical, electrical and plumbing schematics directly on the job site.

Rule of thumb: The less training, support and skills needed to implement an AR solution the better the solution.

Since Apollo Mechanical used Revit and Navisworks to create and visualize their BIM models, they were interested in using their digital designs on site to potentially cut down on rework, which was costly from an operational, managerial and financial standpoint. Self-performing trades like the contracting work done by Apollo Mechanical are always trying to cut down on rework.

HoloLive proved to be a good fit for the company. Describing the initial pain point of implementing the technology, Apollo Mechanical's project manager Eldon Parry commented on the plug-and-play usability and short learning curve of HoloLive. He said that "one of the good use cases we've seen from VisualLive is its ability to get up and running very quickly even with non-experienced users."

Rule of thumb: With augmented reality, a construction company needs to invest heavily in the pre-planning phase for both implementation and operational integration of an augmented reality solution.

When an issue arises on site, multiple people have to figure out what and where the problem is and then prescribe a solution that will not interfere with another workflow. The more effective the diagnostic insight, the less a change costs to implement. Once a change is prescribed, expensive plumbing and sheet metal material is automatically wasted, and project managers have to account for the loss in continuity while rework begins.

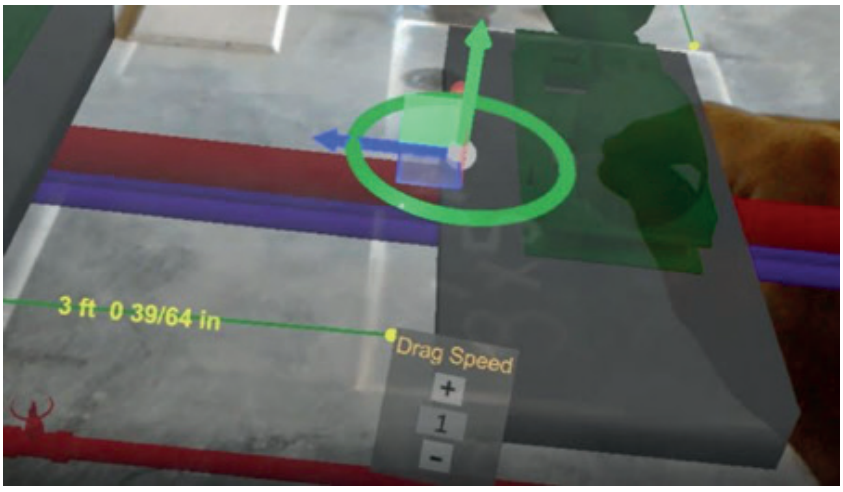
Apollo Mechanical was able to keep the initial phases of a job as a virtual model and make changes digitally. Moving the overall project cycle further into the digital allowed them to enact more prescient planning. The team replaced physical work with digital work to ensure better accuracy and execution once work moved from the digital to the physical.

Rule of thumb: Seeing the model virtually in AR can reduce unnecessary rework and prevent operational and managerial bottlenecks down the line.

A piping system model created by Apollo Mechanical Contractors overlaid on the job site.

Probably the costliest area of rework for Apollo Mechanical is hand detailing, due to the high margin of error. Using VisualLive, BIM, AutoCAD and the HoloLens 2 they noticed an approximate drop in rework of 10 percent, saving the company millions of dollars annually.

Visualizing piping systems at a 1:1 scale has benefitted the company in a similar way, but it illustrates another important point about Apollo Mechanical's integration with augmented reality hardware and software: segmenting different areas for installations and selecting some while being able to block out others helps eliminate conflicts. Without augmented reality visualization prior to construction phases, this selective segmentation is not available, and conflicts arise when building and fabricating on the job site. In other words, they sometimes could not see conflict in a plan until there were in the act of physical construction.



Using HoloLive allows Apollo Mechanical Contractors to show the customer the building designs at scale and quickly implement feedback to make necessary design changes.

DETERMINING THE COST OF IMPLEMENTING VR AND AR TO CALCULATE AN ROI

Though the cost of implementing a VR or AR system continues to go down, the capital required to build, operate and maintain a system is relatively substantial. Getting people on board internally can also be challenging.

Somebody has to spearhead the implementation. If this person gets a greenlight and a budget to implement an AR or VR system, they should always be willing to show engineers and designers in their organization exactly how learning to use AR or VR will help them expedite various workflows. People in organizations and institutions become set in their ways and are wary of adopting a new technology that promises convenience but instead does the opposite.

If you are the one who is pushing for a VR or AR system, be prepared to sell everyone on its benefits. You have to demonstrate why VR or AR is right for your team. VR and AR can easily seem superfluous if a skeptical employee is not interested in trying it. Suggest pain points that AR or VR can help with, then try demonstrating a 3D design in AR or VR to help skeptics understand its practicality.

The challenge of finding existing ROIs should not deter you from creating your own.

Once the VR or AR system is maintained at your organization, track how often people are using it, what they are using it for and why they are using it. These records can help you create estimates for potential gains. Calculate cost avoidance and be prepared for grey areas that require approximations. If a design team finds a problem with a design in AR or VR, it can be hard to determine whether or not the issue would have been found without the AR or VR system. Compare VR and AR usage with typical cost data, and offset the cost of implementing, operating, maintaining and troubleshooting an AR or VR system against the cost of traditionally executed workflows.

Estimated Costs of AR Hardware and Software				
Hardware	**Cost of Hardware**	**Software**	**Cost of Software**	**Total Cost Per Person**
Microsoft HoloLens 2 Bundle	$3,500	HoloLive	$99/month per device	$3,599 initial cost, $99/month additional cost
Windows Mixed Reality Headset (Average cost)	$400	Prospect	$225/month (individual), $350/per month (team with one headset), Enterprise	$625 initial cost, $225 per month (individual) $750 initial cost/$350 per month divided by number of team members
Mobile Devices		MobileLive	$99/month per device	$99/month if mobile devices are compatible
**Computer Hardware costs not calculated.*				

Estimated Costs of VR Hardware and Software				
Headset	**Cost of Headset**	**Software**	**Cost of Software**	**Total Cost Per Person**
HTC Vive Pro	$799	Prospect	$225/month (individual), $350/per month (team with one headset)	$1,024 initial cost, $225 per month (individual) $1,149 initial cost/$350 per month divided by number of team members
Oculus Rift	$300	Prospect	$225/month (individual), $350/per month (team with one headset)	$525 initial cost, $225 per month (individual) $650 initial cost/$350 per month divided by number of team members
Oculus Rift S	$400	Prospect	$225/month (individual), $350/per month (team with one headset)	$625 initial cost, $225 per month (individual) $750 initial cost/$350 per month divided by number of team members
Oculus Quest	$450 average (no pc required)	Prospect	$225/month (individual), $350/per month (team with one headset)	$675 initial cost, $225 per month (individual) $800 initial cost/$350 per month divided by number of team members
Valve Index	$999	Prospect	$225/month (individual), $350/per month (team with one headset)	$1,224 initial cost, $225 per month (individual) $1,749 initial cost/$350 per month divided by number of team members
Pixmax	$449	Prospect	$225/month (individual), $350/per month (team with one headset)	$674 initial cost, $225 per month (individual) $799 initial cost/$350 per month divided by number of team members
**Computer Hardware costs not calculated.*				

CHECKLIST FOR CREATING A VALUABLE ROI FOR BUYING IN TO VR AND AR

1. A formal or informal corporate digitization strategy that allows clients to account for content adaptation and other digital readiness costs separately from the project-based ROI.
2. Use comparable VR and AR use cases that are clearly defined, within similar industry verticals from pilot programs implemented at other companies.
3. Have acceptable and quantifiable business outcomes using familiar key performance indicators and business metrics.
4. Create detailed reports of the behavior of end users intimately involved in VR and AR pilot programs and evaluations.
5. Assign a pilot program leader to ensure that the technology is deployed and managed to reach projected performance and return targets.

CALCULATING THE BENEFITS OF IMPLEMENTING VR INTO YOUR PRODUCT DEVELOPMENT WORKFLOWS

Though there are obstacles towards having accurate ROI, examples are available that show value to product teams from using VR and AR products.

This value comes from:

1. Speeding up different stages of the design and construction lifecycle.
2. Saving costs on transportation.
3. Calculating the difference in cost of making a change to a virtual model versus making a change to the first iteration of a physical build.
4. Saving transportation costs of stakeholders who are geographically distributed by sending them a detailed 3D model for viewing.

ROI ANALYSIS FOR VR/AR IMPLEMENTATION WORKSHEET

ROI Analysis	Year 0	Year 1	Year 2	Year 3
Net cash flow before taxes				
Net cash flow after taxes				
Annual ROI				
Net Present Value (NPV)				
Cumulative Net Cash Flow				
Payback period in years				
Benefits				
User Productivity Improvements				
Increased Profits				
Reduced Hardware & Software Costs				
Reduced Audit Costs				
Reduced Inventory Carrying Costs				
Other Direct Cost Savings				
Other Indirect Benefits				
Total Benefits				
Costs - Operational Expenses				
Software				
Labor				
Consulting & Professional Services				
Total Operational Expenses				
Costs - Capitalized Assets				
Software				
Hardware				
Labor				
Consulting & Professional Services				
Total Capitalized Costs				
Depreciation Schedule - Capitalized Assets				
Software				
Hardware				
Labor				
Consulting & Professional Services				
Annual Depreciation Total				

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