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THE VALUE OF VIRTUAL AND AUGMENTED REALITY IN BUILDINGS AND INFRASTRUCTURE

COWI

> We and our client asked: What if the ceiling was made of a different material? By linking VR and sound, we developed an innovative model for 'virtual acoustics'.

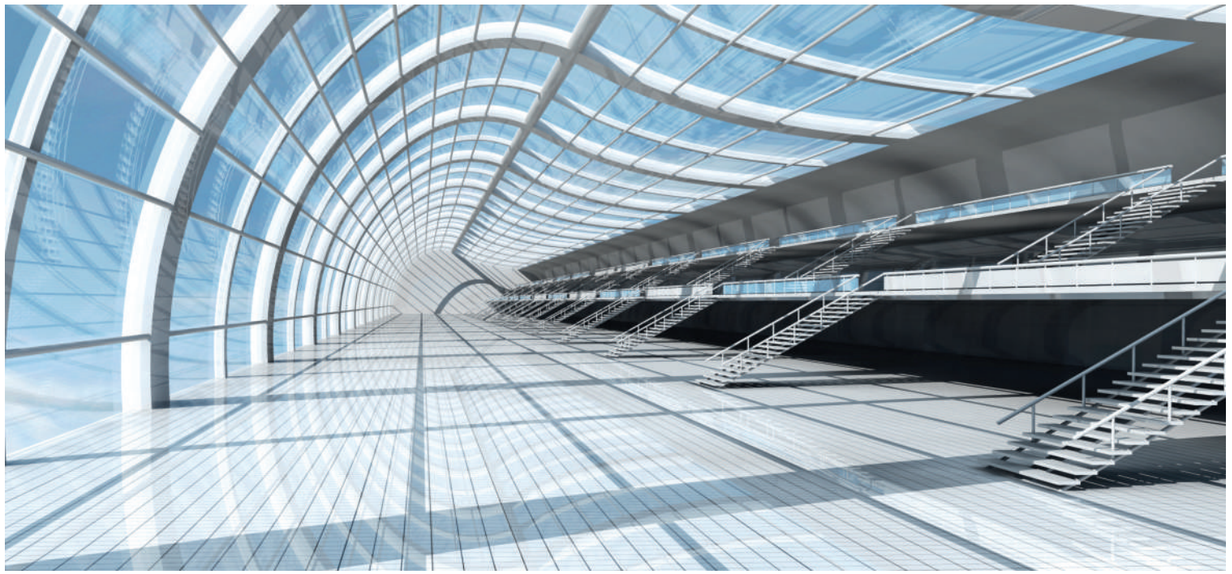
KIM BUNDGAARD, PROJECT MANAGER, COWI

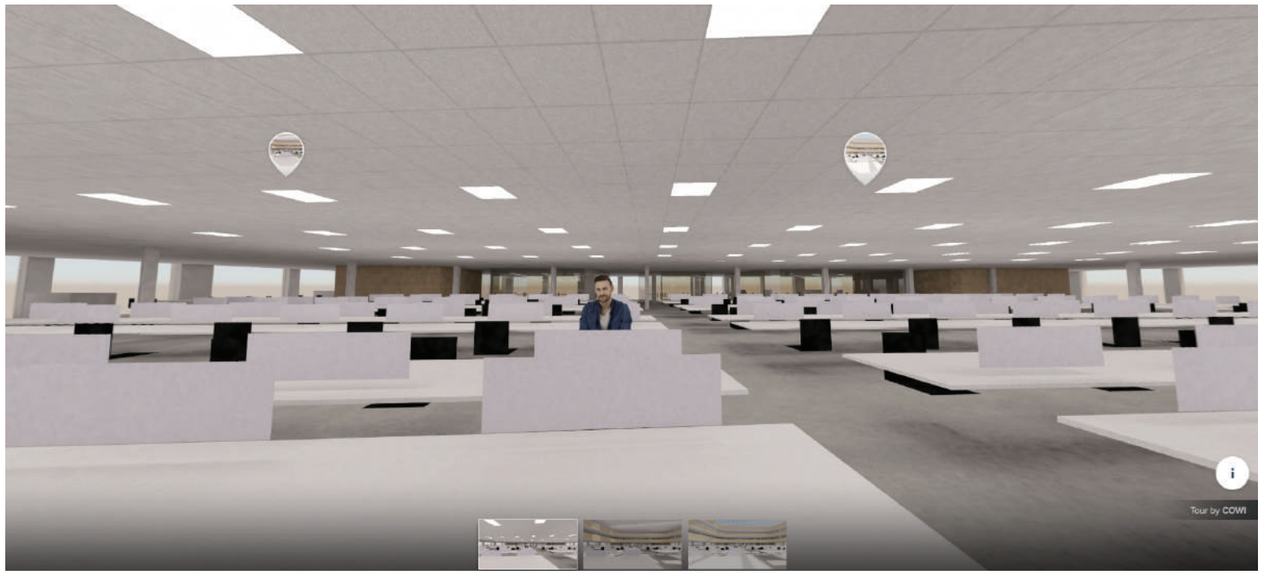
FUTURE APPLICATIONS

Although the virtual model only built on fixed positions, the project inspired new and more advanced application of auralisation and virtual models. In the future, it will be possible to add to the experience of moving around in a virtual model with dynamic sounds and acoustics. However, this requires a library of various sounds recorded in clean and noise-free environments. Besides sounds and acoustics, it might be possible to visualise sunlight, people flow and other things of importance in large office buildings.

Danske Bank's new headquarters will accommodate 4,000 employees and 1,000 guests. The building opens by 2023.

CONTENT





EXECUTIVE SUMMARY

VIRTUAL REALITY
An artificial environment that is created with software and presented to the user in such a way that the user believes in it and accepts it as a real environment.

AUGMENTED REALITY
The integration of digital information with the user's environment in real time. Augmented reality uses the existing environment and overlays new information on top of it.

Virtual and augmented reality (VR and AR) are technologies which represent digital information into new visual environments. These technologies hold enormous potentials for the industries of architecture, engineering and construction (AEC) and are becoming the new standards for representing structures. With VR and AR, it is now possible to take a virtual walk in a not yet constructed environment and to identify otherwise hidden possibilities and shortcomings.

As a market leader, COWI aims at adopting these technologies into our current business, while creating the most value for our customers and partners. In the period 2016–2019, COWIfonden supported a project involving implementing VR and AR in all business lines.

The technologies are moving from infancy to mainstream. With minimal effort, you are able to deliver outstanding value to your customers. To inspire you, we have collected a variety of cases on applications of VR and AR in COWI.

APPLICATION OF VIRTUAL REALITY

The fully 3D-modelled project contains a range of possibilities for applying virtual models. In cooperation with the new tenant, it was decided to link a virtual model to a set of examples of acoustic models. The aim was to improve the decision-making regarding the choice of ceiling.

THE PROCESS

The 3D model was transformed from Navisworks to Unity, a gaming platform for VR. Here, three different noise sources were added – and linked to the corresponding types of ceilings. However, the sound was not dynamic and only auralisations of a few fixed positions was possible.

VALUE OF VR

The experience of various auralisations combined with different visual expressions allowed the client to make a more informed decision about the roof and ceiling of the trade floor. With a good model in Navisworks and some good (but rough) examples of various examples of acoustic solutions, this case is easily scalable to similar projects.

CASE 5: POSTEN, DENMARK

VIRTUAL MODELLING AND ACOUSTICS

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ABOUT THE PROJECT

In the central part of Copenhagen, close to the Central Station, a new neighbourhood is under development. By 2024, the new area will contain a mix of flexible and sustainable offices, housing units, hotels, cafés and retail. Housing 6,000 jobs and 500 new inhabitants – and more than 20,000 daily visitors – Posten aims to become a vibrant urban space. Parking spaces for 5,500 bikes are also being developed. One of the largest tenants will be Danske Bank, the largest bank in Denmark. The trading floor will be the heart of the new headquarters. In any open-plan office building with 350 employees, acoustics is a major issue.

VIRTUAL REALITY IN DESIGN, CONSTRUCTION AND OPERATION

In the period 2016–2019, COWIfonden supports a project regarding virtual reality in engineering projects within the sectors of infrastructure and buildings.

The vision of this project is to enable quick and exact communication of design intent and engineering information based on BIM and advanced reality capture with VR. We seek to improve the overall communication between stakeholders by reducing misinterpretations and to ensure that client requirements are met. The aim is to make VR a valuable aid in the communication of design intent in COWI's projects and to promote innovation by exploring improvement potential and advance academic research in applied VR in AEC projects.

BUDGET DKK 3.5 mill.
INDUSTRY PARTNER COWI A/S
RESEARCH PARTNER Aalborg University
TECHNICAL PARTNER Epiito A/S

The conclusions are clear. VR and AR technologies will be the new standards for model representations in the AEC industries. The major value additions are related to:

- BETTER PROJECTS – increased quality and better decisions
- TIME SAVINGS – faster completion at increased accuracy
- FEWER MISTAKES – improved clash and error detection
- CHEAPER PROJECTS – decreased risk of budget overruns
- INCREASED OWNERSHIP – valuable inputs from future users.

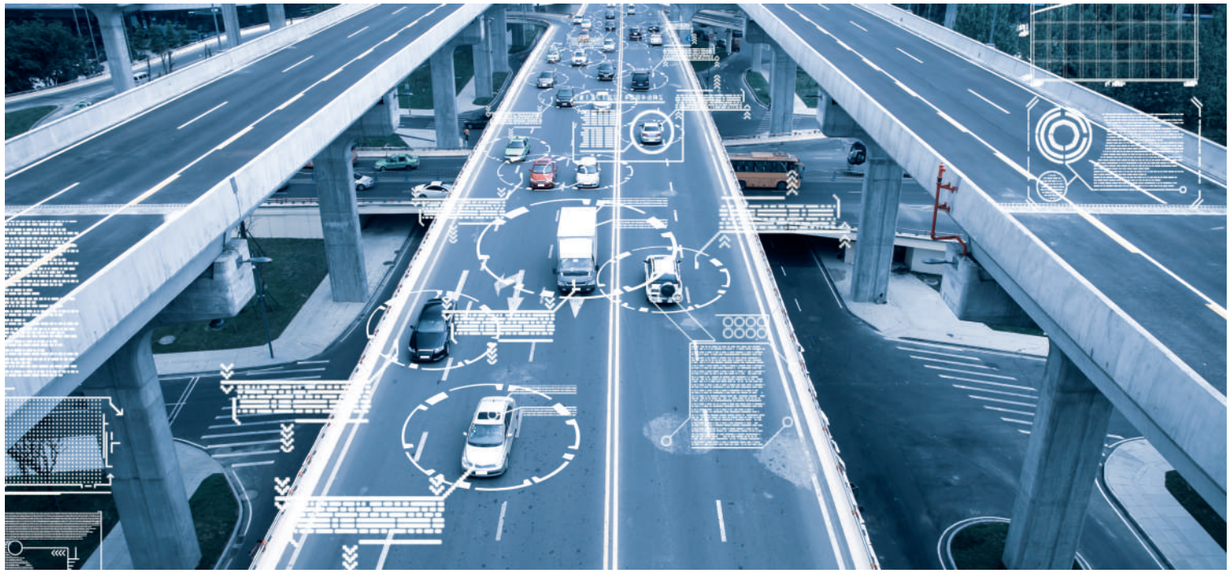
As COWI already uses BIM and 3D modelling on many projects, the addition of VR and AR is a relatively straightforward and natural step in manifesting COWI as a dedicated engineering consultant.

In this brochure, you can explore the value of VR and AR on ten projects. We are looking forward to seeing more projects applying VR and AR to add value to our customers and to COWI.

Yours sincerely,

Birgit Farstad Larsen
Senior Vice President
Buildings (NO)

Peter Hostrup Rasmussen
Senior Vice President
Infrastructure (DK)



TECHNICAL SUMMARY

Building information modelling (BIM) is a driver for more effective engineering. In our projects, we now deploy 3D models as a natural part of the toolbox. Many of us are now used to navigating 3D models comparable to computer games, and together with our partners, we clarify potential conflicts, improve the design and change the layout. A good 3D model also forms the backbone of a VR/AR model.

FAST-PACED TECHNOLOGICAL DEVELOPMENT

The rapid pace of the technological advancements of VR and AR demands constant exploration and exploitation of possibilities. In recent years, the gaming industry has acted as a main driver for the development of VR and AR, and new hardware and software are emerging constantly. Like always, we must be at the forefront of the development in order to stay competitive.

TESTING AND EXPLORING OPPORTUNITIES

During this project, we tested and developed a range of technologies and applications. For example, we developed simple VR solutions just for inspiring decision makers to consider the many possibilities of VR. We also explored the

VALUE OF VIRTUAL REALITY

Taking a virtual walk around the new machinery made the experience of access ways much more real and created a better overview than Navisworks can. For example, when a missing staircase was detected, we simply changed the model.

The feedback from the client was clear: As a working tool in the design phase, the virtual model was more than just a fancy show-off of new technological advancement.

FUTURE APPLICATIONS

In this project, virtual reality was applied in the design phase for fitting new machinery into existing facilities. A further potential lies in the application of a virtual reality model by operational staff, who can easily pinpoint areas of conflicts and potential optimisation. For example, a virtual reality model will ease the experience of reaching handles, navigating inside the plant etc. and has the potential for creating even better projects with fewer mistakes and better working environments.

The project is supported by EU LIFE and is a cooperation between Vestforbrænding, Stena Metall (Sweden) and Stena Recycling (Denmark). The sales of metals from the recycled ashes is worth EUR 300,000 per year.

A APPLICATION OF VIRTUAL REALITY

Before demolishing old production equipment, the area was 3D scanned. The result is a so-called point cloud which can be vectorized and thus we had a usable 3D model. A mog-up of the new machinery was then placed in the model. Now, the tricky part was to fit the access ways, galleries etc. from the existing structure to the new machinery. As it is hard to assess the accessibility in a 3D model in AutoCad, a virtual reality model for presentation through Oculus Rift came in handy.

THE PROCESS

The process was divided in five simple and well-tested steps:

- First, we scanned the existing room and created a vectorised point cloud.
- Second, the point cloud was transformed to a 3D model.
- Third, the point cloud was imported into Navisworks.
- Fourth, the 3D model of the new machinery was added to the model.
- Fifth, the combined 3D model was transformed to Unity for a full VR experience.

All together, these five steps took a few days only.

opportunities of adding sound and acoustics as an extra dimension to the VR experience. Furthermore, we tested the possibilities of AR in several projects.

HARDWARE AND SOFTWARE

We tested a range of hardware and software – and developed some programs and scripts on our own. Some of the hardware that we bought and tested were the expensive and advanced HoloLens, the gaming-oriented Oculus Rift and the cheap and simple Homidi. The hardware is under constant development and we look forward to even smoother VR and AR experiences. We managed to transform 3D models from Revit, Navisworks, Novapoint etc. to Unity and other formats for experiencing virtual models. In addition, we applied Apples ARKit and other tools for augmented reality. Together with our partners from Aalborg University and Epiito, we developed our own app and IFC importer.

THE VALUE OF VR

The various VR technologies are working increasingly smoothly, strengthening the quality of the projects while decreasing the number of mistakes. With regard to AR, the potentials are great but the actual implementations are still immature, leaving inaccurate and manual workflows. VR and AR forms have different types of values when presented to decision makers or applied actively as a tool for architects, engineers, constructors, operational personal etc. As such, the value of VR and AR is linked directly to increased quality of the projects, and indirectly to savings on time or money. In the end, we experience more satisfied customers when applying VR and AR.

In COWI, our VR/AR community is growing. It forms the technological backbone of current and future projects regarding these technologies. If you have any requests, please do not hesitate to contact us.

Yours sincerely,

Jørgen S. Emborg
Technical Director, COWI

Marius Sekse
R&D Director, COWI

DID YOU KNOW?

60 YEARS OF DEVELOPING VIRTUAL AND AUGMENTED REALITY

Virtual reality (VR) was born in the 1950s when Morton Hellig presented the Sensorama and has evolved along with the development of computerized power. Since the end of the 1980s, VR has matured and is now applied in many industries like gaming, architecture, engineering and construction.

In a similar vein, augmented reality (AR) has advanced from simple and ceiling-mounted devices into advanced but everyday applications. With various AR toolkits, numerous hardware to support it and unlimited possible applications, AR will most likely transform our lives and work for the better.

IT IS EASY TO DO VR

In COWI, we have decided to conduct all projects in BIM. Simultaneously, the link from a 3D model presented on a screen model to a VR model presented through VR glasses or other VR hardware has never been easier. As such, most of our projects have the potential to be presented through VR. In many cases, the transformation from BIM to VR can be made in minutes and is almost as easy as 'save to VR'.

> “It was surprisingly easy to create a VR model on top of all the files in AutoCad. The client was invited to walk through the model and assess solutions, accessibility, etc. He was impressed to see how the integration of the new plant found its way in the remains of the old plant and was himself able to provide valuable information for the benefit of his project.
>
> THOMAS JENSEN, PROJECT MANAGER, COWI

CASE 4: VESTFORBRÆNDING, DENMARK

INTEGRATING NEW MACHINERY FOR CLEANING THE ASHES

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ABOUT THE PROJECT

Since 1970, when Vestforbraending first fired up its chimney, the organisation has grown into Denmark's largest waste management and energy company. The primary focus is to harvest the substantial resource value of waste, whether it be for recycling or as fuel for energy production. As part of a development project, Vestforbrænding has agreed to invest in machinery worth EUR 7 million for ash cleaning. The cleaned ash can be used for e.g. asphalt or road fill. The question is how to fit the machinery into the existing plant.

PUSH AND PULL: VR AND AR ARE BECOMING THE 'NEW STANDARDS'

In most countries, VR and AR are now acknowledged as a nice feature, a gimmick or something extraordinary. In COWI, we seek to push the boundaries for our customers and partners by presenting innovative solutions like VR and AR. Our experiences show that when our customers and partners encounter the potential value of VR and AR, they are more likely to ask for – or even expect – applications of VR and AR in other projects.

In few countries like Norway, where BIM, 3D modelling and VR is part of public procurements, our customers and partners expect us to present, discuss and improve projects through VR and AR. The development forces us to stay ahead of the game by providing valuable virtual models for improving the projects to higher standards than ever.

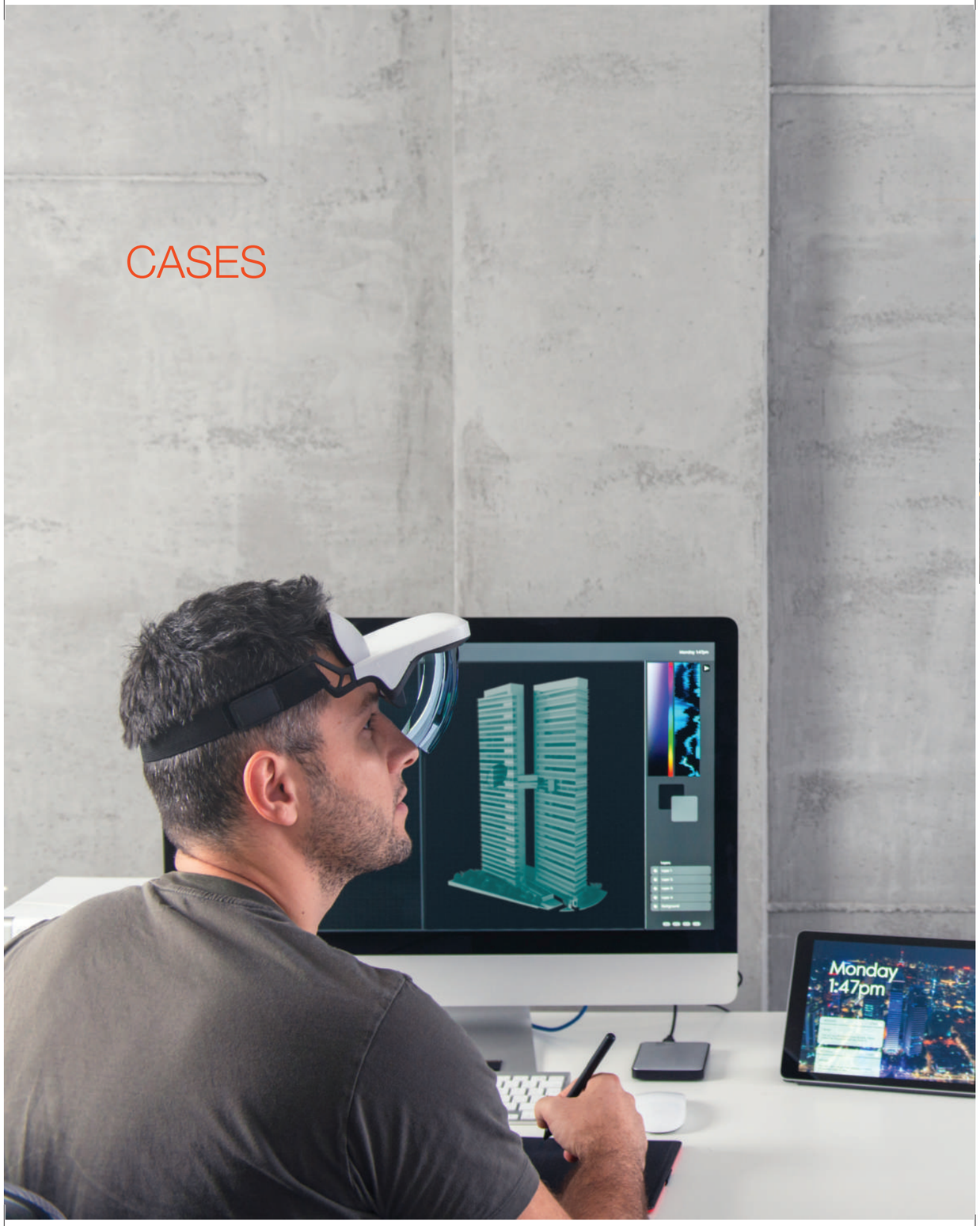
ADDING MORE SENSES TO VIRTUAL MODELS

Many of us are now familiar with VR or AR through various simulations, games, apps etc. However, the visual sense is still predominant as a medium for experiencing alternative realities. Now and in the future, we will experiment with adding other senses to the visual representation.

Imagine, for example, walking around in a virtual environment and experiencing the dynamics of various sources of sound and noise. By making direct changes of ceilings, walls etc. in the model, you experience the differences immediately and can make a more enlightened decision regarding acoustics. COWI and Aalborg University are working on an innovative project regarding acoustics and auralization.

Numerous other senses, like touch, smell, taste, temperature, vibration and pain, can be implemented in the virtual experience. Furthermore, experiences like light, flows, shadow and wind can be visualized. The main limitation is our imagination and entrepreneurship of transforming such products into value for our customers.

CASES



VALUE OF VR

The final videos represent strong tools for decision makers. Statens Vegvesen posted the videos with the final recommendation. Publishing the videos for everyone to watch increased communication with the public.

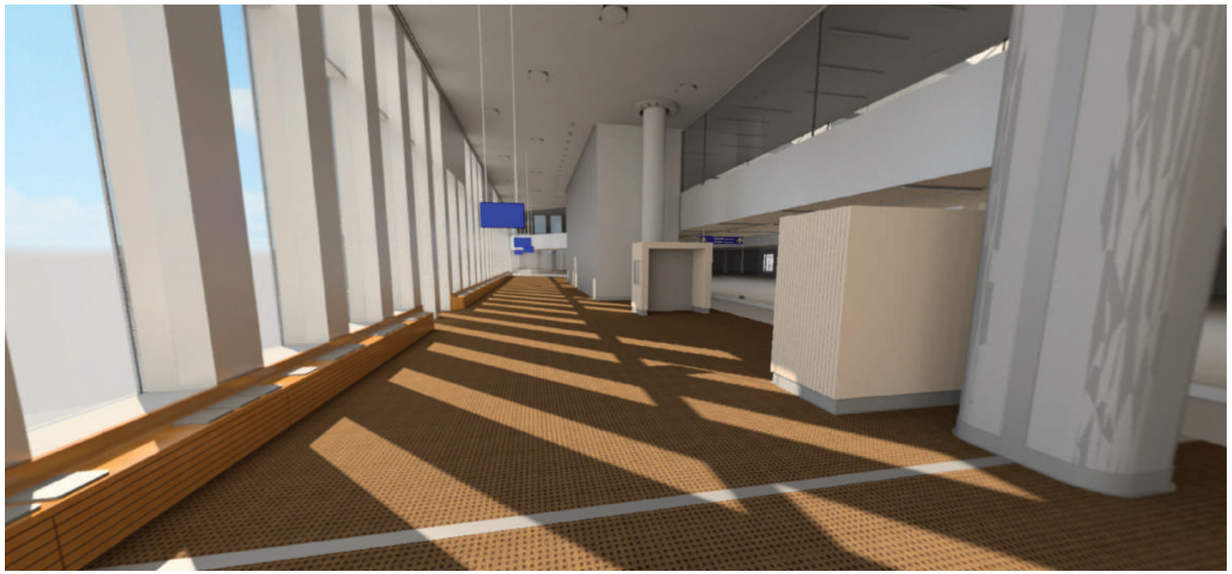
FURTHER APPLICATION

Improving the workflows from BIM to VR will decrease friction and improve the virtual models. Furthermore, huge potentials lie in the application of augmented reality as an operational tool in the design and construction phases.

> Presenting the alternatives through virtual illustrations was of huge value. Put simply, the illustrative videos enabled the client to make a decision on a much more solid basis.

KNUT EKSETH, PROJECT MANAGER, COWI

The client, Statens Vegvesen, posted the virtual videos on Youtube for communicating their decision on the layout.



CASE 1: COPENHAGEN AIRPORT'S NEW PIER E, DENMARK

COPING WITH INCREASING PASSENGER NUMBERS

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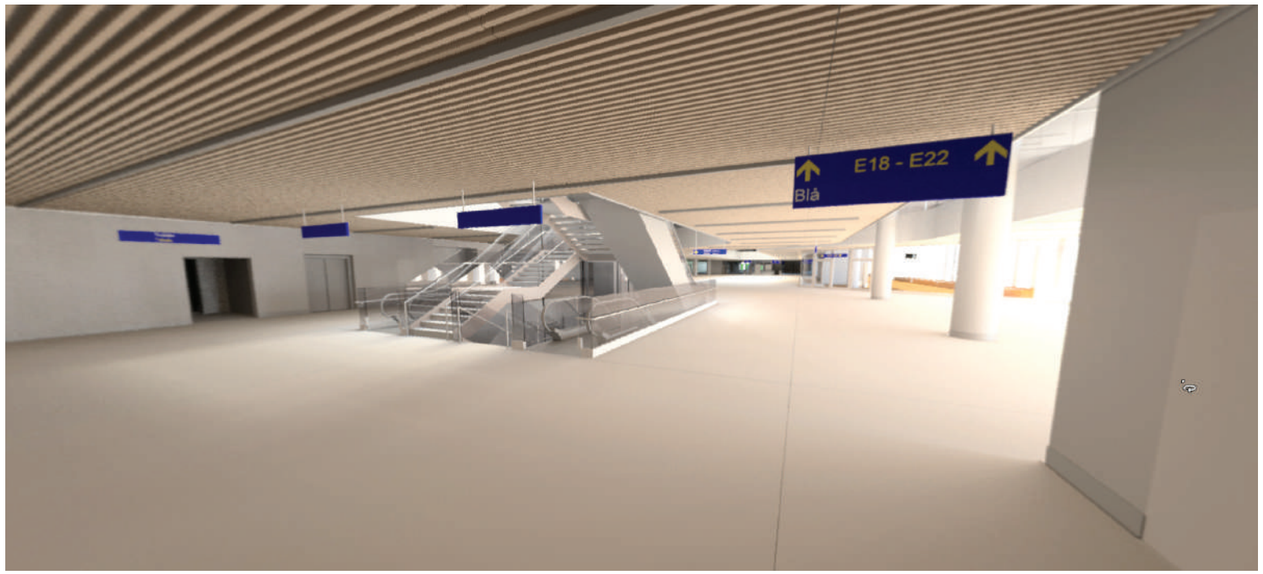
ABOUT THE PROJECT

Over the next 20–25 years, the number of passengers at Copenhagen Airport is expected to increase from 29 million to 40 million. To handle the increasing traffic and to keep passenger satisfaction high, Copenhagen Airports A/S will be investing DKK 20 billion during the next 10–20 years in major expansion plans. As part of the expansion plans, the new pier E will provide critical capacity to the airport as it adds 13 gates and an additional 36,000 m² three-story building with gate lounge areas, bus lounges and mezzanine levels. COWI is the lead consultant for the design team, which also includes Vilhelm Lauritzen Architects and Zeso Architects.

and the public debate. As such, COWI in Norway is experiencing an increasing demand for virtual reality models in various forms from customers such as Statens vegvesen. Like on this project, virtual models enhance the decision-making process regarding different alternatives. In addition, publication of the material increases the public engagement, as these types of replications are much easier to grasp than 2D or technical representations.

THE PROCESS

The infrastructure project was designed in Novapoint, and through cooperation between the BIM manager and the VR team it was transformed to 3D Studio Max for visualization. This calls for close cooperation between the BIM and VR teams to ensure correct inputs and formats. It was decided that a 'simple' 360-degree video was sufficient to enable a better decision process. However, a full virtual reality experience would also be possible, although more time-consuming to produce.



CASE 3: FV. 47, NORWAY

VISUALISING ENVIRONMENTAL IMPACTS ON THE LANDSCAPE

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ABOUT THE PROJECT

Fylkesvei 47 (fv. 47) is a primary road in the western part of Norway. Spanning 75 km, it connects the areas of Sveio, Karmøy and Tysvær. Parts of fv. 47 are included in the plans for upgrading the infrastructure in the area. One of most expensive and controversial parts is the Åkra sør-Veakrossen. With a budget of approx. EUR 70 million, a new road was planned to mitigate the increasing traffic through Åkrehamn – either as a road around the city or as an upgrade of the existing road through the city.

APPLICATION OF VIRTUAL REALITY

To investigate the environmental impact of fv. 47 around Åkrehamn, the client, Statens vegvesen, requested COWI to make a number of illustrations, videos and virtual driving tours along the potential new road for the decision makers

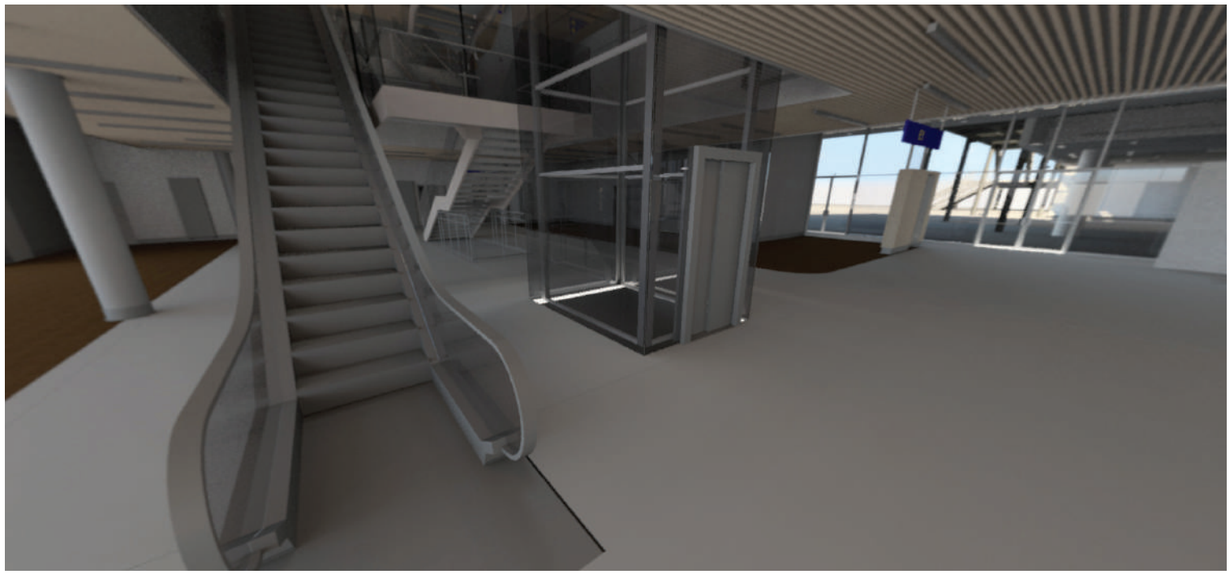
APPLICATION OF VIRTUAL REALITY

First, a VR model of the project was presented through Oculus Rift at a steering group presentation. Although the astonishing and real-life experience was spectacular for decision makers and newcomers of VR, its practical applications were of too little use. Furthermore, technological barrier of setting up the equipment decreased the application of the tool. Hence, a more 'low-tech' but more practical approach was chosen; simple and pre-defined VR models of corridors, gates etc. for operators, technicians and maintenance personal to view on a mobile phone.

THE PROCESS

- The project manager located strategic points of interest for exploration in VR.
- The BIM Manager prepared the file and uploaded it to Autodesk's cloud services.
- The VR models returned to COWI in less than one hour.
- The VR community 'beautified' the models before publishing.

Through this process, more than 25 small VR models were developed, and about 100 Homidi glasses where handed out to the partners. The easy-to-use VR models enlightened the discussions with technical and operational staff.



> I would strongly suggest applying VR models when developing complex designs like an airport, hospital etc. It's a powerful tool for communicating with users not used to deciphering technical drawings. In my opinion, we delivered a better project with a relatively small extra effort.

HENRIK WALLENTIN POULSEN,
PROJECT MANAGER

> In the future, we would appreciate a model where we could pull off the ceiling to look 'under the hood'. Then, we can compare the model with the reality. Does it look right? The more data you visualize in the VR models, the better.

HENRIK WALLENTIN POULSEN,
PROJECT MANAGER

VALUE OF VR

This ground-breaking digital work expects to save project time and costs and for the future operation of the building. For example, by training doctors and nurses in virtual environments, a fully functioning hospital and staff are ready from the opening day. By dealing with potential clashes and shortcomings proactively in the virtual model, and by making subsequent changes in the 3D models and physical layout, additional time and money are saved. The active application of VR is expected to result in an introduction period that is up to 20 period faster and cheaper. With thousands of life-saving employees, the monetary savings are invaluable.

FURTHER APPLICATION OF VIRTUAL REALITY

The permanent installation of the VR cave was a costly affair, accounting for more than EUR 150,000 plus consultancy services. Although such a VR cave creates an extensive overview and produces vast possibilities for massive savings in time and money, only few projects are large enough for this type of VR equipment. Furthermore, the more or less permanent installation hinders application of the VR equipment elsewhere. A cheaper and more mobile edition of the VR cave is needed for many other complex projects to benefit from the opportunities of this technology.

> It is kinda cool that you can have direct contact to the Stavanger University Hospital using an avatar. For some, avatars are something we only hear about in science fiction movies. Now, we have them here at the hospital.

KARI GRO JOHANSON,
PROJECT DIRECTOR, HELSE STAVANGER HF

The Stavanger University Hospital was awarded the 2018 Auto Desk BIM Award

VALUE OF VR

The value of 'low-tech' VR solutions lies in the agility, lightness and rapidness of creating VR models. Also, as these VR representations require no technical expertise, the number of potential users increases. The easy-to-use approach made the communication and decision-making with non-technical personnel much easier, and many mistakes were avoided.

FURTHER APPLICATION

With the successful application of low-tech and easy-to-use VR models, the project team is now prone for exploring more complex VR models (e.g., AR of technical installations and people flow between the gates) and expensive technologies (e.g,. a VR cave). In future applications of easy-to-use VR models, a layer of augmented reality would increase the value.

It was just announced (2019) that COWI is part of the winning team to design and construct the new 80,000 m² Terminal 3 at Copenhagen Airport – a project worth EUR 500 million.

CASE 2: STAVANGER UNIVERSITY HOSPITAL, NORWAY

WORLD-CLASS DIGITAL INDUSTRIALISED HOSPITAL

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ABOUT THE PROJECT

Hospitals are among the most complex building on the planet with increasing demands to care, technology and working environments. The client, Helse Stavanger HF, is undertaking an expansion of Stavanger University Hospital, which will address very ambitious strategic goals, as well as the need to provide treatment capacity for a growing population. At the same time, land use needs to be optimised and personal safety provided for.

> We introduced a 'BIM cave' where we show the interaction in the BIM model. We have had someone located at the hospital interacting with us down here.
>
> KRISTOFFER TUNGLAND, BIM MANAGER, COWI

The project is being run as a BIM project, with substantial innovations in industrialised building processes and digital collaboration. The plan is to build the hospital in the most industrialised manner possible, with prefabricated elements to be assembled onsite. The project has also produced great digital advances to make it possible to bring industrialisation into the BIM model itself. The aim is for the client to receive a functional digital twin of the building for active application in the operational phase.

APPLICATION OF VIRTUAL REALITY

Innovation and success call for constantly challenging boundaries. In the early phases of the project, stakeholders relied on a 3D model and cloud rendering from Autodesk software – including Revit building design software – for daily team meetings, project management and design work. The ability to view and collaborate in the Revit model has improved communication and collaboration, data management and cross-disciplinary workflows. For example, through the VR cave, people at different locations can meet in the same virtual environment.

THE PROCESS

At Stavanger University Hospital, a special VR room was built. Here, the stakeholders are given a real experience of the daily life at the hospital in order to provide valuable and detailed feedback on everything from the design of various structures, layout of operation rooms and wayfinding. The aim is to clarify potential misunderstandings before the design is locked and to ensure a more efficient building process.