# RESEARCH PAPER

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The Missing Link: Introducing the Virtual Inspection Procedure & the Extended Reality Manager

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## ABSTRACT

The Missing Link: Introducing the Virtual Inspection Procedure & the Extended Reality Manager is about finding a way to implement the Microsoft HoloLens and extended reality into the AEC-industry. The authors have looked at how to utilize the HoloLens in construction planning by conducting interviews and tests. When applying the IDDS-theory, it turned out to be the Integrated Process that was the main issue, and therefore didn't focus as much on the technology that is a prerequisite for this procedure. This paper offers an ideal procedure with a process to go with it. It is simple, efficient and hopefully it will be implemented in the AEC-industry in the near future.

## 3 KEYWORDS

- Virtual Inspection Procedure
- Extended Reality Manager
- Microsoft HoloLens
Preface

This paper makes up 2/3 of the coursework of the final semester of our bachelor’s degree in Civil Engineering at OsloMet – Oslo Metropolitan University. The work was carried out between the start of January and the middle of May 2018. The opportunity to write this research paper presented itself at a demo by Trimble at OsloMet, where Trimble issued flyers where you could apply to write this paper. We wanted to write about this subject as we think it is very relevant for our education, and it is interesting for the industry.

The target audience for this research paper is people in the industry, engineering students, and all others who might have interest in the subject.

Writing this paper has been an incredibly fun, educating and time-consuming task. At times we didn’t know if we would be able to deliver an end product, but here it is, and we are quite happy with it. As mentioned, it has been a time-consuming task, and there is a lot of writing, deleting, proofreading and re-writing that the reader won’t notice, but that’s not the point either, we suppose.

Last but not least, we would like to say thank you to all those who provided us with help, experience, and those who made time for us in a busy workday to be interviewed by a group of students. Thank you, Eilif Hjelseth, Mats Fensholt, Andreas Haugbotn, Øyvind Svaland, Eskil Landet, Sigurd Berge, Magnus Norum, and Ernst Erik Hempel. Without your contribution this would have been impossible to finish.

Sted, Dato
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Abstract

The Missing Link: introducing the Virtual Inspection Procedure & Extended Reality Manager is about finding a way to implement the Microsoft HoloLens and extended reality into the AEC-industry.

The authors looked at how to best utilize the Microsoft HoloLens in construction planning by doing tests with the HoloLens and Trimble Connect application, conducting interviews with some of the people in the industry that is familiar with the technology and its areas of use.

As the technology was introduced to the market quite recently, there were suspicions that the technology would be the barrier that prevented the HoloLens to be implanted in to construction planning in the AEC-industry. However, after said interviews and tests it became apparent that the technology isn’t the biggest concern.

This study showed that when the Integrated Design & Delivery Solution was applied to the problem, the biggest issue was actually the integrated process, as such a thing simply does not exist at the time of writing. According to the IDDS-diagram there is a third component: Collaborative people. The conducted interviews showed that people willing to collaborate on this platform exists and are just waiting for the one thing to bridge the gap between Collaborative people, Interoperable technologies, and the integrated process: The missing link.

This paper describes what is believed to be an ideal procedure, with a process to go with it. It is simple, efficient and hopefully it will be implemented in the AEC-industry in the near future.
Sammendrag

The Missing Link: introducing the Virtual Inspection Procedure & Extended Reality Manager handler om å finne en måte å implementere Microsoft HoloLens og dens extended reality i byggenæringen.

Denne oppgaven har sett på hvordan man best utnytter Microsoft HoloLens i konstruksjonsplanlegging ved å gjøre tester med HoloLens og Trimble Connect programvaren, holde intervjuer med noen personer i bransjen som er kjent med teknologien og dens bruksområder.

Ettersom teknologien ble introdusert til markedet relativt nylig, ble det først antatt at teknologien ville være bareren som hindret HoloLens i å bli implementert i prosjekteringsfasen av byggeprosjekter. Det viste seg likevel etter nevnte intervjuer og tester at teknologien ikke er den største utfordringen.


Denne oppgaven beskriver en ideell prosedyre, med en tilhørende prosess. Den er enkel, effektiv og forhåpentligvis vil den bli tatt i bruk i byggenæringen i nær framtid.

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Definitions
Virtual Reality –
VR is when the real reality is completely blocked, and the virtual objects are the only visible reality

Augmented Reality –
AR is when virtual objects is placed on top of the real reality.

Mixed Reality –
MR is similar to AR in which its objects placed in the real reality, but with the addition to have them interactable the way VR is.

Extended Reality –
XR is used as a collective term for VR, AR and MR.

Redlining –
is to make annotation in the model to measure height, width, length ETC. And make revision clouds in the model.

Abbreviations
VR - Virtual Reality
AR - Augmented Reality
MR - Mixed Reality
XR - Extended Reality
FOV - Field of View
FM - Facility Management
HSE - Health, Safety and Environment
QA - Quality Assessment
VIP - Virtual Inspection Procedure
XRM - Extended Reality Manager
1. Introduction

This paper is meant to provide background for and explain choices made in the accompanying procedure known as the Virtual Inspection Procedure (VIP) and introduces a new role in the construction planning workflow – the Extended Reality Manager (XRM).

These findings are the result of a challenging process in which we had to find our own way to a significant degree, as the subject is new and unexplored. There were almost no resources available to base our research on, and the results presented in this paper came into being through a lot of trial, error and creative thinking. As a consequence of this, the paper does not follow the standard format for a bachelor’s thesis; it has a less strict approach as several aspects of a traditional research paper does not really fit into the work that we did.

Our primary ambition with this paper is to provide the AEC industry with a new set of tools to bring their workflow into the 21st century. Hoping to avoid the usual fate of many bachelor’s theses who end up never being read, we have strived to keep this one short and to the point and avoided unnecessary delving into heavy theory in order to make it an appealing read for busy individuals. In short, we hope that this paper can provide a useful starting point for the tech pioneers of the industry and provide measurable benefits in the form of time saved, increased quality and last but not least, reduce costs.

1.1. Background

1.1.1. Introduction to Mixed Reality technology

Augmented Reality and Virtual Reality (AR- and VR-technology) isn’t such a new and groundbreaking technology as many may think, as it was introduced to videogames as early as 1991 (Horowitz 2004), but hasn’t been recognized to the degree which it has today, until recently. In recent years, there’s been an expansion in the production and usage of – mainly – VR-technology, with the introduction of Oculus Rift, HTC Vive, Sony PlayStation VR and Google Daydream, to name a few. Virtual Reality is, in short, a pair of glasses with a computer screen attached right in front your eyes, and it enables you to experience and interact with a different reality, maybe a new destination, a game, or maybe for research purposes?

Mixed Reality (MR), which is the main focus in this paper, is a combination of AR and VR, gives you the opportunity to combine your surroundings with virtual data in the shape of holograms, whilst interacting with them. By March 2018, there isn’t a lot of products that support Mixed Reality. Microsoft HoloLens was the first commercial head mounted Device (HMD) to use the technology, but there are upcoming products such as Magic Leap and Meta2 who are also based on MR-tech.
Since Microsoft HoloLens is the only MR product available to everyone at the moment, this paper is based on the use and experience with them. HoloLens has been available as developer edition, until recently when the commercial edition was realized early 2018.

Trimble Inc. wanted to explore the possibilities of MR-technology, as well as try to understand why it isn’t used in a larger scale in AEC-projects. In collaboration with OsloMet, and the writers of this paper, it will try to look at the possibilities, as well as bridging the gap between the industry and the MR-technology.

1.1.2. Research Study

As preparatory work we have conducted a research study to learn more about the implementation of MR in the AEC industry. One of the assumptions we make is that today’s technology is so advanced that the real limitations concerning the use of the technology is how we use the technology. Given that our paper main focus is to implement Microsoft HoloLens we assume that the technology in the HMD are good enough to be used in the examples we give, or that with relatively simple adjustments can be used in those examples.

In the background for this paper we state that implementing BIM has proven to be beneficial and in the last years BIM has been a requirement for many projects, at least the big projects. Most of the research papers that are older often look into the possibility and advantages of implementing BIM, therefore we tend to look for newer research papers that comment on the present use of BIM, and preferably related to AR, VR or MR.

Our method for finding information was to use some keywords in different databases. For example, search for “MR + BIM” or “Mixed Reality + BIM” in google scholar, engineering village, IEEE and Oria. It became that obvious that HoloLens are quite new technology, or XR in the AEC industry in general does not have too many papers on it. Despite that there are many promo videos on the internet and many companies that see the potential is has and are in the process to figuring out how to use it.

As mentioned in the introduction there weren’t any processes regarding the implementation of the technology. The paper would require more practical and hand-on research and input from the industry.

1.1. Purpose

The construction industry is famously slow to adapt new technologies. There are several reasons for this, including cost and skepticism in conservative board rooms, but a major one is a lack of procedures for using new technology in a meaningful way. One of the principal obstacles is the cyclic, unpredictable and hard to standardize nature of work in the construction industry, with most projects lasting only a year or two and involving people who have not worked with each other before. This paper aims to rectify this issue by
introducing a new, flexible and effective way of utilizing XR technology in construction planning.

As students about to head out into the real world, we (the authors) are of course eager to get any advantage we can when it comes to standing out in a competitive job market, and when we were presented with the opportunity to write this paper for our commercial partner Trimble (see below) we immediately jumped on the chance. That the technology in question, Microsoft HoloLens, is groundbreaking and on the cutting edge of what is available to consumers today was hardly a drawback either, and this was a golden opportunity for us to gain insight into a technology that most people in the engineering field has no firsthand experience with.

The purpose of this paper is to explore ways to integrate into or exploit the Microsoft HoloLens technology in the planning stage of construction projects. The subject for this paper was chosen by Trimble Inc. and announced at a demo event at OsloMet’s premises in the fall of 2017. During this event, flyers about the opportunity to write this paper were handed out to students who were interested, and we sent in a pitch and got selected shortly afterwards.

We chose to write this paper in English in conjunction with our external mentor at Trimble. This choice was made in order to make the paper available to the greater market, and not just the Norwegian one. Partially as a consequence of writing in our second language, and partially by choice, the language of the paper is quite concise and to the point. We felt that a paper written by engineering students, intended for other engineers and managers in construction, would benefit from avoiding unnecessarily complicated language.

As for Trimble’s reason to want to research this area, and also our reason for wanting to write about this topic, we can look at HoloLens technology through the so-called Johari Window(Luft and Ingham 1961). This method is primarily meant for assessing individuals but translates to looking at new technologies quite well. In this scenario “us” would be the authors and Trimble and other parties who are trying to utilize MR, and the “others” would be the construction industry in general. Looking at the situation when we started our work, it would look something like this:

Here we can see the four “panes” of the Johari window. The areas are as follows:

The Open Area (1): This is the information that is known to both us and others. As
implied by its small size, this was very limited when it came to HoloLens implementation in construction.

The Blind Area (2): This is the information that is unknown to us but known to others. As we started work, this was very limited as well, but others knew a few things that we did not simply because the subject matter was new to us.

The Hidden Area (3): This is the information that is known to us but not to others, which in our case was a little bit about the technology itself, and after a bit of research that proper procedures or standards for using HL did not exist.

The Unknown Area (4): As the name implies, this is what is unknown to both us and others. As one can see, this area is larger than the others, implying that when it comes to implementing HL, most parties (us included) were in the dark as to how when we started working. Making this unknown area smaller is key to making it viable for the industry to use HoloLens technology.

As one can see, there is a clear gap between today's situation and the goal of utilizing HL technology (this is discussed in depth later). Bridging this gap is, in a nutshell, the purpose of this paper.

1.2. Research problem
Initially, the scope of this paper was to look at implementing HoloLens technology in transport planning specifically. As such, the working title was "Implementing Microsoft HoloLens in transport planning". However, after performing a research study and conducting interviews, it became clear that Mixed Reality is such a novel technology in the construction industry that the sources and knowledge needed to adequately address this question simply does not exist. Furthermore, as one of the goals of this paper is to produce something that gets the industry's ear, we decided to broaden the scope to include the whole construction industry and not just the transport sector in order to maximize potential interest. In light of this, we rephrased the research question after having gathered information. Considering the novel nature of the subject, it is only natural that discoveries that demand a tweaking of the initial parameters are found later in the research process.

We felt that editing the research question during the research process was unproblematic considering that the research yielded very little to no information that concerned the transport aspect of the initial paper question/working title, and that this paper is less strict in its scientific approach than what is the norm for bachelors' theses.

Hence, the research problem this paper aims to answer, is:

How can one best utilize Microsoft HoloLens technology in construction planning?
1.3. Limitations

This paper won’t take in consideration neither the hardware or the software aspect of Microsoft HoloLens, due to the fact that this isn’t the area of expertise of the authors. This doesn’t mean that this paper won’t mention the technology aspect of it, but it will mention the limitations regarding the findings and assume they will be resolved.

This paper also bases the use of Microsoft HoloLens to Trimble Connect. From the experience with Microsoft HoloLens the Trimble Connect application was by far the best implemented and most useful in relation to this papers research question, also with Trimble as a partner for this paper provided useful insight and support when using the application.

The solution presented is adapted the use of Microsoft HoloLens and Trimble Connect, but ideas behind the solution could be brought to other part of the technology, but his is not considered in this paper.

2. Theory

2.1. ISO

As a result, in this paper it will be represented a process map and procedure that base on terms and definition introduced in ISO 9000:2015(Standardization 2015) and ISO 9001:2015(Standardization 2015), both are standards for quality management systems. ISO 9000:2015 defines and explain the fundaments and vocabular that ISO 9001:2015 uses, and also show a graphical representation of the relations between different terms that are introduced in the same standard. Figure 2 shows the presents the relation of the class ‘process’. ISO 9001:2015 is the requirements for quality management systems.

Figure 2: From ISO 9000:2015 Figure A.7 - 3.4
2.2. Cost/influence

A central topic in this paper is the cost/influence diagram. This represent the correlation between influence or impact from stakeholder, risk or uncertainty and the cost in conjunction with the project time, Fig 3. This is a simplified illustration that shows the increase of cost as a function of time, and similar but opposite, the decrease of influence also as a function of time. The general theory behind this diagram it so represents the cost increase with increased project time in order to try to make decisions earlier in the project to save money. Not only will this decrease the cost, but also give more influence to the stakeholders in terms of giving them more power and involvement in the decision-making process, because their influence and impact is of a higher degree. (Indelicato 2009)

2.3. Integrated Design & Delivery Solutions

IDDS is the center of the three imperatives: Collaborating People, Integrated Processes and Interoperable Technology as visualized by Fig 1. The theory of IDDS states that with good implementation of the three imperatives mentioned, the projects using this will have significantly shortened timespans, shorter payback time, inevitably be a reduction in construction costs, reliable delivery and improved quality, wider economic contribution to society, reliable modelling and delivery of sustainability, and building estate/area scale will improve carbon footprints and other sustainable outcomes. (Owen, Amor et al. 2013)
2.4. Flowchart
A process map is an activity broken down to specific processes that are defined with a start and a stop. Fig 6 shows a representation of the activity from ISO 9001:2015. There is predefined definition for the shapes used in the process map. Fig 5 shows the shapes and their meaning which is used in this paper. It’s normal to give different roles within the activity a dedicated ‘swim lane’. This means that each process is assigned to a role within the activity and is connected with arrows to the process in which it’s depended, and the required document or data is connected to the right process in the right time. This is used to get a better visualization of the activity.

2.5. Microsoft HoloLens
HoloLens is a self-contained mixed reality device. It runs on a custom version of the Windows 10 operating system. The operating system has an interface with a series of apps that can be downloaded from the Windows store. These apps are made especially for the HoloLens. It’s now possible to buy to versions of the HoloLens (as of May. 2018), either the developer edition for $3000, just the HoloLens, or the commercial suite for $5000, which includes the same HoloLens from the developer edition, but with a warranty and enterprise features(Microsoft 2018).

The HoloLens also allows to combine Microsoft Cortana with other apps, with simple voice-activated commands.

2.6. Trimble Connect
The app which the procedure is based on is Trimble Connect, as it is the best and most fluent app that uses the HoloLens technology to view 3D-models, while also having a browser-, mobile-, and desktop-application(Trimble 2018). As of now, there are a variety of ways to log in to the Trimble Connect, either with a Google account, Trimble Account, or a QR-code provided by the Trimble Connect mobile app. Trimble Connect is available to anyone, with the free version that only requires a Trimble Connect user. The way the Trimble Connect app is today, to-dos has to be created in the desktop-, mobile-, or web-app, but they can be viewed and edited in the HoloLens. The premium version also allows to take measurements with the HoloLens, and it gives the user access to the Collaboration mode, which allows multiple HoloLens users to view the same model at once.
3. Method

This section discusses a selection of methods that were considered for this paper, presents the chosen method, and details the execution of the chosen method.

3.1. Choice of method

Considering the subject of this paper, there were a few common research methods that immediately stood out as viable options, those being the qualitative method and the quantitative method. We will not expand on the two methods here as we consider them to be common knowledge to potential readers. In order to make an intelligent decision, we looked at the results of the research study to see if they could point to a method. Following are a short look at how the two methods lines up with said results.

3.1.1. Quantitative method

The research study showed that the field of expertise on MR technology is very small indeed in Norway. Hence the pool of potential respondents to a survey would be far too small to yield any useful insights. A presentation from Trimble put the number of TC for HoloLens users at just over 300 people worldwide as of February 2018, a fact which illustrates this point. Furthermore, preliminary talks with Trimble indicated that the number of people in Norway eligible for a survey would likely number around 10-20 at most. Considering all this, utilizing a standardized survey in this case would most likely not produce any useful results or new insights.

3.1.2. Qualitative method

As mentioned above, the research study showed that the number of people with knowledge about MR technology in the engineering field in Norway is small. This, coupled with the fact that the technology is so new, means that those few people are pioneers who are very passionate about the technology’s potential and have well-funded opinions about how it should be implemented. On this basis, it seemed obvious to us that the only research method that made any sense in this case was to use our contacts in Trimble and in the university to set up semi-structured interviews with a few of these pioneers and try to learn as much from them as we could. In other words, we chose to utilize the qualitative method for this paper.

3.2. Chosen methods and implementation

In order to perform the semi-structured interviews, we first had to select who we would contact. Where one usually would set some criteria to single out eligible interview objects,
we had to narrow ours down to just two: That the person has some knowledge and experience with MR/VR technology, and that they must be connected in some way to the building industry on the engineering/planning. The reason our criteria were not stricter is, as mentioned earlier, that the pool of people meeting the two that we did land on amounts to a handful of people in the entire country. In other words, if the criteria were stricter, or if there were more of them, we would end up with just one or two, or no, interview objects. The result of this is that several of the interview objects land somewhat outside the scope of the research problem, which looks at construction planning specifically.

On the other hand, interviewing people who are in slightly different positions in the industry makes their input broader and more diverse, enabling one to look at the subject matter from several angles. This can only be a benefit, considering how new and relatively unexplored the subject matter is. As the research study showed, there is possibility that this paper will be one of a very few papers written about the implementation of MR technology in the engineering/planning industry, and as such it might be more beneficial to future readers if it manages to avoid the narrowest possible definition of the research question.

The list of potential candidates for interviews was compiled from suggestions from our internal mentor at OsloMet and the external mentor at Trimble, as well as input from some of the candidates themselves. The candidates were contacted by email, where we introduced ourselves and the subject and asked for an interview. The interviews themselves were conducted at the candidates’ workplaces, and was, as discussed above, semi-structured. As we were three people conducting them, one of us took the role of head interviewer, while the other two supplied additional questions if they had any ideas.

3.2.1. Hands-on approach
In addition to the interviews, we had access to one and sometimes two HoloLens units that were used to get a feel for how the user experience is today, and what is possible in the Trimble Connect software. These were supplied both by the university and by Trimble. In particular we focused on trying out the collaboration functionality as this is central to our procedure.

3.3. Quality Control
3.3.1. Validity
Considering that we specifically chose people for interviews who have experience with the subject, one can assume that the results that were found are as valid as they can be. While the interviews were conducted in a quite informal manner, all the interviewees are working professionals within the AEC industry and their opinions are as well founded as any when it comes to the future potential and present challenges with MR technology. The informal nature of the interviews was also the result of a conscious decision on our part, in order to
get as many novel ideas as possible on the table and not be limited by notions of seriousness or what is conventional.

3.3.2. Objectiveness
The main potential source of error in our findings is the fact that we only talked to people who are believers in the potential of MR/VR in construction. Apart from the interviewees from Norconsult, who were more inclined to think that VR had an edge over MR, everyone who was interviewed firmly believed that MR technology has the potential to revolutionize or greatly improve the way the planning phase is conducted in construction projects. Considering that our pool of potential interviewees represents the cutting edge of experience with MR/VR in the AEC industry in Norway and the fact that all those interviewed sees great potential with it, this points towards an industry-wide consensus on the possibilities of the technology.

4. Results
This section addresses the interview made with the different persons in the different parts of the industry and with different experience considering XR. These summaries are written based on interpretation of the notes and the idea mentioned during the interview. They are ordered in chronological order by earliest conducted first. The procedure is also mentioned in this section, but the different aspects are explained further in the solution. The experience of the hands-on use of the HoloLens and Trimble Connect is conveyed.

4.1. The interviews

4.1.1. Interview: Andreas Haugbotn, 3D-specialist, ViaNova
Andreas Haugbotn works at ViaNova as a 3D-specialist. A 3D-specialist is basically the same as a BIM-coordinator, meaning that his job is to prepare BIM-models and coordinate the dataflow in projects.

ViaNova is a consulting firm located in Sandvika, Bærum just outside of Oslo. They have consulted on several projects in Norway, and they are the developer of NovaPoint, a computer program used for road planning.

Andreas has tested HoloLens in a project where they used it in collaboration with NyeVeier and the project owner, were the project owner did not have access to HoloLens and therefore participated with visual access to the model. In that project they discussed sightlines under an overpass by placing themselves in various places in the model to get a more realistic image on how the sightline would appear. Andreas felt that using HoloLens gave them a better understanding of the sightlines than by only using a 3D-model on a computer. It is advised to view video 1 referenced in the source section.
Another problem they resolved by using HoloLens was to run a collision test on a colliding manhole. They used the model to show the present collision to the project owner, then they had a premade suggestion on how to avoid the collision. In that example the project owner agreed over the skype call to the new suggestion.

The project that Andreas had tested HoloLens on is a project that is in the production stage, but he said that the issues that was reviewed in that example could also have been managed in the planning stage as well. Andreas believed that HoloLens could have been used with good results to showcase suggestions in the planning stage. For example, where different models could be represented separately to a stakeholder to highlight different suggestions to a problem, while also informing the stakeholder of the difference in cost, material use, environmental implications, or other differences. Andreas based his beliefs in other projects where they had been using similar technology to test this.

In Andreas’s experience HoloLens seem like a better choice than any VR glasses in terms of spatial awareness. In VR glasses you get completely disconnected from the reality by blocking the field of view, but with MR there are always reference point you can use. This makes it much easier to be aware of yourself in the model and in the real world.

One of the advantages HoloLens has over VR is that with the overlay of the real world means that constructions people can use HoloLens as interactive guidance for building, similar to the way Ikea has tested HoloLens to build a chair, see video 2 referenced in the source section. And based on the same usage ThyssenKrupp made a similar video see video 3, but with the difference in maintenance, arguing that the technician could visualize the service task beforehand and be better equipped for the task. Also, during maintenance, the technician could visualize the task while doing it. And when he need expert help he could phone a better qualified person for the job that could guide trough while getting the HoloLens feed via Skype (in that example skype was used, but it doesn’t limit itself on skype, that’s just what’s available now)

The other main advantages with HoloLens over VR is that HoloLens is a Head Mounted Device(HMD). Meaning that it is self-contained, and all data exchange happens over either Bluetooth or Wi-Fi. The only time it is necessary with a cable is when it need to be recharged (it is also possible to transfer files using the cable, but as we experienced it is much easier to use Wi-Fi because it has the possibility to sync and refresh changes or new projects very easily). The VR-devices that are being used now (HTC Vive, Oculus Rift, ...) requires a powerful computer and setting up sensors. VR works well in a set location (that’s why many companies have a dedicated VR room), but it faces problems out in the field. Now VR on construction sites are used with a BIM-kiosk. Because of the connection to a powerful computer VR is available to run much bigger models than HoloLens. One of the main limitation of the HoloLens is the processing power.
According to Andreas HoloLens does not replace a BIM-kiosk in the future but works as an addition to the BIM-kiosk. He doesn’t see HoloLens as a replacement to existing tools for visualizing BIM, but as an addition.

Andreas meant that at present the steps required to view the model in HoloLens from a modelling tool are too long and complicated. Andreas said that he usually needs an hour to prepare a model to make it visible HoloLens. In an ideal world the is no need for a 3D-specialist to prepare the model for viewing, it should be as easy as open a PDF file, in his words. Some of the steps required now is to limit the model to fit what you want to see and remove the part that are irrelevant and reduce the polygon count (reduce the number of triangles that make up the geometry).

Andreas would like to improve the to-dos in the HoloLens. When the interview was conducted the use of to-dos was limited. To perform to-dos, it had to be created in Trimble Connect on a computer beforehand, then be checked off in the HoloLens without the possibility to make new ones. Andreas think that one of the easier functions to be implemented/improved in the HoloLens is to have the opportunities to make to do list in the HMD and make redlining. With the implementation of this function it would increase the value and usage of the HoloLens to make it more attractive for companies to use.

As of now it’s possible to mirror what the person using the HoloLens see through a computer. By logging into the IP-address of the HoloLens the HMD can be controlled, or at least some functions, through a shared internet. This is a function of Microsoft, which means that it’s non-intractable with programs within the HoloLens. Andreas would like to have an improved version of this to increase the potential use of HoloLens. He meant that with the possibility to interact more seamlessly between computer and HoloLens and the programs within the HoloLens, it would ease the workload. One example is to see changes in the model in real time by modeling on a computer while wearing the HoloLens to get a better perspective of the model through HoloLens.

One of the biggest issues HoloLens has is the problem with outside use, according to Andreas. If the HoloLens are used outside it cannot be used with strong sunlight because the holograms becomes invisible in the screen in the HoloLens. This has a cheap, but cumbersome fix by using big sunscreen outside the HoloLens. The other problem using HoloLens outside is the problem with positioning. The HoloLens needs to have walls to reference position. In an open field that is a problem, unless there are set up temporary walls which again might interfere with moving around in the model.

4.1.2. Interview: Øyvind Svaland, BIM-coordinator, Veidekke

Øyvind Svaland is a BIM-coordinator at the leading Norwegian contracting firm Veidekke and has experience with trying out HoloLens in a construction site, see video 4. He said that
he is the one of very few people at Veidekke (or in general) that has used HoloLens and he try to use HoloLens actively in his work.

Veidekke is Scandinavia’s leading entrepreneur and property developer.

A lot of people talk about the potential HoloLens has when it’s been properly developed, but Øyvind said it can be used in any construction stage now and give value to the projects. He sees especially potential in the FM stage of a project and used in QA. From Øyvind experience it’s easier to execute QA in 3D. Also, the Skype function could be of use now. It’s possible to see what the user of the HoloLens are watching, in similar way as the streaming of HoloLens to browsers does, through a skype call. Not only can someone show their view, but also draw and annotate with arrows on the real world through HoloLens to highlight different aspects. This makes it easier and more streamlined for different professions to collaborate on site.

Even though Øyvind stated that HoloLens has potential now, it also has a lot of barriers that it need to overcome to be used better and increase its appeal. The problems associated with hardware show sign of immature technology. The FOV are too small, it’s too sensitive to light, the size of the HMD is too big in terms of formfactor, too expensive, and text input are too complicated are some of the barriers Øyvind has identified so far in relation to hardware.

In terms of software the HoloLens are also lacking. The way the operating system works is that some small programs, mostly the built-in programs, can be viewed and used as a virtual window, but bigger programs (like Trimble Connect, SketchUp, Skype etc.) take the whole FOV and hides the other programs. Therefore, makes it impossible to use with other programs without exiting (blooming) to see the interface again and then the program freezes and hides inside the window. Øyvind was also not impressed with Cortana. He felt that the implementation of Cortana was not good enough as it is now.

In general, the software of the HoloLens and Trimble Connect aren’t good enough to be viewed as a valuable asset in the industry yet. One of the reason for this, according to Øyvind, is that the fundamental functions and software aren’t good enough. One of the reasons the problem with HoloLens is that it’s hard to add information to the model. Text input is hard and time consuming, if not a Bluetooth keyboard is used. Another reason is that modeling in HoloLens is also complicated. The limited the gestures limits the usage. In most of the VR-devices there are controllers that makes modeling easier.

Øyvind has used the Trimble Connect app. He was satisfied with the user-friendly interface of the program, but he said it was lacking in terms of splitting the model to smaller parts and the implementation of to-dos are not good enough. In the HoloLens Øyvind uses there is only the possibility to change exiting to-dos, but not make new ones. There is a possibility to auto update the models in Trimble Connect from different modeling tools, but this is not an integrated process so there is a bit cumbersome setup process, note that there is an add-
on for Revit that are supposed to auto update the model, but this function has not been tested. Trimble Connect, or any other app for HoloLens for that sake, needs to have the possibility to filter out objects in the model. For example, show only the concrete in a project to measure the mass.

Øyvind has a lot of faith in MR as technology. He believes that MR gives the opportunity to have the best kind of information, with that he means that the digital model can be placed in the real world and with a good use of BIM any information that is necessary information can be accessed. This is obviously not the present version, but some of the potential the HoloLens has and in Øyvind’s opinion one of the most important.

Øyvind had a lot of vision and possible applications for HoloLens. One of the ideas is that communication can be drastically improved. In a way that the right information can be given to the right person with right level of detail. Another idea is to have geographic location that tells the person what is to be done on site exactly where the person is. Information can also be stored in the object, in a sense that makes people airtap the object and every type of information connected to that would be displayed, removing the need to look for or look through many files to find the information, but instead have it ready when it is needed.

In the ideal world, any changes to the model or other information that can be read or accessed through the HoloLens will be automatically updated when a new revision is available. Giving the user of the HoloLens the newest and most correct information at all times. If the progression plans are linked with the model, the model would adapt to where in the process it is and give the right information accordingly. To make this possible Øyvind said that a good cloud-based storage and access to the information must be the basis. With the functions that are available, and the way Trimble Connect are setup this seem to be a reasonable assumption that this is possible without too much adaptations to the exciting HoloLens or Trimble Connect.

When asked about the difference or advantages of MR and VR, Øyvind said that MR can be used in the way VR is used. To the extent that the whole FOV can be occupied with the holograms. Besides the small FOV, sensitivity to light and processing power that are a problem to this day, MR could replace VR, theoretically. The main advantages MR has to VR is that when Holograms are placed in the room it’s easier to maintain a reference to position, instead of being disoriented when taking the VR-glasses off.

One of the problems with implementing HoloLens, or BIM in general, is the old-fashioned contract structure and regulations. Still the contract form of most project is designed to be in paper formats. Even with the high use of 3D modeling tools for both engineering and architects it’s still used papers on the actual site. Many of the pilot projects that are being carried out as a modern ‘paperless’ construction site is just forced use of BIM to try to use it to the full potential. With HoloLens there is no need for printing actual papers. Even the older more old-fashioned workers can view the plans in either 3D-model or as a 2D paper drawing inside the HoloLens. This means that the implementation of BIM doesn’t become
that forced and the threshold for using more modern tools are lowered to a standard that’s more adapted to the current building manner. On the note that BIM should not be forced, Øyvind made it clear that model, processes and information should not be forced to fit HoloLens, but instead made for HoloLens. Since the industry is very old-fashioned many don’t understand the point of using time and money by using the new technology when the old way gets the work done. From Øyvind’s experience the industry find the technology disruptive.

Øyvind also spoke of the possibilities of using HoloLens for safety on site. For example, the HSE-protocol be conducted using HoloLens or other aspects of HSE. Another use for HoloLens is with Traffic safety revision¹ (TS-revision). TS-revision is based on the idea of zero death or seriously injured in traffic(Vegvesen 2005). HoloLens could support TS-revision in a way to visualize a project with its sightlines and other issues even before it’s build. The basis of decision greatly improves.

To make HoloLens attractive for use, it need to be plug and play. If the threshold is too high the industry will be to reticent to make use of the new technology. This is something Øyvind states is important, if not it can be hard to introduce HoloLens in a highly old-fashioned multibillion NOK industry. Another point made in relevance of how the HoloLens must be of easier implementations is that its need projects to be designed for MR, and not adapted to MR. meaning that models, standards, rules, databases, instructions or other documents needs to be available in HoloLens.

Øyvind also mentioned the video demos presented by Thyssenkrupp and Ikea. Showing some of the potential HoloLens has.

4.1.3. Interview: Sigurd Berge and Eskil Landet, Architects, Norconsult
Sigurd and Eskil are architects at Norconsult. They use VR (Oculus rift) in projects like Sundvollen, which is explained later on. They had no experience with HoloLens other than videos showing HoloLens. Therefore, the interview dealt with the use of VR and not AR/MR.

Norconsult is the biggest engineering consulting firm in Norway, and are involved in a variety of businesses, such as energy, transport, environment and architecture.

From Sigurd and Eskil’s experience it’s easier to design in the planning stage and easier to present the model by using VR. Sigurd and Eskil have experience with showing models to stakeholders that don’t have experience with view models on 2D paper or on a computer. For example, the neighbors of a project get to see the model from the perspective of their property and get to see the end product and get to have a better understanding of the projects and therefore are better suited to give feedback. While giving a better

¹ Traffic Safety revision (EN) – Trafikksikkerhets revisjon (NO)
understanding it also create enthusiasm. They also found it easier to different professions to work together using VR.

As mentioned they used VR with success at Sundvollen, which according to Sigurd and Eskil sparked the use of VR at Norconsult. They saw potential in using VR because it gave them a new perspective and that led to better basis for making decisions. At Sundvollen, Norconsult are building a train bridge across a river. One of the key point of the bridge was to try to make it affect the environment around as little as possible. It then became topic to decide what height the bridge should be. The immediate intuition led to the conclusion that it should be as low as possible, but then the flood would be a problem. Therefore, they used the VR glasses to view the bridge in different heights, and then made a decision based on what they experienced to be the best solution through the new perspective.

To setup the VR model is a bit different than setting up for HoloLens. For VR they basically create a game with the model as basis and then use a simple button to move around. To visualize the model the VR-glasses has to be connected to a powerful computer, commonly referred to as a gaming computer. It’s also required to have some motion sensors to give the VR-glasses some point to reference movement.

Sigurd and Eskil has used VR for four years and to their experience Unreal Engine was the best program to use when this interview was conducted. A problem with VR is that it’s difficult to streamline the process of making VR-ready models, but the graphic quality that the models have are quite high, and with enough time since it’s made as a game the graphic can be very realistic.

The old way to make models, when this was done on papers, was to pay for a section of the model that was printed, but with the increase of BIM-models it’s a bit more complex to bill for models based on the previous business model. Therefore, when Sigurd and Eskil make models for VR the focus around billable hours is a bit too high to let them play around with the VR-mode.

A barrier with VR is that there is a lack of knowledge around the workload of making the visualization. Many project owners would like to make VR-models but are not familiar with the workload that requires to make it, and therefore is unfamiliar with the price of have a VR-model made.

Given that VR aren’t that much used it’s great to be a leading, according to Sigurd and Eskil. The project at Sundvollen was given a lot of PR because they had used VR with such a positive outcome and included the community in the process.

Sigurd and Eskil was a bit reticent about HoloLens because it’s a bit too new, in that the HoloLens showing sign of immature technology. They meant, when the interview was conducted, that there are too many problems with HoloLens to be used, at least when compared to VR. Some of the problems that Sigurd and Eskil pointed out was the limitation of outside use, the gap between the actual HoloLens and the demos, and the limited field of
view that HoloLens has. Sigurd and Eskil believed that HoloLens has a long road ahead before it can be used in a similar way VR is used when the interview was conducted. They saw a potential for HoloLens use in the FM stage of a construction. With the HoloLens it would be possible to ‘look’ inside the wall to see everything hidden and get the properties of the objects inside the wall. Such as size, material, time of placement, time of replacement, or other properties that are relevant.

4.2. The procedure

The AEC industry is very old-fashioned in terms taking new technology and processes into use. The industry desires to collaborate better between different profession and people, which is obvious through the recent adaptation of VDC, ICE, LEAN, etc. The Technological advancement is far more advanced than the technology used in the industry today. Based on the interviews, research, and the experience acquired it’s obvious that there is gap between the three imperatives listed in the IDDS.

The way the industry is trying to bridge the gap, created by the three imperatives not being tied together, is to solve it by putting in money and force the technology into projects and with time the problem will be solved, there is no clear process or idea behind the implementation. Companies buy expensive equipment and hires graduates and/or people with competence with dealing the equipment. The procedure linked to this paper proposes a solution to bridge the gap. The procedure itself is a tool that focus on a process, Virtual Inspection, that uses the technology, Mixed Reality, available to make people collaborate in order to add value to the project. To ensure that this process, and other processes, is used correctly a new role is introduces to construction planning.

The way the industry has handled problem so far has proved beneficial in bigger projects, but this is a time-consuming, costly, risky, and unspecific way to solve the problem. The Virtual Inspection will offer a simple and cost-effective solution that can add value to all projects, and the new role is a whole new expertise that has a high focus on the collaboration between people for earlier and better stakeholder involvement that in turn adds value.

4.3. Hands-on experience

The hands-on experiments resulted in numerous cases of technical difficulties. These were primarily problems with logging in to the Collaboration Rooms in Trimble Connect, which we in fact never got to work despite numerous attempts. Here it must be mentioned that the Collaboration feature of Trimble Connect is in beta testing, and hence can is a finished product. There were also some difficulties with logging in to the Windows operating system of the HoloLenses themselves.

Once able to use Trimble Connect (which functioned completely fine except for the issues with Collaboration), we found that the software rendered very detailed and lifelike models,
with a user interface that made manipulating the models easy and natural once one has gotten used to using the Gestures to interact with the HoloLens.

5. The solution

This chapter explains the foundation and assumptions for the procedure, the process map and the XR-manager. The XR-manager is explained in even further detail in the XR-manager chapter. This chapter also explains the three most important aspects of the process: democratization, collaboration, and economy.

This paper uses the term Virtual Inspection in two ways: as the name of the procedure and as a process.

The Virtual Inspection procedure act as a summary where the general idea of the Virtual Inspection process and the XR-managers role is explained and is put into a context.

The Virtual Inspection process is the process that allows the implementation of HoloLens in construction planning. It is the XR-managers task to manage the aspect before, during, and after the process.

5.1. The gap – missing link

The main idea behind the procedure is to allow better collaboration for more people. Based on the interviews there are an industry wide wish to increase stakeholder involvement and give more people ownership of the project. As stated by the cost/influence diagram, the IDDS, and the interviews the increase in stakeholder involvement will decrease cost and project time. The fig 7 is the conclusion based on the interviews as visualized through the IDDS representation. The technology imperative is advancing faster than the other imperatives this is referred to as the gap. the theory of IDDS sates that with good implementation of all the imperatives the advantages of IDDS will occur. The reason for the gap in the AEC industry lies in the nature of the construction projects. Every project is unique and have a relatively short lifespan from planning to end of production, this makes streamlining complicated. The industry is also very old-fashioned in terms of taking advantages of the new technology. The solution presented in this paper is the missing link that will bridge the gap between the imperatives.
5.2. The difference to our ideal solution and the present – assumption & limitations

At the time of writing, the technology is not ideal for the procedure linked to this paper, as there are some obstacles, in both hardware and software, that prevents people to take better advantage of technology.

Considering the hardware aspect of the HoloLens, as mentioned by the interview objects, it would be beneficial to implement GPS, for better reference to movement in an open area, have the cellular data to remove the need for internet, expand the field of view, and develop a solution to the light sensitivity issue. None of these pointers are necessary to resolve before using the Virtual Inspection procedure, but it would increase the area of use and make the device more intuitive.

The software aspect of the HoloLens is the most critical, as the interface today is making it difficult for stakeholders to quickly set up and use the device. This procedure proposes an option for the stakeholder to scan a QR-code as they turn on their HoloLens, which will be read by the sensors in the HoloLens, and will directly open Trimble Connect, and they can take part in the model as a guest. The XR-manager will not have this option, as they have to organize the model, setting up the collaboration and manage the Virtual Inspection process. The XR-manager interface will be relatively similar to how the HoloLens is used today, but the idea for the guest user is to start the Trimble Connect application right away as the user turns on the device, to minimize time and effort before the Virtual Inspection process. This is grounded in the fact that there is a variety of technological knowledge amongst people, and therefore lowering the bar by simplifying the interface. The guest user will also have certain limitations inside the Trimble Connect application for the same reason. They will however, have the option to make revision clouds, redlining properties, and comments while also have the ability to communicate with the other participate. The limitations will be restricted to movement inside the virtual inspection, by giving the XR-manager the responsibility to place the user in the right space in the model, to avoid anyone in the inspection suddenly disappearing, which will draw focus away from the model and the ideas it represents. It’s required to be on the same internet connection to use the collaboration feature of Trimble Connect in the present version.

The procedure considers the aspects mentioned in this section as resolved, and it won’t impact the processes represented in the process map for the procedure.

The Virtual Inspection procedure is adapted to the HoloLens and Trimble Connect, but the Virtual Inspection process could be adapted other technologies, but that is not explored in this paper.

The design manager is considered to be in close relation to the XR-manager and therefore would have a HoloLens ready for use, if this is not the case, the preliminary processes should apply to the design manager as well.
5.3. Virtual Inspection – the procedure & the process

5.3.1. The Procedure

The Virtual Inspection procedure will firstly have a small summary. The summary is composed by an introduction, the assumptions, the purpose, and the advantages. Then the XR-managers role will be explained in terms of task, responsibility, and necessity. Then the most important processes will be explained and put in context. The last page contains the SQI, the Simple Quick (Ideal) Instructions, to demonstrate the level of technological proficiency expected from participants in the Virtual Inspection process.

The processes presented in the Virtual Inspection procedure act as a summary and simplification of the processes represented in the process map. This is to keep the procedure simple, but still explain enough details surrounding the processes to make the reader be reminded of the processes or give a general understanding and context to the solution.

5.3.2. The flowchart

The process map will give the reader a better understanding of the roles participating, the preliminary processes, the closing processes, the documents or data needed, and the result from the Virtual Inspection process. This will show how the XR-manager ties the different processes together.

5.3.3. Roles

There are four roles mentioned in the process map. It’s apparent that the XR-manager have the most processes and responsibility in the process map. In regard of the Virtual Inspection procedure the XR-manager act as technical support, a guide, enables collaboration, and manage the changes from the Virtual Inspection process. Normally the stakeholder term is broad and would contain anyone with interest to the project, but in this process map the XR-manager, design manager, and project owner are excluded from the term, because they have their own dedicated swim lanes. The project owner is present because this role will approve or disapprove changes based on the feedback from the stakeholder. The design manager seems to not have that much to with the process, but he/she is the head of the design team and the official link between the project owner and the design team.

The process map attached to this paper has four swim lanes to easily convey the general idea of the Virtual Inspection process. The swim lanes need to be adapted to the current project, e.g., more stakeholder lanes, or there might not be a design manager and the head of the design team must be adapted accordingly. The most important lane is the XR-manager, in the XR-manager section of this paper the necessity for this role in explained.

5.3.4. The significance of the colors used

The purple processes in the process map represent the preliminary processes to the Virtual Inspection process, the dark purple for the XR-manager and light purple for any other
stakeholder (including the project owner and design manager). The green represents the Virtual Inspection. The red processes should represent any process after the Virtual Inspection process. The orange data and document are required for the preliminary processes. The blue is the results/changes which originates from the Virtual Inspection process.

It’s also important to note that the adaption to the processes before and after the Virtual Inspection is to be adapted the current project, e.g., some project might require less of the purple processes and more of the red, or it might even need multiple Virtual Inspection processes.

5.4. The Simple Quick (Ideal) Instruction (SQI) – explained
The Simple Quick (Ideal) Instruction, or the abbreviation used SQI, is attached the procedure to demonstrate the level of technological proficiency this paper considers as the ideal simplification of the technology aspect with realistic assumptions to what is possible to simplify in the short foreseeable future. The SQI will have to be altered to fit the technology used to perform the Virtual Inspection process and the current technological situation of that technology.

Note that the troubleshoot section remains empty. The XR-manager should edit this section as new issues occur and propose a solution. The XR-manager should also actively give feedback to the administrator of the technology to contribute to advancement of the technology.

5.5. Democratization – giving more people better understanding
The reason the XR-manager uses the term XR and not BIM is because the XR-manager uses the XR technology to communicate the model to the stakeholder. XR, and especially VR and MR, give the user a better depth-perception. Furthermore, this gives the user a better sense of size and scale. If the stakeholder is not adequate with technical drawing and find the 3D-models (shown on a 2D-screen) disruptive, the XR perspective could be used to give the stakeholder a better understanding of the project, and therefore, give more people a better understanding of the project and what impact it has. The XR-manager acts as a guide during the Virtual Inspection process gives the opportunity to elaborate further into detail on the different aspects of the model. This gives as many stakeholders as possible a broader understanding of the project, regardless of the stakeholders’ technological proficiency and understanding of technical drawings, i.e., this will be beneficial to the society as a whole.

If the stakeholders understanding of the project increases, their influence on the project will also increase. With an increase in influence and an increase of stakeholders, more people will have affiliation to the project and their voice will matter more. This is why this paper consider the democratization aspect of the process and technology to be important.
5.6. Collaboration – allows high stakeholder management
One of the main points with the Virtual Inspection process is to connect the stakeholder, the project owner, and the design manager. Collaboration between different professions and stakeholders has proven beneficial in previous projects. The Virtual Inspection process allows high stakeholder involvement early in the planning stage. With the better understanding of the project by the stakeholder, the stakeholders could understand the concept and ideas behind the different aspects of the model even when the level of development is relatively low. This will better the stakeholder participation in planning and contribute to collaboration.

This form of collaboration will hopefully be able to help stakeholders come with specific feedback to each project, as opposed to them just agreeing or disagreeing, without really understanding what is presented to them.

5.7. Economics – decreased cost and project time.
One of the biggest motivators for the increased stakeholder involvement is that this has proven to cut cost and save time in planning and production stage. Increased stakeholder involvement will result in decreased cost because the important aspect of the project discussed and resolved earlier, e.g., it’s easier and cheaper to move a wall on 3D-model when it’s not built, but much costlier when it’s built. With increased stakeholder involvement will also more decisions be made in the in the planning phase and not the production phase, meaning shorter total project time, because a day in planning is worth more than a day in production (because of the eagerness and pressure to start producing).
To elaborate further on the subject of cost-efficiency and better time management. The illustration of pushing the point-of-decision could help understand one aspect of the advantages in term of the economy of the project. This is a simplified visualization of the point-of-decision. In fig 8 the progression of the project is represented by an increase of project time from left to right. The point where the line splits is defined as a crossroad where the project faces a problem. Each of the lines emerging from the crossroad represent a unique solution to the problem. The condition for this concept is that one of the lines has to be chosen, and the line left out represent a solution with no contribution. The red vertical line represents the point-of-decision on the current processes used. The blue vertical line is the point-of-decision by using the Virtual Inspection procedure. The basis on the advantages by pushing the line is offered through higher stakeholder management and increased understanding by the stakeholders. The green arrow represents one of the tasks of the XR-manager. By pushing the point-of-decision the project to an earlier point don’t need to use unnecessary time and effort by designing two solutions, when the solution not chosen will add no value to the project. The purple area represents the saved time and effort.

In terms of the HoloLens some investment needs to be made. Compared to the total project cost of larger projects the price will be relatively small, and if this is used on more than one project the profitability of the HoloLens would appear quite favorable, if issues got resolved by using the HoloLens. For smaller project the opportunity to use the technology on multiple project might be considered a requirement. The main focus on the Virtual Inspection process is to utilize the technology to the highest degree, i.e., use the technology
to ensure high stakeholder involvement to receive the benefits mentioned in the last paragraph and by the IDDS theory. It’s hard to estimate the actual cost-efficiency of the HoloLens and the Virtual Inspection process, given that the effect would appear as a decrease in the outgoing cost on the financial statement, and it’s complicated to compare the cost of construction projects because each project is unique in its own way. The effect would most likely appear in the long-term evaluation.

Other technologies would require different investment, and the profitability would change according to the price of the technology and estimation of the cost-efficiency.

6. Extended Reality Manager – XR-Manager

This section will elaborate on the new role this paper has introduced to construction planning. The Tasks, responsibilities, requirements, the necessity will be thoroughly explained, the development of the role in conjunction with the BIM-coordinator will also be mentioned to a certain degree based on some assumptions. The XR aspect of the title is already explained under the Democratization section of this paper.

As mentioned the level of technology proficiency of the users are expected to vary and the XR-managers tasks relative to the technological aspect is to act as technological-support. As a technological-support the XR-manager would be tasked to simplify the setup process by adapting the SQI and perform as many of the unnecessary steps for the stakeholder as possible. If the stakeholder face problems in the setup process the XR-manager should be available to assist. During the Virtual Inspection process the XR-manager should act as a guide to navigate the participants around the model and assist if any technical problems that may arise. The BIM used in the Virtual Inspection process needs to be adapted to the format. As for the Hololens and Trimble Connect, the BIM must be simple and small enough that the limited processing power can handle the file. The XR-manager has to prepare the model for inspection before the actual process takes place.

The guide task has also another aspect to it. It’s to inform the features of the project. The project might represent different solutions and ideas to problems which aren’t self-explanatory. It’s therefore important the XR-manager to convey the assumptions and groundwork for those features to increase the understanding for the participants. The reasoning for this is based in the Democratization section of this paper.
During the Virtual Inspection process the XR-manager is the connection between the stakeholder, the project owner, and the design manager. The design manager is considered the connection to the design team, even though the XR-manager is considered a part of the design team, it’s because the design manager has the highest authority. Some stakeholders may also be a part of the design team, then the connections must be adapted accordingly. FIG # illustrates a simplified connection between the different roles. It is the XR-managers responsibility to make sure that the communication is sufficient between the roles. It is of the utmost importance that the XR-manager possesses impeccable public relation skills.

When the changes that has been discussed at the Virtual Inspection process has been properly defined. The XR-manager will have to manages the changes to the BIM. It is in this process where a new Virtual Inspection process could be held to show the solution to the changes previously discussed, and the effectiveness of the solution and be assessed. The XR-manager requires expertise regarding BIM. The advantages of the XR-manager managing the changes is that the XR-manager has first-hand knowledge regarding the point of views from the other participants in the Virtual Inspection process.

The paragraph above mentions the task of the XR-manager. With these tasks follows some responsibility. For the technical aspect, the responsibility of the XR-manager is associated with the technology working as flawlessly as possible, so that the focus remains on the model. The XR-managers is also responsible to inform the necessary information regarding the model, so that as many persons as possible understand better, i.e., increase stakeholder involvement and influence. What might be considered the biggest responsibility is to make sure that the attendees of the Virtual Inspection process are communicating with each other, i.e., manages the stakeholder management.
The way this paper fit the XR-manager in the organization of a project is under the design manager, but over the BIM-coordinator. One illustration of how the XR-manager fits in a project is already given in fig 9, but FIG # is another way to visualize the connection between the XR-manager and the other roles. In fig 10 the hierarchy of the project is visualized by degree of influence. In this illustration the internal stakeholder is considered the profession that make up the design team, e.g., architects and consultants, and the external stakeholder is anyone but the design team and the project owner.

The reason this role is introduced is because the technology is too disruptive as it is today, there is a lot of stakeholders that don’t have sufficient understanding of the technical drawing and the 3D-model doesn’t make sense when it’s hard to evaluate true scale and very little information is given, and stakeholder management isn’t efficient enough as it is today. This is a lot of problems and instead to adjusting and tweaking the exciting role of the industry. it’s easier to assign all of the problems to one role, because they are connected, at least when using the Virtual Inspection process.

It’s important to separate the BIM-coordinator from the XR-manager. A BIM-coordinator handles the information and dataflows in a project, but don’t have any managing responsibilities tied to the BIM. The BIM-coordinator acts as a tech-support for the different professions that come together to make the whole BIM. As mentioned the XR-manager coordinates the BIM-coordinator, but through the Virtual Inspection process the XR-manager can manage changes to the BIM based on input from the stakeholders.

It would be reasonable to assume that a BIM-coordinator could be promoted to fill the XR-manager position. One of the requirements this paper recognize is the expertise in BIM. Another important requirement is the necessary technological proficiency surrounding the technological aspect. Given that one of the XR-managers responsibility to manage the various stakeholder a good public relation is also of the essence, as mentioned.

Since the paper focus on Microsoft HoloLens, which is a MR device, the original tittle of the role was MR-manager. It was later realized that the procedure might not limit itself just to be used with MR technology, but could also be adapted to VR and AR. Therefore, it was natural to expand the tittle to XR to include the other technologies as well. This paper hasn’t
look into the possibility to adapt the procedure and processes to VR and AR, but this is something that can be explored further.

As mentioned the AEC industry still lacks in technological advancement, therefore the technological expertise the graduates possess could be of great attribute for companies. Given that the technological expertise is a sought-after skill and level of technological expertise educated at universities and colleges have a high standard compared to the industry. It’s reasonable to assume that the BIM-coordinator will eventually become an entry level job, or junior job, and that the senior equivalent could be the XR-manager.

This paper focus on the role of the XR-manager in the planning phase. It would be reasonable to assume the role could add value to other phases in construction projects. This is not explored in this paper but could be explored further.

The paper also focuses on the role of the XR-manager in the AEC industry. Given that other processes have been beneficial to adapt to other industries the XR-manager could add value if properly adapted to other industries. This is possibility is also not explored in this paper but could be explored further.

7. Discussion

The gap that is presented in this paper is based on initial experience when the research started. The research study proved the little papers regarding the implementation of HoloLens. The initial meeting with Trimble enhanced this suspicion. When presented with the possible candidates applicable for the interviews, the presence of the gap became even clearer. The interviews proved that there is a small number of people in the industry that have taken the technology into use, and there was no clear process of how to use the technology for any aspects.

The IDDS theory present the different aspect and their relation to one and another. The technology is by far the most advanced of the three, but the technology in under constant development and new technology gets introduced so fast that it’s too hard get sufficiently acquit with the technology before new technology renders the old unfavorable, and the compatibility between technologies is low. Since every construction project is unique and have a short time span, it’s hard to have a set of processes general enough to fit every project, meaning the integrated processes aspect of the IDDS is lacking. This is defended by the old-fashioned contract structure and regulation that the whole construction project is based on, as mentioned by Øyvind. When Sigurd and Eskil make models, the way Norconsult bills the customer is based on the old way of making technical drawings, this also point to that old processes gets adapted to the new methods introduced to the industry, instead of making good processes that uses the new developments better. With the introduction of VDC, ICE, LEAN, and big room, the industry is trying to get more people to collaborate better, but these mindsets are not new and innovative. Other industries have been
implementing these much earlier. This proves that there is an industry wide consensus to make better the collaboration between people, but the industry is lagging behind.

In interviews and conversations with Trimble, there were a common understanding that implementation of the XR will be beneficial for the industry. All of the three interviewees tried to use XR in their work, but none of them had any specific suggestions on how to solve the problem with the implementation. The interviewees mentioned the barriers and how they would like to use the technology ideally. The solution presented in this paper wasn’t mentioned by in the interviews. the solution uses the point of views from the interviews to try to solve the problem.

Since this is a solution the industry hasn’t requested, there might be a risk of the industry to refuse the Virtual Inspection procedure, because the benefit might not outweigh risk. Since this is something nobody have tested, at least to this extent, there is the possibility that no one in the industry dares to bet on this procedure and the measures included. Andreas at ViaNova has tested some variety of the Virtual Inspection process, based on that the Virtual Inspection process seems to have potential. With that in mind, the complete procedure hasn’t been presented and explained to any in the industry, so there is no viable input from the industry. The internal mentor on the other hand, has been presented the idea many times, and given positive feedback, and also help shape the procedure and the XR-manager role to fit the industry best.

The Virtual Inspection procedure might not fit every project. The processes are claimed to need adjustment to be adapted to the project, not every project might profit from the process. The main point of the process is to allow high stakeholder involvement, but with smaller project there might only be one contractor and the only stakeholder could the project owner, to use the Virtual Inspection procedure and the introduce the XR-manager could work against its purpose. The introduction of a new role to a project would obviously increase the cost, because the new role also needs payment, in bigger project the contribution of the role to the project would outweigh the cost.

The Virtual Inspection procedure is based on MR, but as mentioned this is not limited to that technology. The mixed reality aspect of the HoloLens isn’t used in the proposed procedure, in terms of interaction between the real and the virtual, but as Andreas and Øyvind mentions it’s easier to have spatial awareness in the physical room using MR. The advantages of HoloLens, not to be misunderstood with MR as a technology, is that there is no need to connect the HoloLens to anything physical because it’s a HMD. The limitation of the HoloLens is the processing power, this is significantly lower that the most VR-devices has through a proper computer. Even though this paper considers the differences in MR and VR, and their respective devices. The point isn’t to put the technologies up against each other but be aware of the differences and advantages of each to use the best fitted technology. The AR aspect isn’t considered to any extent in this paper.
The technology, as it is today, is too disruptive. The threshold to use the technology is too high. The number of processes Andreas and Øyvind has to do before the model is ready to be view by the HoloLens is too many. Similarly, the setup process Sigurd and Eskil has to do to making models ready to be view in VR is also too complicated. But on the other hand, the new technology also generate enthusiasm. For Norconsult the enthusiasm created valuable PR.

There are some prerequisites taken to be able to perform the procedure. the prerequisites originate from the points made in the interviews regarding the barrier Microsoft HoloLens face to be more intuitive and easier in use, but also from the personal experience. The Microsoft has quite recently released a commercial suite of the HoloLens, the difference between the developer edition and commercial suite is that the commercial suite has an additional warranty and the enterprise features. The hardware is similar in both, and therefore, does this paper consider the Microsoft HoloLens as still in developer stage.

Even with a common concession of the advantages with BIM in the industry, most of the projects have desired delivery of the model basis through technical drawings, as mentioned by Øyvind. Given that the industry is slow to adopt new processes and technology, it’s reasonable to assume that the implementation of HoloLens through the described solution, if there is any implementation at all, will be slow.

This paper has elaborated on the possible advantages of using the procedure and the XR-manager, but have also mentioned that other aspect, such as exploring the use of VR instead, that may yield advantages as well. Since none of the aspect mentioned though out this paper haven’t been looked into, there is important to note that guaranty that these will prove beneficial.

The reason for the XR-manager role is based on the need for a BIM-coordinator in today’s use. Since there is a need for a BIM-coordinator to coordinate the dataflow on a BIM, the need for an XR-manager take responsibility of and manage the Virtual Inspection process and the processes leading up to and following, would follow in those same lines. To illustrate the necessity even further the XR-manager might be passive and execute the different task poorly, and therefore the processes before, during, and after the Virtual Inspection might render the process meaningless and just be a waste of time. Not only will the this show the necessity for the role but also show how the XR-manager and the Virtual Inspection process is depended on each other. Without the process the task and responsibilities of the XR-manager would disappear, and as mentioned the Virtual Inspection requires a clear manager.

Based on the previous discussion explaining the gap present and why the process is the missing link that will bridge the gap. It is important to note what the process initially does. The process act as a tool that uses the technology to make people collaborate better. The process is essentially a platform where people can work together, held up and made possible by the technology. It seems the industry is particularly focus on the technological
aspect, as interviews showcase. The interviewees have used the technology to make people collaborate, but there weren’t any well-defined processes to make this possible. The Virtual Inspection procedures goal is to define a set of processes that will aim to solve this. To oversee this the XR-manage role step in and takes the responsibility for the execution of the processes.

As collaboration increase the cost will decrease. This is firmly based in the IDDS, and the interviewees also believed in this statement. With the potential of increased cost-efficiency companies may find the procedure more appealing, and also defend the initial cost of acquiring the necessary components.

the XR aspect is an important aspect because it allows more people broader understanding. This will in turn allow for higher stakeholder involvement. Furthermore, this will enable the involvement of the society, which will be beneficial from an ethical point of view. The involvement of the community at the Sundvollen project had a positive effect on the planning, according to Sigurd and Eskil.

In regards of the procedure this should act as easy to understand visually-aided summary of the Virtual Inspection process and the XR-manager and put the aspects into context. This is based by this paper desire to produce something of use to the industry. The procedure would also act as a sale pitch to get the reader wanting to read more on the basis and ideas behind.

8. Conclusion

Initially, the purpose of this paper was to bridge the gap between XR-technology and its potential users, and provide a realistic and generic procedure. The end goal, to bridge this gap, was clear, and the certain parameters was decided on. The path from start to finish however, were not laid out, and there were some trial and error along the way. After conducting all the interviews, it became more obvious what was preventing the MR- and VR-technology from being used to its potential in the AEC-industry. When doing the research study, and in talks with Eilif Hjelseth, the mentor for this paper, it was decided to focus on the IDDS-theory about collaborative people, interoperative technology, and integrated processes. As the collaborative people already exists and it is reasonable to expect the technology to evolve into what is required for this kind of assignments in the foreseeable future, the focus had to be aimed at the integrated process.

Therefore, we came up with a process and procedure we believe would be valuable for the industry, as well as simple enough to be applied to almost any project provided that the procedure is followed. As stated in the solution-section, for the procedure to be effective, it is essential to put a XR-manager in place, as well as acquire the technology. Once this is in place, according to the Integrated Design & Delivery Solutions, one would, in theory, have
everything in place for shorter timespans, shorter payback time, reduction in construction costs, reliable delivery and improved quality, wider economic contribution to society, reliable modeling and delivery of sustainability, improve carbon footprints (ref: IDDS, theory-section). Of course, to achieve all of these would be ideal, but even if implementing the Virtual Inspection Procedure results in only a number of them, it would still add value to any potential users.

Seeing as this procedure is a first attempt at bridging the gap and is currently untested, it will obviously be possible to improve it once it has been used in practice. For further research, it would be recommended to distribute the procedure to different players in the industry and have them use it for some time, and then provide feedback. Exposing the industry to this new approach to construction planning would alleviate some of our difficulties in finding people with experience on the subject, and as such making it easier to have it validated by the industry.
Sources


Videos Referenced by the interviews:
2. https://youtu.be/D_3kQjZe3U4

The Procedure
Introduction:
In a world of ever faster technological development, it can be a challenge to keep up and make actual use of all the amazing technology that is available. As our research has shown, the main reason for this is a lack of frameworks for how to implement new technologies into existing workflows. In the AEC industry, where no two projects are alike and the parties involved change from project to project, having these frameworks in place is particularly difficult. Add to that conservative and cost-oriented executives who don't see the technology's potential, and it is clear why digitalization is moving so slow in the industry. What is needed is new tools to address the primary issue, namely that of a lack of frameworks, and using them could produce benefits that would persuade even the most old-fashioned engineer that there is a lot to be gained from utilizing new technology efficiently.

This is where the VIP and XRM comes in. The VIP (Virtual Inspection Procedure) is a procedure for promoting smart decision-making and enhanced collaboration in construction planning. When implemented by a new position in the design team, the Extended Reality Manager, the VIP provides benefits in terms of amongst others: Improved stakeholder management, reduced waste of time in decision-making, and a reduced number of conflicts in BIMs (Hence avoiding costly mistakes).

Advantages:
This procedure will be beneficial as it will provide higher stakeholder management by a higher collaboration-rate than as of now, where stakeholders will be able to give feedback on a project in a much more streamlined, faster way. For much the same reason, it will create a higher stakeholder engagement and a wider democratization, as the bar of understanding complex buildings is lowered when it is presented in 3D-view instead of on 2D paper. It will be enable stakeholders and project owners to notice critical errors and collisions in an earlier stage of planning process, which could prove to be both time- and cost-efficient.
The XR-Manager – XRM

The XR-manager task is to act as tech-support before and during the Virtual Inspection process, guide the participants of the Virtual Inspection process, ensure a good collaboration between the participants, and manage the changes to the BIM.

The responsibility of the XR-manager role is to make the technological aspect manageable to as many people as possible, make sure the collaboration is sufficient, and the changes made are based on the feedback from the Virtual Inspection process.

The XR-manager have a good expertise regarding the technology use, BIM, and have good public relations.

The stakeholder management is a complex an important aspect, therefore there is need a dedicated role to make sure the stakeholder have sufficient understanding of the model, and can take care of any issue that might draw focus away from model and the ideas it represent.

Requirements:

To use this procedure there needs to be a Building Information Model (BIM) ready for reviewing by a Stakeholder. This doesn’t mean it needs to be finished, just that there is a need to have a concept, solution, or idea that could offer value to a Stakeholder, and the opinion of the stakeholder could offer value to the Project Owner.
The Procedure

1. Preparing Trimble Connect and setting up Microsoft HoloLens
   The XR-manager upload and prepare the model in Trimble Connect and set up the Microsoft HoloLens to make it as easy to use for the stakeholder and the project owner. The XR-Manager then ships the Microsoft HoloLens to the Stakeholder and the Project Owner.
   a. The model gets adapted to fit the format of the HoloLens, regarding file size and polygon count
   b. Simplify the setup process for the stakeholder and the project owner

2. The Stakeholder and the Project Owner sets up the Microsoft HoloLens
   The stakeholder and the project owner set up the Microsoft HoloLens following the Simple Quick Instruction Manual provided, and log in using the QR-code.

3. Starting and conducting the Virtual Inspection
   The XR-manager get notified when the stakeholder and the project owner is ready, then starts the collaboration in Trimble Connect. The XR-manager guides and inform the stakeholder of the different aspect of the model, while the stakeholder comment on the aspects and the project owner can address the issue.

4. Preparing and making changes
   The XR-manager make the changes based on the approved changes from the stakeholder in cooperation with the Design Manager and the rest of the project team

Note:
in this procedure it limits itself to a single Stakeholder, but this can be expanded to multiple Stakeholders. To read more about the procedure, the XR-manager role, and the underlying foundation read the paper linked to this procedure.

The Simple Quick (Ideal) Instruction Manual:

Mounting the HoloLens
To mount the Microsoft HoloLens, use the scroll wheel to adjust the headband, and make sure the whole screen is visible.

The Buttons
The power button is located at the back of the device. This turns the HoloLens on and off if the button hold a long period. If pressed for shorter period the LED-lights located on the back will light up according to the battery left. On the right side there are buttons for increasing and decreasing the volume. On the left side there are buttons for increasing and decreasing the brightness of the screen.

The Gestures
There are three gestures to use to navigate the holographic interface, which you execute in the field of view of the HoloLens. The Air Tap, where the user simply taps on an application or an icon, very similar to a left mouse-click on a computer. The Pinch, where the user pinch on an application or an icon, to move it around in the holographic view. Can also be used in the same way as the Air Tap. The Bloom gesture is executed by making a fist with the finger pointing upwards in the field of view, and then opening it up. This opens the menu for the operative system.

How to setup:
1. Power on
2. Log in this QR-code
3. Calibrate the gaze
4. Calibrate the gestures: Airtap and Bloom
5. Log in on Wi-Fi; alternatively, 4G-connection.
6. The device is now ready for connecting to collaboration

Troubleshoot
Appendix
The Flowchart
Virtual Inspection Procedure – VIP

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Troubleshoot
Virtual Inspection

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