**Interviewee 2**

**To what extent is the construction industry prepared to embrace the transformative technologies of Industry 4.0?**

There are differences between the different disciplines. It also depends on what you mean by the next level of the industry since we have different tracks in the evolution of technology. But in general, the architects are better prepared from my point of view. They are already working in digital environments with quite advanced CAD tools, and they are starting to feel the need for connecting them through interoperability procedures. They are working more and more with the BIM servers. For example, Revit has some kind of cloud service as well as other major software providers. Basically, in the early phases of planning and calculation, they are quite prepared. But when you're talking about the building construction companies, they are very diverse in when it comes to the potential of taking up the next generation of digital technologies.

The question is broad, but I think in general the industry is not very well prepared. But of course, if you are talking about big companies, they will have teams that are very well prepared. There will be forerunners among the bigger companies. Then you have most companies that are smaller, some of which don't even care about this. The margins are so small in this field, so that they just have to deliver, and they have many other problems to think about rather than IoT, AI etc.

**What major benefits can AI bring to the industry?**

The most obvious thing that comes to my mind is the ability to take decisions more efficiently. If you have an AI process that can quickly suggest, propose, or warn about things that you might not have considered, then you will be able to take better decisions. So, it’s like having an assistant to keep all the different options in mind and to be more agile in your decision-making process and in your operation. The AI may be text-based or the image recognition type where you can have cameras warning you or seeing things or measuring things in the construction site continuously having like some kind of digital twin that is updating all the time that you can have a full picture of what is the state what is the predicted state. This kind of help functions I think is the most promising.

**What are the disadvantages or risks, if any, of adopting AI in the construction industry?**

Chat GPT is a very good example to discuss when it comes to trusting AI, trusting some kind of machine that very quickly and confidently can just give you some solution. And then you trust it because you don't have time or maybe you're you are sloppy or lazy or whatever the reason is, and you are not really looking into what it does. But it can't solve your problem. It can only help you to do things.

There are so many other risks regarding the ethical considerations which is a big topic — what to do now with all these problems that come up from this rapid evolution.

**So, from your experience or work of producing digital twins, have there been any particular challenges that you faced in this regard?**

When we are training models, there are always a lot of problems. There are the challenges of edge cases and anomalies, things that that suddenly don’t work. Even if you are correct in many cases then suddenly something is wrong — and sometimes you might not even notice that it's completely wrong — that can have a very problematic outcome. If it's right in nine out of ten times you still have to be careful with what you're using it for. The automation process is very critical or sensitive. You really have to take a step back and see what will be the implications of if we are scaling up.

**What data characteristics do you think are unique to the services or products provided by the construction industry?**

The spatial characteristics come into mind. An interesting aspect is that data can be dangerous or risky. Things like calculations and simulations that can risk the lives of people if not done correctly, for example a building collapsing due to an earthquake. The sustainability part of it, I would say is very interesting. You have geometric parts and volumes, and as I said you have the critical calculations from these of volumes as well as the energy consumption calculations and sustainable or environmental properties. We have legislation on the energy calculations from many years ago, so the data is often connected to this kind of mandatory calculations, and the people who perform this must guarantee that it is accurate enough so that we can reduce energy consumption and carbon emissions.

Then, the interoperability between systems is very interesting. You have the problem that you need to move data between tools, systems, and the actors in this kind of collaboration and that is problematic. Maybe that's not specific to the building construction but areas like medicine and banking have come much further because they also don't have that heavy amount of data for example, 3D representations for very huge projects that you need to shuffle between systems. There are always problems and the risk of losing information when you're sending it between different systems, for example when converting from Revit to the open standard IFC format, which is critical in some processes where you need to maintain all the data.

The other challenging thing when it comes to architects, they need to represent their work in very realistic rendering. That is something that is very specific to this industry. Not only do you need to show things in 3D, but you also need to show the lighting, the material characteristics so that the customer will know in advance that what how it will look and how it will feel. And this is a very laborious process. If you are thinking about all the different aspects of a new building — how it should be used, how it will be operated, how it will feel, how is the daylight coming in, etc., all of this has to go into the data model and all of it has to be calculated.

**How would you characterise the general quality of data produced by the construction industry in terms of key data quality criteria such as accuracy, completeness, and timeliness?**

If you're talking from a supply chain perspective then you have all different cases here. You have everything from nonsensical, worthless data collection to pretty good stuff that some leaders in the industry are trying to do. So, I think you get all the range, but I don't think that there are perfect solutions yet even in the best cases. There is a long way to go to really make this open. Even if you have some cases where you really can benefit the interoperability between systems and you can connect a chain or several partners, normally this is a proprietary solution that is built for these actors, which is far from the ecosystem we want where things are open and standardized. And in most of the cases I would say that we are far from digitalisation. When it comes to majority of actors, you have the thousands of smaller companies that don’t really participate in research projects. You have all these big companies that are active with their R&D department. Also, researchers want them to participate in their projects because that's how they get their funding. So, in the supply chain in European projects for example, you always have very digital companies like Siemens and Airbus. They of course they are the leaders in this. You get some good results, but you also get proprietary solutions because they want to tie people to their systems.

**What data skills should the industry focus on building for adopting AI technologies?**

In general, we need to upskill the workforce. It's very hard to say what skills exactly because things are moving so rapidly. We may need prompt engineers, people that really know, for example, how to work with ChatGPT, how to formulate the perfect prompts for our businesses. Then you can train our own AI models at the enterprise level and work with that. You need people that know how to work with AI tools, but it depends on what tools we get from now on. But then I think specifically talking about architects and construction engineers you have scripting tools and the low-code/no-code revolution. So, you will have more of this kind of tools with which you do scripting like ‘Grasshopper’ and ‘Dynamo’, and which I think will also leads to more demand for interoperability. I think that the combination of scripting and leveraging AI models will be really good. It is already possible to generate scripts from ChatGPT which may or may not work but can be a basis for developing solutions. A lot can be done with scripting in combination with AI tools.

You need a certain level of understanding of scripting but in the end, you don't need to be an expert programmer to get something done. At an intermediate level you can develop a lot of things from parametric generative design to any kind of data processing script. That is very powerful because you will not get locked into specific tools on that level. You can be more flexible and solve specific problem much more easily because you can go down a level lower into the code.

**How would you describe the proficiency level of data literate professionals? Considering that they are not expected to become IT experts, what must they be able to accomplish?**

That's very hard to answer but I think in general it's good to include scripting in education so that everyone has, some kind of baseline skill. But in the end that will be individual how far you are able to go. In what we call the low code environment, you have nodes that can be dragged around and on which you can click and edit the script. This kind of low-code scripting is not meant for software engineers whose work involves so much more than just that. Scripting is basically when you have a function which takes an input and then you produce some output, and you have some kind of code logic inside of the function. But you need to be clear about what you're doing — I need from such-and-such data to produce such-and-such data. So, you just have to get to the level where you can glue that together in a script and then you're fine. You don't have to deal with the difficult part of programming like packing, producing, versioning, and testing.

So, I think there's a good opportunity to work more efficiently with this kind of scripting level for engineers, but I'm not sure since I am a software developer and not specifically from the construction industry.

**It is sufficient that only if you construction professionals develop these special skills or do you think that there is a need for more widespread adoption?**

I think it needs to be more widespread, specifically for construction engineers because their work is quite heavy on the calculation side, and that goes with many other professions where you have more calculations, it's more relevant to use software tools.

Looking at the of older generations of the existing workforce, they didn't have this before, so the question now for them is if they should learn or not. But I think that the next generations will just have this naturally because they have been raised in a more digital era. But it's also a challenge for the education system because we really must update the skills of the educators. Programming has been removed from some education programmes, and I'm not sure why. The resources are not very good at some of the universities, and they are lagging behind. I see that it would take years to change the education system to bring technical skills related to AI, but the change needs to happen now.

**To what extent do you think that AI adoption is related to BIM adoption? Can we benefit from AI technologies without widespread or consistent implementation of BIM?**

I'm sure that that will have a big impact, but right now I do not see how exactly. The graph based neural networks will impact very deeply how BIM modelling works because you have a kind of hierarchical data structure making up a site with a building or group of buildings, with relationships between different elements. You can train models on that to provide different kinds of estimations or propose different solutions. We just haven't seen so much of it yet, but it will happen.

**So you think that the two are related, not just parallel paths…**

Well, I think AI has been a separate area or topic previously, but now we will soon come to the to the situation where AI will be applied on everything. So it will not be it will not be a question if BIM and AI should be combined, everything will be combined with AI. Construction will be more to digitalized and as part of that we will use any kind of media or tool to make work more efficient. AI will be used so but there will be a lot of improvement and changes in the coming years.