## Interviewee 1

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

Briefly as a background, I'm an architect, I'm in research and practice. And I lead certain key design digital developments within architectural practice. But to look at the industry at large, I think, it's happening in bits and pieces, let's say at different levels. From my local context in Scandinavia, I would say that some areas are quite progressive, and maybe certain logistics processes in construction.

But I think, overarchingly for the process of design and construction in the built environment, there's not much preparation. The more overarching transformative processes have quite some way to go. There is a general expectation that the industry might transform quite a bit. What we're seeing right now is a lot of different attempts by new actors are trying to rationalise, automate or optimise early-stage design and planning, while you also have the old actors like architectural practices catching up and trying in their own ways. So, I think the short answer is that it's different at different stages, and because the industry is so fragmented with many different actors, there's no way to do a holistic transformation.

**By logistics, are you referring to the production and manufacturing end?**

Yes, it could be also on the construction site. There are certain tests or automation processes for some aspects of building elements, managing general logistics such as delivery on site. With all these things of course, there is a lot of data which could be managed in more efficient ways, there are a lot of different initiatives there. But the general process of architecture and construction has not changed because it's governed by legislative and other regulation. So, to transform that part is something different. And again, if you have a big contractor, they can control their own processes and they can transform perhaps easier, but they are also dependent on many producers and so on.

**As a key technology in Industry 4.0, what major benefits can AI bring to the industry?**

This is again can be many different things. I think from my perspective as an architect, it's dealing with managing information. We have a hard time within the field of knowledge management— how do we remember everything we did the past 10 years, all the different solutions? When you're working as a consultant, you're in the here and now all the time with a particular project, and individuals are skilled and have great knowledge, but if they are replaced, you lose that knowledge. So, I think a main asset would be to make sure that nothing is forgotten of the solutions we already have — make that available, searchable, data mining of previous solutions, etc.

And then we have the whole realm of automation in terms of things like generative design — the possibility to explore many more design variants. And here I believe it's important to conduct those processes with the notion of ‘human in the loop’ where specialists or very skilled people can observe and interact with the automated processes.

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

An example would be what we see now with the image generation initiatives such as ‘Midjourney’ is that we're not prepared for this in the in terms of legislation. I'm thinking about copyright. You have machine learning systems that are trained on, for instance, the art of thousands of artists who were never approached and asked. We are awaiting where that will lead and how do we need to transform that side of things. But I also think there might be a risk in believing that pure data and automated processes are better solutions always. There’s a risk in believing too much in what technology can resolve. We are building our society and a lot of different competencies are needed. There might be a risk that we lose knowledge because we replace people with automation in different areas. That could mean that we are not prepared for new situations or new problems etc.

In general, there will be a transformation of the industry, as I said before, but for individual companies, there's of course a risk to lose their businesses or at least partially. But that's more from a commercial perspective.

In the practice where I'm a partner, we do invest quite a lot in our own development. Where we know we cannot do things on our own we collaborate a lot. But we still think it's important that we understand the processes. Where AI might play a role, we want to avoid the black box mentality when maybe another actor would provide us with a tool that automates some process and supposedly makes things more efficient. We are liable for what we deliver so we need to know on what grounds decisions have been made, or that an analysis of a certain kind, such as an environmental analysis is actually correct. So, we have the ability to look into these processes and co-develop them, while a small architecture consultancy might completely depend on what someone else provides, or they might be completely replaced by processes like these.

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

First of all, what we're seeing now is very unstructured data, which is typically considered as less valuable. You don't know how to process it and so on. And you have data coming from many different sources. For us it ranges from geo-based data which is important for how we plan our cities and our environments, to analytical data that may be relating to future climate issues, to a whole range of data that involves the performance of materials, and how we assess things like circularity or climate impact. And that relates back to the whole production of building elements, relating to either a bio-based or mineral-based materials and what climate impact they have.

It's a very complex puzzle because on one hand we need to use the data to be able to create sustainable environments for the future long term, and we also must keep track of the material that we use and where they are sourced from. There are so many kinds of data that are relevant and we're trying now to guess the best picture possible that can inform all decisions. Our field is quite diverse. There are big investments made into it, and there's a lot of material used in construction— it's commonly said that accounts for 40% of the climate impact, globally.

Also, the ownership of data is an issue. Not all the data that we would like to use is readily available. And that can differ from one country to another. Geo-based data for instance, in some countries like Finland is very open and accessible, whereas in Sweden where I am, it's a bit harder to get access to that data. Data can be proprietary of course, to companies, so that's a big challenge.

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

It's a diverse situation, and it comes back to where that data comes from. There are so many different sources, so in essence there is a great variety of data quality. I'm not sure if how well data is structured is also part of the quality, as that is a big issue, and how well it is organized is a big issue because it can be organized in different ways. And there are no set standards, really. There's work going on to do that, but as per the previous discussion, data really belongs to very different realms. It's one thing to consider the data generated by a major company and in terms of its processes and so on. But then you need to have access to data from municipalities, or climate data and all of these things. So, there's a lot of variety there.

**In your experience when you collaborate and you receive data from other actors, how challenging is it to work with that data?**

We often need to restructure data and find our own ways to do that. The deliverables we make today are still quite conservative. We deliver construction documents, which follow certain agreed upon standards and the amount of data that's connected to those digital models, for instance, is always increasing.

Data today is primarily meant to be used for the construction of, for instance, a building, but we're seeing also how that data can in the very near future be used for the management of buildings over their whole lifetime. But there's still a mismatch here. What I mean is that the information and data needed to manage a building may not be the same as what you need to build it.

But we have to process a lot and we are building up our capabilities. We don't have in-house data analysts yet, but we're getting there.

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

This question is entangled into many different areas where we work. We need to build up general understanding of how to work with data—that's for sure. But we also need to combine that with an understanding of what that data represents. For instance, we have big teams of environmental specialists, and they target different areas such as material performance, sustainability factors, and so on. We put a big effort into circularity and reuse of building elements. Then we need to couple that with an understanding of whatever way we manage data that is, for instance, carried into the material library for future use.

So, we need to combine knowledge from different disciplines and competencies that are more traditional with the understanding of how data is handled. We are really at the part of the process where big decisions are made that affect the sustainability of future buildings. We’re not in the position of dealing a lot with the business or market side —which is of course a big field— and the data used to assess if an investment should be done and so on. Our clients are making those calls, but I think that there is a need for financial analysis to be more integrated with the other different aspects.

**Do you think that it is sufficient that only a few professionals or technicians develop a special proficiency in data skills?**

In management we see the role of being a ‘broker’, meaning that you're familiar with the needs and requirements of, and have competences from different fields. So, from my perspective, we need to have architects who are proficient in managing data, but not all architects have to be that, but we need this in-between zone of specialist that are proficient with double or triple skill sets in order to have functioning collaborations. If you separate the two and you have people with pure data analysis or management competencies, and then from our perspective, more conventional architects, you will not make the matches needed to proceed with developing processes at a fast rate. So, in general you need to have people who are skilled both in the area of data and the context where they operate, but then you can have deeper specialists on both sides. But I think these brokers are key to understand the needs and the purposes of data in a dynamic context.

**How would you describe the proficiency level of data literate professionals? What must they be able to accomplish?**

An example within my domain would be what we refer to as computational design. We have 15 to 20 people in our organization who work within that domain out of about 800 people. They are architects or engineers by training, and they picked up digital skill sets and proficiency in data management on top of that. But we have no professional programmers. That's working for us today because it's more important to understand the needs and requirements of the tools that we develop and so on. But in the near future, we will need to have people that come from the other side, with a deep understanding of programming and how to manage data, but also with an interest in the applications provided. But the people we have now, they are the brokers that I talked about before. They understand the needs within our practice and our projects. But in order to create very robust solutions you need people who comes from the specialist side. That's why we collaborate often with other parties.

**Building Information Modelling has been advocated as indispensable for the industry's progress, yet adoption is slow and even met with resistance. What effect does this have on adopting AI technologies?**

My thought on BIM and how it has been developed is that it's has come out of the end of the process in which deliveries are made i.e., what information is needed to construct a building. It has not come from the starting point of — What is the problem to be resolved? What's the situation in the city? What's the need in this building or how it's being used? So, BIM is very efficient in the later stages of processes, to manage data. We already see that AI is being used to optimize solutions at very late stages, and you could argue, of course, that BIM is anything that deals with information and modelling in architecture and construction. But the field of computational design I mentioned, is coming from another end where you develop processes that target the needs and the performance of the building over time rather than its construction only. Some would argue that computational design is part of BIM, but I think it's important to remember where it has come from, and I think it needs to evolve. It’s certainly a factor in the applications being used for BIM processes. We already see applications of AI, but its use is quite sub-optimized. It deals with particular problems in certain areas and often, too late in the process. That's why we see other efforts from the early stage of design and planning, of trying to figure out, before you even consider how something should be constructed, what it should do, what kind of building is needed here, what's the best solution that, for instance, in a residential building provides good daylight in all flats or contributes in a positive way to biodiversity on the site. All of this is not covered within BIM. It's limited today to just the optimization of the construction process, not the conceiving nor the management of the building.

**To what extent can construction data be leveraged for AI technologies without widespread and consistent BIM implementation?**

I think what we'll see in the near well in the future is that our idea of BIM needs to be transformed. It has to be much more holistic. It's not the BIM of today that will grow into earlier stages and management. There's a whole new kind of more, holistic approach where AI can make the difference that's needed.

And with within our industry, the issue is that we typically develop solutions as part of our building projects so that each new project becomes a small step for a new way of working. We don't have the resources to, close shop and not do any construction for five years to develop the best new system. We need to do it on the fly all the time. And I think that's more or less the case for all actors. That is also a reason why development may be a bit slow. But I think one needs to view the process in a different way that does not focus on the construction phase only but on the whole life cycle performance of what you build.

**Do you have any further recommendations for improving data skills in the industry?**

I think it differs depending on where you're at, so I can only really talk from the point of architecture consultancies. Higher level of understanding of how to work with data is good in the broad sense. It's a very tricky question—this is in fact in what I work with on a daily basis, but it’s still hard to pinpoint.

I think there are two aspects to what we do. We try to automate certain parts of our design processes. We are familiar with certain problems that take a long time to resolve and so we have a team that do proto software development, making tools for their colleagues which they use and test, and then they develop newer versions of those in the next projects. So that's gradually improving our processes, and this development team is well grounded in architecture and engineering, but they have these skill sets that I talked about before, so they understand what kind of data is needed for a good delivery and they understand the process.

The other thing we're doing very actively, especially in my core team, is to go into projects that are ongoing where some solution is needed but there's no way to spend a couple of months to develop a software to resolve the issue, but you have to do it on the fly. That's a particular skill set, which means that under the duress of a project, you're able to develop, with whatever means available, solutions that works for that context. These are not robust software but smaller methods that provide value. And then over time, we collect these initiatives and try to make them more generic whereas originally, they would only be applicable as particular solutions. So, I think that kind of skill set is important for us as a consultancy because we don't have a huge development department in the company where I'm a partner. We are employee owned and we control all our investments and so on, but we're still very much affected by the market. Most of us are active in projects all the time, so we need that ability to find the best solution for what's happening right now.