Artificial Intelligence in Architecture and its Impact on Design Creativity

A Study on how Artificial Intelligence Affect Creativity in the Design Process

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Abstract

Purpose – This paper explores how creativity is affected by implementing Artificial Intelligence (AI) in the design process. Current usage of AI and desired areas for its use in the Swedish architecture, engineering, and construction (AEC) will be investigated to form an understanding of its effect on creativity in the design process.

Methodology – The study conducted five (5) interviews with industry representatives as well as a literature and document study.

Findings – The thesis contributes to understanding how new technology such as AI can affect creativity in the design process. It explored how the creative process is currently structured and how it will be affected by the implementation of AI. It provides an overview of the desired applications of AI in the AEC sector and how these can change the design process in the future.
Sammanfattning

Syfte – Detta arbete syftar till att utforska hur kreativitet påverkas av implementering av artificiell intelligens (AI) i designprocessen. Nuvarande användning av AI och dess efterfrågade användningsområden i den svenska arkitektur, ingenjör och konstruktionens (AEC) sektorn kommer utforskas för att forma en förståelse av dess påverkan på kreativitet i designprocessen.

Metod – Studien genomförde fem (5) intervjuer med industrirepresenteranter, samt genomförde en litteratur- och dokumentstudie.

Resultat – Arbetet bidrar till en förståelse av hur ny teknologi så som AI kan påverka kreativitet i designprocessen. Studien bidrar till en överblick av efterfrågade användningsområden för AI i AEC sektorn och hur dessa kan ändra designprocessen i framtiden. Arbetet utforskade hur den kreativa processen är utformad idag och hur den kommer påverkas av införandet av AI.
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1. Introduction

The development of digital tools throughout the last century and the emergence of highly technological advancements such as Artificial Intelligence (AI), Machine Learning (ML), Internet of Things (IoT), and digital twins have made significant changes and improvements to the way we work and interact with each other. These advancements have enabled the consumption and analysis of large amounts of data in a shorter time than any human ever would be able to do. Suppose computing technologies and the intellectual skills of technologies, such as AI, progress at a similar rate as we have seen for the past 50 years. In that case, people that live today will see the evolution of such technologies surpassing the logic and information of humankind and likely have a personality that is indistinguishable from humans (Merritt, 2016). This can raise questions regarding what place AI will have in the future of our world. As people are concerned with being replaced by non-intelligent machines today, you could guess that there would be greater concern when intelligent machines such as AI start to outperform humans at work in many aspects. It becomes apparent that humans and AI will have to coexist and so the question of who will make decisions for companies will be of great concern. Which decisions will the AI take, which decisions should humans take, and which decisions would be made in collaboration? (Haenlein and Kaplan, 2019)

Even if there is a long way until we can experience an AI with characteristics like those of humans, the AI we have today needs to be addressed in how it will be developed for the future as it can be expected to have a great impact on our society. In the meantime, we can look at how implementation of AI affects human traits such as creativity, which this paper will explore with an architectural viewpoint. With creativity being a very complex human trait with many factors at play, and that plays a big role in design thinking, the effects AI has on this trait becomes interesting. Digital platforms and tools have since their introduction in the early 60s been seen as supporting design thinking with simulation, and modelling of design options. They are also viewed as enablers to enhance cognitive strategies and skills, such as creativity (Lee, Ostwald and Gu, 2020). As the development of drawing tools have gotten more and more advanced since the introduction of digital tools like CAD and CAAD in the early 1960s, there is a need for exploration into how the future technologies such as AI will affect the creative design process. Not only because it is a relatively new technology, but because the technology itself challenges the more complex human traits such as creativity.
Unfortunately, the advancements in technology have not had the expected effect on the architecture, engineering, and construction (AEC) industry as one might have wished. Despite the technological advancements, the AEC industry has, in many ways, failed to efficiently adopt and implement the digital tools and take advantage of their potential to streamline the workflow and processes of the industry as it continues to lag other sectors (Chowdhury, Adafin and Wilkinson, 2019). This can be explained by the complexity of the industry but also by its old age and reluctance to change the way it works. The many disciplines involved in the industry choose different ways to approach digitisation, and disciplines have made progress at different paces, leading to difficulties in integrating processes between them (Fioravanti, Novembri and Rossini, 2018). This is clearly shown in a recent study by Bosch-Sijtsema et al. (2021) of the Swedish AEC industry, where the various disciplines, which are client, lead design engineer/architect and contractor, prioritise different technologies. The study shows that Building Information Modelling (BIM) is the most prioritised among the disciplines, and it’s pretty equally distributed. Still, for the lead design engineer/architect, AI/ML is the most prioritised, and they outmatch every other discipline in that area.

1.1 Purpose
The purpose of this paper is to contribute to an analysis of how AI will affect the creative processes that occurs in the design phase of construction projects. The paper will explore how this increasing trend of investment and prioritisation in AI will alter the design phase and how that will affect creativity. The paper is exploratory and will utilise semi-structured interviews to answer the research question that is:

What place does AI have in the design process, and how does it affect the creative process?

2. Background
2.1 Artificial Intelligence
The birth of AI can be traced to as early as the 1940s, where firstly encountered in a short science fiction story by Isaac Asimov. The story depicts a robot created by two engineers, where the plot revolves around the *Three Laws of Robotics*: (1) a robot may not injure a human being or, through inaction, allow a human being to come to harm; (2) a robot must obey the orders given to it by human beings except where such orders would conflict with the First Law; and (3) a robot must protect its own existence as long as such protection does not conflict with the First or Second Laws. For generations, the story inspired scientists in
robotics, AI, and computer science. However, *The Bombe*, which was built to break the German Enigma code, is considered to be the first computer and was created by the English mathematician Alan Turing, who brought the ideas of computing intelligent machines to life. In 1950, Alan Turing published the article "Computing Machinery and Intelligence" which to this day is still considered the benchmark for identifying the intelligence of an artificial system (Haenlein and Kaplan, 2019).

The word Artificial Intelligence was later coined in 1956 during a summer research project at Dartmouth College in New Hampshire, hosted by Marvin Minsky and John McCarthy (a cognitive scientist and a computer scientist). The field of AI has since had its ups and downs; following the years from its founding, the area flourished. One of the earliest programs was the famous ELIZA computer program, a language processing tool that was able to simulate conversations with a human. Later in the 1970s, there was a critique of the possibilities of AI; a British mathematician stated that the computer programmes would only be able to reach amateur levels of intelligence and that common-sense reasoning would always be beyond the programmes reach. Following this, both the British and the U.S governments cut funding for AI research but later increased research in the 1980s when Japan started to invest heavily in AI (Haenlein and Kaplan, 2019).

Since then, AI has found its way into many sectors, evolving from beating world champion chess players to being able to identify human faces, distinguish between pictures of cats and dogs, and much more. It has found its way into the AEC industry, where its possibilities are endless but not yet fully exploited, as the industry is still learning about this relatively new technology. AI is part of the concept of Digital Construction, which can describe the integrated approach of new technologies in the AEC industry that are meant to make construction safer and more productive. However, the development of AI has been met with concerns regarding robots and machines taking over jobs and the more fictional situation of machines becoming sentient and dominant over humans. Despite the concerns, AI has a great potential to revolutionise the industry in many ways and has done so over the past few years. In construction, AI can, for example, enhance design output, draw buildings within constraints such as building codes, cost, time, and size constraints, and at the same time do clash control with other drawings, do risk scenarios and suggest solutions to mitigate them (Fewings and Henjewele, 2019). Other options for designing a building are for the AI to design with concern for movement patterns of human beings or vehicles, altering the design in relation to noise exposure, or design from a perspective of heat radiation or light input.
This can move the design to optimise energy usage in a way we might never have seen before, making some buildings look very futuristic and advanced as they are shaped by the environment they are in.

In architecture and engineering, AI and ML can be found in what is called generative design. The generative design technique consists of generating the best design options, with a strong focus on the best design solution. Contrary to regular design simulation, where you work with a lot of data and with data that is result-based, where each simulation takes place in different test environments, and the result is based on what you ask for, the generative design process takes simulation to the next level. Instead of giving answers to the question, you ask, like; Does this work? What if we change this? How does it work? The generative design will provide the solution to the problem faced by working in an iterative process that learns in each iteration within the given parameters and rules; it provides something that works and lets the designer stop asking questions and start asking for solutions. Generative design tools are, seen by researchers in design thinking, as supporting creativity as you are allowed to generate and explore many design alternatives in early design processes, leaving space for creative potential in divergent thinking, which is seen as an essential trait of creative people (Lee, Ostwald and Gu, 2020).

On the manufacturing part, AI is working through robots, manufacturing, assembling pre-drawn designs, and suggesting possible manufacturing improvements. AI is also incorporated with heavy machinery when excavating, tunnelling, mining, etc. With the help of sensor technology and AI, autonomous vehicles can carry out this type of work, navigating tunnels and avoiding obstacles without putting human lives at risk (Fewings and Henjewele, 2019).

2.2 Creativity
Creativity comes in many forms and definitions; how to define it has been a discussion for many years, and there still seems to be some disagreement or incompletion on the definition of what can be considered one of the most fundamental human capacities (Kim, 2020). The most simple and elemental definition of creativity comes from the Oxford Advanced Learner’s Dictionary (no date) and states that creativity is:

“The use of skill and imagination to produce something new or to produce art”

The Oxford definition is relatively straightforward and could be seen as a simple definition of the word creativity. Still, due to its complex aspects, the oxford definition is insufficient in this study, and a demand for a more precise definition of what creativity is is highly sought
after. A reason for the very different approaches to creativity is the interdisciplinary nature of creativity. How the word is defined is subject to which creative context action is performed; in a business context, creativity can be completely different from an art context or a psychological context. This is one of the areas in which researchers agree that creativity is created in a specific environment, and those surroundings play a crucial part in creativity creation. Amabile (1983, p. 358), defined creativity as:

“behaviour resulting from particular constellations of personal characteristics, cognitive abilities, and social environments”

Amabile’s definition says nothing about producing something but describes how one is creative in their persona. She does characterise creativity as something novel and useful but leaves it out of the definition. A third definition of the word is from Plucker et al. (2004, p. 90):

“Creativity is the interaction among aptitude, process, and environment by which an individual or group produces a perceptible product that is both novel and useful as defined within a social context”

In the definition, Plucker clearly states that creativity happens in a state of producing something novel and useful, just like Amabile characterised the word, and that it occurs in a specific environment or social context. Kampylis and Valtanen (2010) studied and reviewed 42 definitions and over a hundred collocations of the word in an attempt to redefine creativity. Among theorists and researchers, Kampylis and Valtanen (2010) found common ground in the definition of creativity; it occurs in a specific environment, it includes producing something that is novel and useful, creativity is an intentional process, and that creativity is an individually important ability.

The reoccurring words are novel and useful, and you must put those words together to get creativity; it is not just something new or just something useful; it must be both.

3. Framework

The surge of interest in creativity began in 1950 when Joy Paul Gilford held a speech at the American Psychological Association, addressing the lack of research in creativity, imagination, and closely related subjects. He mainly addressed the interest in understanding creativity in educational contexts. Since then, many researchers have studied creativity and created concepts and models to understand its complexity. This chapter will explain the four
P’s model of creativity, which Mel Rhodes introduced in 1961. Despite its old age, the model is still widely cited by researchers of creativity, and due to its nature, it can be applied to many different disciplines, such as engineering, music, art, education, etc. (Lee, Ostwald and Gu, 2020; Kim, 2020).

When Rhodes published his famous article, he had collected over forty definitions of the word to create a comprehensive framework and create an understanding of what creativity is, explain how it can be developed, why some products or ideas are more creative than others and discern the levels of creativity. Rhodes approached the question of what creativity is by dissecting the word into the four Ps. His answer was:

“The word creativity is a noun naming the phenomenon in which a person communicates a new concept (which is the product). Mental activity (or mental process) is implicit in the definition, and of course, no one could conceive of a person living or operating in a vacuum, so the term press is also implicit” (Rhodes, 1961, p. 305).

The first P, which is person, concerns the information about “personality, intellect, temperament, physique, traits, habits, attitudes, self-concept, value systems, defence mechanisms, and behaviour” (Rhodes, 1961, p. 307). How this different information correlates to being creative is the starting point in creating a profile for creative people. Many researchers have tried to create a general profile for creative personality, identifying the main characteristics to find out whether creative people have similar personality traits. Some of the traits that have been found in creative people are intrinsic motivation, divergent thinking, openness to experience, risk-taking, nonconformity, and robust imagination. It is essential to understand that these traits are merely tendencies of a creative personality, and if a person shows any of these traits, they are not necessarily a creative person. However, a person who fits in any of the traits in the creative profile has the potential to be creative if they are put in the right environment where their creativity can flourish (Kim, 2020). Meaning that the creativity behaviour is different across different domains and that it is subject to both personalities and to the environment that personality is put in.

Process is the second P which covers the cognitive operation of a person, such as motivation, learning, thinking, communicating, and perception (Rhodes, 1961, p. 308). Mainly the creative process concerns the process where a person is faced with questions and problems and what causes them to come up with original ideas and solutions. One might ask how their thought processes are set up and whether creative people traverse similar thought processes to
generate innovative ideas and solutions. There is yet common ground in whether creative people have similar thought processes, but at least some collective view is that creativity can be taught. The creative process can be derived from *The Art of Thought* by Graham Walls, published in 1926, which consists of the four steps of the creative process: preparation, incubation, inspiration, and verification. The first step, which is *preparation*, is the process in which one collects the available data in the form of listening, observing, asking, reading, comparing, analysing, and relating all kinds of information found. This information needs to be processed by the brain and by the person in the second stage of *incubation*, letting the person study the relations of the gathered information and contemplate the broad range of possible solutions. In the third step, *inspiration*, different ideas can pop up, and the person might have "eureka-moments," which one might think are sudden bursts of genius thought. Still, they are unconsciously derived while being in the incubation stage. The final step is *verification*, where the idea or solution is applied to the problem. The person can now verify their ideas, convert them into an object or speech and then take a step back in the stages if their solution needs more preparation and incubation.

*Press* is by Rhodes (1961, p 308) referred to as the relationship between human beings and their environment. Environments are the physical and social conditions that a person is subject to in their creative process or person. Environments can be either supportive or constraining in their nature. They act as a moderator to the variables of the creative process and person without directly shaping the creative outcome. Such social environments can be school experiences, physical surroundings, workplace environments, family upbringing, cultural traditions, and the historical milieu (Tang and Gruszka, 2017). It is essential to know that people work differently in different environments, they form ideas from their perceptions, imagination, and sensations, and they uniquely perceive their surroundings. These influences lay the foundation in which original ideas are formed, so the environments a person is subject to pose as a reflection of the thoughts that that person comes up with. There are different types of press; Kim (2020) recalls alpha and beta press, where alpha press refers to the total objective world and beta press is the significant part of the objective world. Which part of the objective world that is significant is individual to the creative person and can, for example, be how one reacts to loud noises or different kinds of music. An important aspect of social press is the concept of time, as we know that original ideas in the creative process require incubation (stage 2) and reflection, which is directly connected to time. Time is a social press as people are often subject to different deadlines in their environments, such as
work, school, and different social contexts. Some people prefer to take time in their creative process and thrive in environments where they have no deadlines, while others are motivated by tight deadlines and high-pressure environments. There are some environments in which innovation and creativity are difficult to support; one of the most eminent settings is education. This setting is particularly challenging as teachers must address the unique needs of students, and at the same time, they must satisfy the state and federal school policy.

The product is the final piece of the puzzle in Rhodes framework (1961, p. 309). Ideas are derived from human thought and then communicated to others in different shapes and forms. They represent the product of thought and can be presented as words, paint, wood, metal, stone, inventions, patents, performance, and many more forms. For an idea to become a product, it must become tangible, and for the idea to be original or creative, there must be some novelty in it. Products are directly connected to the creative process; for example, a painting represents the artists' thoughts and environments they were in when the painting was painted. Archaeologists and investigators examine products such as artifacts and crimes and then proceed to trace the events and thoughts that led up to the time or moment when the product was conceived or performed. So, the product relates back to the person, which then relates to the process they had and lastly to the press they were under, connecting the fourPs in a complete structure where each P work has an individual identity, but only together do they form a functional concept of creativity.

4. Method
This chapter will describe the processes I went through to try to answer the initial research question: What place does AI have in the design process, and how does it affect the creative process?

The research question originates from a deeply rooted interest in architectural design and buildings in general, being amazed by the creativity of architects in designing virtual and physical structures and objects that move and affect peoples’ daily lives. How they navigate the complexity of the AEC industry and find unique ways to solve the current and emerging problems in the industry by altering the design. The shape of a structure influences every aspect of the AEC industry, cost, and land use, material use, heat loss, noise exposure, light exposure, and energy use, to name a few examples. As digital tools have become more and more complex and are developed to simplify and assist architects and engineers in tackling
these problems, I had an increased interest in exploring how these digital tools affect the creativity and originality of architects and their design process.

Especially interesting has been the emergence of advanced digital tools that utilise artificial intelligence to generate shapes and forms and even complete buildings. I asked myself what position the architect will take when there is AI who can draw the design and how will this tool be used? How will the creativity of an architect present itself in AI-driven design? How will the architectural touch be expressed in AI-designed buildings?

This thesis began as an investigation into the status-quo of AI in the design phase in the Swedish AEC industry. Mainly focusing on architects’ use and applications of AI and other industry representatives that are working on or have worked in projects and/or implementations of AI or similar digital tools in the industry. Relating the use of AI and similar tools to the creative process and creative possibilities that might emerge in this new era of technology. The methodology used in this thesis consisted of five stages: (I) An exhaustive study of the available and relevant literature, (II) a study of the current questions raised by industry representatives in different industry forums, together with the literature, construct relevant questions for interviews, (III) conducting of semi-structured interviews, (IV) analysis of the material produced from the interviews, (V) relating the literature with the interviews to form a conclusion.

Stage (I) was carried out through the scientific portal Primo (provided by KTH-library services), which in many cases links to other portals such as ScienceDirect, ResearchGate, and Wiley Online Library. The keywords that were used were: artificial intelligence, creativity, design creativity, generative design, digital construction, design thinking – combined with architecture or variants of architecture. The literature study was performed to form an understanding of what artificial intelligence is and its applications to the AEC industry and an understanding of what creativity is in its pure form and related to design thinking.

Stage (II) was performed to examine the status-quo of the AEC industry in Sweden by mainly using Google to find articles, blog posts, company reports, webinars, and similar media produced by companies and trailblazers that are concerned with the questions regarding AI implementation and application in the AEC industry. The material also provided names for potential candidates to interview in the third (III) stage, as those who are currently interested
in AI in the AEC industry and those who write about it are possibly those with the best insights on the subject and can provide firm ground in answering the research question.

In stage (III), semi-structured interviews were performed with industry representatives that have their current occupation in the AEC industry, work with education closely related to the AEC industry, such as civil engineering or architectural engineering university education, or have previously worked in the AEC industry or educational systems related to it. A list of interviewees can be found in Table B1 in Appendix B.

The interviewees were chosen based on their research on the relevant topics to my thesis and/or experience from projects and implementations related to AI in the AEC industry.

Candidates were sent a cold-email invitation to participate in a 30–45-minute interview via Zoom; the email gave information about the nature of the thesis and my interest in interviewing the specific candidate for the purpose of answering my research question. Interview invitations were sent out in segments of a few (two to four) invitations at a time; this method was used to ease the scheduling of interviews and let me evaluate the quality of the invitation based on email responses. As many of the candidates work regular jobs, their availability and willingness to participate were limited, so it was expected that some of the invitations would be left without a response. The first round of email invitations was left without responses, the invitations were then reconstructed, and the next round of candidates was more carefully chosen. Candidates were now chosen based on personal recommendations, and they were also informed that I had been recommended by John/Jane Doe to interview them. This approach proved more successful and led to more responses and interviews. In the first interview, the person was asked at the end of the interview if they could recommend candidates that could be of interest to me and the thesis. This technique snowballed the candidate list and multiplied the number of candidates for each performed interview; it proved quite successful as the response rate increased greatly.

Each interview was performed in a semi-structured way with a set of predetermined questions (see Table A1 in the appendix). The questions were mostly open-ended questions, allowing the interviewee to discuss additional topics they feel are important to the interviewer. This gives the interview approach an advantage by enabling flexibility to explore unexpected topics and gather detailed information in an exploratory manner, contrary to using close-ended questions. As open-ended question usually allows the interviewee to speak freely and passionately about specific subjects that they have many years of experience, the interviews
can tend to become unexpectedly long. It was, therefore, important to find the right questions to ask to keep the conversation on track and to avoid extensive and time-consuming transcription work. Each interview covered the same topics: artificial intelligence, generative design, creativity, design creativity, architecture, digital design, and other closely related topics, but the interviews were also focusing on the specific topic that the interviewee had the most experience in. Every interview was conducted online in Swedish via zoom and lasted 40 minutes up to one hour and 20 minutes. To aid in the analysis of the qualitative data from the interviews, the interviews were recorded with the permission of the interviewee and later transcribed by hand in stage (IV).

Stage (IV) consisted of transcribing and analysing the content of the interviews. As the interviews were performed in Swedish, it was natural to have the transcriptions in Swedish. Therefore, it was important to consider possible issues in translating, for example, quotes. Due to the length of each interview, transcriptions held a large amount of words of information resulting in extensive work in sorting out relevant information for further analyses. The vast material was divided into four key documents, where each document represented information related to one of the four Ps (person, process, press, product) described in the framework section. The data was divided based on what each answer, or section of an answer, meant to the creativity framework and the four Ps.

In the final stage (V), the data gathered from the interviews and previously read literature were presented as the findings of the study and formed the basis for the conclusion of the thesis.

5. Findings
This section will present the findings for each of the four Ps in the framework of creativity; the findings are mainly based on the interview material and partly based on literature.

5.1 Person
This part presents the findings on how the interviewees relate to creative people and how they perceive creativity. This is not specifically linked to AI but is highly related to how creative people might work with AI and how AI can be creative itself.

None of the interviewees had the same definition of what creativity was, but there were many similarities in their answers and their general interpretation of how one is creative. The most reoccurring pattern was the connection to divergent thinking in that creative people are
viewed as problem-solvers. They can find new connections between the pieces of the puzzle and use their intuition to find new ways of solving problems.

Many of the interviewees also connected the creative persona with a *robust imagination*. Using their imagination to put things together that are unusual and norm-breaking. Imagining future events or outcomes that are significantly different from what is currently happening or what is expected to happen, trying things in many ways to see the possible solutions from different perspectives. This trait was mostly brought up in the context of children’s creativity, relating their imagination to not being inhibited by experience and reason, leading to creations or actions that are unconventional and unusual.

*Openness to experience* and *risk-taking* was mentioned by some, relating to people that are willing to try new things and are open to new ways of working. Some described being creative as daring to trust their gut and doing more than you can do, moving out of your comfort zone, and taking risks.

The least recognised traits were *intrinsic motivation* and *nonconformity*. Where the first was related to being most creative in positions where the interviewee felt that they were helping the other part and that it gave them personal satisfaction rather than being motivated by rewards, such as payment. *Nonconformity* was not directly discussed in any of the interviews but is in some respects related to *robust imagination* in doing norm-breaking things and going against the stream.

5.2 Process

This section will present findings on how current processes in the design stage are set up in the industry and in which of those processes the interviewees believe AI can aid. It is important to understand that the processes presented here are not the creative thought processes that the interviewee undergoes when designing or when being creative, but they are directly linked to how those processes might change and be affected by using AI.

There is a consensus that the design process has become inflated with the use of more data, data that has previously been hard to access or not even considered. With more data, architects can show their customers that the design is based on evidence, making decisions based on the available research and proven experience. The data used reflects much on the problems that the industry and the world currently face, that is, the challenges of climate change. Architects use much of the data to optimise several aspects of construction; such data could be how every square meter in a building is used, utilising this data to convert unused
space into usable space when doing property development. Other areas covered in the design process are light exposure, energy usage, and noise exposure, areas which architects have always considered in design but can now more thoroughly and evidently prove their design decisions on as these are also parameters that drive the design process. One of the interviewees explained the importance of this increase in data:

“This data is exactly what we need to draw conclusions and become better, we can now dare to decrease the dimensions, build smaller and more slim solutions that we haven’t dared to do before without the data”

Others also saw the potential of more data, especially when given to architects, as they are seen as “more open to novelties compared to other disciplines in the sector”, and that they are “proven to be good at analysing and drawing conclusions based on the data.”

However, despite how good the increase in data sounded to many of the interviewees, there was also a deep concern with the industries' fixation with data. One said that the industry “truly believes that data is the new gold” but raised concerns about what data they were talking about. Especially data related to digital twins were brought up by several interviewees; some were bewildered by the amount of data put into the digital twins, data that is completely unstructured and useless as no one knows how the data can be used. This sort of data was seen as non-value giving data and relates to different disciplines' attempts to create new businesses with new technology. The problem expressed here is that those new businesses completely disregard how the business will create value for the industry and particularly how it creates value for the customer and end-customer.

The value creation to customers and end customers was expressed by a majority of the interviewees. This was not specifically related to introducing AI but more generally to the introduction of new technologies and digital tools. The interviewees saw a problem in how many disciplines are too focused on making money from new technologies. They rely too much on the data part; as one expressed, "they focus on making cool new services”, and then they miss the important part of getting those services and technologies to create value. They would like to see a process that puts more focus on the end customer and that connects the design to the customer and their demands. This is seen as a critical part of the new digital revolution of the industry, redirecting the focus to the customers and end customers to create real value for them. This is believed to be achieved by inviting the customers into the design
process, letting them communicate their demands, and showing them the design consequences of their demands.

Many of the participants had a positive but restricted view of AI in the design process, as they compared it to the introduction of early BIM and how that was seen by many as “the holy grail” that would solve every problem the industry has. The collective view was that AI could do good work in the iterative process of design, simulating many design alternatives in a short span of time. As the AI can process a vast amount of data, it can be a good tool to keep all the parameters in check and show the limitations and possibilities of stressing different parameters. Parameters related to energy use, noise exposure, and light exposure that today take up much of the time in design processes; being able to show many design alternatives can shorten this process. The complicated part of having many design alternatives is the process of sorting and choosing between them. This process is described by the participants as very reliant on previous experience and intuition, which some believed could be a difficult task for an AI. One participant believed that the number of suggestions and number of variables could be difficult to navigate through and compared it to the extensive data that sometimes can become a “jungle” of information that creates more problems than solutions.

This was a process where participants stressed the importance of what type of data you put into an AI and how you collect that data. “How can you transfer the knowledge, experience, and intuition of an architect into an AI?”, continuing with “an experienced architect can, for example, immediately see if a staircase is comfortable to walk in”. Another showed concern about where the data would come from, will it be democratic and equal data? “there is a risk that you get stuck on old solutions”. One also expressed that

“the AI is only as good as its data; if you put bad data in, you get bad results, so it is important to not be too overconfident in AI, you shouldn’t be afraid to use it either, but you should be perceptive to its limitations”.

Another area of application for AI was minimising the use of material. With its application in 3D printing, participants believed that AI, together with 3D printing, can achieve forms and shapes that weren't possible before. For example, construction elements that can hold less material and use fewer resources to produce but hold the same or better qualities than their counterparts. This is believed to then enable architects in their creative process to stretch the boundaries of geometry and create non-standardised shapes that, with AI and 3D printing, can be realised in the built environment but only if the AI can handle the logistics required in
construction when parts are non-standardised, which the industry can’t handle efficiently today.

5.3 Press
This part will present findings regarding the pressure that is exerted on the industry and on the people working in it regarding the design process. What kind of pressure do the participants believe AI has, and where can AI relieve some of that pressure.

One of the pressure factors that the participants brought up was the pressure put on a design by the demands of society. The design must satisfy the inner works of the societal ecosystem; new housing needs proximity to recreational areas, grocery stores, gym, school, work, transportation, and so on. Areas must be created with concern for safety so that people feel safe when walking home from work or when shopping for groceries. Most recently, have been the increased pressure on building sustainable with concern for the environment, incorporating renewable energy sources in new construction such as solar panels, and building green.

Respondents expressed that in some cases, there is pressure from the client to use specific tools and specific formats. Tools that one might not be familiar with or comfortable with using. This also reflects on the pressure to innovate and develop new technologies and techniques; one participant expressed that even if you innovate, it is not necessarily being rewarded and shown appreciation for. A few of the interviewees highlighted that architecture is an old ancient tradition where many buildings constructed today are quite similar and look the same, people have a common perception of what a home should look like and what they like, so there is little room for experimental architecture as there is a pressure on designing traditional. However, a few participants mentioned that AI-generated and AI-influenced architecture might find more use when humanity starts to inhabit space as there are no norms and traditions that pressure design, except for the harsh climate of space.

With new technologies entering the design process, participants expressed difficulties in implementing them and involving people in the process, especially since new ways of working and introducing new technologies put a lot of pressure on people to adapt and improve. One respondent noted three different ways they can react, either with an open mind and wanting to learn, or they say that they understand, but they don't, and then there are those who completely shut off and are not interested and reluctant to learn new things. So, there is
pressure on both implementation of new technologies and pressure on those who must adapt to it.

In terms of relieving pressure with the use of AI, participants see the potential for AI to aid in incorporating demands and rules from society into the drawing and planning tools. Ensuring that the architect can develop their design in relation to the requirements as they become more integrated into the process. As forementioned, participants also see big upsides on the material optimisation part for AI, reducing pressure from society on the environmental question. One participant mentioned that tools that help drive the design towards more sustainable solutions with aspects to energy use, heat- and noise-exposure can:

“empower the architects' design decisions and not fall for the pressure when sustainability coordinators suggest that you should change a glass façade to an isolated wall... so we can evade falling into the hands of the coordinators that wish to lower the concept from the beginning”.

Some of the participants mentioned that there is a future possibility of AI replacing architects in the design phase as the industry is so focused on making money and not creating value. Leading to a point where there is pressure on the architect to show that their knowledge and experience are invaluable and cannot be replaced by an AI.

5.4 Product
This segment will present findings regarding where AI has a role in the final product, what types of AI products respondents can see emerging right now, and what they want to see in new AI products.

Participants recognised a few areas where they believe AI products can do good work for the final product. The most reoccurring area was value creation, where participants suggested that the AI can keep track of requirements from the customers and that it can keep track of all the parameters customers might want to change the design from. Some respondents saw the potential with AI to perform fast simulations and many design iterations, which could help show customers how the design would be altered when focusing on different parameters, making customers able to set better requirements and more clear demands on design for the architect to consider. When the design can be created with respect to the customers’ demands, the final product becomes the best version of itself, thus creating value.
Most of the interviewees had a common view that AI tools would aid in different areas of optimisation. Mainly energy optimisation and material optimisation both in the design and construction stage and in the operational stage were mentioned. Today these processes take a lot of time due to extensive calculations and repeated changes in the design, so for an AI to do these steps fast would be an improvement for the final product. Respondents also saw possibilities for AI to improve worksite safety by simulating workplace scenarios of handling different materials and construction parts and simulating new shapes and forms that might be easier to handle. Another aspect of safety is the social safety mentioned previously, where participants want to see AI helping in improving social sustainability by, for example, gathering data from Google Home, Amazon Alexa, Siri, etc., to figure out what people want to have close to their homes and inside their homes, then use this information when creating new housing areas and get a product that is socially sustainable.

Almost none of the participants anticipated that AI would completely generate buildings in the near future, even though AI might be able to do so at the moment. There have been experiments on AI-generated buildings, and one of the concerns is that those buildings lack “soul” as expressed by participants. The AI has the ability to create four walls, and a roof as those parts are defined by rules, but the soul of a building reflects more on the experiences and intuitions of architects. This sort of data is said by the participants to be very hard to capture in an AI, “how can you transfer intuition into code?”, especially for more unique buildings where there are fewer data samples. One participant made an example:

“it’s hard to imagine that an AI would figure out to construct the Swedish National Bank in black granite because dark materials symbolise weight, and then to make it quadratic as that is a shape that signals stability”.

The transfer of experience and intuition and the things that make us human is a difficult challenge to overcome for AI so that it can generate the soul of a building. A participant expressed that even though the AI isn’t that smart today, the soul can be achieved in different ways:

“The product will have a soul when the customer and the customer’s customer can be involved in shaping the soul by being able to be involved and understand the consequences of different priorities and parameters and be able to design the soul in line with their business and product”.


6. Discussion

This chapter seeks to interpret the study’s findings from the interviews and relate these findings with the theoretical framework and previous literature. It will follow the structure of the previous chapters, dividing the chapter into the four Ps: person, process, press, and product.

6.1 Person

The respondents related creative persons to each of the seven personality traits that are presented in theory. With divergent thinking and robust imagination being most mentioned, openness to experience and risk-taking was rarely mentioned, and intrinsic motivation and nonconformity were the least mentioned traits. Problem-solvers were a repeated personality trait, and this is highly reflected in the industry's nature as there are many dimensions and parameters that need to work together.

Whilst personality traits might not be the first thing you think about when looking at buildings, those personality traits reflect on the person behind the design decisions that lead up to the final product. Architects need to be creative in filtering between design alternatives and adhere to complex problems, meaning that they need to be divergent thinkers, they need robust imagination, they need to be open to new experiences, and they take risks to produce the best possible houses, structures, and spaces.

As the creativity P person is usually studied by psychologists and in a more psychological matter, there are sufficient limitations to the interpretations of the findings, which relates to the structure of the questions as well. The study merely identifies traits to its best ability despite the author having no previous background in psychology.

6.2 Process

The findings show that many parts of the design process have been overwhelmed with using more and more data. In some regards, data is very welcomed and is being used to make better decisions and qualified conclusions, but at the same time, there is a fixation with data being the new gold and is used in areas where it poses no value. The digital twin is considered to be one of those areas; participants felt that digital twins today are not developed enough to add value to the design process and contain too much unnecessary data.

The value-creation process in design was one of the main topics from the participants; they wished to see fewer tools that are made to create more business and money; rather, they
wanted tools that add value by being inclusive and more focused on the customer and the customers' customer. AI is believed to play a part in these new tools as it enables vast amounts of data processing and offers great simulation possibilities for architects to display many design alternatives for customers in a comprehensive and progressive way.

Simulation was also noted as very useful in the iterative stage of design as architects need inspiration from looking at many design options. Inspiration being a key element in the creative process and it’s the stage where the person might have “eureka-moments” where new ideas pop up (Rhodes, 1961). Fast simulation processes can then offer more alternatives to choose from and from a wider source of inspiration with the right data.

Generally, the participants believed that entirely AI-generated buildings are quite far away in the industry, as they see problems with translating experience and intuition from architects into code. There is no doubt that an AI can generate buildings, but the question remains of how that building will be interpreted by the public and if anyone would like to live or work there. AI does have its place in the design process but is presumed to appear in more data-heavy areas than in aesthetic representation. Such areas are material optimisation, energy optimisation in relation to both energy use and energy distribution, and parameter control regarding building requirements and customer demands.

While the interviewees cover a wide range of the construction sector, few have any real experience with AI as it is still a new technology for the industry. This might limit or exaggerate the potential they see in using AI in the design process; it would be interesting to interview an AI developer and see where they see possible implementations in construction.

6.3 Press

The main pressure point put on the design was the increasing demands from society; environmental and sustainability demands were most prominent. Social sustainability such as proximity to recreational areas, schools, work, grocery stores, etc., and environmental sustainability such as incorporating renewable energy sources and building green.

New technology also puts pressure on the design process, both in terms of implementation in the workflow and in terms of inventing new technologies. Leading to designers needing to work with tools they are not comfortable with, thus limiting their creative potential.
AI was seen as a tool to help relieve some of the pressure, by getting more data and incorporating demands and rules from society into drawing tools would help the architects create more evidence-based design and fulfilling the set demands.

Press in this report is more concerned with the pressure set by technology on the sector as that is potentially the only part where AI can be implemented. But as the creative process is so much more complex than the tool the architect or designer uses, it would be interesting to see the more work environmental pressure. Relating to theory where for example, workspace, light exposure, noise exposure, and time constraints are fundamental factors of creative space and thus study which environments architects feel most creative (Kim, 2020; Tang and Gruszka, 2017).

6.4 Product
The reoccurring theme of optimisation and value creation also reflects on the products the participants see being implemented in the design process. These are also products that will have an impact on the final product itself. Participants see more improvement of the products in fulfilling requirements rather than a paradigm shift in aesthetic representation towards more futuristic design as the sector is still very characterised by tradition and traditional shapes and forms.

The findings regarding product are merely speculations of where AI products will find its space in construction, as there are very few products being used in the industry at the time of the study. This opens up to exciting future research when and if AI has become more of a commodity in the design process and perhaps even generates complete buildings.

7. Conclusion
This thesis provides an overview of the desired applications of AI in the AEC sector and how these can change the design process in the future. It explored how the creative process is currently structured and how it will be affected by the implementation of AI.

The study finds that many of the desired applications of AI would try to solve problems that the industry has had for many years and are struggling in several areas. Such areas were efficiency and optimisation, areas where BIM once was believed to be the solution to those problems and that some today think AI will solve instead. In line with Bosch-Sijtsema et al. (2021), there are high expectations on AI and excitement regarding its possibilities and opportunities in solving the many problems of the AEC sector. AI and digitalisation still
prove to be hard to implement and hard to use correctly in the industry, as also mentioned by Chowdhury, Adafin and Wilkinson, (2019). The problems with correct usage of new tools are found by the study to be that the tools are too focused on solely saving money and should instead be focused on creating value for customers, which is seen as the solution to this problem. The challenge emerging for the industry is to take the first difficult step in figuring out how to appropriately use the digital tools so that value-creation for the customer comes first. Then in the long run, save money by building from experience, instead of finding short-term money saving solutions which is the case today. If those problems will be solved by AI is for future studies to explore, but the paper finds a positive attitude toward the potential of AI in these questions.

Creativity proved to be a fundamental part of the design process, and several factors were identified as creativity affecting. Process and press can be argued to be most affected by AI as these are areas where AI can alter the design process. In the creative process, AI can serve as a tool for preparation as more data can be found, analysed, and visualised, which further affects the next steps of the process, incubation, inspiration, and verification. AI had a two-sided effect on the press, one side where it could relieve pressure from other identified sources and one side where it acted as a pressure itself as it’s a new technology that the sector needs to address in one way or another. While the effects on product can be reflected in process and press, with the outcome of the product being a consequence of process and press, the effect on person was much more difficult to identify. As person mirrors the personal traits creative people have (Rhodes, 1961), the effect AI has on these traits requires a more psychological approach. The identified traits in the study can be argued to prove valuable for the implementation of AI in the design process, as participants expressed several challenges with the implementation of AI, so to face these challenges, creative people who possess the creative traits are required, divergent thinkers, risk-takers, people with an openness to experience, etc.

The thesis contributes to an exploration of creativity in the design process and how AI can affect that process. It presents an insight into contemporary challenges in the industry and proposes possible areas for AI to solve them. With the background of the creativity framework by Rhodes (1961), the thesis connects AI with the design process by looking at factors that might not usually be considered when introducing new technology. The thesis does not only look at the potential of AI products, but also explores the effect the product itself has on the people who will work with it. In the case of Chowdhury, Adafin and
Wilkinson, (2019), and Fioravanti, Novembri and Rossini (2018), difficulties in implementation of new technologies in the AEC and the issue of disciplines approaching new technologies in different ways are presented as problems for the sector, this might be because of the way they have been introduced. As the thesis finds several concerns regarding implementation of AI it also finds solutions and future guidelines for its implementation to be successful which will be much needed for the AEC to keep up with new technologies. The creative process needs to be considered in the development of AI products, especially for the design process where there is much space for creative potential that enables the creation of something novel and useful, which in its essence is creativity (Kampylis and Valtanen, 2019).

As AI is yet to be implemented in the industry, the study lays a foundation for possible future studies of presented cases when and if AI products will be used in the design process and then how the creative process will change accordingly.

7.1 Sustainability
Sustainability was a reoccurring subject in the study and had a clear theme toward material optimisation. Innovations and new technologies prove to be key ingredients in moving toward a more sustainable future, for example renewable energy sources such as solar power have had the need to be innovated several times for it to be effective and efficient. The construction industry is no exception to innovation and have always strived to build better with less material, more efficient buildings, and less waste. To face these challenges, AI, as found in this study, is a facilitator in reducing material use. By giving designers more data to make slim solutions with less material and make buildings more efficient in terms of square meter usage, so that less space is wasted. In the environmental sustainability aspect AI will play a big role in the industry as it is currently struggling with material waste and optimisation.

AI does not only present itself as a tool to increase environmental sustainability, but also as a social sustainability tool. Already established data sources that were presented in the study like Google Home, and Amazon Alexa, might serve as starting points for AI to build socially sustainable. By for example looking at what people desire to have in the proximity of their homes. The challenge here would be to make sure that the data collection doesn’t infringe on the personal integrity.

Regarding financial sustainability, AI can help by perhaps anticipating financial events that effect the prices of construction materials or services, buying material at cheaper prices and
buying material at the ideal time of the construction to avoid stockpiling or delays. However, events like these are always hard to predict correctly as there are many unknown risk factors at play. Economic and social sustainability are often closely related, if as mentioned above, the AI can help in creating socially sustainable and attractive housing, that would have effects on the economic situation in those neighbourhoods. Attractive housing can help fuel the economy with new work opportunities on those areas and higher living standards.

As this study finds many possible implementations of AI it is important to know that it is up to the user on how the technology will be used. Digital tools like AI, as previously mentioned, are enablers to enhance cognitive strategies and skills which are key parameters in driving innovation and creating creative processes and products that will tackle the sustainability challenges the construction industry and the world are facing.

7.2 Limitations
Naturally, obstacles and limitations have affected the outcomes of the thesis. The novelty of AI in construction and in common tongue is considered to be one limitation, as many of the interviewees had limited knowledge of AI and little to no experience with working with AI. Some were more experienced in AI than others, but all participants had a great experience in the construction sector, which proved to be a strength when analysing the potential use of new technologies such as AI. Another limitation is the number of interviews performed which could be explained by the limited timespan and novelty of the research area that made it difficult to find keen interviewees with relevant backgrounds. Despite the wide range of competence of the interviewees, it would have been favourable to the thesis to interview people who develop AI products to see possible implementations and to interview people with similar experience to those who were interviewed to further verify the findings of the thesis. Regarding creativity, it is possible that a more psychological approach to those questions would be preferred for different results and better analysis in those areas, but as I am no psychologist, this poses a limitation to the study.

7.2 Further Recommendations
Further recommendations suggest performing more interviews, preferably with people who are more experienced with AI. Collaborate with psychologists who have more experience with personal traits and that can formulate relevant questions and analyse them with appropriate background knowledge.
Reference list


## Appendix A

### Table A1. Interview Template

<table>
<thead>
<tr>
<th><strong>Demographics</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>Who are you?</td>
</tr>
<tr>
<td>D2</td>
<td>What have you done for the past years in the construction industry/education?</td>
</tr>
<tr>
<td>D3</td>
<td>Have AI had any part in those projects?</td>
</tr>
<tr>
<td>D4</td>
<td>What are your experiences with AI in those projects?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Experience with AI</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Where is the AI implemented?</td>
</tr>
<tr>
<td>1.2</td>
<td>Has it been successful?</td>
</tr>
<tr>
<td>1.3</td>
<td>Where does the industry want more AI?</td>
</tr>
<tr>
<td>1.4</td>
<td>Where do you expect to see AI implemented in the industry or in your line of work?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Creativity</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>What is your perception of creativity?</td>
</tr>
</tbody>
</table>
| 2.2 | Do you consider yourself creative?  
*How does it show?* |

<table>
<thead>
<tr>
<th><strong>AI-related to creativity</strong></th>
<th></th>
</tr>
</thead>
</table>
| 3.1 | How do you think AI affect creativity?  
*In the design process?*  
*In other industry related processes?* |
| 3.2 | Do you believe that AI can enhance creativity or limit it? |
Conclusive questions

C1 Based on what we talked about in the interview, do you believe there was something we missed that you would’ve liked to talk about?

C2 Do you have any contacts, colleagues or friends that might be interested in participating in an interview?

Appendix B

Table B1. Interview Participants

<table>
<thead>
<tr>
<th>Respondent</th>
<th>Role</th>
<th>Sector</th>
<th>Years of Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>Associate Professor</td>
<td>Architecture</td>
<td>20+</td>
</tr>
<tr>
<td>R2</td>
<td>Executive Director</td>
<td>Construction Innovation</td>
<td>20+</td>
</tr>
<tr>
<td>R3</td>
<td>Senior Architect</td>
<td>Architecture</td>
<td>20+</td>
</tr>
<tr>
<td>R4</td>
<td>Professor IT</td>
<td>Construction</td>
<td>20+</td>
</tr>
<tr>
<td>R5</td>
<td>Digitisation Strategist</td>
<td>Construction/Architecture</td>
<td>20+</td>
</tr>
</tbody>
</table>