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Addressing Existing and Changing Roles in the Construction Industry

Current and Future Transformations of Professional Roles toward Fulfilling Industry Demands.

Master's Thesis in the Master's Program Design and Construction Project Management

Leonid Burtcev

Damilare Daniel Omiwole

DEPARTMENT OF ARCHITECTURE AND CIVIL ENGINEERING

CHALMERS UNIVERSITY OF TECHNOLOGY
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www.chalmers.se

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Leonid Burtcev

Damilare Daniel Omiwole

Department of Architecture and Civil Engineering (*Some Subject or Technology*)

Design and Construction Project Management

Chalmers University of Technology

Abstract

The Construction industry is currently buffeted with continuous transformative processes and demands, the like that has never been experienced before. The subject of the resulting change in literature has been explored relatively sparsely, the introduction and evolution of digital technologies and sustainability thinking and their increased propulsion for the AECO in terms of upgrading existing skills, responsibilities, and competencies to meet new norms and recommendations made by society, clients, and regulatory organizations in the industry. In addition, there has been existing research speculating how the construction practice would be in the future, including outcries of new engineering competencies that would be needed in the near future. Nonetheless, there has sparsely been in-depth work to determine how individual professional roles are being altered through their adaptation to the various industry change processes. This study provides a foresight of how professional roles in the construction industry will be developed. In addition, the study will help ascertain from a historical viewpoint through literature and experience of active professionals the trends and changes in their work experience in the Swedish AEC industry over the years and the various drivers influencing these changes. Following a comprehensive literature review combined with deductive analysis of the empirical data from interviews, a mind map was developed to demonstrate findings and analyze how professional roles are perceived to develop in the future. Through the findings of this study, we could redefine the development of roles as a progressive process that is first depicted by new ways of working and new responsibilities, upon which the growth on either of these fronts would require that a new entity become accountable for the new responsibilities, and independent of existing roles. The findings show that digitalization, sustainability, and collaborative working practice have contributed to future role development.

Meanwhile, achieving the industry goal of being more efficient, enabling digitalized systems, adopting more sustainability solutions, and becoming data-driven serves as drivers of change that influence professional roles in the industry. The study's conclusion will provide insight into the future expectations of stakeholders and policymakers for managing change processes in the Swedish AEC industry. Especially by implementing strategies to upskill professionals' IT competencies, automate routine tasks, increase sustainability or circularity engagements, share common operating databases, and facilitate interaction between these development pathways.

Keywords: Role development, Future of the roles, Driver, Trends, Changes, Sustainability-based roles, Digitalization-based roles, Structural engineer.

Abbreviations

OSC – Off-Site Construction

VR – Virtual Reality

AR – Augmented Reality

AI – Artificial intelligence

ML – Machine Learning

IoT – Internet of Things

ICT – Information Communication Technology

BDS – Building Description Systems

SDGS – Sustainable Development Goals

LEED – Leadership in Energy and Environmental Design

GLIDE – Graphical Language for Interactive Design

AECO – Architectural, Engineering, and Construction Operation

CAD – Computer-Aided Design

BPM – Building Product Model

GBM – Generic Building Model

BIM – Building Information Modelling

SD – Sustainable Development

IT - Information Technology

IM – Information Management

GIS – Geographic Information Systems

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1 Introduction

In the mind of every active construction practitioner, manager, company, and customer today lies the challenges the future holds for the Architectural, Engineering, Construction, and Operations (AECO) industry. Newly emerging technologies, legislation, or regulatory demands have the tendency to initiate rapid or gradual changes in the construction sector, which affects the culture and pattern of work for professionals. This introductory chapter introduces briefly the background and context of our theme in addressing the existing and changing professional roles in the construction industry, especially in the Swedish context. In addition, the research aims and questions to be investigated were introduced alongside the ethical considerations that had to be put in place for the purpose of this research.

1.1 Background

Today's adoption of digital technologies has increasingly been a critical factor in initiating more efficient and effective operations in the Swedish construction industry (Jacobsson & Linderoth, 2012). The ongoing digital transformation aspects include but are not limited to areas with widely acknowledged themes like digitalization, sustainability, lean management, and even new procurement methods that are increasingly discussed today in the industry at various levels (Gomez-Trujillo & Gonzalez-Perez, 2022; Ibem & Laryea, 2014). Ongoing discussions, reports, and research are published addressing digital adoption relevance to the construction industry, especially here in Sweden.

The emergence and growth of advancing technologies have continued to raise demands to upgrade existing skills, responsibilities, and competencies in the AECO, to fulfil the new regulations and recommendations set by society, their clients, and regulatory bodies in the industry. Thus, significant actors set their vision to align with Sweden's National Agenda and insights for its Sustainable Development Goals (Nina W. et al., 2015). An example of this is the recent new demand for executing life cycle assessments for all projects in Sweden since the 1st of January 2022 (Hasth, 2022), which also brings up the notions of upskilling, reskilling, and the need for filling obvious skill gaps. Now the construction Industry is engaging in upskilling, outsourcing, or employing lifecycle experts to meet this new demand and creates the need for a strategy. To be able to determine how they could or should better position themselves through the ongoing industry transformation to remain relevant and thriving while envisioning the future of trends and work direction.

There is an ongoing transformation in the Swedish construction industry towards sustainability focuses on reduced environmental and climatic impacts. Moreover, such aspects as digitalization, automation, intelligent monitoring systems, use of innovative materials, new collaboration systems, and the development of digital business models are referred to as; 'the next normal in construction' according to (Mc Kinsey Company, 2020). It is continuously characterized by an expanding scope of responsibilities of current practitioners and higher expectations demanded of entry-level personnel for the construction industry.

Analysing and understanding the changes within roles today and in the past, based on general societal trends, shift in way of working and environmental concerns, will help the construction industry to adjust its way of working, strategically position itself for further development, and adjust it focusing areas with projection into what the future would look like. Just like (Hans W. et al., 2009) a few decades ago, when they published within their compendium of conference publications, a few works of literature briefly addressed the changing roles and challenges.

Regarding all above, the study will focus on forecasting the development of three selected roles in the AECO industry. Development of the roles connected to digitalisation-based roles, sustainability-based roles, and structural engineering role will be estimated and analysed for future forecasting. Consequently, this research will explore how several professional roles and competencies are being altered from their current state.

1.2 Scope & Limitations

Addressing existing roles in the construction industry is a broad theme that includes many factors, areas, and topics. The topic has been narrowed down to several aspects for the qualitative study. Since the study will be done in collaboration with a construction company located in Sweden, results from the interview will be primarily based on the data from that company and will be contextualised in the Swedish construction sector. In the meantime, the literature review will not be based only on the findings limited to the Swedish construction sector, although it would take ample part of it. Secondly, the research will consider only the three specifically selected roles and focus our empirical aspect to information obtained via interviews of professionals actively engaged in the construction industry in those roles.

The selection of roles to be considered was firstly due to the level of literature available concerning professional roles over the past years. Secondly, it was discovered that there was a broad range of past and current research that provided information concerning the industrial transformation due to factors like digitalization and sustainability before and after the 21st century. Therefore, in addition to deciding to assess the first two selected roles, it was expedient to select another traditional role that has seemingly remained consistent over the years but is actually experiencing changes. Therefore, the role of the structural engineer, which is quite vital to successful production in the construction industry, was selected for the scope of this research. In summary the three roles that were selected include:

1. Digitalization-based Professionals (e.g., VDC/BIM specialists)
2. Sustainability-based experts
3. Structural Engineers

Those roles will be discussed only from an operational perspective, including responsibilities and tasks. Aspects like economy, productivity, efficiency, teamwork, and collaboration, as well as the legal parts, will not be included in the study. Other traditional engineering roles like site engineers or project managers could have been selected, but we limited our study to these three because of the limited period for conducting this research. Lastly, the duration of the research is limited to 21 weeks.

Moreover, the main goal of the study is to forecast the development of the roles, emerge of new ones, and the transformation or replacement of existing ones. Therefore, the research on the historical aspect will not be highly intense.

1.3 Aim & Research Questions

The aim of this research is to determine the historical growth and changes that have been documented in literature, and from professional experience of respondents. The culmination of information from both ends improves the quality and consistency of information received, to achieve the goal of this study in providing a foresight of how the roles are going to be developed in the future. Meanwhile, employing transparency in analysing obtained data qualitatively would enhance deductive reasoning to address our research questions. It would help in determining the Current and Future development of selected professional roles toward fulfilling industry demands, through a reflexive assessment of what has happened in the past.

Adapting to the fast-changing ways of working is one of the primary skills professionals require today, as current trends influence many traditional roles. In our case, Industrialization, digitalization, and sustainability are seen to have shifted the way of working in roles such as structural engineer, replaced some, and created many new ones. Moreover, new demands, changing regulations, and industry expectations from external stakeholders like consulting companies, clients, and authorities also have a similar influence.

Although many changes are already implemented, many more will come. Such goals as zero net greenhouse gas emissions by 2045 still have a couple of years to achieve (Swedish Climate Policy Councils, 2023). Additionally, such aspects as EU Taxonomy and the fourth industrial revolution will significantly impact shifting roles and way of working.

In order for this pilot study to show, observe and achieve a forecast of the impact of changes in the construction roles, the following research questions have been formulated:

1. How have the following roles developed over the past 30 years? (Rq1)
 - a. Digitalization-based professionals
 - b. Sustainability-based professionals
 - c. Structural Engineers
2. What are the drivers, changes, and trends for those roles (Rq2)
3. What could the future of the selected roles look like in the AECO industry? (Rq3)
4. What are the potential future new roles that might emerge from the selected roles? (Rq4)

1.4 Ethical aspects

Given the possible effects that future positions in the construction industry could have on employees, the environment, and society, ethical issues were an essential component of this research effort. The research was planned to protect worker safety, promote environmental sustainability, and encourage fair labour practices. It was also planned with the ethical ideals of respect for persons, beneficence, and justice.

The chance to ask questions and withdraw from the study at any time was provided, and participants were given information about the study. The obtained data would be kept anonymous to keep participant identities confidential in all publications and presentations. It would be one of the precautions to safeguard participant privacy and confidentiality.

The research team adhered to ethical standards throughout the investigation and thought about these standards when analysing and interpreting the findings. The research has significantly advanced knowledge of future jobs in the construction industry in a way that is both technically sound and ethically responsible, despite some limitations and difficulties linked to the ethical issues of this study.

2 Method

The structure of the study follows a qualitative approach. It starts with a literature review using a segmented timeline, followed by an empirical part consisting of interview results. The discussion section that follows includes the findings of the literature review as well as the empirical results section, which are combined and analysed for a further conclusion section.

The selected roles represent the current main direction in the industry in the form of digitalisation and sustainability, together with the development of a regular role such as structural engineering. By focusing on the development of digitalisation and sustainability aspects in terms of drivers, changes, and trends in the construction industry, it is possible to draw a parallel with the roles working with these aspects. The role of a structural engineer is seen as a role that is influenced by external factors such as legislation, digitalisation, and environmental thinking. By studying the development and the factors that have influenced the role of the structural engineer, it is possible to make a future assessment of how other roles may develop in the future and what factors will influence their development.

The structure of the literature part based on the development of the roles is performed in four different periods, as shown in the figure below, including changes before 2000, from 2000 to 2010, from 2010 to 2020, and from 2020 to 2030. The findings from the four selected periods will allow us to identify the different paths of each selected role.



Figure 1: Showing the different periods of literature analysis.

The use of a different timeline in the literature review helps to structure the information, makes it easier to find and to visualise the information. Although there are many changes that took place in different decades before 2000, it was decided to generalise the timeline that took place before the year 2000. The main reason for this was the lack of time and the limitations of the scope. Although the timeline is divided into decades, some connections between them have been considered. The use of a timeline also helps to examine the transition of industrial trends driven by different forces, while also focusing on digitalisation and sustainability requirements. It is important to note that the timeline is applied to the development of roles and not to the literature findings. That is, the literature review focuses on the context of the roles during the given timeline in the text rather than when the study was published.

The literature review explores different theories, existing studies and information about the selected roles based on the following themes: a driver of change, changes, trends, role transformation, new responsibilities in the construction industry, future demands, sustainability goals, digitalisation, etc. The same words were used as keywords to find relevant research for the study in reputable databases such as Chalmers Library, Science Direct and Scopus, including search engines such as Google Scholar.

The following significant part of this research is based on the empirical data obtained from face-to-face and via Teams interviews. Personnel were selected according to their relevance to the research question and the study, prioritising roles that are based on digitalisation (such as VDC managers), sustainability experts and structural engineers. The chosen method was chosen because of the better quality of the data obtained and the flexibility of the data collection. A total of 17 interviews were conducted where the interview was recorded, transcribed, analysed, and summarised. After comparing the information gathered with the literature review, the results in and discussion section was written based on the aim of the study and the research questions.

For the results part, a mind map (Figure 7) was created to visualise the selected role development in the construction industry. All data presented in the mind map combine both literature review and empirical results. As all interviewees work in Sweden, the mind map represents the role development of the Swedish AECO industry.

It is important to mention that the study is conducted in cooperation with a construction company based in Sweden, which provides more accessible contact to the required personnel. In addition, the questions for the interviews are related to the themes explored in the research questions and are presented in appendix (see Appendix 1).

3 Literature Review

The construction industry has been confronted with the challenge of adapting to transition and increasing demands driven towards achieving a way to do the right things more efficiently, effectively, and less costly (Mc Kinsey Company, 2020). Therefore, propelling forces have been employed that have been aided by the progressive advancement in technology, and over the past few years, we have seen the industry's transcending penchant for sustainability. In addition, most of these drivers are employed together and not just independently. For instance, the Lean theory, as a widespread notion for adoption, is seen as being more effective when it is integrated with other frameworks like the Virtual Design and Construction (VDC) methods, Building Information Modelling (BIM), location-based planning using GIS improvement systems, and collaborative planning methods taking advantage of the visual enablement of the BIM. That is, the drivers of industry transformation operate dependently one on another, such that most benefits and purposes are derived from their integrated use (Kifokeris et al., 2020).

The ongoing industrial transformation, which expressly results in the importance of addressing the changes to professional roles, has been driven due to various societal goals, including the pursuit of sustainability within the AECO industry (Müller et al., 2018). All this in addition to digitalization, especially in terms of BIM adoption for collaborative operating processes amongst actors and professionals. Studying the benefits of digitalization in the construction industry provides a better understanding of the goals and directions that need to be settled (European Commission, 2021a). The analytical report written by the EU outlines the driving forces and perceived challenges of integrating digital technologies to tackle pressing societal issues like the labour crunch, overall global competition, resources, green efficiency, and sustainability (European Commission, 2021b). The rationale for resolving these challenges is using innovative ways to enhance business processes, decrease economic expenses and market mandates for sustainable development, and to reduce carbon footprints, amongst others.

According to (Alaloul et al., 2018), for the construction industry, the definition of digitalization opines the inclusion of new and innovative digital technologies in the various dimensions of the construction business, encompassing design, planning, project development, production, and end-of-life phases in the construction practice. Meanwhile, the primary objective of digitalization in the construction industry is to enhance efficiency, reduce waste and improve the traceability of the entire construction process, which also corresponds to the sustainability aspects. Over the recent two decades, adopting the VDC and BIM, more particularly, has fostered broader digitization opportunities in the construction landscape. Primarily through enabling the merging of transformation tools and collaboration of industry professionals or teams (Alaloul et al., 2018).

3.1 Definitions of terms

As said before, this research aims to identify the key drivers, changes and trends that shape the roles under study. As a result, it is critical to define some of the key terms used in this study, such as *drivers*, *changes*, *trends*, *digitalization*, and *sustainability*. Clarifying these terms will ensure a collective understanding of the concepts and allow an accurate interpretation of the research findings.

Drivers: Refers to the varied factors or forces that influence and shape the direction and course of change in a specific context. These drivers can be internal or external, and they can come from a variety of sources, including technological advancements, environmental changes, and others (For instance, Climate change, Global Warming, or Net Zero Vision)

Changes: Refers to a visible and time-specific shift or transformation process during an ongoing era of driver or trend (For instance, mandatory LCA calculation that started in Sweden Jan 2022, ensuring that the CO2 calculation and impact of all production processes or materials are estimated).

Trends: This represents a general direction or pattern of behaviour or occurrence that is becoming increasingly common or popular, which could be backed up with empirical data to show steady characteristic changes or development over time (Indeed Canada Corp., 2022; Market Business News, 2023). (For instance, Sustainability)

Digitalization is about transferring and employing digital tools rather than analogy ones. In the industry, it refers to a change in processes, tools, methods, and documentation. It is, however, about digitalizing existing information and transforming existing processes and practices to utilize digital technologies fully. Automation, artificial intelligence, big data analytics, and other digital tools are used to optimize operations, increase efficiency, and improve decision-making (WalkMe, 2023).

Sustainability: It makes reference to the Brundtland Commission's 1987 definition of sustainability as "meeting the needs of the present devoid of compromising the capability of upcoming generations to meet their individual needs.". A balance of economic development, social well-being, and environmental protection is also required. It is based on conservation and stewardship principles to ensure that resources are used to promote long-term human and ecological health (UCLA, 2023; United Nations, 2023b).

3.2 Timeline

To achieve a well-structured literature review of the research theme for addressing changing and newly emerging roles in the construction industry, the timeline was divided into decades with several sections. These four (4) decades are purposed to get a broad historical perspective of how the selected professional roles have changed over the years. There is no way to have an outlook on future of these professional roles without making up for the past or the current changes.

The first section focuses on the significant drivers of industrial changes that influence the construction industry during the specific decade emphasizing digitalization and sustainability. The subsequent sections review the understanding of how selected professional roles have been transformed or changed both internally and externally because of these drivers.

The ensuing literature's structure tries to define the notions of the driver of change, trends, and the changes themselves from before the 21st century until now. While the obtained data gives a historical perspective on the selected roles, it will be used with other objective sources to determine how they could soon become.

3.3 Before 2000

This section presents the development of sustainability and digitalization and the evolution of the selected roles before 2000. It provides an overview of how the selected roles emerged, the spread and implementation of the changes, and the main drivers behind them.

The 20th century shifted the way of living radically. This time has witnessed the start of the technologies used today daily. Many significant milestones during this time pushed science to develop innovative technology, materials, and energy sources. Such events as the World War II, the nuclear program, and the aerospace race laid the ground for further implementation of newly emerged technologies. (Eiseman H. J., 2023) Wrote about the last half of the twentieth century by saying that:

“By the year 2000, technological developments had removed traditional barriers of time, distance, and space that defined technology a century earlier. In the process, the emerging technology relied more on electronic rather than mechanical devices, more on knowledge than materials, and more on information than industrialism.”

3.3.1 Drivers, trends, and changes

During the last 50 years, the construction industry has witnessed various transformations. Among the prominent trends that can be seen and most documented are health and safety, sustainability, and digitalization, upon which sustainability hinges on its three tiers which are social, ecological, or environmental, and financial (SAP Company, 2023).

In the 20th century, the third industrial revolution started by creating the first electrical digital computer (Erik Gregersen, 2023a). Such revolutionary technology substantially changed the world and allowed us to work more efficiently. Concerning work in the construction industry, the first significant digital tool was made in 1957, which is thought to be the first CAD program called *Design Automated by Computer (DAC)*, developed by Hanratty (Patrick Waurzyniak, 2010). Later emerged Building Description System (BDS) in 1975, *Graphical Language for Interactive Design (GLIDE)* in 1977, and 2D CAD in 1982 gave an understanding of the advantages of virtual design and construction. Besides the software, another big jump is the connection of the computers in the distance that started a new era of the internet. Officially 1st January 1983 is considered the Internet's birthday (Online Library Learning, 2023). Further development of the “BIM” is focused on expanding the software's functions and considering the house's design, management, and calculations. The most significant interest gained was *AutoCAD* for making drawings, while understanding management importance and benefits came later.

The first climate change actions can be considered done by the US in 1965 after the “*Restoring the Quality of our Environment*” report (US Government, 1965). Back then, some of the suggestions were to implement taxes for pollution which would work as a driver for less polluting processes. Another big event that influenced everyone was the world's first conference on the environment (United Nations, 1972) which contributed to an “*Action plan*” and the start of a dialogue between countries about sustainable aspects.

The last decades of the 20th century are rich with many environmental regulations. For instance, in 1987, the Montreal Protocol was signed, aiming to phase out ozone-depleting substances' production and consumption. Afterward, the next decade continued with a worldwide environmental convention in Brazil, Rio de Janeiro in 1992. There, “*Agenda 21*” was presented as a global task for all countries and authorities to work towards sustainable development, including CO2 reduction (United Nations, 1992). Later international agreement on reducing greenhouse gases, the “*Kyoto Protocol*,” was adopted in 1997 but entered into force only in 2005 (United Nations, 2023c, 2023a). Right after that, the first version of “*Leadership in Energy and Environmental Design*” (*LEED*) was released in 1998 by the U.S. Green Building Council (USGBC) (Richards Jennie, n.d.). Those protocols and certificates were supposed to regulate and popularize the sustainability concept.

In the meantime, in Sweden, one of the earliest laws to address environmental protection was the “*Environmental Protection Act*” of 1969 (Riksdagen, 1969). Construction-related pollution was included in the framework for regulating environmental pollution established by this act. Some years later, Sweden's “*Planning and Building Act*” influenced the construction industry in 1987 (Riksdagen, 1987). It mandates that buildings be built in a socially and environmentally responsible way. The last thing that happened in this decade in Sweden was the implementation of a significant piece of legislation, “*The Swedish*

Environmental Code,” which entered into force in 1999 to promote sustainable development (The Swedish Environmental Code, 1998).

3.3.2 Transition due to Digitalisation

BIM is the primary digitalization process implemented in the construction sector in recent decades. However, before it became what it is today, it underwent several transformations. Professor Charles Eastman at the Georgia Tech School of Architecture is counted as the father of BIM (Aryani et al., 2014a; Georgia Tech, 2023; Latiffi et al., 2013). In 1975, Eastman developed a recent technology for improved coordination during the design phase called *Building Description Systems (BDS)*, which employed a graphical user interface and database for information retrieval (Aryani et al., 2014a; C. Eastman, 1976; RIB, 2017). The advantages of BDS include the ability to define, edit, and organize many parts and the ability to detect design incompatibilities.

Unfortunately, BDS did not gain widespread popularity due to its accessibility limitations for many designers. In 1977, Eastman and his colleague Henrion introduced *Graphical Language for Interactive Design (GLIDE)* (Aryani et al., 2014a; C. Eastman & Henrion, 1976; RIB, 2017). GLIDE used the same concept as BDS but had additional features such as building elements and improved accuracy and reliability. Although it was primarily used for structural design review, cost estimating, and data accuracy monitoring, there were limitations to the program. Both BDS and GLIDE were limited to working only with the design part of the project, which led to the development of a new program called *Building Product Model (BPM)* in 1989 (Aryani et al., 2014a; RIB, 2017). The new program was expanded to cover the application, estimation, construction process, and involvement of construction players but only focused on product information. The most significant difference between BPM, GLIDE, and BDS was the project library, which consisted of information based on the project’s life cycle (Aryani et al., 2014a; RIB, 2017). At this point, there was already a strong connection with *Computer Aided Design (CAD)* which gave more freedom and opened more possibilities, but it was not enough. The AECO industry needed to expand the program for design and construction management purposes. Therefore, Eastman and his college Siabiris presented a new program based on the BPM called *Generic Building Model (GBM)* in 1995. GBM integrated information from all project stages, allowing the use of available information anytime for multiple collaboration points among stakeholders (Aryani et al., 2014a; C. M. Eastman & Siabiris, 1995; RIB, 2017).

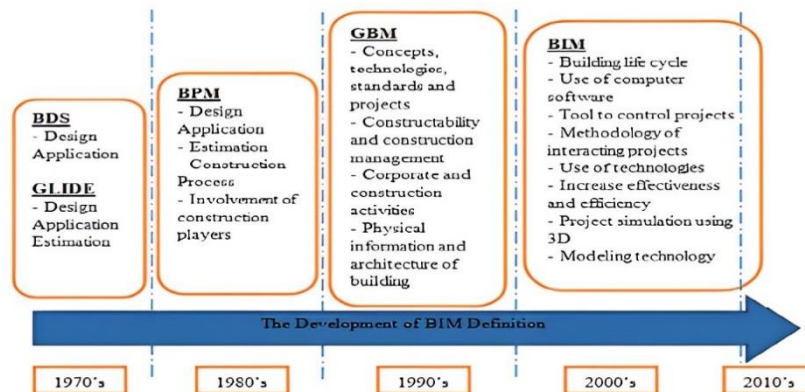


Figure 2: Development of BIM definitions (Aryani et al., 2014b)

3.3.3 Transitions due to Sustainability

The concept of “*Sustainable Development*” is much mature than it seems. Hanns Carl von Carlowitz was the first author that speaks about it back in 1713 (Grober, 2007; Hans Carl von Carlowitz, 1732; Keiner, 2005). He wrote about the reasonable use and maintenance of the woodland to hand it over to the future generation (Grober, 2007). The ideas Carlowitz wrote about are remarkably like the thoughts of the Brundtland Commission that provided the most popular working concept of sustainability "Sustainability is a type of development which meets the current requirements of society while not compromising the ability without compromising the capacity of later generations to fulfil their basic needs" (Dorin Paul, n.d.; Keiner, 2005). This definition of sustainability is still used nowadays.

In 1972 United Nations Conference on the Human Environment was the first worldwide conference to consider environmental issues. This event identified 26 environmental principles and contained an “*Action plan*” for three main categories followed by recommendations. This conference started the environmental movement and set a direction for further improvement (United Nations, 1972).

A big push that influenced Europe in 1974 was the *Health and Safety at Work Act* in the United Kingdom. The act sets out general duties for employers towards staffs and members of the public and for employees towards each other (Health and Safety Executive, 2023). Such acts have influenced other countries to adopt and implement their H&S policies, as well as the further emergence of other H&S organizations. In 1975, the US Congress passed the *Energy Policy and Conservation Act*, oriented on building efficiency standards (Congress US, 2023; Energy.Gov, 2023). It was one of the earliest such laws in the world.

Later in 1987, the “*Brundtland Report*” was published after an assemblage of the United Nations leaders on the world commission for environmental development in 1983 (United Nations, 1987b). It was considered for sustainability to become a global agenda for a long-term planned change from 2000 onwards (United Nations, 1987a). It inferred that strategic planning is to be done to make environmental propositions. In place of this, decisions on how to foster intra-national translation of cooperative efforts were made towards achieving common economic and social objectives, resolving familiar challenges, and ensuring conservative and judicious use of the resources they currently have towards the future aspirations in the world community (United Nations, 1987a).

Further, in 1996, Third International Green Building Conference and Exposition were held in San Diego, California, to minimize the environmental impact of buildings (Fannee et al., 1996a). This event is a milestone in developing the green building industry and recognizing the importance of sustainable construction. At the same time, the construction industry was widely recognized as a significant contributor to several environmental problems, such as deforestation, air and water pollution, and the release of greenhouse gases. As a result, there was a growing movement to find ways to diminish the deleterious impacts of construction processes, and promote more sustainable building practices (Sandanayake, 2022).

Using social, economic, and environmental challenges as a starting point, Agenda 21 seeks to advance sustainable development on a global scale. In the document released by the EU (European Commission, 1997), critical areas for action are highlighted, such as lowering poverty, enhancing health and education, fostering sustainable agriculture, conserving natural resources, and lowering pollution. It highlights the necessity of global cooperation and participation from governments, NGOs, and the corporate sector to achieve sustainable development (European Commission, 1997).

3.3.4 Transitions and roles affected.

This part will evaluate the role's main tasks, focus area, and responsibilities. Those roles are structural engineer, sustainability-based expert, and digitalization-based expert, like the VDC or BIM specialist roles. Previously described trends and changes caused the evolution of the roles. Some new roles have been created, while others changed the working tools. The roles will be discussed and observed during a limited timeline, approximately from 1950 to 2000.

3.3.4.1 *Digitalisation-based roles*

According to our literature study, the role of the BIM manager started to be mentioned in the literature of the AECO industry after 2005. It says that before the year 2000, there was no such role as a BIM manager concerning adopting BIM in the changed timeline. However, as mentioned before, various program software laid a foundation for further BIM appearance. Such programs as BDS, GLIDE, BPM, and GBM were used by organizations for computer-aided design (CAD) and project management purposes (Aryani et al., 2014a; C. Eastman & Henrion, 1976). Therefore, most of the time, the relevance and purpose of using these programs include how it is employed by professionals, such as architects, engineers, and project managers, to perform their purposed tasks.

However, in the early 1990s, Computer-aided design became quite valuable in the engineering design process with its accompanying software capability. For instance, the former physical hands-on drafting changed into 2D CAD technology, then developed into the 3D design for their drafting, and modelling processes (Aryani et al., 2014a).

3.3.4.2 *Sustainability-based roles*

During the literature study, the role corresponding to environmental aspects was not found in the construction sector. The specific name of the role was not found; however, the movement of sustainable buildings was started before 2000 along with many different organizations, like the *United States Green Building Council (USGBC)*, which was established in the early 1990s (U.S. Green Building Council, 2023). Although there was no specific role of the "*environmental manager*," several projects were focused on constructing green buildings. William McDonough and Partners are one of those persons that supported green buildings, promoted sustainable green building, and have been seen as architectural leaders in the Green Buildings field. In 1992, McDonough was looking into the future and wrote about water, air, and waste management. He wrote several principles that should be considered for a sustainable future, such as "Eliminate the concept of waste; Evaluate and optimize the full life cycle of products and processes, to approach the state of normal systems, in which there is no waste." (Fannee et al., 1996b; William McDonough, 1992).

One of the main focuses of the sustainability concept before the year 2000 was optimizing the use of materials. Many construction professionals were exploring ways to use more environmentally friendly materials, such as recycled materials and sustainable woods, and ways to reduce the waste generated by construction projects. Another critical area of focus was energy efficiency. With the growing awareness of the significance of reducing energy use and greenhouse gas emissions, designing, and constructing more energy-efficient buildings, implementing passive solar design, and using high-efficiency heating and cooling systems. McDonough wrote about the importance of the design and implementation of the elements "*Earth: materials, use, lifecycle, Air: pollution, noise, Fire: heating, energy, Water: consumption, treatments*" as a primary concern for the environmental program (William McDonough, 1992).

Overall, no specific role or job title focused on the work regarding environmental aspects of consideration in construction before 2000. Some individuals and organizations were dedicated to promoting more environmentally responsible construction practices.

3.3.4.3 Structural Engineer

The history of structural engineering goes back more than 4000 years to the old Pyramid of Giza. Since that time, a lot has changed. New characteristics of existing materials, new materials, new calculation methods, new formulas, new constructing methods, and much more have been developed since then. The famous “*finite-element method*” was first presented by Turner in 1956 and later fully clarified by Zienkiewicz in 1965 (Gupta & Meek, 1996). This revolutionary method and the technological revolution significantly pushed the structural engineering process. Such a program as NASTRAN made for NASA (National Aeronautics and Space Administration) to analyse the finite-element method made it possible to construct various complex structures and accurately predict the stresses (Macneal, 1974). In 1970 with the public version of Finite-Element Analysis (FEA), software analysis of structural engineering was used much more. For instance, construction of the *Sydney Opera House* in 1973 was calculated by structural engineers on the computer using such technology for the first time (Ove Arup & Co., 2016; Peter Hoggatt, 1973a, 1973b). Later in 1980, the construction industry was one of the first to automate its design process; for instance, Computer-Aided Design was presented in 1982 and used by engineers in many different projects (Storey, 2017a; Sutphin, 2005).

Furthermore, changes in the tools and software used in practice resulted in a change in methods and the working process. Before the advent of CAD, engineers used manual tools for designing buildings and creating drawings. All those sketches and planes were made by hand using significant papers, a pencil, and other tools such as compasses, protractors, and rulers to create precise drawings and diagrams. Before creating a design, engineers used mathematical calculations, tables, and charts to estimate the correct dimensions of structural features such as beams, columns, and foundations. Additionally, to the drawing, engineers needed to visit the sites to take measures, oversee the project, conduct inspections, and execute manual load testing methods of the materials (Andrew Storrier, 2021; Rare Historical Photos, 2023).



Figure 3: Drafting process (Rare Historical Photos, 2023)

However, the manual working methods were time-consuming and did not allow us to add some design project changes easily. Therefore, the modern age of developing drawings began in 1963 with the invention of Sketchpad, the first graphically interfaced CAD program. Since then, significant intellectual and

financial investments have been made in CAD programs. The introduction of CAD software in the 1980s and its massive popularization in the 1990s revolutionized the field of structural engineering, allowing engineers to create more detailed and complex designs in a fraction of the time (Andrew Storrier, 2021; Rare Historical Photos, 2023).

CAD completely changed the way of working for structural engineers. It helped in optimizing the time-consuming, challenging aspect that was critical for the engineers, being able to create a precise design for every detail, change or modify different elements and check for compatibility of the components, made it possible to expand the structural engineering role (Andrew Storrier, 2021; Rare Historical Photos, 2023). Regarding parallel changes in environmental trends, such aspects as new materials, sustainability, efficiency, and risks will need to be considered during the design process. However, structural design, structural analysis, material selection, inspections, and collaboration are still the primary responsibilities of the structural engineer that did not change a lot (Andrew Storrier, 2021).

3.4 Between 2000 and 2010

This section will outline the advancements in sustainability, digitalization, and the evolution of the chosen professions between 2000 and 2010. The review will summarize how those positions arose, how the changes were popularised and implemented, and what the primary motivators were to pursue higher productivity and efficiencies that have always been essential.

3.4.1 Drivers, trends, and change

Digitalization and sustainability can still be considered the main objectives in the AECO industry. The demand for utilizing new ICT technologies to facilitate innovation in the construction industry has continued to grow over time (Jacobsson & Linderoth, 2010). According to the research, these demands for adopting new practices and working methods are being impressed upon contractors by their clients (private or public), while they also do the same with the subcontractors. It is evident and illustrated in using 3D-based building information models to oversee or manage projects.

Developing and adaptation of digital software during this decade has become one of the main tasks in industries worldwide. Software created for the AECO industries continued to develop and become more popular. The first BIM-oriented software, JetStream and Revit, emerged around 2000 (LetsBuild, 2017). However, Autodesk won the race for BIM software and has become the most used software in the AECO industry. Adoption and transition to BIM started slowly in 2005, wherefrom the use of BIM in construction projects became more frequent. Another revolutionary technology during this decade was the emergence of USB flash memory (Erik Gregersen, 2023b), which led to many other digital devices, such as portable phones and laptops. Those products change a lot again, connections on the distance become less a problem as well as the transportation of the information and access to the information.

Moreover, the prominent level of Information Technology (IT) adoption during this decade created many opportunities for the AECO industry. Zainon & Salleh (2011) highlighted the importance of implementing a flexible IT system for the management effectiveness of the construction sector. The authors identified five dimensions of IT that provide infrastructure flexibility and mention several benefits such as cost and timesaving, improvement of communication, effectiveness, and enhanced competence. Along with the increased interest in IT, the environmental aspects get more essential attention. The climate aspect was one of the main topics in the world arena and raised many debates. Weather changes become more noticeable which were linked to human-caused emissions and become one of the main drivers of climate change (John Vidal, 2009; Larry West, 2019).

However, some of the main drivers for sustainability, especially those linked to the environment are the regulations made by authorities and demands raised by private clients. In the meantime, authorities got a better understanding of the problem and how it was resolved, which pushed many to make some changes. Another rating system realized this decade was “*Green Star*” by Australian authorities with the goals and intention to improve the environmental efficiencies in the buildings (Building Council of Australia, 2003). The notable change that affected the construction sector in Europe is the *European Union Energy Performance of Buildings Directive* (The European Parliament, 2002). This directive mandated that all buildings must have energy performance certifications and that member states of the EU adopt minimum energy performance requirements for buildings. As a part of sustainable development, China released its green certification standard for buildings in 2006 (NEEC, 2006), positively affecting the construction industry there.

During this decade, the environmental aspect became more popular, and besides certification, some countries realized several regulations and guidelines that promoted the development and increase of renewable energy use. US (US Government, 2005), Germany (Erneuerbare-Energien-Gesetz (EEG), 2000), and other countries implemented energy acts as a future direction for development. Establishing new energy-efficient standards influences the construction sector to build more energy-efficient houses. At the end of the decade, the Swedish government presented a new regulation on environmental management in government agencies in 2009 (Riksdagen, 2009). This regulation introduced requirements for all government agencies to have an environmental management system to systematically work with environmental issues and reduce their impact on the environment. Some years later, the *Sweden Green Building Council (SGBC)* was founded in June 2009 by thirteen Swedish companies and organizations (SGBC, 2022). Since then, they have been working towards sustainable building and promoting sustainability in the construction industry.

3.4.2 Transition due to Digitalisation

Construction projects involve complex relationships between parties from various professional backgrounds to accomplish a same aim. Their complexity stems from the documentation and conceptual visualization that has historically been done or shown manually. According to conventional practice, most actors use a two-dimensional (2D) basis of information exchange, often leading to miscommunications unsuitable for complex projects (Aryani et al., 2014a). These miscommunications lead to construction process errors such as design errors, drawings that are not updated, time and cost overruns, and poor work outcomes due to design integration collisions.

Therefore, the urgent need for Information Communication Technology (ICT) is set to manage the information flow and documentation process. It also promises to provide the consistency and reliability required in the construction industry. A leading example has been the introduction of Building Information Modelling (BIM), facilitating more efficient and integrated information management systems. According to (Aryani et al., 2014a), the definitions and growth of BIM have grown in six critical application perspectives, including design, estimation, construction process, building life cycle, performance, and technology.

The AECO sector continues to grow, with several projects becoming more extensive and complex. New circumstances are now needed for implementing ICT to improve project performance and expectations and fulfil the needs and requirements of the industry. Therefore, the Generic Building Model (GBM) has been transformed into Building Information Model (BIM) over time. Its application expanded with its inclusion for use from the early design phase through the post-construction phase. Its implementation spanned many projects in countries like the USA, Finland, HK, and Australia. For instance, since 1988, the CIFE research

organization at Stanford University has gradually developed practical engineering and management solutions to improve performance and push the boundaries of innovation and sustainability in the construction sector (CIFE, n.d.). Before 2005, BIM had become known as a technology for simulating the construction and operation of a facility using computer software and used primarily for managing information and organizing tasks, duties, and processes throughout the project phases, including planning, design, construction, maintenance, and demolition (AGC, n.d.; Aryani et al., 2014b).

According to Aryani et al., 2014, BIM was adopted as a new methodology to improve AECO's performance in managing construction projects. By 2008, it had evolved into a project simulation that consisted of a 3D model of the project component integrated with crucial information relevant through all the project phases. From 2008 to 2013, BIM grew as a technology revolution that transformed how buildings are designed, constructed, operated, and maintained, leading to a change in basic assumptions in the AECO industry (Allen & Shakantu, 2016). According to the research, BIM is now considered a set of digital tools that aid in managing construction projects and improving planning, design, construction, and operation through collaboration and information management. In addition, it is also viewed as a set of design management tools that offers advantages throughout the construction project phases, driven using 3D CAD software programs. A discussion in 2009 ensued, highlighting how the implementation of BIM will eventually require or inspire both technological and organizational changes and new interaction patterns between supply chain actors (Succar, 2009). It has been seen and increasingly embraced in the industry today.

3.4.3 Transitions due to Sustainability

The most significant impact on the construction sector affected the LEED (Leadership in Energy and Environmental Design) rating system. Even though LEED started in 1998, more popular it becomes with the 2nd version in 2000. According to (Richards Jennie, n.d.) LEED made a considerable impact on both the design and reconstruction process. By influencing all aspects of the building, it became a bit more expensive but gave many positive results as a higher real estate value, sell price, and operation cost, among many other benefits. Although LEED is worldwide, China made its own certification called “Tree Star,” pushing contractors to build more sustainably (Zhou, 2014). Such direction is essential as one of the countries that build the most. This certificate also helped the governmental environmental plan to reduce CO2 emissions.

A study carried out by (Geißler, 2013) in accessing the sustainability transitions through environmental assessment practices of the past decades agreed that renewable energy, energy efficiency, and CO2 emissions are becoming more critical, along with legislation that various countries are implementing. The transition and future direction toward a sustainable future are becoming more apparent, the influence of regulations on many industries in combination with certifications will produce crucial results. For instance, environmental management and thinking will become more popular and attractive to customers and pose to positively impacting the industry (ibid).

As mentioned, the Kyoto Protocol became active in 2005 in addition to the EU's development and implementation of the Emissions Trading System (ETS) (European Commission, 2023). However, neither of those regulations do have any direct impact on the construction industry. The biggest contribution of the protocol to the AECO industry is regulation and standards regarding greenhouse gas emissions (Adshead, 2011).

3.4.4 Transition and roles affected.

The following sections will evaluate the selected roles during the earliest decade of the 21st century. Since this time was influenced by digitization, sustainability, and digitalization in the AECO industry, the main change in the role is connected to its adoption of the new tools and requirements.

3.4.4.1 Digitalisation-based roles

BIM manager as a role started spreading widely in the middle of the 2000s. Together with the adaptation of BIM technology, new challenges show up. To be able to adopt the use of BIM, many companies in the AECO industry began to include BIM as a required skill or competency, especially for architects, engineers, construction managers, and project managers, people with the right competencies needed to be hired or educated, even though it turns out to be at additional cost for the company. Deeper implementation of BIM required a new potential role of “*BIM manager*”, also known by such names as *Information Manager*, *Virtual Construction Manager*, *Modelling Manager*, *Model Integrator*, *Virtual Architect/Engineer*, *Digital Contractor*, *Digital Project Coordinator*, *Building Modeller*, *4D Specialist*, *IDS Champion*, *BIM Champion*, *BIM Administrator*, *BIM Integrator*, *BIM Coordinator*, *BIM Leader*, among others (Barison & Santos, 2010; Sebastian, n.d.; Wamelink -Bk & Kingu, n.d.). Hence the role has many names, the role and responsibilities are still not specified. Therefore, BIM can be used in many ways, such as design, management, engineering, and modelling. The following roles and responsibilities developed to be most common in the AECO industry:

BIM Modeller or *BIM Operator* – responsible for creating, developing, and extracting 2D prints from the model. The position of a *Draftsperson* might be developed into a *BIM Modeller* since it is still easier to handle 2D drawings onsite rather than small tablets. Besides the blueprints, *BIM Modeller* could be responsible for *3D*-, *Cost*, *Sequencing*, or *Detailing Modeller*. The tasks can be pretty comprehensive; therefore, they need to be fortified with the understanding of drafting, designing, specifying, sizing, verifying, documenting, and detailing during the design process.

BIM Analyst – has the main task of performing analysis and simulations of an existing BIM model—a sort of virtual building inspector for performance, safety, and circulation. One point of view was that the BIM manager’s role could be a route for a younger professional to become a proficient project manager of the future (the role was assumed to provide a short-term solution to closing the competence gap of existing practitioners). In addition, the possibility of a separate BIM manager role in the future was expressed due to more complex BIM processes evolving.

BIM Software Developer – is an expert in is an expert who creates and adapts software to facilitate integration and the BIM process, who is responsible for plug-ins to BIM servers, integrated project management tools, and data repositories.

Modelling Specialist – Modelling Specialists are IT experts who collaborate with subject matter experts from many fields of the AECO sector to create software solutions that fit the IFC standard. They support IFC extensions and know IFC modelling and data structure ideas. Moreover, they map IFC classes to Exchange Requirements (ER). IFC data exchange still needs experienced personnel to guarantee the integrity of exchanged data in each organization because of the complicated structure of BIM models.

BIM Facilitator – a person who helps other employers that are not skilled yet with BIM issues. Assist engineers with visualizing the model and managers with extracting information from the BIM model for further planning.

BIM Consultant – can have distinct roles based on the goal. BIM Consultants help companies without BIM experts adopt and implement BIM by guiding project designers, developers, and builders. Separate roles can be consisted of generating medium to long-term strategies, making action plans, developing implementation plans, and performing those processes.

BIM Researcher – has a remarkably similar role to BIM Educators, who work with universities, institutions, or/or government for researching, developing, and coordinating purposes. It is included in the leading industry, company, and society knowledge development.

BIM Managers – have an inclusive definition, and the primary definition of this title is a *coordinator*. Managing people in the implementation and maintenance of the BIM process and guiding the team in decision-making are one of the primary responsibilities of the *BIM Manager*. *Model Manager* can be related to *BIM Manager* roles as well. *Model Managers'* primary duty is production model management, information integration from many stakeholders in the construction process, and the model's version administration. Moreover, some roles might be extended or changed depending on what field BIM Managers work in. *BIM Managers* can be at Design Firms or General Construction, for example. Besides coordinating different working groups, future skill upgrades for employment and motivation can be planned. Estimating the time and cost of BIM implementation and forming a working group can also be part of the BIM manager's responsibility.

Those roles described by (Barison & Santos, 2010) were most common during this time limit. However, a professional working with BIM could have tasks of several of those roles named above depending on the project, experience, or company. Moreover, most of those roles are not allowed to make some decisions about the design, construction, or engineering solutions and organizational processes. However, many similarities can be found by reading the descriptions of those distinct roles. Many roles overlap with each other, which makes it less efficient and productive. BIM training creates issues for companies, production, and employers (Kraatz et al., 2014). The research opined that companies must educate those people, resulting in additional costs and time. In the meantime, these employers must adjust to the new reality and spend time learning new, digitalized working methods. Therefore, some companies are trying to collaborate with universities to train students and better experience exchange (Kraatz et al., 2014).

3.4.4.2 Sustainability-based roles

The role of sustainability experts had begun to gain increasing awareness before the 2000s, especially with the implementation of environmental regulations for handling waste and greater control over handling raw materials and hazardous inorganic materials. It happened because of the widespread estimate that the AECO industry was responsible for 40% of man-generated waste from 40% of the total material used (Baumann, 2003). The Swedish construction industry was mentioned to have taken the implementation of sustainability strategies head-on according to research carried out in 2021 by (Gluch & Månsson 2021a), whose respondents mentioned a peculiar incident referred to as “*The Halland’s Ridge scandal*”. This incident brought about the need for awareness and having a delegated professional devoted to handling issues of curbing environmental solutions.

Furthermore, the event (which involved a toxic chemical leakage due to a sealant used in a tunnel project), which was taken up even as a media scandal, made a wake-up call to the emergence of a new professional who is pressed with the responsibilities to manage the ensuing challenges and prevent further similar ones in the future (Månsson, 2021). The resulting constructive change in the Swedish construction industry has continued to gain recognition and organized to create a widespread practice for the reduction and elimination of wastes (whether lethal or not) and collaborative work between enthusiasts under the same theme (Månsson, 2021). As an additional contribution, the author mentioned that to control better the environmental impact of projects, programs, and demands that strived for regulations and necessary compliance started being included in project execution. Thus, the green perspective urges how professionals define their responsibilities for continued engagement as crucial to project delivery.

Shortly after the accident in the early 2000s, the establishment of *Environmental Management Systems (EMS)* and other environmental assessment tools increasingly created more structured coordination and responsibilities but mostly on existing roles (like the Quality, Health & Safety, and Environmental managers), as extras without eliminating primary responsibilities (Malmqvist, 2004). Nevertheless, as the responsibilities and administrative requirements increase, especially with the emerging combined use of the EMS and *Quality Management Systems (QMS)*, their context of operation has transformed into the unique role of environmental managers or coordinators (Månsson, 2021).

As environmental practices continued to develop alongside the role of the environmental managers, it also trended as a competitive factor, where they could serve as key decision-makers in handling environmental issues and changes. Meanwhile, environmental sustainability was still not part of the core business preparation and planning, but their specialization introduced the prospects of presenting the business as green, although not in-depth (Malmqvist et al., 2011). This increasing dialogue and cooperation amongst professionals led to the full adoption of building certification systems that were earlier established in the 1990s under different classification systems like the *Building Research Establishment Environmental Assessment Method (BREAM)*, *Leadership in Energy and Environmental Design (LEED)*, including the Swedish assessment system "*Miljöbyggnad*" (Malmqvist et al., 2011). It further helped to promote environmental practices and to legitimize the environmental workers' professional role.

Shortly into the 2000s, the EMS adoption, alongside other new environmental practices, began to decline and even out until a movie titled "*An Inconvenient Truth*" was released by Al Gore in 2006. The movie's central focus was on climate change (Månsson, 2021). In a brief time, it quickly transformed the spotlight of discussion in the Swedish industry on eliminating wastes or neutralizing chemicals and energy-centered technical discourses. The consequent result was new requirements on energy efficiency to be made on a Swedish national level for building standards that must be achieved and upheld. Thus, by the mid-2000s, the AECO industry was already at the forefront, engaging in several discussions on energy and how to develop energy-efficient buildings to save cost (Högberg et al., 2009). Heavy investments in knowledge build-up towards energy efficiency through research and developmental means continued a few years after it came to the limelight. Soon after, the cost aspects emerged, including the Life Cycle Costing (LCC) methods in developing communities with energy-efficient buildings. Overall, in the 2000s, the timing, context, and maturity of the issue of energy efficiency continued progressively ahead of the environmental and sustainability practice (Högberg et al., 2009).

In the recent past decade, aspects such as the life cycle assessment have gotten more prominent attention. According to Oostra (2009), implementing the life cycle perspective forces the AECO industry to build more effective long-term relationships with its clients. According to that research, such changes could create new possibilities, restructure the professional chains, and emerge new roles. The research added that the structure of projects today tends to add value for lifecycle consideration regarding the interconnected

of involved project teams, from the client to subcontractors, in building long-term relationships. Contractors, suppliers, and subcontractors must create linked value chains to handle these complicated assignments. It will be possible to innovate and set ambitious targets to construct high-quality, sustainable buildings with added services thanks to these interconnected chains. Current parties can expand their roles to include duties previously belonging to other current parties (forward and backward integration). New roles will follow new business models.

3.4.4.3 Structural Engineer

For structural engineers, the growing application of computer-aided finite element analysis software and digital tools has helped make their designing process much faster and more efficient. An example includes software for carrying out load-bearing capacity determination and member optimization. These digitalization trends that have made the structural engineers' traditional work processes more effective; have concurrently aided the sustainable aspect to growing bigger and bigger, influencing even more roles in the AECO industry (Jensson, 2017). The research elaborated that the start of those trends caused changes in structural engineer roles due to technological advancements, construction practices, and an increased focus on sustainable and green building design. As mentioned before, the streamlining of processes, along with once trends, has expanded the tasks and responsibilities of structural engineers. In addition to regular duties, sustainability, efficiency, and communication considerations must also be applied (Jensson, 2017).

Beyond administrative advantages, the emergence of BIM was also the next stage in software development and sustainable integration into the design process. BIM technology streamlined design solutions and construction processes, simplifying partnerships. At the same time, BIM enabled us to narrow our focus and create buildings that are far more sustainable and energy efficient. The structural engineer had to take the building's sustainability into account in addition to its structural characteristics. (Moon, 2008; Ochsendorf, 2008; United Nations, 1992), in addition to the improved technology for structural analysis and increased risk management standards. Demands for seismic modification and designing earthquake-resistant structures increased. Engineers were given increased responsibility for developing innovative solutions that would guarantee the safety and stability of buildings and infrastructure during earthquakes (Ellingwood, 2001).

Smaller factors like 3D printing and new materials made a more extensive diversity of structural designs possible. However, the previously mentioned primary duties continue to exist. However, the function of a structural engineer continued to change in response to the shifting demands and difficulties faced by the construction industry, with a greater emphasis being placed on technology, sustainability, and safety. As opined by (Riccardo, 2009) at the University of Trento. The research opined that the complexity of advancement and innovation experienced by practicing engineers from the design to construction phases had created such a gap that no real education, vocation, or professional experience can cover it (Riccardo, 2009). Such gaps include the growing adoption of various operating codes for all construction processes or stages that must be adhered to.

3.5 Between 2010 and 2020

This section will outline the advancements in sustainability, digitalization, and the evolution of the chosen professions between 2000 and 2010. The review will summarize how those positions arose, how the changes were popularised and implemented, and the primary motivators.

In this decade, according to Hinings et al. (2018), the primary characteristics of the industry tend to focus on practical day-to-day action. For instance, when the private or public client experience difficulties attempting to charge the contractors and subcontractors with new demands, the seeming lack of competencies or vital products now raises barriers to process innovations. It has been observed to have become an objective constraint of digital transformation Hinings et al. (2018).

3.5.1 Drivers, trends, and changes

The fundamental forces behind the AECO industry's change have been identified as major players. They include private and public clients who are still ready and willing to demand the use of various technologies (like BIM) to ease IT-enabled change processes in the working procedures of various companies, both internally and externally. (Vass & Gustavsson, 2017). To comprehend the challenges linked to the resulting change processes, continuous attempts towards adapting and fulfilling the new demands due to the ongoing change process have influenced the construction industry especially. According to the research, the combined effects of digital innovations continue to bring about novel actors and their constellations, structures, practices, values, and beliefs. Therefore, it could change, threaten, replace, or supplement existing rules of the game inside organizations, ecosystems, industries, or fields (Vass & Gustavsson, 2017).

One of the significant drivers of transition due to sustainability in the Swedish construction sector was reflected by the regulatory agency (Boverket, 2016) to evaluate the necessary administrative or control measures needed to adapt the construction sector to the environment and climate reasonably. It will help push the desired transition the country wants to experience. According to the report, the objective purpose was highlighted:

“It is part of the Housing Agency's instructions that it must work to ensure that the environmental goals, which the Riksdag has determined for environmental work, are reached. If necessary, the Housing Agency shall propose measures for the development of environmental work. The environment and climate are also clearly highlighted within the framework of Agenda 2030, the UN's global goal for sustainable development, which was adopted in September 2015. The environmental goals committee proposes that Sweden should be climate neutral as early as 2045. As seen, there is reason to work for such an environmentally and climate-adapted construction and property sector as possible.”

Thus, it became expedient that construction industry project teams must analyse some increasingly demanded areas like the construction industry's environmental impact stemming from a life-cycle perspective, ecosystem services, and climate adaptation. For instance, in 2017, the Swedish government strived to push the climate policy work in the construction industry; the Riksdag established prospects for long-term but time-bound emissions targets (Ministry of Climate and Business, 2017). This bold, progressive move, inspired by the most notable *Paris Agreement*, pushed toward limiting global warming temperature levels drastically below-industrial levels (United Nations, 2015a).

3.5.2 Transition due to Digitalization

The construction industry has recently embraced digital technologies such as BIM, automation, cloud storage or systems, software developments, unmanned aerial vehicle systems, and virtual or augmented reality to increase efficiency and better stakeholder collaboration. These technologies have enabled construction workers to visualize better, plan projects, and monitor the progress of construction work in real-time. The Digital twin is the new and increasingly adopted concept (Sepasgozar et al., 2023).

Nonetheless, challenges limiting the adoption of digital technologies in the construction industries from a review of four key players in Sweden highlighted some examples. It included highlights like the culture of working organizations, enabling legal platforms, inadequate required competencies and skills, and information exchange safety (Linderoth et al., 2018).

Greater interest in the digital model developed other technologies that have introduced modern technologies such as AR, VR, drones, sensors, and scanners. Oculus Rift, Google Glass AR, HoloLens, and other products emerged between 2010 and 2020 (Bernard Marr, 2021). At the beginning of 2013, DJI company presented a commercial drone; since then, drones gained colossal popularity and have been adopted by many industries (Mario Poljak, 2023). The same happened with scanning and other technologies. Most are oriented to be combined with a digital model for better efficiency and higher quality. Such changes and opportunities have had a positive impact on the AECO industry. Reconstruction projects, design phases, health and safety, and many other aspects have been improved.

2011 here were a few challenges in BIM deployment as a widely used digitization feature in the construction business (Sebastian, 2011). Due to its benefits, the BIM is now viewed as a digital tool; however, it was found that changing traditional work habits was challenging as a result. Which would then need to adapt to new workflows and deal with specific legal difficulties. The study by Sebastian (2011) also identified a few organizational adjustments that a BIM deployment might require:

- As a result of the implementation of BIM, a new position known as a "*Model manager*" is required, whose duties include providing and maintaining the necessary technical fixes for BIM functionality, administering information flows, and augmenting the ICT skill sets of stakeholders. Yet, it does not enforce decisions on issues relating to design and engineering solutions or organizational processes.
- The effects on intellectual property rights will be felt.
- It will alter the way payments are made and call for a "*new share of payment*" in the preliminary design stage.
- It will also alter how open international standards are used.

In the Swedish construction industry, digitalization transition, otherwise also regarded as digital transformation in some literature, has become an evident contributor in facilitating businesses' drive towards environmental sustainability. According to Mathijs Daemen & Fanny Hansson (n.d.), this conservative industrial sector could capture the value of its work by implementing applicable digital technologies.

3.5.3 Transitions due to Sustainability

Later in the onset of the 2010s, the perception of sustainability developed into incorporate social issues and enforce expectations for the suitable means of reporting or creating sustainability reports using the current working techniques. At this time, the expertise of environmental experts transcended into them being called sustainability managers because of an increase in the scope of what they take responsibility for, including oversight on the use of environmentally friendly materials, reduction of wastes, and optimizing the use of energy (European Environment Agency, 2017).

Nowadays, these sustainability managers collaborate with all other teams and roles, employing their lifecycle knowledge and sustainability thinking starting from the design and planning, operation, and end-of-use aspects of various projects (Gluch & Månsson, 2021a). They ensure that regulations and set standards

relating to the sustainability theme are well adhered to, utilizing recommended initiatives, viable solutions, and programs to assist their immediate company's reduced influence on the environment. During this decade, the full-building lifecycle valuations targeted strive to evaluate construction projects' environmental, social, and economic impacts. It creates better all-inclusive, and unified consideration of the impact of structures on the environs and society (Gluch & Månsson, 2021a)

Thus, in addition to the growing adoption of sustainability in the construction industry, it even co-supported the adoption of BIM tools, simultaneously becoming a tool driving improved design or modelling, construction, and operation of efficient and sustainable building systems. Nonetheless, at the close of this decade, a trending call for attention became required to divert attention from the technical, environmental, or economic influence of sustainability adoption, not only focusing on the two-sided aspects of sustainability (Reyes et al., 2020). Thus, the sociocultural factor that could support or hinder the adoption of sustainability practices came under intense pressure. The research opined that the successful adoption of sustainable thinking in the company must consider the human factor and socio-cultural dimensions. A framework covering the intrinsic and extrinsic sides demonstrating the crucial action areas was given to facilitate the industrial transition motivated by sustainability. (Reyes et al., 2020). The framework is based on personal motivations, values, beliefs, and communities that act as significant stimulants for a more strategic approach to sustainability as a driver, including the human-based aspect with technological and economic dimensions.

The complex idea of sustainability has also been gaining ground in every industry thought process. According to (Daneshpour & Takala, 2016), the last few decades have been marked by trends and significant development intended to structure this idea's intricacy. Hence, through numerous innovative implementations in the industry, efforts to improve the efficiency of construction processes and descriptions of energy use, dimensions, and indicators to highlight essential developmental routes in sustainability are outlined. Today, multivariate techniques and methodologies such as product-based, quantitative, and integrated assessment tools are used to measure sustainability (Daneshpour & Takala, 2016). It is an overall strategic approach with the broader focal areas mentioned above informed by this practical implementation.

3.5.4 Transition and roles affected.

A comprehensive and objective look into the trends and changes experienced by the chosen professional roles selected for this research is discussed below.

3.5.4.1 *Digitalisation-based roles*

Although most jobs created after the BIM implementation remain, some roles, responsibilities, and visions have changed. As it was mentioned before, many of the roles overlap with one another, and most of them are not standardized. Looking into the standardization of roles would require a clear explanation of the role and its acceptance by the industry. Nonetheless, some roles become more established by the AECO industry than others, for instance, *BIM Coordinator*, *BIM Manager*, *Information Manager*, and *BIM Modeller* (Davies et al., 2017; Jacobsson & Merschbrock, 2018a; Kassem et al., 2018).

BIM Manager is usually taken as the lead designer of the main contractor who oversees the coordination activity between BIM Coordinators, arranging and running BIM project meetings, leading the collaboration process, developing, and delivering execution plans, and overseeing quality. The role can also be adjusted to the project's state, for example, Design or Construction phase *BIM Manager*. In general, *BIM Manager* overwatches the project progression.

BIM Coordinator is responsible for coordination clash detection, managing model, information, and communication flows, monitoring, and coordinating design changes, supporting new working procurement, and being a boundary spanner and technical developer. *BIM Coordinator* was seen as a project member with the highest BIM competency (Jacobsson & Merschbrock, 2018a).

BIM Modeller – can be characterized as the production role. Daily tasks consist of creating, modifying, and maintaining the BIM models for a project using various BIM software tools.

Information Manager – the client side usually takes this role and does not involve the designing process. Also, it does not require knowledge of BIM all the time. Despite this, it is like BIM Manager (Davies et al., 2017; Kassem et al., 2018). My primary responsibilities are to gather, develop and administrate the project's information process, protocols, and procedures, as well as manage the files and sharing of the information.

Described roles are the most common roles in the AECO industry. However, depending on the scope of the project, several tasks of a single role can be separated into several such as *BIM Designer*, *BIM Strategic*, *BIM Estimator*, *BIM Specialist*, *BIM Technician*, or *BIM Engineer*. Those roles can create electrical, mechanical, and plumbing systems, analyse, and simulate building performance, estimate quantities and costs, or provide specialized knowledge in a specific BIM-related area. Consult companies might have the role of *BIM Consultant*. Otherwise, most of the time, those tasks are done by some less specialized role. (ACCA software, 2021; Davies et al., 2017).

Existing BIM roles today that can be seen include the following: *BIM Manager*, *BIM Coordinator*, and other *BIM specialists*. (ACCA software, 2021; Davies et al., 2017). The figure below represents the hierarchal order of the interaction of simple BIM-based roles. The BIM manager oversees the team and is closely related to the BIM Coordinator, who is mostly the one with access to the central file information, and all design changes must go through him as well. Most people working on the same project were connected to the *BIM Coordinator*.

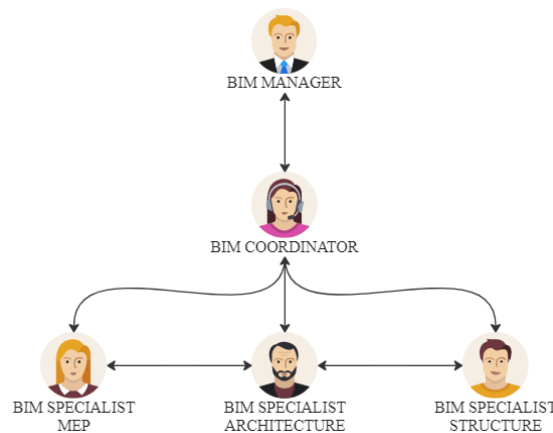


Figure 4: Traditional BIM roles

However, it should be noted that although many BIM roles changed focus from technical aspects to coordination and integration specialties, this did not exclude or undermine the required knowledge of the technical part (Jacobsson & Merschbrock, 2018b). Furthermore, other roles are project- or organization-oriented which making separating and finding limits more difficult.

3.5.4.2 Sustainability-based roles

At the onset of the 2010s, the perception of sustainability increased significantly to include social aspects, enforce demands for proper reporting, and make sustainability reports using available working methods (Daniella, 2018). At this time, the expertise of environmental personnel transcended into them being called sustainability managers because of an increase in the scope of what responsibilities they now assume. In other words, it would include oversight on environmentally friendly materials, waste reduction, and optimizing energy use (Daniella, 2018). On the other hand, the growing adoption of sustainability at this time in the construction industry aided the professionals involved in working closely with other teams. This proposition was well co-supported by adopting BIM tools, which was simultaneously becoming a tool driving improved design or modelling, construction, and operation of efficient and sustainable building systems (Gluch & Månsson, 2021a).

Halfway through this decade, in 2015, the Paris Agreement in addition to the *17 Sustainable Development Goals (SDGs)* began to raise awareness and create a comprehensive understanding of sustainability (including the three recognized environmental, social, and economic dimensions and how they interact) (United Nations, 2015b). As a result, the focus has indirectly shifted once again from how energy-efficient a building could be to the problem of emissions avoidance across all stages of the building's life cycle. The research and conversations that have emerged from the AECO industry tend to focus on themes that suggest cradle-to-grave, or circular economy, thinking and initiatives as the best way forward. (Malmqvist et al., 2018). Meanwhile, the Climate Act and policy framework for Sweden were created to achieve zero greenhouse gas emissions into the atmosphere by 2045 (Ministry of Climate and Enterprise, 2021).

According to (Fossilist Sverige, 2018), large construction companies in Sweden, alongside environmental practitioners, and the media, have come together to create awareness and a common strategy for the industry to reach the targets the country has set on being fossil free. Most importantly, the country has several passionate activists voicing environmental concerns. A strong example of this is the "*Greta Thunberg Effect*" towards awakening the public drive to take actionable steps in mitigating climate change (Sabherwal et al., 2021). Therefore, to stay relevant and legitimate in the industry, sustainability has become intrinsically crucial for companies to remain and appear authentic. Therefore, the role of sustainability practitioners became more tangible, and specialist roles (like the "Sustainability Manager" or a "Sustainability Engineer") were generated to that they could perform as ambassadors for furthering sustainability practice within the AECO industry with unique responsibilities (UGREEN, 2023).

3.5.4.3 Structural engineer

The structural engineer position and responsibilities continued its budding trend toward meeting the changing needs and challenges of the construction industry. Alongside its focus on ensuring structural resilience, a new purpose and focus have been on technology, sustainability, and safety concerns. Thus, the construction industry continues to progress steadily, making remarkable changes over the years that sometimes are regarded as disruptions (Storey, 2017a). According to that research, the founding tenets that have been underpinning all the structural engineer's decision-making and practices in the field over the past four decades are becoming increasingly outdated, and the conventional roles of the consultancy have evolved in ways that could never have been made-up just ten years ago (Storey, 2017a)

In a study of the past and ongoing industrial revolution to understand how technology has transcended and influenced the changes in the industry at large. The World Economic Forum (World Economic Forum,

2016) published the Global Challenge report with insight into how the workforce would be influenced, including the competencies and skills demands that are to be expected. Better insight is obtained by looking into the future transition of the 20th century and the deepening influence of technology in core driving areas like automation, robotics, and artificial intelligence. The construction industry always has a significant stake in the economic status of the nations, and the measure of the level of development is by no means left out to feel the impact of these changes. It includes the structural engineering profession, a vital part of the civil engineering practice and profession (World Economic Forum, 2016).

Nevertheless, the structural engineering role is expected to continue to evolve, primarily since they have always led the frontiers of civil engineering’s adaptation of technological solutions to tackle several problems. For instance, the traditional methods of data crunching, documentation, and delivery became automated; while other instances included their adoption of computer-based analysis, drafting and detailing, and building information modelling (Storey, 2017b). This continuous transition and adaptation demand on the structural engineering professional has placed a heavy demand on them to leverage the available opportunities and focus on the task that requires the intuitive and practical input of the structural engineer's understanding of fundamental concepts. Thus, according to WEF, there is a demand for structural engineering experts within this decade to undergo a fundamental shift in the level of thinking required. Demand is for professionals who can interpret and draw insight and rational decision-making from models and demonstrate an ability to make judgments based on discovery and exploration of new possibilities intuitively, as shown in Figure 4 below.



Figure 5: Showing the fundamental shift in thinking for professionals in the industry.

Furthermore, (Storey, 2017b) supported the inference that soft skills like emotional intelligence, communication, collaboration, and the ability to transcend skills into the new world of virtual design and modelling in real-time, are most preferred in the industry today. According to (SEI, 2013), the structural engineering role is experiencing much contrition with developing standards, codes, and specifications for use in design practice. These have helped to develop new perspectives within their roles, like performance-

based design, multi-hazard design, and performance monitoring. Maintaining these new perspectives requires they stay consistently sharpened and equipped with advanced skills to meet increasing demands that could drive the emergence of new specialties, as technology never continues to develop.

There was a joint futuristic summit by the panel at the Structural Engineering Institute in 2008 to set the profession’s solid identity vision until 2033 (SEI, 2013). Strategic focus includes predicting the future structural engineer's career role and staying proactively active with a well-defined change mechanism alongside ongoing technological advances. According to (Vilutiene et al., 2019), the use of Building Information Modelling throughout the entire spectrum of the AECO industry has transcended to the structural engineering roles to enhance their pattern of operation over the years, as shown in Figure 5 below.

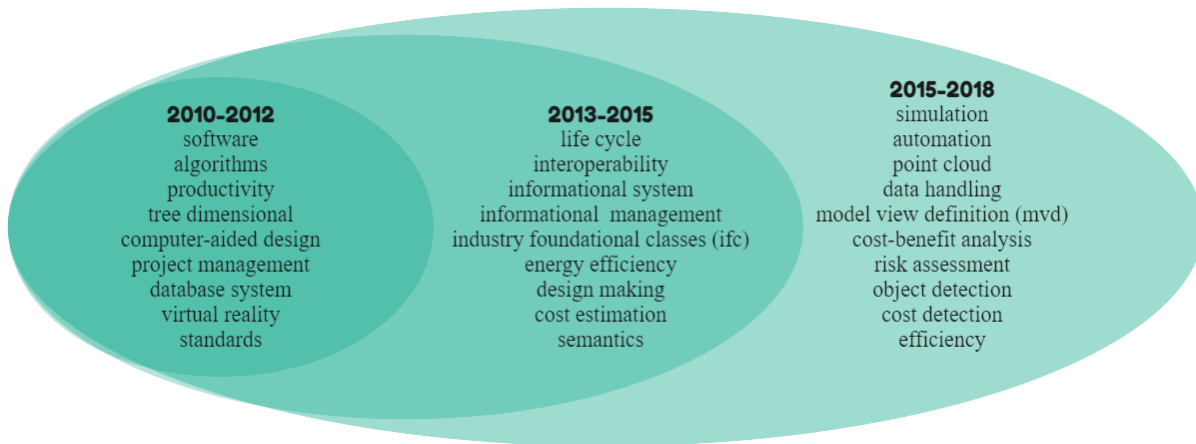


Figure 6: Evolvement direction of BIM in structural engineering

In addition, these recent developments in BIM adoption by the structural engineering profession through the creation of enabling policies are being followed by a shift in the need for information management, interoperability with other systems and tools, automated decision-making, and finally, process automation is driven by extensive data analytics and simulation adoption (Vilutiene et al., 2019a).

3.6 Between 2020 to 2030

In the following literature review section, an overview of the current perception of these roles will be achieved, which will help us create an entirely conceived outlook of the selected roles based on some themes. It would include the drivers and trends, alongside corresponding changes that this digitalization and sustainability-based roles have experienced. The literature information would be succinctly highlighted and presented as connected to the roles that are being investigated.

3.6.1 Drivers of change and trends

Trends of the current decade, according to (Alaloul et al., 2020), are influenced mainly by digitalization and automation, and they will lead the industry into the fourth industrial revolution in the bid to achieve working more efficiently, ensuring routine tasks are easily performed to streamline the entire designing and design review processes. Thus, technologies such as BIM, the IoT, AI, and robotics can be integrated into the construction industry to improve efficiency by streamlining work processes and employing the automation of routine tasks to enhance productivity and bolster safety strategies and solutions (Alaloul et

al., 2020). Nevertheless, according to Forcael et al., (2020), challenges like lack of awareness, resistance to change and limited resources will often have to be dealt with during these transformations. However, the stakeholder can implement the technologies more efficiently through collaboration and interdisciplinary approaches.

During the last few years, circularity has gained more attention and is developing into a new trend. The study by Owojori et al., (2021) shows a significant growth of interest in circularity as a concept in the AECO industry in 2019. Besides the benefits in the environmental aspect, implementing a circular economy will also bring benefits in social and economic aspects. According to Anastasiades et al., (2021), the research on the direct reuse of construction components that focuses on strategies for designing buildings for disassembly in the end-of-life stage is of particular importance because it can ease the environmental impact of the construction industry. The recently published ISO 20887, (2020) also advocated designing buildings for disassembly and using standard-sized components. However, to the authors' knowledge, the role of standardization in this process remains unexplored. Therefore, in this paper, the evolution of standardization is studied to identify the drivers for standardization and currently available standards that aid and support ISO 20887.

The study conducted by Anastasiades et al., 2021) concluded that most criteria are introduced from a fiscal rather than an environmental point of view. In addition, ISO 20887 seems to be the first standard for reusing building components. Through an integrative conversation of the available types of construction standards, the problem areas obstructing the required further standardization are identified: protectionism of contractors who perceive standardization as a threat, protectionism of manufacturers who are reluctant to change the organization structure, and designers who seem least aware of the requirement to implement the circular economy in the construction sector.

In the strive towards facilitating the SDGs and fulfilling the UN 2030 agenda, according to Di Vaio et al., (2023), there is a need to quantify and ensure accountability in practice accurately. It can be achieved through an in-depth revision of what the circular economy principles should entail while transitioning towards it as a long-term perspective. In his words:

"The circular economy's maximum capability and advantages must be re-designed under circular economic model development processes, an excellent situation to support working environments and motivations in the face of augmented demand and natural capital. Material progression management or new business models in product design are not particularly extensive and come under tactics for large-scale resource-saving."

Further findings from the report align with that of (Jabbour et al., 2019), who opined that by 2030, the European GDP could rise by 11% if the CE principles extend to various economic and industrial sectors. In addition, while CE poses opportunities for conserving and preserving the earth's resources, actors like the contractors need to take advantage of their current technical competence and opportunities at their disposal (Valdani et al., 2021). It must be done independent of external forces, for instance, by undertaking the challenge of reusing components or recycling materials in current or pilot projects to explore this knowledge area.

According to Munaro et al., (2020), the construction industry required needs business models that are focused on avenues of deepening or increasing the residual value of materials construction materials. Especially since these circular business models have prospects that would aid improved integration of stakeholders within the construction industry's value chain. Government-supporting incentives, subsidies,

laws, and tax regulations must be established to bolster decision-maker's performance towards introducing circularity principles. It would promote the development of buildings and a more sustainable built environment.

3.6.2 Transition due to Digitalization

Despite the constant planning, the construction business finds it extremely difficult or uncertain when making accurate predictions for changes and expectations over the next two to five years. However, even though numerous significant technologies are developing, current tendencies toward sustainability continue to alter simultaneously: how people operate. While some are more focused on completing a particular task, others that are revolutionary could become disruptive. Nonetheless, the goal remains that these technologies are adopted across the industry to solve daily tasks.

New roles will emerge while digitalization and industrial transformation are experienced within construction. Adopting various digital platforms, systems, and technologies will cause many changes. Some core technologies that are continuously being highlighted based on their relevance, rapid growth in awareness, and importance include sensors, IoT, automation and robotics, 3D scanning and printing, drones and other unmanned aerial vehicles, VR and AR, AI, digital twins, and digital construction platforms (Bosch-Sijtsema et al., 2021). Others also include digital logbooks, digital registries of property (cadastre), digital permit systems, and other public digital requirements or standards used in procurement (European Commission, 2020). Although all those technologies are not equally implemented in the construction industry, many have enormous potential to make a significant output.

For example, 2022 garnered much attention to AI and its possibilities. Several AI services in different fields have been realized, which showed how AI could be used across other industries. According to (Pan & Zhang, 2021), AI in construction engineering and management (CEM) can create more reliable, automated, self-modifying, time-saving, and cost-effective processes. The article highlights three primary functions of AI in CEM: modelling and pattern detection, prediction, and optimization. AI can be used to develop models that help with complex problem-solving, automate decision-making, detect patterns, and predict outcomes. Additionally, AI can optimize project operations by considering numerous factors and interrelationships (Pan & Zhang, 2021). The practical value of these research topics lies in addressing the challenges of implementing digital technologies within CEM, especially in terms of the uniqueness, labour-intensiveness, dynamics, complexity, and uncertainty of its potential.

Furthermore, (Yin et al., 2019) had the notion that although BIM might be one of the most used tools in design planning today, many projects still do not use BIM to its full potential as a management tool. Therefore, the implementation of BIM in the construction sector will continue and become more complex over time. High interest in AI technology might combine BIM with AI for more intelligent construction management throughout the project lifecycle. BIM provides a real-time platform for collecting, sharing, and analysing data, while AI enables complex problem-solving and intelligent decision-making with fewer errors and higher efficiency. However, the status of the integration is still at an early stage, and there is a need for supplementary research to explore the potential of the hybrid framework based on BIM and AI (Pan & Zhang, 2022; Yin et al., 2019).

Besides integration with AI, BIM can be integrated with VR and AR regularly. Such companies as “XYZ REALITY,” “GAMMA AR,” and many others provide AR solutions for the construction industry in real-time (Gamma AR, n.d.; XYZ, 2023). AR is mainly used as a tool that simplifies inspections. With it, the inspector can easily see the differences in construction and designed BIM models, report them, suggest a

change, and see the coming installation processes. Site managers mainly use this technology, and it is changing their way of working (Sadhu et al., 2023).

Moreover, BIM developers are needed to ensure the software will work as it should. Creating cloud BIM-based data for integration with VR, AR, and GIS for OSC processes can be challenging (Yin et al., 2019). However, future demands are going towards digitalization and making a digital ecosystem consisting of all data about building performance. Furthermore, there is potential for developing “smart houses” that can be connected to create “Smart cities” in a more extensive ecosystem for more efficient management (Goyal et al., 2020).

Integration of technologies into the construction industry depends on a wide range of factors that have kept it to a slow but progressive start. These include the constraint of different inter and intra-organizational and cultural factors in the industry, not just a mere transparent dependence on time for adopting these advancing innovations (Shojai & Burgess, 2022; Susanne et al., 2012). Alongside other past research, decades of experience and exposure to the industrial revolution have proven that the industry’s progress would not be curbed, especially with the pace at which modern technologies continue to advance. The only challenge would be combining these units into one functional ecosystem. According to (Forcael et al., 2020), BIM works as a bridge between modern technologies; it could be the one software that will serve as the basis for different technologies to interact. Inclusively spanning from those working with cloud storage to GIS users, it could be the one tool to interlink them all.

In addition, in research carried out by (Disney et al., 2022), the unique influence of enabling digital technologies for increased innovation is said to disrupt the traditional work system. These innovations are driven towards enhanced communication, cloud computing, and user-friendly digital viewing systems with BIM. In that research, this disruption inevitably resulted in a shift of critical players’ responsibilities and relationships within the design and management teams. It was characterized by a shift in the contractor’s business mode, higher expectations of design accuracy with BIM, and even cost calculations. The shifts experienced appeared to be minute, but they challenged the pattern and traditional logic of project delivery (Disney et al., 2022). This practical adoption of full digital technologies, the Total BIM concept, was employed in the Celsius project.

A more significant focus on environmental aspects in the construction industry is evident. Different methods and ways of thinking are already implemented and used during the design phase. However, the Building Sustainability Assessment (BSA) integration is not yet established (Carvalho et al., 2020). The research resulted from a higher interest in sustainability management, where BIM can significantly contribute to building sustainability assessment. However, it identified some limitations and challenges in standardization, interoperability issues, and the lack of expertise. According to (Kuzminykh, 2022), new aspects such as circularity have started to become a trend in the construction industry, resulting in new planning and management methods. Significantly enhanced by BIM, it is increasingly becoming easier to integrate circularity into the construction industry, even from the design phase. The methodology involves creating digital information for each material according to circularity characteristics. With that, a digital database will be created, allowing stakeholders to track the circularity performance of the materials (Kuzminykh, 2022).

3.6.3 Transitions due to Sustainability Drives

According to (Lind et al., 2016), whenever sustainability (or Sustainable Development) is discussed today, it seems to appear to have become a construed policy (-ies) as a multifaceted notion, integrating the ecological/environmental, economic, and social dimensions as the most widely appreciated and assessed.

From the economic perspective, sustainable development is about attaining (at least) an agreeable state of livelihood - a safe and equitable space – for all within the planet's ecological limits. The concern for the "environmental scape" is to encourage continued developmental activities that do not endanger the stocks of natural resources, species, and ecosystems (Lind et al., 2016).

The resolution to reduce the building's environmental impact significantly contributed to the sustainable construction pursuit. Several tools, including the BIM and LCA assessment tools, have promoted this endeavour, especially in construction, by improving efficiency in using and consuming materials (Xue et al., 2021a). The research further identified the key drivers of pursuing sustainable building design, the recent challenges, and best practices for future adoption.

Circularity or circular economy (owing its background to industrial ecology) is rapidly emerging as a political and economic proposition for global developmental goals away from the linear economy (Ogunleye et al., 2022). However, there still exist several gaps in knowledge of how to hasten its adoption, especially in the construction industry (Osobajo et al., 2022). Although the entire perspective of its potential is barely explored, if combined with BIM-based LCA, it would enhance the comprehensive assessment of entire buildings for reusing, recycling, refurbishing, and deconstruction of building materials and elements (Xue et al., 2021b). There is currently little research on circular economy effects in areas like supply chain integration, building designs, policy, energy efficiency, land use, offsite manufacturing, cost reduction, and management of the whole life assessment with oversight on cost, risk, health, and safety. However, there has been extensive growth in research on resource use and waste management in the construction industry (Osobajo et al., 2022).

According to (Yang et al., 2022), implementing circular economy strategies across all sectors strongly aligns towards reducing carbon emissions to about 45% in 2030 and absolute zero by 2050. It has created a unique need to reduce the reliance on non-renewable energy sources, resulting in adverse climatic conditions being experienced and pollution to the environment. In addition, Circular economy (CE) policies can establish eco-waste management systems that optimize the efficiency of the ecosystem, minimize the use of resources, and deter degradation of the natural environment, thereby lessening the constraints each country faces (Yang et al., 2022). According to Osobajo et al. (2022), there is a need to establish a solid knowledge bank about circularity to establish the best practices or methods of adoption. It would help to unravel the areas that could be focused on for further research.

The Sustainability drives would be incomplete without assessing the social aspect and efforts being made. Over the years has developed to be recognized as CSR, or corporate social responsibility, which has been hailed as a potential solution to the problems caused by globalization that impede the attainment of sustainable development (Herrmann K., 2004). CSR addresses issues like financial imbalances, environmental degradation, and unfair labour practices, all inherent to globalization. CSR continues to emerge as a viable remedy for the inadequacies of national policies, global agreements, and corporate activities to ensure sustainable development is a reality even in construction projects (AL Mahmoud & Doloi, 2015).

3.6.4 Transition and roles affected.

Recently, there seems to be an emerging awareness and demand for new competencies in the construction industry. According to the article by Westerström, n.d., there is now a need for a new breed of engineer, trained with a thorough understanding of industrial, architectural design, and construction processes to bridge the resulting gap today, especially with the increasing and technologically driven construction

industry. For instance, the new requirements in Sweden address necessary competencies, academic training, curriculum, and industrial training. This ongoing transition led Lulea University to create a new academic path and curriculum of Industrial architecture to adapt to the industrial transformation and growing technological demand in the industry (Westerström, n.d.).

3.6.4.1 Sustainability-based roles

According to (Gluch & Månsson, 2021b), the role of professionals has been initially singularly to uphold the environmental sustainability ambition within the construction industry, a challenge they have undertaken solely before being regarded now as sustainability professionals, with a broader perspective requiring interaction with other experts in closely related areas. Their life stories and experiences in that study show their practice background stemming from environmental management, starting 20 years back and transcending broadly into sustainability. They are integral to the construction industry's project-based nature in collaborative project delivery with other professions (Gluch & Månsson, 2021b). With this increased extension of their role complexity from various contexts, attempt to redefine how the sustainability manager's role is being construed to determine their unique complexity, relating to the development of the role itself and the embedded business strategy.

One of the concluding contributions for future research by (Gluch & Månsson 2021b) is that it would be an excellent standpoint to determine how sustainability professionals would further develop as their scope extends into various contexts. The three basic tiers of sustainability definition—in addition to this, going by a recent attempt to define how the sustainability manager's role is construed. The unique complexity of this role was evident, as it was streamlined only to the business strategy and not the development of the role itself (Borglund et al., 2023).

The sustainability expert's effectiveness heavily depends on how much collaboration or value co-creation they could facilitate sustainability solutions adoption within and outside their firms (Arnold, 2017). It created a collaborative structure for assessing stakeholder influence and societal obligations in construction projects. They were intended to assist stakeholders in identifying their roles in various challenges and to enable collaborative actions by clarifying their obligations to address the challenges of ambiguous responsibility typical within construction undertakings (Lin et al., 2018). In the same year, for instance, Corporate Social Responsibility became vital to sustainable development in the UK and Europe (Elgergeni et al., 2018).

According to (Mariani et al., 2022), this collaborative framework is evident for achieving the SDGs in the significant European Union context. The research findings were purposed to assist sustainability practitioners and policymakers in the public and non-profit sectors to recognize and take advantage of new opportunities for value creation through collaborative innovation. As well as to better design current and future collaborative efforts aimed at sustainable goals, thereby advancing the implementation of Agenda 2030 (Mariani et al., 2022).

3.6.4.2 Structural Engineer

According to (Debney, 2020), there remains uncertainty on how the industry disruption is set to influence the vital role of the structural engineer. The technical ability and training of the structural engineer remain undeniably invaluable despite growing trends that depicts changes across the industry, like the automation of routine analysis and design tasks, the elimination of paper-based documentation, and the increase in competition from other consulting business. In addition to this, there has been an increasing need for more soft skills on all fronts for current young engineers to have the impetus to continue to upskill themselves to

meet multifarious demands that continue to emerge, technologies that continue to be invented, and problems that continue to evolve (Debney, 2020).

Furthermore, according to the predictions made in the earlier decade about the future of the structural engineer, now it can be seen vividly how the expected changes are coming to life and consider what more the future holds for this vital aspect of engineering (SEI, 2013). For example, the demand for a higher level of collaboration is partly driven by technology and modeling software for material selection and detailing instead of traditional workshop drawings that enhance the prefabrication process. The lingering question remains how adopting advancing technologies could infer a possible increase in commercialization, flexibility, and diversification for the structural, with the aid of Artificial intelligence. According to (SEI, 2013), current trends are observing structural engineers embracing the ongoing change dynamics and diversifying to focus on more specific areas like the façade design, cable-supported structures, and prefabricated modular components.

Additionally, there is an increase in the implementation of one core aspect of technology that seems to have created different opportunities for the structural engineering practice (Thai, 2022). It involves training computing systems toward predictive decision-making while maximizing their processing power for resolving complex systems and numerical computations, commonly called Machine Learning. The computing system's concepts, libraries, and open-source Python (programming language) codes are being increasingly adapted to create the structural engineering database. The focus of these intentions is being driven towards the adoption of this innovation within broad areas of application, including structural health monitoring and damage detection, structures resilience to fire hazards, load resistance, reliability, and deformation of structures, material (concrete) mix design (Thai, 2022).

On the other hand, the construction industry is adopting the triple bottom line model, which expresses sustainability thinking. This model encourages the planning, use, and relocation of structures and the demand or needs for methodologies illustrating the life cycle of structures. In particular, regarding the planning, design, material selection, and assessment of structures. It promotes planning for the use and relocation of structures and the desire for or requirement for methods that illustrate the life cycle of structures within the planning, design, material use, and evaluation of structures (Kc & Gautam, 2021). The research indicates that new methods of planning, design, material use, and sustainability assessment techniques are emerging and evolving rapidly. However, there is still a gap in these tools, showing the absence of a thorough or concise strategy that considers structures' combined resilience and sustainability throughout their existence. The integration of structural resilience (against hazards) and sustainability are crucial for the structural engineer of the current day and has been a popular subject of research in the discipline. (Kc & Gautam, 2021).

(Vilutiene et al., 2019b)'s extensive review of BIM-related publications discovered that the application of this tool for structural engineering has been growing consistently since 2014. Although most applications have been towards information management, more must be done to see how it could be employed in technical decision-making. It is possible by employing multifarious IT-enabled tools and systems, including cloud computing, scanning using laser, visualization, and simulation methods or platforms, for facilitating an automated construction process in the future (Oraee et al., 2022).

3.7 Comment

During the literature review, quite a few publications regarding future role development were found where the recent research works have focused on modern technologies or trends, and how they might influence industry. There was limited information or documentation regarding the resulting changes in existing or

changing professional roles in the construction industry and how it has possibly resulted in the emergence of new ones. Including the demands of new competencies in the construction industry at large. It poses a further challenge and gap from the literature review, while this research addresses what the future holds for the spectrum of roles considered.

4 Empirical result

As a part of the study, the interview has been conducted with professionals in the Swedish construction industry, mainly in our partner company, which plays a significant role in the country. They have also been selected based on their varied years of experience and exposure to responsibilities in digitalization-based, sustainability-based, and structural engineering roles. The following section will present the collected results based only on the information provided by the interviewees. In total, 24 people have been contacted by several large construction companies in Sweden, of which 17 answered and agreed to be interviewed. Out of 17 interviews, ten were performed in person, and the remaining seven were conducted digitally with an average duration between 35 to 50 min per person.

Therefore, to a broader perspective and information in our empirical research, relevant professionals were chosen to cover distinct aspects of similar roles and have different experiences of working in the construction industry. All conducted interview was transcribed and analysed. Based on the analysis of the gathered information will present different drivers, trends, changes, and future perspectives of the studied roles. The results will be presented separately for the roles with respective drivers, trends, changes, and future development of each role. However, combining all results by the respondents, today's primary goals are to be more *efficient*, *data-informed*, and *sustainable*. The last part of the empirical results will present connections and relations between the roles and their impact on each other. Table 1 presents the positions of all interviewed people with correspondent experience in the construction industry.

	Name	Position	Experience
Digitalization Based roles	Respondent 1 (R1)	VDC Manager	5 years
	Respondent 2 (R2)	VDC Specialist	12 years
	Respondent 3 (R3)	Development Manager	16 years
	Respondent 4 (R4)	VDC Specialist	13 years
	Respondent 5 (R5)	VDC Specialist	8 years
	Respondent 6 (R6)	Development Manager	32 years
	Respondent 7 (R7)	VDC Manager	1,5 years
Sustainability Experts roles	Respondent 8 (R8)	Innovation Manager	17 years
	Respondent 9 (R9)	Sustainability Manager	9 years
	Respondent 10 (R10)	Sustainability Manager	8 years
	Respondent 11 (R11)	Sustainability Manager	22 years
	Respondent 12 (R12)	Sustainability Specialist	9 years
Structural Engineers roles	Respondent 13 (R13)	Design Engineer	1 year
	Respondent 14 (R14)	Structural Engineer	8 years
	Respondent 15 (R15)	Design Engineer	22 years
	Respondent 16 (R16)	Construction Engineer	17 years
	Respondent 17 (R17)	Concrete Specialist	18 years

Table 1: Showing interviewed respondents with respective positions and role.

4.1 Digitalization-based roles

The following section will present the result of the interview carried out with digitalization-based roles. In total, it was seven people interviewed from two companies. Experience and the respondent's position vary greatly, providing a broad view of the studied area.

4.1.1 Drivers

According to the respondents, several drivers have always been during that time. Back in the 80s and 90s, the use of 2D software was connected to the effectiveness of the design process. R6 says that *“the driver, in the beginning, was probably to make the design process more efficient instead of making all the adjustments with a paper and a pen.”* However, as R6 also pointed out, there were also demands for using the 3D visualization:

“I know that when they built the oil rigs in Norway in the 80s and 90s, they had to do this three-dimensional. So, they developed software because it was impossible to ensure that the reinforcements they are getting would fit in.”

Furthermore, at the beginning of the 21st century, as several respondents pointed out, there was no clear understanding of the benefits of BIM except 3D visualization; therefore, many companies used 3D technology as a visualization tool. With time benefits of using the model were defined by the R6 as follows: *“To be more efficient within our processes have been the drivers before.”* R6 also pointed out that a complete understanding of using the model came when *“we saved by them 12,000 Swedish crowns per collision”*. After seeing the value of the money saved, the future development of the technology was targeted. Using the 3D model and checking it for collisions has become more practical and common among new projects. Above all, R6 said the following:

“And then when we learned that, OK, what if we add more information to this, we could do smarter analysis like energy. If we had this U-value of walls, we could do automated calculations and see whether this would fit.”

Additionally, R4 added another driver for BIM and 3D visualization. R4 argues that it is helping to achieve a mutual understanding of the project *“The driver is that people can understand it. It is like they can almost feel it.”* The first step of a model is the visual part that everyone agrees on, and the second part is the information that needs to be included in the model. In addition, R4 says that it is more straightforward if *“communication is not based on language. Pictures are easier to understand.”* The construction of the building shifted more towards solving all aspects and possible issues during the design phase or, as R6 explained, *“To know what we're going to build before we do it.”*

Regarding today's drivers, the answers from the correspondents were similar and corresponded to the goals mentioned above to be more *efficient, data-informed, and sustainable*. One of the main drivers of the AECO industry is the *demands* from clients, regulations made by the EU, Sweden, and the company itself. As R1 says, clients have many demands that need to be fulfilled related to environmental aspects, collected data, and efficiency. Demands from municipalities are connected to the environment, durability, security, and other aspects that must be fulfilled. On the company level, though, R1 and R3 pointed out that demands are to be competitive in digital data, information, and in processes. Another driver is the environmental aspects that come as the requirements from clients, municipalities, and the company's ambition. Objectives are based on collecting data about LCA, CO2 water, energy, etcetera, and data from an early stage of involvement in the project. As R6 said, *“Sustainability reporting is now a driver.”* Moreover, an exciting

aspect mentioned by R6 is that implementation of the Corporate Sustainability Reporting Directive (CSRD) drives all three goals, arguing about new requirements and needed data for the reports until 2024. Further, R6 added the following, pointing out the consequences if companies are not ready for this change:

“I don't think that so many of the companies in the construction business have realized what the new demands are.”

The most significant aspect many mentioned in one way or another is that *“information is a driver today.”* Talking about the efficiency of the processes for business development and shared understanding of the data from previous projects, information needs to be collected and structured. Mentioning data R6 said the following:

“A year ago, I would say that the driver is to be more data-informed, have the information, and be able to learn from each other and to be able to compare within the company.”

Additionally, R6 added that the collected data could be used for many purposes. Many others agreed that using the data in further projects will increase the efficiency of the projects in many aspects, such as time, money, and quality. R5 believes that a big focus was put on *“getting control of all our information and seeing it as an asset”* to get the value of the data during the design phase. Moreover, according to R6, the question that always was in mind is, *“How do we create the design process more efficiently with fewer errors in the design process for people constructing construction later on?”*. The solution from several respondents was to find a balance and not put all information into the model but use the BIM as a source of information. Pointing out the weight of the efficiency and development, R3 said, *“If we just sit still, we will be out of business.”*

4.1.2 Trends

As a result of drivers, trends correspond to the goals and drivers. Asking respondents were asked about different trends connected to digitalization roles in the past, and many agreed that development of it was going slowly. It started with a raised interest in 3D visualization and developed into the BIM with clash detections. R2 mentioned that they first needed to ask if the project wanted help with BIM, and after some years, they came themselves. During those years, understanding the benefits led to a long-term BIM trend, and R6 acknowledges that *“customers have asked for more and more digital information.”* When working in BIM became a standard, the so-called BIM trend shifted lately to collecting and using the collected data. Several respondents agreed that today's big trend concerns the need for data or information. Having a standardized approach for data collection and management would serve a great deal of usefulness for such integral themes as collaboration, circularity, etcetera.

Concerning the trends, respondents often mentioned other digital technologies such as AI, digital twins, and many others. Every respondent agreed and mentioned today's AI trend. Interest in it is growing, and use of it as well. Interest in digital twins, though, has been in the industry for a while, but with the new demand for data for everything, it got more attention. However, R4 and R5 said that digital twins would be a part of every project in the future and that implementation of it *“will be solved by itself if the industry will do what they do.”* It was also mentioned several times that digital twins would correspond a lot towards sustainability, which is a trend. Using a digital twin simplifies many calculations needed for different certificates and contributes even more to the new trend in circularity.

4.1.3 Changes

Changes were a response to different trends, demands, and drivers. Respondents mentioned several changes that they remembered related to the digitalization roles. The first ever was the use of CAD in 1989, which went smoothly into three dimensions, used mainly by architects, but even though R6 remembers that *“We draw the reinforcements in the concrete three dimensional before 2000. This was before Windows..”* Later, the popularization of BIM in 2005 R6 describes how 3D drawing used by architects and engineers was focused on creating the design phase more efficiently. Together with a higher interest in the BIM, a VDC position was created in 2010, although R5 complains that the *“role should be to support others to do the same thing they do now in a new way”* while instead, VDC’s main task is clash control and responsibility of the model. Since information on time, cost, energy, sound, and much more was added to the model, many pointed out that the big challenge was the employees' lack of knowledge and education needed to be dealt with. Even though the technology is not new, the problem remains even today. R7 says the following:

“People now realize that you can save money by having a good BIM model and extracting information from there instead of doing it the old-fashioned way.”

According to R6, there is another aspect that has changed is sustainability; before, the company was the one that was pushing sustainability, and now it shifted to the other side when the regulations pull the company. Furthermore, specifying changes in the sustainable aspect, R6 says that *“it shifted from wanting to be more sustainable to now having it so.”* Together with sustainability, the way of working has changed. All processes have been connected, simplifying the calculation, purchasing, extracting the information, and accessibility. The changed way of working happened on the collaboration level as well. Nowadays, a company creating its library of different models and data has changed its thinking. As R3 claims, *“It’s not the company’s specific information that is important, it’s the industry’s,”* pointing out the importance of sharing the information for efficiency and everyone’s benefits.

4.1.4 Future

The respondent's most challenging part is foreseeing and predicting the future development of the roles and the industry. However, several significant aspects have been defined. Emerge of the *data-driven goal*, *new software*, and *technology*, more minor aspects such as *collaboration*, and *change in processes* together with *new roles* have been the main topics.

4.1.4.1 Data

Other significant future aspects are connected to the company’s development and goals. The vision of compiling process information to a unified database is connected to achieving more efficient operation in subsequent project stages if this has been well utilized during the design phases. It provides structure to save and make data accessible for companies to implement construction information management (CIM) strategies for making immediate savings in time and cost while improving efficiency in the production process. It is envisaged that the data collected will be sourced from all types of current and past projects, across all phases of the projects, including data from the model (2D to 4D) used by the various professionals engaged in the projects. Although achieving this poses a herculean task for the industry, several respondents admitted it is possible, especially with the big trend in data and embedded business opportunities they have seen. In short, *“data is information that gives advantages,”* said R5.

4.1.4.2 *New software and technology*

Likewise, data, new software, and modern technologies will be developed, as mentioned in R5. Respondent R3, who is working tight with the software, complains about its complexity and insists that new software should include more database options. One example that is needed is “*An object without a visual representation,*” mentioned by R5. Designers want to add details like screws, bolts, lock cylinders, and other intricate details without visualizing them. All those details help to calculate more accurate prices, costs, impacts, and quantities. Regarding the future model, R4 said the following:

“Design should be exactly as the building we're going to build, and it should be a digital twin.”

Besides emerge of new software, respondents mention an increase in modern technology used in the ACEO industry. Technology that was mentioned the most is AI and machine learning. Many respondents are sure AI will be widely used and help with various aspects. It just needs to be learned to do the right things. They are also sure that AI will positively affect such tasks as design solutions, calculation, sustainability, tenders, and sensors analysis which is another growing trend. R7, together with R5, points out the slow implementation of the technology into some roles, that AI will be helping in the beginning just a bit and slowly take increased tasks upon its virtual shoulders. First, AI can be an assistant or later used for solution suggestions. R6 emphasized that no one knows when AI will come and how fast it will take us to adopt it. The challenge and hindrance to its application is the lack of knowledge, awareness, or understanding of how it could be explored, especially since many experienced professionals do not want to lose control or oversight of their traditional way of working or the position of responsibility occupied.

“They cannot always now see the value of what we are doing; they have to start. Start, and then they will figure it out. OK, this gives me some value. Maybe I can do this, this, and also this.”

R5 insists that AI is a ground-breaking technology that will simplify for older employees to accept AI. Thanks to the ability to ask/talk/send a request to AI with specific questions and get a wide-open answer or a hint, likewise, chat GPT from OpenAI. Moreover, some younger employees in the company are using several AI tools for small tasks.

The early-mentioned sensor trend is the second most popular answer regarding innovative technology. The digital twin will be connected with multiple sensors here and there for gathering and analysing many different building parameters. The goal is to collect the information from the sensors into some data that can be useful for future projects and maintenance. R5 specified that “*There is money to be made in the area of sensors*” and later added that the company researched how much it will cost to add sensors and how beneficial it is for its revenue. The difference was 1 to 10.

The respondent also mentioned innovations such as robotics, AR, and VR but in a smaller scope. Many are already using those technologies in distinct phases of the project. Some robots are used for scanning and drilling holes, and some adopt VR for planning and presentation or use AR in production. The respondents described many ways of slowly using or implementing modern technologies. However, everyone agreed that new tools would eventually be part of the roles.

4.1.4.3 *Collaboration and change in processes*

A big challenge that many are working with is collaboration within the industry. Many respondents complain about insufficient collaboration on a digital level due to different models, names, parameters, and

much more. R2 talked a lot about the need to be more open between companies and standardization of the information between companies. As a suggestion, R2 suggested that every product's name can be standardized based on the Global Trade Index number (GTIN). Arguing for standardization and more collaboration, R6 said the following:

“With other companies, we can invent our way of doing it internally. But since 70% of what we do on all construction projects is happening in other companies, not our own, we have suppliers and subcontractors, and we need their information digitally.”

All those steps are beneficial for everyone and have a significant impact during the design phases. Better collaborations together with modern technologies will also change some processes. R4 believes that prefabrication will increase its impact and be applied not only on the structural part but also will include prefabrication of the pipes, ventilation, electrical channel, and many other parts of the building. R4 see future construction as assembling the prefabricated pieces and drawing a parallel with LEGO. Automation, machine learning, and AI involvement can increase productivity and efficiency. R4 said that one man could do a ten men's job due to database digitalization further added R4 that it would be possible for small companies to challenge large companies in productivity and quality. The same applies to the environmental aspects. All respondents noted that demands for sustainable building are rising, and companies that will be prepared for future CSRD regulations will have an advantage.

4.1.4.4 New roles

Discussing the emerging (maybe new or a modification of existing responsibilities) roles is connected to the information provided obtained so far from the literature and empirical data above. Many respondents pointed out the need for new expertise for handling the collection and analysis of data alongside a comprehensive understanding of the construction processes.

R6 mentioned that they have attempted to employ some data analysts without a building engineer background, but it did not work out. Additionally, R6 said, *“We have started to look at data analysts to employ them. We have a couple employed already, but we will employ more.”* While the design manager will add data to the model, another needed role will be a data manager who will take care of structuring coming and existing data.

Focusing on the existing roles, everyone agreed that most of them would be changed in one way or another. The current role of VDC manager was mentioned many times as a role that can be automated. R1 and R7 agreed that such responsibilities as clash detection, data extraction, and drawing can be automated. That design manager might take on the VDC manager's responsibilities, while VDC will be less about virtual design and more about information management. The VDC role can automate tasks such as price estimation, calculation, and quantity take-off. Talking about cost estimators, the example that R5 gave is the following:

“9 of the ten projects, 80% of the items are the same means that it can be automated. The cost estimator role will change to analysing, and we no longer need that many. The goal is to connect the design to the pricelist so the price can appear automatically without calculating it manually. For that, we need to build and structure the database.”

Talking to R6, other roles that are not related to the model were mentioned. The automatization will affect the LCA and CO2 calculators, even HR and finance responsibilities. He added the following:

“We will probably have fewer administrators, and we will have fewer people working with HR, we will have fewer people working with finance. We will have fewer people working with tender engineers and so. We will more or less use the data to be more efficient in our job.”

Not every respondent was talking about some specific roles that would lose their value, although everyone agreed that many roles would be changed. Alongside the shift, many pointed out that roles and responsibilities might be automated, but most people will stay in the company and have other responsibilities. For example, R6 acknowledges the following:

“Today, we have people working with sustainability reporting in our projects. They will be out of work in a couple of years. The people who work with this would probably work with us in the future but with other things.”

Due to the natural shift towards data-based processes, responsibilities will be less manual. Focusing on future responsibilities, R5 insists on the following:

“It will be more focused on the stuff that makes a difference, analysing if this is right or wrong; what about if we choose this option instead, and you just drag and drop different stuff in and say, OK, this will cost this much instead..”

The vision that R6 has is that with the same amount of people, the company will be able to build more. Although most people will stay with the company, R6 admits that some might leave due to the challenges with the employees' education and the employees' unwillingness to change old habits. He comments as follows:

“We will probably lose 20% because they cannot continue to work for us. They will have to work for someone else. Because we must fulfil the legislation, we must continue to digitalize. We must be more efficient; if we cannot adapt, we will be out of work.”

Even though changes are unpreventable, many respondents specify that changes will not happen rapidly. The company is not there today, and automatization will happen step by step. An interesting comment given by one of the respondents, R2, said, *“I will work for not having a job,”* referring to the automation of responsibilities within the roles.

4.2 Sustainability-based roles

Interviews with experts and practitioners, whose primary roles in the construction industry have focused on sustainability, provide an elevated level of insight to answer poised questions towards determining how their role has transcended over time from their lens and what is to be expected soon. Out of their wealth of experience over the past decades in taking responsibility for solving sustainability questions in the Swedish construction industry. Admittedly, of the Six (6) professionals interviewed from two leading companies in Sweden, they have all had their competencies and professional roles developed over the years. Considering their range of experience spanning about three decades in combination, they have been invested in solving problems through responsible positions centred on innovative research, environment, and sustainability.

Although all the respondents acknowledge that the construction industry has the long-term goal of earning the recognition of being sustainable, it is pursuing this on several fronts through several subgoals and

targets. These futuristic targets exist at different organizational levels, including the industry, company, or project levels, and could be timebound or project based. The goals included increasing focus on the most innovative and cost-effective way of achieving climate neutrality and biodiversity and assessing chemical contents during material selections. One of the R8 clearly stated:

“...climate mitigation for most intents and purposes is the most important goal... achieving like net zero (0) emissions. The goal has not changed, but the understanding of the urgency. If you look at the road map for the Swedish construction industry in detail, it used to be that some of these goals were far off and not engaging people. Now most companies and countries have goals set for 2030, which is quite soon.”

Furthermore, the comprehensive information about how vital paths towards achieving these goals have been diffused across all industries, including the Swedish construction industry. The subsequent discussion is based on the respondents' (in sustainability-based roles) witness reports in their professional journey over the past few decades. Thus, detailed information on the drivers' perceptions, trends, and changes they have experienced so far is provided without excluding their perspective of the future.

4.2.1 Drivers

Admittedly to most respondents, there have been evident and consistent drivers in the construction industry's strive toward sustainable development targets within and outside of itself. In the response of the significant driver perceived in their roles, Global warming was the first mentioned and fundamental driver according to four (4) of the respondents in this role. The increased awareness of society in general to this challenge continues to propel all industries to take all actionable steps.

Instead of rising to the challenge posed by this most recognized driver of change, other sub-drivers have influenced the changes in their roles over the years. Following an increased awareness of this enormous challenge, administrative regulations, and legislation are being implemented to ensure new standards and ways of working are enacted to combat the challenge and preserve the future. In addition, R9 mentioned how the “*Miljöbyggnad*” standards exist in Sweden to ensure oversight of the building and property sector. According to one of the respondents, R8:

“... the drivers for the past five years have mostly been related to climate change mitigation in different ways or forms. We have customers who are realistically the ones driving change within this industry. That is one of the main drivers, and the other one is legislation. A lot of directives and regulations from the EU that work as drivers. For instance, in the past ten years, updates to standards regarding the energy performance of buildings.”

Furthermore, R16 claimed that organizational roadmaps are being implemented; “... *the construction businesses and concrete industry or organizations have their road map towards climate neutrality in 2045. Our road map also drives towards net zero 2045.*” Starting from the United European Union front to the individual companies (based on the general business profile or project-based). An illustration is the climate neutrality or zero (0) emissions target of 2045. Indeed, other drivers are strongly featured within the empirical data. R11 believed the availability of green funds or incentives could drive “*the green bonds and the ways to fund these projects by green loans*” if provided by the government for companies that achieve set standards in their projects. It has also been a compelling force for companies to engage and increase their understanding of why they need to engage.

Another insight of a driver is quite visible in Sweden provided by respondent R9, included the legal requirements of taxonomy and Corporate Social Responsibility (CSR); *“... sustainability has broadened from being a lot of environmental requirements to include the social parts as well, thanks to the taxonomy and the CSR...”*. These paradigms have gained tremendous influence as institutional ideologies for defining business culture today, to define their stance or position as active contributors to the sustainability agenda. Last but not least, as a driver is a role that digitalization plays in the execution of sustainability-based innovative ideas, according to R8, who stated, *“...main drivers will remain the same... digitalization as a driver for change and... Climate mitigation will still be the number one target...”*.

4.2.2 Trends

There have been exciting trends in sustainability roles over the past decades. Empirical data shows that these trends have resulted in varying shifts in respondents' roles and responsibilities. Significant emphasis was placed on how the initial emphasis and demands for energy efficiency in new and existing buildings have shifted toward the legal climate requirements. Respondent R9 acknowledges this, saying, *“... from the beginning looking back in buildings it was energy requirements, both from a legal opinion and our customers often harmonizing... Then you could see the shift towards more climate requirements...”* This also agrees with R11's statement; *“...comparing to what it was five years ago... in the pre-construction phase, we now do early climate calculation. to see where we have the largest impact results from the building.”*

Meanwhile, another consistent trend observed from all the respondents in their role focus on meeting global warming challenges and reducing climate impact is the circularity and reuse of materials. Respondent 12 claims that *“... major focus right now for us is the reuse of materials, especially... heavy building materials like concrete... now more focused on whole building parts”*. Respondent 10 (R10) believed; *“... circularity and the reuse of the material... is a new trend I can see in my work... To meet the challenges with global warming and to reduce the climate impact in projects.”*

An overview of the trends garnered from empirical data shows the influence of the drivers where the demand for energy efficiency remains prevalent. All the respondents agreed that the transition towards being climate neutral continues to set lofty standards for energy use and performance requirements on buildings, even on a project-wise basis. Respondent 12 (R12) reports that; *“...the knowledge about materials is increasingly important... knowing what we are building in our buildings... the technical specification and details about the material to reuse”*. Thus, the need for knowledge and know-how to achieve this continues to increase since certifications must now be provided before executing new constructions.

4.2.3 Changes

Notable changes have ensued over the years in sustainability-based roles, especially in their way of working or the expectations demanded of these professionals. One of the notable changes experienced was the increasing complexity and demand from these professionals and the need to acquire and manage substantial amounts of data. According to respondent 8 (R8) who mentioned that; *“...we work with energy, indoor climate, CO2 emissions, moisture safety, certification systems... things that will affect many other disciplines optimizing towards one specific thing, but adding more and more, it becomes complex to find optimal solutions... thus some sort of computer-aided optimization comes...”*.

According to R10, further in line with the changes above, a detailed description of all products and materials' environmental impact from suppliers is increasingly demanded use in design and to structure

procurement processes; *“...to manually talk about these climate calculations and comparisons between materials, go to the EPD (Environmental Product Declarations) and pick the environmental impact from there and calculate. That is more manual work. I hope it will be much simpler in the future.”* It is consistent with the input from R9, who opined that the EPD is the standard identifier for materials data gathering and database creation:

“I have been working in parallel with purchasing, and they have been driving the work to reach a common language and working with the standardization of material identifier... so that we will be able to, in the end, digitally collect and store data from different databases.”

In line with that, the purpose of collecting materials' data goes beyond when records must be kept, and information provided to the client side in the industry. R9 buttressed in their statement that; *“I have seen the possibilities... and the problems around data handling... you always need to have the data to make the best choice and to collect data into the logbook, for our customers during maintenance and so forth”*. On the other hand, the use of computer-aided optimization makes the sustainability-based roles more factual over time and able to put figures behind all their propositions. According to R12, *“...the big change is the LCA, the possibility to count numbers towards climate change... how we measure it?... And now, actually put numbers if we choose this material instead of this. The main change is that we have something to touch, to grasp.”*

On the other hand, there was an increased importance of the sustainability-based professional role in the industry, even from the early phases of planning and design. According to R16, *“There's more collaboration between the structural engineer and the LCA specialists to form together the proposal of how the building could be formed or built, and what materials do we use to achieve a certain level of climate impact.”* Furthermore, it serves more significant advantage in determining KPIs for core decision making in agreement with R9 *“it's always good to... find KPIs to... measure the development work that we are doing and find ways how to collect data..., use the data to draw conclusions and also make the right selections”*.

In addition, R9 also affirmed the importance of collaborative working and concerted efforts towards sustainable development goals and thinking across boards. By saying that:

“To work efficiently with sustainability, we need to have many different competencies working together and understand the goals from the beginning when you start the project... in terms of selecting the right material, construction design or production process... to be aware of the requirements and what you must optimize.”

The same respondent also mentioned how dissimilar roles have specific duties in the transition for sustainability in the industry today, saying:

“The key is not to look at sustainability as something on the side. Sustainability will be something that everyone working in the construction industry in distinct roles have their part to play within the sustainability work. It is not only the sustainability expert that works with sustainability but even the purchaser or the construction engineer. The distinct roles have their part to play in the sustainability work.”

Thus, the change section has shown how sustainability-based professional roles are continuously transformed, and the thought patterns altered for a higher inclination towards sustainability-oriented

solutions and practical adoption in the industry. Greater emphasis was placed on the key focused roles now play in an administration and the need for collaborative functions for all professionals working independently or as a team.

4.2.4 Future

According to most respondents, the future is hugely built around the current progressive work within the circularity trend through various facets. According to Respondent 10 (R10),

“...I think circularity will continue... we have been working a lot with new production, new construction, not so much as renovation. I think there will be more to rebuild or change the use of already existing buildings. Then I also think if we build new buildings, we will care more about how easier it will be to deconstruct or change the use of the building...”

Meanwhile, R9 was of the firm opinion about circularity; *“Circularity is just a way to reach different sustainability goals. It is not the goal in itself; I think it could be a way of decreasing the usage of our natural resources. For example, we need to be better at working with circularity; to reach climate goals and to decrease the use of natural resources.”*

Thus, even though we could affirm a conscious effort to reduce resource use and embrace more circularity, the challenge of whom to take responsibility for and give assurance of reusing elements remains. Consequently, adopting new materials that proffer the climate neutrality solution would garner more audience. Respondent R16 had something to say about this; *“The tempo of introducing new materials will have to increase, but construction is kind of a slow business, so there is a different discrepancy... we must be on our toes and quick to determine how can we use new kinds of materials to reduce climate impact and that is durable.”*

Furthermore, the future currently holds the prospect of handling the goal of becoming fully data informed. According to R12, *“... to reuse materials in the building, we need to know something about that material... What is this material, and how does it work? What is the technical specification? Can we use it in another building?... If we could for our models put in information, making it possible to reuse..., or achieve like the data-informed society, our industry is still behind a lot.”*

Similarly, R16 also contributed that towards this future goal, there is still work to be done; *“... we need data... to be data-informed to make good decisions but then we need to cooperate with our suppliers to get the data”. The demonstration of R11 in their sustainability-based business unit demonstrates how data-informed they aim for; “... now we have systems where we gather data from our buildings to see the energy or other statistics and automatically report it, but we want to have systems that can evaluate the data and maybe put signals back to the building... To know where the energy use can be made smarter.”*

On the other hand, R12, although consenting to continually improving systems or tools that could provide enhanced simulations to collect, evaluate, report, and optimize building energy use. The respondent still added that competence is needed in bolstering this front; *“... I just think that we haven't come to that point that we are so good at, like putting information in our models about the material that we are building in, and also like connecting it to the actual material.”*

Two respondents, R9 & R11, agreed on the critical role taxonomy would play in the future role of the sustainability-based professional. Respondent 11 opined that; *“... in the future, taxonomy is going to be*

important... the certification systems are working to align with the taxonomy, so I think it will be a large issue". While respondent 9 said:

"... the effect and the focus with taxonomy is to avoid doing optimization just towards one goal with the risks that we might decrease the possibilities to optimize in one of the other areas, for example, biodiversity and the climate as too obvious ones... the effect would be that we need to help the overall perspective so that we look from a broader perspective."

Other contributions by most of the respondents, as regards the outlook of their role and how things are expected to be in the future include. The many expectations from the respondents, including the vital aid digitalization is set to provide in enhancing the implementation of sustainability solutions. For instance, Respondent R8 has an opinion on how much artificial intelligence (AI) and algorithm-assisted optimization can help create tools, programs, and datasets.

4.3 Structural Engineers

The dire importance and consistency in both the job description of the structural engineering profession over time in the industry had made it seem as though no slight changes have been inflicted on professionals working here. Empirical data would elaborate more on this based on a collation of respondents with several years of operational experience in the Swedish Construction industry. Respondents have dynamic exposure to active research and dynamism in their current roles through other responsibilities.

An overview of the constant industrial transformation is well reflected in their understanding of the long-term goals and targets within and outside their organizations. In short, the earmarked goals that these professionals were aware of included the Zero Emission targets until 2030 and the plan to operate in a familiar, standardized, or unified way for all professionals in similar roles. Meanwhile, sustainability adoption for more effective functioning was a secondary goal in lowering carbon emissions, especially in Sweden.

Lastly, all five (5) respondents mentioned the long-term goal and expectation of achieving the interconnectedness of various systems and professionals, co-working together towards becoming a data-informed unit, and enhancing their ability to make intelligent and optimized decisions.

4.3.1 Drivers

Exciting insights into the drivers influencing changes in the structural engineering professional role were obtained through the interviews. Most importantly, concerning the Swedish construction industry, most interviewees had a singular notion of what driver they have influencing their role and the industry. R13, R14, and R17 stated that the roadmap to being fossil-free and climate neutrality is the main driving force in the construction sector.

On the one hand, R14 gave a fascinating analogy of the drivers of changes in the structural engineering role and emphasized how it could be relevant in other areas as well. In this analogy, we had carrots and sticks representing two perspectives working closely together as drivers. The carrots are the internal business incentives or requirements, and the sticks are the external requirements. According to the R14:

"The carrots are business intents or incentives to be developed as knowledge processes to handle and meet sustainability requirements. On the other hand, sticks represent the requirements that can be put on the governmental level when we talk

about sustainability. They can also be at the Client level, where clients make specific requirements concerning sustainability. These carrots and sticks must go hand in hand. Otherwise, there is no drive."

Consequently, the pattern and orientation of thoughts today in the industry are changing to be more environmentally inclined. According to one of the interviewees, the charge to lower the carbon footprint globally is also taking effect across the entire industrial sector, including the construction sector in Sweden. R15 mentioned that this had changed the construction industry to look beyond the conventional concrete and steel construction materials toward constructing with what has a lower carbon footprint. In R15's statement:

"...I can see that working with timber is more popular now because it has a lower carbon print. More students that I meet only want to focus on the timber. That knowledge has risen because more people are looking, even into more different components in the concrete, to have a lower carbon footprint."

In addition to the above opinions obtained, R17 pointed out in simple words an obvious but easily overlooked driver that has ever experienced a shift! According to the respondent, there has been a change in the driver from focusing on a reduction in cost and material use (old driver) to a new path that focuses on the reduction in labour hours (time) used to execute a process or project.

Last but not least minor driver uncovered for this professional role was introduced by R13, who believed that the setup of specialized teams to work on sustainability solutions has also influenced the structural engineer's role greatly. This driver, in agreement with R15, also heralded a few secondary goals or requirements influencing their traditional responsibilities to explore satisfying the requirement on Energy savings through several LCA (Life Cycle Assessments) methods or by utilizing modern digital technologies and tools to improve work effectiveness.

4.3.2 Trends

The following excerpts were obtained throughout interviews to determine the trends they have observed or experienced so far, according to the respondents' wealth of experience. One of the respondents, R15, had a strong opinion on how their role had developed over decades of exposure to the use of computers for working with 3D modelling, structural detailing, and automated calculations with Mathcad and other platforms towards creating new digital documentation instead of paper blueprints, folders, and fax machines or using python programs to analyse data and obtain different alternative solutions.

Exclusive of the trends in the optimization and digitization of the structural engineering role, that was an agreed phenome for all respondents. It was interesting to discover another core driver of change: an increased demand for sustainability and competence requirements to execute the responsibilities needed. In mentioning this, R14 mentioned, *"...We need to rethink this and get this competence in at the same time as we do the design because we need to base our design on the choice of material or component or what we have in the logistic system. So, this is a trend that comes with the requirement and the business Incentives."* The former seemed to be an old trend, as R15 mentioned how calculating indoor energy use and moisture became mandatory after about ten years in practice. R15 shared that, *"...we were looking at how much will the insulation thickness be according to a total energy calculation. I had worked for like 10 years when it started becoming a compulsory demand to do it. In the beginning, we did it to show that we could calculate, but it was not important what the result was."*

In addition to the drivers highlighted above, R14 shared how their role and the construction industry in Sweden are currently experiencing a push for declarations to be carried out according to the ISO standards and will be made mandatory soon. The respondent mentioned how; *“...The environmental party in Sweden is pushing for a change of procurement based on the lowest CO2. When they had the Ministry of Environment in position, they pushed this department extremely hard to introduce requirements for declarations. So now we must start declaring our constructions according to the ISO standards.”*

R15 had a contribution that affirmed this change and extra requirement or responsibility that is being made of them towards more priority respecting low CO2 contributions:

“We are now doing LCA calculations, just like when we were starting to do the energy calculations, but we do not have anything to measure it against because we're now just training to do it... ”

Furthermore, another recent trend became known while gathering empirical data. R17 had an insight into the growing demand for circularity as it influences the entire decision-making for the design, construction, and end-of-life phases. Within the entire construction process, the focus has been towards increasing in-project demand for reducing the level of carbon emissions or use of non-environmentally friendly materials like plastics. R17 opined that:

“The specific demand for circularity is a growing driver that will affect more in the coming years. The structural designer could use virgin or raw materials that were homogeneous when it came to quality. There will be many variations in material properties in the design phase, more consideration of reusing material, reduced new materials supply, and more circular materials.”

Finally, there are some general trends that most of the respondents affirmed and selectively pointed out. R16 emphasized the increasing use of robotics and autonomous systems in onsite construction. Meanwhile, R15 elaborated on the increasing focus on using timber to achieve a low carbon footprint. But in Sweden, it is a bit more complicated and not commonly preferred, as concrete remains more preferred since, despite the trend and its positive potential, the Swedish regulatory demands unconditional the use of concrete.

4.3.3 Changes

Like the respondents, it is relatively easier to say that many changes have also been observed in the structural engineer's role, even though the title has been consistently preserved. The structural engineering respondents pointed out that they have observed notable changes due to sustainability over the past few years. According to R14, *“... time and we have seen continuous change the last 10-15 years regarding sustainability, how we use it and how we push and pull?”*

R14 illustrated that adopting lifecycle thinking and expertise is invaluable to help evaluate uncertainty in variables or make material specifications at the design stage instead of waiting for the LCA and LCC to be done when the design is completed. According to R14, *“... you can do your LCA and LCC in a design stage where everything is very unsure, and you need conceptual thinking. You need to have tools to provide this and help with the uncertainty in the variables...”*

On the one hand, respondent R17 mentioned how the increased demand for quality has dramatically influenced his role, especially in terms of having the oversight responsibility of building physics, where the responsibility had before shifted majorly to the Architects and now is slowly drifting back towards them alongside the trends for low carbon design. R17 stated in their statement:

“The demand for quality when it comes to building physics increased and affected me personally... Before then, the architects did it, but it shifted when we needed quality in the building physics knowledge. We need to change the role responsible for this kind of solution now that the trend of the structural designer right now is the carbon low carbon design.”

Consequently, concerning the structural engineer’s role here in Sweden, there has been a change in the pattern of regulation or control systems guiding their work, to them taking personal responsibility for the decision-making process. R17 had an opinion to share about their personal experience of it thus; *“Although I did not experience that myself as a structural designer, I saw when I started, many people that had been working and learning structural design with SBN 80 and the control systems related to it, were changed to BBK 94. That has greatly changed the role, documentation, detailing, and calculation of the structural design work. Now it is called “Egen Kontroll”.*”

A deeper insight into the respondents' understanding of the changes the industry is experiencing had consistency in need for practitioners who have been at the driving front of the structural engineering area of expertise. R13 believed it could be difficult for this set of persons to change how they have worked for decades, especially if they are soon to near retirement. Although R14 had more to emphasize on the changes that the structural engineer and other significant roles in the construction profession must experience, to achieve the long sought-after data-driven practice. According to R14, *“... roles need to develop in that area, and I do not mean we need data scientists. The structural engineer, BIM, and Sustainability, and sustainability experts need to be more data-driven.”*

Meanwhile, R14 provided more clarity on how achieving a data-driven practice in construction depends hugely on required proficiency, experience, and practical knowledge of how the industry functions. Especially after failed attempts to employ external data – experts with little or no knowledge of the profession to achieve this before. R14 shared that:

“We have tried several times to use data scientists, but we always see that they should have competence in the sector. I was wrong. You need to have the domain knowledge and the domain knowledge and ownership, which is so crucial for designing and using a data-driven practice.”

Respondent 17 also agrees with the contribution from R14 and emphasizes the importance of having everyone in a team working together with complete comprehension of how to handle the scope of work. According to R17, *“The first thing that needs to be done in projects is to increase the knowledge by getting everybody on board. To ask questions like, what do we need to do in this project? How should we solve this problem, and how that affects the project's production?”*

In conclusion, all respondents agreed on the ongoing efforts to automate the routine processes in the structural engineering profession, but without impeding the role or bringing up a new profession, other than facilitating its continuous development. R14 gave an insight into how that could create time for exploring more innovative solutions and the creativity of practitioners, terming it as the creative space.

4.3.4 Future

Technology, sustainability, and changes in the role itself were the main topics regarding future aspects of the structural engineer role that the respondents mentioned.

4.3.4.1 Technology

Talking about one of the eldest construction roles in the world, R13 mentioned that there is a small risk of reducing or losing structural engineering jobs because there still is an apparent need for professionals' knowledge of the final solution. However, the common trend of using data for future projects also influences structural engineers. R16 believes that more connected digital systems will be developed for evaluation, economic calculations, and sustainable solutions. R14 added that gathered data from previous projects would be stored and reused in new projects or machine learning models. For that, some new data management, statistics, and analysing tools might be used for optimizing and obtaining the best answers or solutions. Alongside the data creation, AI adoption will influence the structural engineer role, says R16 together with R15. Continuing what was mentioned in the beginning, R17 said the following:

"I think that the structural designer will still have a role in the project, but the work will change radically, or it will at least be possible to do the work uniquely. We will see more of the possibility to optimize specific parts with AI and some reinforced learning techniques."

R14 also believes that combining AI with a database can make some new software able to generate possible models, assess sustainability, or even reproduce reinforcement details from the BIM.

4.3.4.2 Sustainability

A transparent vector of developments everyone mentions is the mutual understanding of the sustainability aspects among the experts. R16 and R14 insist that experts will need to use new innovative materials because the Procurement process is based not on the lowest cost but on the lowest CO2 emission. R17 added the following:

"Before, we needed the structural designer to build something that was mainly focused on buildability and low cost, but now we have the low carbon factor coming in. Thus, we need to ensure and put together the structural designer with the production team, alongside the support of the climate calculation specialist."

This, together with more futuristic and longer planning of building construction to last longer, would be quite a big challenge, argues R15.

4.3.4.3 Future changes in the role

As mentioned earlier, concerning the need for experience, R13 added the crucial need to be open to changes and the need to be flexible. Regarding simple everyday tasks, R14 agreed that common design tasks in structural design would disappear and be done autonomously. However, involvement in the new software, according to R14 and R15, will require you to become efficient at programming, specifically Python language, and deploy it on various platforms.

Another substantial change that might redefine the structural designers' responsibilities is Boverket's regulation to let structural engineers choose which design code to use for different elements. R17 said the following:

"Boverket will no longer require structural designers to use Eurocodes... to see how we could increase innovation and decrease costs within the building sector... let

industry take more responsibility for the solutions combining various codes for all building elements.”

Such changes in the regulations might be followed by certifications requirement for structural designers or engineers in Sweden. Additionally, R17 said it might also come up if the design regulations or standards change for establishing insurance.

Respondent R14 also contributed to how the structural engineering practice would be transformed, giving a culminating perspective of the expected changes in logic and decision-making. He mentioned that:

“We need to build knowledge and experience around using digitalization for database creation, and so on... We need to change the way we introduce materials in the process, as today we specify the material characteristics that we want for the structures we designed, and this enhances the material development with green concretes, recycled materials, components, and etcetera. We need to rethink this and get this competence in simultaneously as we do the design because we need to base our design on the choice of material or component or what we have in the logistic system.”

5 Discussion of Research Findings

Many experts are talking about the onset of the Fourth Industrial Revolution, an extension of the previous ones that have changed the world through digital technologies or autonomous machines replacing manual jobs and tasks. There are various explanations for this, but the drive for productivity, efficiency, and economic benefits are among the most important. Although many jobs have been lost, new ones have been created. Today, we are on the brink of a new technological revolution that could further change the world with emerging technologies, some of which are already in use. The challenge for companies today is not to define them, but to determine their potential application to create new products and services.

Today, it is easy to see how each new technological revolution boosts productivity. It is imagined that AI and automation could change the future like the steam engine changed the past. The market demands higher quality, safer and cheaper products, and improved project adaptability, while the government demands sustainability, circularity, and emissions reduction, leading to future changes. According to (The Future of Jobs Report, 2018), adopting AI and robotics would result in about 75 million jobs being replaced by machines and 133 million new roles. The same report estimates that by 2025, 85 million jobs will be replaced, and 97 million new roles will emerge (The Future of Jobs Report, 2020). Dynamic changes with the potential of AI can be seen in various industries today. For example, IBM CEO Arvind Krishna recently shared their plans to pause hiring for back-office functions such as HR, saying that *“I could easily see 30% of that getting replaced by AI and automation over five years.”* which equates to about 8000 jobs (Bloomberg, 2023).

Similarly, in this study, we asked whether the same would happen in the construction industry. We have focused on the future development of digitalization-based roles, sustainability-based roles, and structural engineer roles. By combining data obtained from the reviewed literature and empirical interview results, a mind map was created to accurately predict the future development of these selected roles by evaluating their past and current development paths. In addition, this study approaches role development or role change from the perspective of drivers, changes, and trends; because of organizational, business, or societal demands. Based on the information gathered from the qualitative and empirical studies, the resulting chronological mind map is presented below in (Figure 7); for each selected role related to the construction industry.

5.1 Introducing the Mind Map

The mind map in Figure 6 shows drivers in yellow, changes in blue, and trends in green, connected by arrows to represent the relationship between one on the other. Meanwhile, each tab is placed approximately according to the chronological order and correspondent timespan concerning its corresponding role. Some tabs contain country initials and the year of impact. Orange tabs represent some external factors, red tabs represent some future changes or goals, and below the chart, the main goals of the roles can be seen. It is important to note that although this mind map contains much detail, it may not cover everything. Nevertheless, it provides an overview of Swedish-oriented data from interviews and literature. However, trends and drivers can differ for 1 or 2 years depending on the company and context.

Moreover, they were placed according to when they were noticeable or adapted as a driver or trend. The summary is based on respondents' experience and literature findings that have been interpreted and summed up. The figure shows that the drivers, changes, and trends are consistent and interrelated, with a push-and-

pull effect on each other. In other words, sustainability affects digitalization and vice versa, as both significantly impact all the other roles.

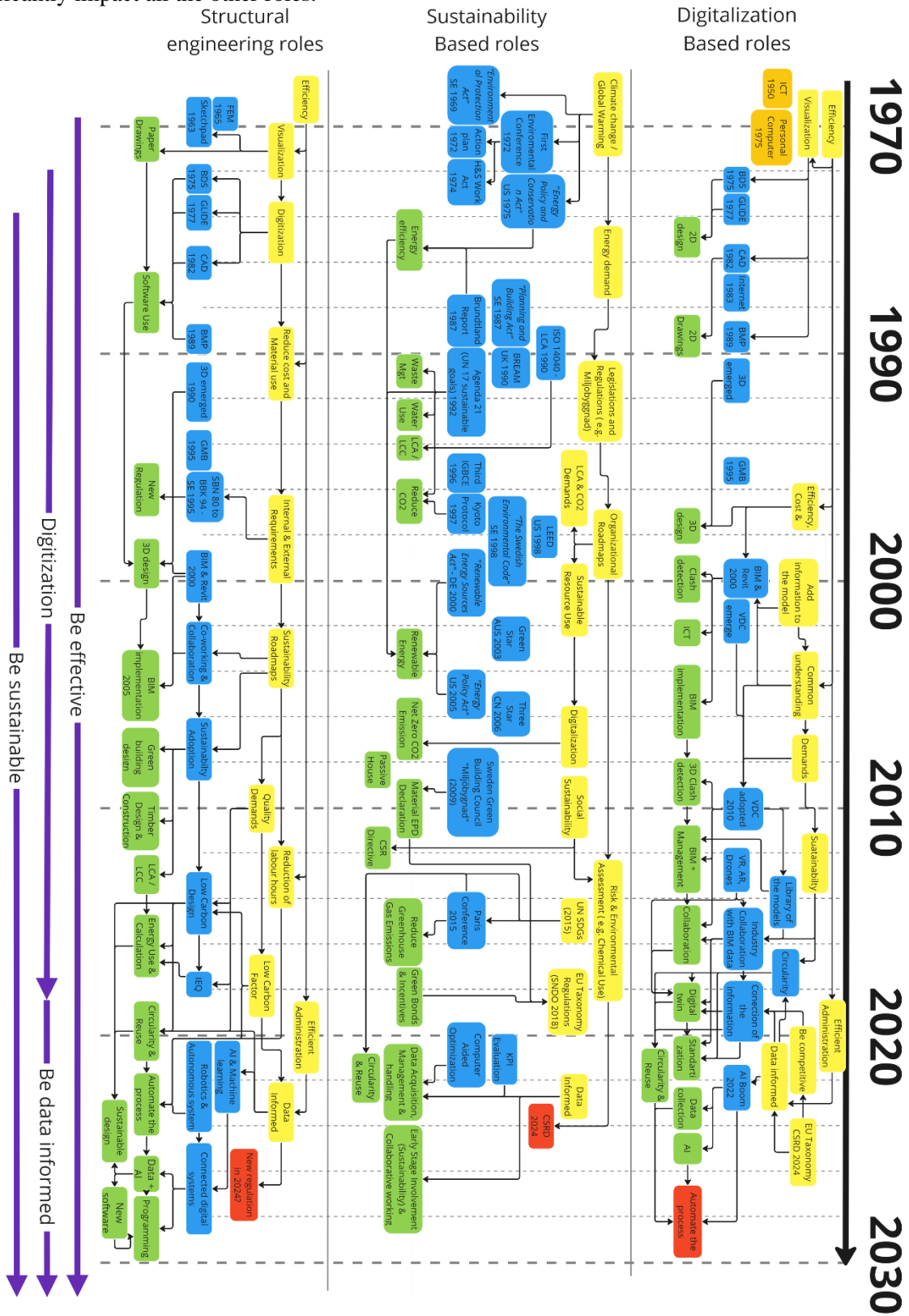


Figure 7: Showing the timestamp of the development of selected roles based on the drivers, trends, and changes

5.2 Overview of the Roles Development

If we talk about roles in general, the development of roles is usually represented by the addition of new responsibilities or a change in the way of working. Once a role becomes too large to be handled by a single person, an extra person is needed to take over a part of the responsibilities, and a new role emerges. Over time, the tasks performed by this person are adopted in the company, and become daily tasks, as was the case with BIM implementation. First, it emerged, then it was adopted by companies and became part of every project task. According to our findings, the evolution of roles happened, as mentioned, with the addition of new responsibilities and/or new ways of working due to the new software and processes. These new responsibilities and/or new working methods are adopted again, and the cycle starts as shown in Figure 7 below.

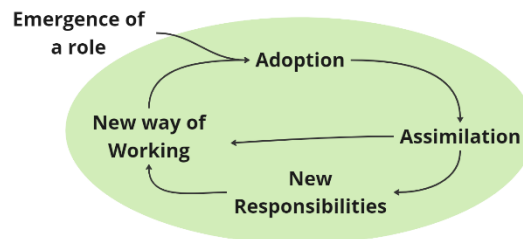


Figure 8: Development of the role

In addition, new responsibilities are usually facilitated by releasing new legislation, regulatory demands, and requirements. The Sustainability professionals or respondents, at the forefront of several changes, provided details on the chronological expansion of their professional roles. The emergence of changes was influenced by adding new responsibilities to existing roles, resulting in a snowball effect. For instance, we noticed that many roles had expanded their responsibilities due to environmental regulations and requirements of sustainable development goals. For example, structural engineers now need to focus on low CO2 emissions.

The change in how we work today is linked to the digitalization and digitization attempts of the AECO industry. Digital tools became more popular in the early 2000s due to increased efficiency and flexibility, even though the software was not as user-friendly as it is today. A confluence of opinions in the literature and interviews noted that using digital tools dramatically contributes to the growth of sustainability adoption. For example, conducting comprehensive lifecycle impact and cost analysis would have been much more difficult without the help of databases and software such as the Open-LCA.

The literature and data obtained show that most traditional tasks go through about four stages of development, including the emergence, adoption, part of a job (assimilation), and automation of the task (Figure 9).

Emergence → Adoption → Assimilation → Automation

Figure 9: Stages of the development of the tasks

For example, machines have already replaced roles such as bank tellers or toll booth attendants. We are now seeing the emergence of self-driving cars that will eventually replace all drivers. Copenhagen has introduced a self-driving metro and Dubai is planning to introduce a self-flying taxi. We believe the same will happen with many construction tasks, and the industry is striving to have an autonomous system that covers routine activities to facilitate more efficient operations.

If we analyze the structural role as a role that external factors have only influenced, it is noticeable that most of the drivers and changes are related to sustainability or digitalization. Based on literature and empirical data, it can be opined that sustainability and digitalization are one of the main drivers influencing the change and development of this role. For instance, the environmental trends that started in the 20th century have gradually developed into the sustainability focus that we have today. It would be fair to add that everything in modern Sweden, from academic education to professional practice, could always be linked to some degree of contribution to sustainability. Many business profiles continue to adapt their business cases to include their contribution to sustainability in environmental, economic, and social terms, while their ethical contribution has also become more prominent. However, digitalization and digitization that started a bit earlier have also become a strong trend. The emergence of all kinds of software, growing demands, and new opportunities have driven developments for many years. Even today, many respondents said that although digitalization is still widely adopted in Sweden, many in the AECO industry still use old methods for information extraction and other processes.

As one of the respondents said, digitalization and sustainability will continue to influence the development of other roles and support their coworking together for further development, as shown in Figure 7, especially since most of the roles are slowly transitioning towards achieving a data-driven and sustainable society. For example, BIM professionals and structural engineers now need information on the price and quantity of products, including their equivalent in CO2 emissions and energy consumption or impact: all these demands and much more force the industry to evolve and adapt to new working methods.

In addition, developing the digitalization-based role is linked to adding more data and information to the modelling system. Eastman (Aryani et al., 2014a) mentioned in his research that the development of a new program usually happens because something was missing in the old one. The advent of BIM has allowed adding more information to the model and performing all the necessary calculations at the early design stage. However, as some respondents pointed out, additional specialists (VDCs) were needed to manage and facilitate the data flow as the amount of data increased. Over time, the direction shifted to focus more on the data, including collecting, storing, analysing, and reusing the data from project to project. In a way, it helps to solve the knowledge-sharing problem that large companies usually have. At the same time, the company will be able to make better calculations, estimates, management, and the product itself based on the data from previous projects.

In terms of sustainable development, it is more linked to the requirements of climate regulation. Therefore, many new laws, regulations, and targets have been set to achieve a global environmental objective. This implementation would be much more difficult without software to facilitate the process. However, regulations are becoming harsher and more demanding, necessitating additional resources and exceptionally qualified personnel to cope with emerging difficulties. As mentioned in the empirical results, the upcoming taxonomy regulations would cause problems for those companies that are not prepared. Another major challenge mentioned during the interview is that adopting sustainability solutions had not seemed cost-effective for the industry, which already operates on a low-profit margin basis. Low interest in adopting sustainability initiatives and poor regulatory control allows companies to do the bare minimum or even not follow the regulations. Tackling this challenge has led to the stringent enactment of regulations from the government, like the Corporate Social Responsibility Directive (CSRD), by 2024.

5.3 Future role development

The table below showed a summary of the various perception of the respondents based on how much their role and responsibilities that have would increase. An analysis of their responses to questions based on answering the fourth research question is presented in the table below. It provides an overview of how each roles that has been selected to obtain our empirical data be envisaged to evolve in future. The following discussion ensues to assess the sustainability – based, digitalisation-based and structural engineering roles, based on the 6 strongly expressed opinions amongst respondents on how their roles would develop.

		Future Perception(s)																	
Role Category	Respondents	AI-Assisted Optimization	Unique Information Database Creation	Software Development	Automation & Robotics	Circularity (Reuse, Recycling & refurbishment)	Taxonomy	More Sustainability Engagement	Digitalization	Low Carbon Materials	Increase in Energy Efficiency	Data-Driven (Collection, Management & Analytics)	LCA Determination	Innovative Materials	Collaborative Working	Low CO2 Procurement	Competence Need / Curriculum	New Design Codes & Rules	
		Digitalization Based roles	R 1	1				1				1							1
R 2			1	1					1				1				1	1	
R 3					1									1			1	1	
R 4	1		1	1	1												1		
R 5	1		1		1									1				1	
R 6	1					1			1					1				1	
R 7	1					1								1					
Sustainability Experts roles	R 8	1	1	1							1						1		
	R 9						1		1				1						
	R 10	1					1	1	1		1					1			
	R 11	1			1	1	1	1		1							1		
	R 12								1	1	1	1	1						
Structural Engineers roles	R 13				1														
	R 14	1	1	1	1				1				1	1			1	1	
	R 15	1	1		1		1												
	R 16	1			1									1		1	1		
	R 17	1						1		1						1	1	1	
Number of Tallys		12	6	6	6	9	1	4	5	5	4	1	9	1	3	8	3	3	2

Table 2: Showing a surmise of respondents' future perception of their changing roles

Driven by technological advancements, changing client demands, and a growing awareness of sustainability and demand for more structures resilience, the AECO industry is changing rapidly. Today, adapting to these changes is observed with new demands. Every company is involved nonstop in discovering new working patterns to address emerging challenges. Thus, based on the information on the current driving demands, requirements, posed challenges, and long-term industry goals obtained so far, we envisage that the current roles will be mostly developed in the following directions:

- Be data-driven and informed.
- Adoption and use of AI
- Automation of manual or routine work
- Focus on collaborative working between companies
- Focus on sustainability and circularity (reuse and recycling)
- Expansion of the responsibilities, knowledge

Most of the respondents from our empirical result accented that their company's and industry's goal is to become data driven. Although most worked within our primary partner company in Sweden, we also saw similar opinions from respondents who were part of other major industry players. Although most of the respondents from the former, with ample years of experience, claimed that they were at the forefront of the shift in focus to become a data-driven company themselves. Nonetheless, we had no data to confirm if this claim or decision was right or wrong. Maybe further research could dissect this later.

In addition, according to the respondents, they have tried many strategies within their companies, some of which worked well, while others have been less effective. However, the use of data seems to be the next step for the AECO industry as there are many opportunities and possibilities to explore, as seen in other industries. But creating a central data system or database requires most employers and professionals to develop competencies for gathering, analysing, interpreting, and using the data. According to one of the respondents, it will not be a mere Excel computation with many numbers, but companies will look to create a self-learning AI-controlled system that employees can chat with to obtain the correct information in the shortest possible time. A discussion of the potential AI adoption would require a complete thesis on its own, but from our empirical data, it is evident to affirm assuredly that the use of AI would grow exponentially. For instance, development managers have noticed that manual or routine tasks that could be automated will become delegated to AI, which could reduce the number of employees, although they insist on the opposite.

Automating manual work will affect almost every role; tasks such as cost estimation, clash control, material selection, LCA, and CO2 calculation can be automated and done in two clicks. According to our empirical data, this creates creative space that can focus on other aspects such as collaboration, planning, etcetera. Qualitative collaboration between companies in a project has always been a requirement, and this has always been a challenge in the AECO industry that strives to be improved, especially in this digital era. For instance, our interviewees spoke a lot about finding common working ground, facilitated by using information management in the building model. It creates avenues for much sought-after higher efficiency, fewer errors, and a better understanding of project execution.

A greater focus on sustainability is another aspect that the majority of professional roles will need to focus on increasingly. Sustainability plays a significant role even from the early planning and design phases of projects, with its impact visibly increasing across the AECO. For instance, the structural experts also mentioned how sustainability thinking had become a significant decision-making criterion in their current responsibilities.

Another general opinion featured in the literature and our respondent's responses is that flexibility is in mind. Being able to adapt to new demands and challenges is particularly important. Learning to adapt and use modern technologies, software, methods, regulations, etc. is one of the most important qualities people need to have. The industry needs professionals with local knowledge, experience, and capacity to do what needs to be done. Otherwise, companies will be forced to find unique competencies that can help.

5.3.1 Digitalization-based roles

The previously mentioned automation of routine processes, AI as an assistant, and the creation of vital information databases seem to be near-future developments for digitalization-based roles. Many, including those working as VDCs, agreed that their current position is only for temporary managerial oversight and will change in the future. According to these respondents, tasks such as collision control can be automated and/or subcontracted, while new roles will be more about overseeing the project and helping with the model rather than fixing it. As this role changes, VDC as a name will likely disappear, and the new role will be

called something else. The introduction of AI may also force these managers to be familiar with coding to manage better and understand the processes.

The increased use of data will also create new responsibilities in facilitating and structuring the data that comes in and out of the model to enhance business requirements for data management. New software might directly link comprehensive building models for calculating the LCA, and CO2 contribution, amongst others. Respondents also envisage a single interconnected platform that **supports** the entire system for planning, design, operation, maintenance, and other stages requiring data management. Such a system, combining different technologies, could, for example, influence the traditional procurement process. Its use would help model management roles with oversight to control the flow of information, access, and changes. These tasks could also be delegated to current model management roles.

There is a strong and growing confluence between digitalization and sustainability, as evidenced by the consistent trends toward implementing various sustainability solutions. Therefore, as environmental aspects are being incorporated into all phases of the AECO industry, some sustainability knowledge may be needed for better strategic engagements in the future. The same can be said for the use of software and digital tools, as the inability to use computers, adopt BIM and manage data could lead to the loss of a job or a reduction in the employability of professionals. Thus, training and supporting the competence growth of employees could be part of the responsibilities of today's VDC managers.

5.3.2 Sustainability-based experts

According to our interviewee, the future for sustainability experts in the construction industry today is both uncertain and promising. The shift in work processes toward data management aims to facilitate sustainability-based solutions, supported by the increased use of AI-friendly software. There would be a need to create a portfolio of databases that can be universally adapted for implementing sustainability solutions within the country and even globally. Based on this, the knowledge to handle, maintain, and use the dataset will be critical. Some upskilling may be required to ensure continued efficient operation. According to our empirical data, this envisaged creation of a central database, coupled with modern IT platforms, would support the engagement of sustainability professionals in all operational phases, including planning, analysis, design, drafting, and monitoring. These interconnected digital systems would work together for impact evaluation and economic calculations.

According to our respondents and literature review, as sustainability thinking spreads across the industry, the future focus will be on using innovative materials with a lower environmental impact, currently considered as low-carbon materials. They also expect a renewed focus on energy efficiency in buildings. Therefore, the greater focus on the choice of low-carbon materials, energy savings, and many other aspects will increase the role of the sustainability expert in the project. An interesting contribution during the interviews was how the sustainability experts focus could be largely influenced by external factors, which tends to create quick transitions towards meeting global needs or urgencies. For instance, the recent higher interest in renewable energy, efficiency in energy use and reuse, has been an aftermath of the war crisis that caused a drastic reduction in Europe's largest energy supply system. In fact, it even increased industries' investment allocations, demands and research engagements for green energy.

In addition, our respondents mentioned that the importance of their role would increase with more oversight responsibilities in the company. In short, sustainability professionals could move from a supporting role to a core managerial decision-making role. Therefore, encouraging further interaction and collaboration between professional teams. Finally, the new CSRD regulation based on social sustainability will increase

over the years and become a core focus and part of their daily routine. Concerning this regulation, respondents highlighted the importance of collecting and using data for the reports.

5.3.3 Structural Engineers

Structural engineers cannot avoid the potential impact of machine learning and AI. Machine learning models, which learn from a library of solutions to past problems, provide scope for optimization and obtaining the best solutions to new challenges. Therefore, giving us another reason to create and use unique databases for analysis, design, or modelling tasks. However, the reality of realizing this potential depends on how experienced structural engineers are. Using an existing database in combination with AI will also require them to increase their efficiency by developing their programming skills to explore these possibilities with their local skills and expertise.

All these expected future changes in the role of the structural engineer pose a risk of loss of essential experience and competence due to the automation of these small tasks or outsourcing them to achieve lower costs in the execution of their design work. The position and responsibility of the structural engineer in the future might automate many routine tasks, including basic calculation processes. Some respondents believe there is a risk of losing or displacing some professionals whose responsibilities would be carried out autonomously.

On the one hand, most respondents emphasized that sustainability is becoming an essential part of their responsibilities. In particular, with the trends towards circularity and reuse, the industry needs professionals who will take responsibility for ensuring the integrity of structural components to recommend them for reuse. In addition, recommending innovative low-carbon materials would help drive the sustainability agenda and be part of the structural engineer's priorities.

Meanwhile, our empirical data suggest a growing national concern for the industry to re-strategize its efforts from building new housing to bringing existing housing up to modern standards. There is a need for structural engineers here, as around 70% of all buildings were built before the 2000s and do not always have the correct blueprints. Achieving this would create a new demand for vital input, where the structural engineer will be one of the critical components of the project.

5.3.4 Emerging Roles

The question of emerging roles has been on the surface since the start of the study. Will some new roles emerge, or will it just be a shift in responsibilities? Based on the research findings from our review of existing academic literature, some roles may emerge in the IT part of the AECO industry. Respondents identified a strong need for data analytics experts with knowledge of the construction industry, as all the data coming from different sensors needs to be appropriately collected, structured, stored, and analysed. Experience or knowledge of the construction industry is critical in this regard, as this proposed engineering data analyst will need to understand the type of data, why it is essential, the correct values, and much more.

The emergence of new roles is likely to be inevitable as the responsibilities of professionals become more significant and broader. For example, at some point, structural engineers may be overburdened with work that includes applying sustainability solutions. It could lead to new professionals combining less structural engineering and more sustainability strategy solutions.

5.3.5 Challenges for Change Adaptation

Despite the potential for growth and change in the construction business, supported by several factors from both empirical and literary sources, there are also barriers for professionals in the industry to solve in adapting to future change. The limitations or anticipated difficulties that professional roles must overcome are discussed below in many theme areas.

5.3.5.1 Education

By its very conservative nature, the construction industry is struggling with the challenge of adopting digital technologies like BIM. Such changes provide a different routine or pattern of working that experts in the field are not well acquainted with and are not willing to change. According to our respondents, this unwillingness to learn and change the comfortable working pattern is mainly applied to older people, whom the industry still needs for their wealth of experience and knowledge transfer. These challenges highlight the apparent skills gap in the industry and help to meet the needs of the industry in addressing them. For instance, a new academic curriculum would be required to equip young and future engineers to meet their personal and industry expectations.

5.3.5.2 Collaboration

The interactive working and knowledge-sharing foundations of collaboration within or between companies in the industry today need to be fully utilized and continually improved to achieve the goals and objectives set. For example, creating a collective agreement to ensure that there are standard rules for the use of data, standardization, sustainability solutions, and other aspects that can help make collaborative processes easier. As one respondent said, it is time to implement change, not just propose it. Implementing multiple solutions in the construction industry is not a responsibility for a single person or business unit. It would require a collaborative effort and fundamental understanding from all teams.

5.3.5.3 Software

There is still a significant need for software developers who can perceive and understand the complexity of the construction industry's production needs. The construction industry in Sweden is doing a tremendous job in developing appropriate and user-friendly software to provide solutions from the planning and design aspects. However, much effort still needs to be completed to integrate and manage information from models effectively to meet the industry's goals and provide comprehensive solutions.

5.3.5.4 Data Security

Most construction companies still see the challenge of handling, storing, and integrating data into a single database as a considerable risk, especially when maintaining their competitive advantage and protecting their organization's intellectual property. As a result, aspects of technology like *cyber security* have received increasing attention over the years and have become an essential part of the industry. Addressing this data security challenge for the construction industry would be a massive boost to developing IT systems and solutions that are more vital and relevant to this industry.

5.3.5.5 Outsourcing

Another challenge for the industry is outsourcing. Ironically, there is a labour shortage in Sweden, which has increased partly due to the industry's strategy of outsourcing technical tasks. The reasons are to solve tasks at a low cost and achieve a higher profit margin. It has affected the industry in diverse ways, both in design and production. This outsourcing has created a challenge in that extra effort must be made after

obtaining the design or calculations to ensure the quality of work is done well. It also includes some social challenges, such as the language barrier and distinct levels of intellectual and computer skills.

According to one of our interviewees, there is a risk that young engineers will be unable to do the simple things that build competence and experience due to outsourcing. For example, there is a gap in the industry's basic hands-on training of young engineers when plain design tasks are outsourced cheaper.

5.3.5.6 EU Legislations

According to our research data, an additional challenge for the construction industry today is how quickly it can keep up with new EU legislation. Some examples of such legislation are increasing requirements for low-carbon materials or forthcoming taxonomy. These pending approvals could potentially cause disruptive changes to professional roles or add new responsibilities to keep up with upcoming requirements or trends. It would be a considerable challenge for professionals to keep up with this and to deviate from their traditional ways of working as required by new upcoming legislation.

5.3.5.7 Sustainability Application

The industry's knowledge of sustainability adoption has continued to grow over time. Now awareness has progressed to the challenge of meeting climate targets and reducing resource use (reducing waste, toxicity of materials, and reuse) through a commitment to circularity. In addition, structural engineers and construction experts need to optimize material use and structure resilience by engaging in the discovery and adoption of low-carbon materials for use in the industry. If the construction industry can fully adopt comprehensive sustainability solutions, although it could be expensive upfront, aspects like reuse and repurposing of elements would contribute to cheaper production and maintenance.

5.3.5.8 Ethical challenges

The question that many are increasingly asking is whether humans will be replaced by robots or AI bots that can do the job in the same quality or even better. The recent Hollywood writer's strike against underpayment and unethical use of AI is another sign of this issue (Leonard Bernardone, 2023). Is it ethical to substitute human work with robots or AI work? A long time ago, the human population underwent a similar radical change in the form of the Industrial Revolution, and as we can now see, it went pretty well. Will there be an AI revolution? The problems it will bring can be estimated to some extent, but only time will tell.

6 Conclusion

This study presents a chronological development of three selected roles, digitalisation-based roles, sustainability-based roles, and structural engineering role, over the past 40 years. Furthermore, the study presents a future estimation of the development for the selected roles. The information presented in the study is gathered from both the literature review and the empirical study conducted through 17 interviews. Collected information was analysed and presented in a mind map together with discussion on role/task development and future perspectives.

In conclusion, achieving a successful assessment of the overall evolution for the selected roles requires that one look at the transitions from and before the last three decades to the present day. Taking the structural engineering role as an example, the apparent adoption of digitalization tools and sustainability thinking contributed to defining its future change. The same is true for the other roles considered. Thus, currently the main drivers influencing professionals' roles are digitalization and sustainability, alongside several pieces of legislation. The most important is that these drivers, although they mostly started differently, have developed, and are now working together to achieve the set goals.

However, adopting modern technology is more welcomed because it facilitates operations that are more efficient, while adopting sustainability is slower because it is not cost-effective. Regardless, emerging and changing stringent regulations keep forcing companies to adapt to new requirements and challenges. Nevertheless, this study concludes that future development will focus on achieving environmental goals through digitalization. The broader use of digital technologies opens up new opportunities in construction production, focusing on reducing routine processes that consume time and resources.

One of the key features of the future could be data collection and management, mainly facilitated by the increasing influence of automation or AI-enabled autonomous systems across the industrial sector. The resulting role development would be characterized by the automation of routine tasks and processes or the emergence of new responsibilities, which may lead to new professional positions. In conclusion, despite the emergence of new roles or responsibilities, there is undeniably a considerable need in the industry for significant upskilling of the existing professional workforce. Whatever the future outcome of these professional roles, the current fourth Industrial Revolution cannot be stopped. It would be accurate to say that this outcome is not yet definable and can only be imagined.

7 Recommendations

Briefly, from an analytical perspective of the study and data obtained so far, a lot of ideas and questions emerges that would be invaluable and provide recommendation for further research. For instance, which part of the construction industry in the Swedish sector should be repositioned to meet the upcoming industrial challenges?

Meanwhile, further research could be done to determine who should take on the huge responsibility of training or upskilling future and current industry professionals. It would help to ponder critical issues like, if the academic institutions should be charged with developing new curricula that focuses on building the practical skills that industry needs. Otherwise, should industry develop more effective upskilling processes for its workforce, even though this may be financially intensive? In addition, should young professionals make a personal commitment and take responsibility for their own self-development, despite their current study or work demands?

In addition to the above, further research recommendations may include considering how these key drivers would influence other active and practical professional roles in the construction industry. Including assessing how much more needs to be done to determine the appropriate framework for the adoption of AI and other digital solutions in the AECO industry.

8 Sustainability Contribution

Executing this research will contribute to companies that are developing and influenced by the industry's expectations to achieve sustainable development goals. The research will address the extent of sustainability integration in the Swedish construction industry. It will address plausible solutions on how changes have influenced the primary roles of professionals in the industry. In addition, organizations (both academic and industrial) can use the results presented in this study to understand how different professional roles are changing in the light of sustainability. The findings can be used to develop frameworks or guidelines for adapting and being at the forefront of change.

This study will also contribute to academic research and pave the way for further research questions that academics can explore to apply more sustainability theories and concepts to business. Understanding how the industry has approached sustainability in practice and how much influence this has had on professionals. Most importantly, the historical perspective gained and communicated in this research. The mind map will help engage change managers to take positive and proactive steps to anticipate, adapt to, or meet current customer or industry demands. It would ensure that future generations' futures are safeguarded to meet their needs and demands (Stubbs & Cocklin, 2008).

9 Statement of Contribution

The work in this research study has been carried out with absolute commitment and complete collaboration of both partners. With the mind-set delivering high quality work and generating utmost result, each member of the team has been equally motivated and dedicatedly committed to ensure our scheduled milestones or deliverables are ready either ahead or on time. It has been an interesting, learning and self-development process for us in brandishing our team working skills.

10 Appendix

10.1 Appendix 1 - Interview Questions

General Introduction

- Introduce yourself, name, and professional work experience duration.
 - Can you give us a brief overview of your career path and how you arrived at your current role?
 - What are the most important skills or qualities you have developed over your professional journey?

Drivers of Changes

- We ask about their understanding of the terms' drivers, trends or changes and give our brief description.
- What are the main **drivers** or **reasons** that have created Sustainability role and caused it to change over time?
 - How have these **drivers impacted** your organization and your specific role?
 - Are they (drivers) **relevant only** for the **past**, or are they still actively **causing** more changes **nowadays**?
 - What was the **goal** the drivers are trying to achieve?

Trends

- What kind of **trends** resulted because of the **drivers** you have described?
 - What kind of **trends** have you seen or **experienced** during your professional career that have **impacted** your industry?
 - Are there internal **targets** within your company that you had to **work towards** in your role?
 - Were there set **expectations** on you to achieve anything specific.

Changes

- How have **changes** in the industry impacted the Sustainability roles and the industry?
 - Can you describe a specific instance where you had to adapt to a major change in your industry or organization?
 - Were there new challenges and demands that came with it?
 - Did it result in changes in tools you use, the culture or way of working, new demands, and responsibilities, etc?
 - Do you have an idea of other **related roles** or colleagues that were **influenced** by these **changes**, and how?

Future

- How do you perceive that the **Sustainability role** will **evolve** in the future, and what **skills** do you think will be most important to stay ahead?

- How do you think **emerging technologies** or new **ways of working** will change the AEC industry in the next 5-10 years?
- Why do you think so? Are there some **trends** or **changes now** in AEC industry or ones you foresee?

Conclusions

- How do you stay **up-to-date** on industry **trends** and emerging **technologies**?
 - Can you **describe** a specific area of the AEC industry that you think will experience **significant growth** or change in the coming years?

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