The Digital Transformation of Construction Worksite Safety

How much added value would AI bring for workers and work-environment safety?

Master's thesis in Design and Construction Project Management

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ABSTRACT

The aim of this paper is to look into the digital transformation of the construction worksite, more specifically to the impacts of Artificial Intelligence for workers and work-environment safety. The scope converges on the more tangible consequences of safety rather than health and focuses on the impact on safety roles and performance as well as implications for jobs and collaborative dynamics between construction organizations. The thesis pushes forward the current state of safety performance and collaborative relationships both in theory as much as in practice and stresses the shift of performance measurements and success factors for the former as well as the roles and goals for the latter. The study adopts the abduction method and is theory rich as a result of the novelty of the field and lack of adequately rich interview participants for the empirical section. Still, the abductive reasoning method enables rich interpretations of the interview acquired qualitative data to be derived in the discussion. The study sought out to verify and answer several questions and statements to which a majority were successfully explored while others require further exploration.

Keywords: construction safety, AI, digital transformation, change, digital, construction organization, AI for safety.

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List of Acronyms

AI – Artificial Intelligence

ANI – Artificial Narrow Intelligence

AR – Augmented Reality

BIM – Building Information Model

DT – Digital Transformation

HS – Health and Safety

NN – Neural Network

ML – Machine Learning

VR – Virtual Reality

1 SECTION I – INTRODUCTION TO THE STUDY

1.1 INTRODUCTION

The rise of digital transformation (DT) across all industries has deeply taken root in today's incremental progress and advancements with the arrival of technological revolutions such as digital twins (Panetta, 2019; Edirisinghe, 2019), IoT (Agarwal, Chandrasekaran and Sridhar, 2016), Artificial Intelligence (AI) (Agarwal, Chandrasekaran and Sridhar, 2016; Polyanin et al., 2019; Alsheiabni, Cheung and Messom, 2019) and the globally data-oriented focus they have enabled. So much so that authors Polyanin et al. (2019) have inferred that human society is undergoing a digital industrial revolution as a result of the fast-increasing processing power and massive data sets which feed ever more complex algorithms (Panetta, 2016).

Conventionally, the construction industry has opted for slow and incremental advances due to its volatile and unique nature (Zhou, Goh, and Li, 2015) which makes for specific project-based technological and processual improvements difficult to scale up to an organizational level much less to an industry level (Agarwal, Chandrasekaran and Sridhar, 2016; Costello, 2020). Nonetheless, the construction industry is one that is lagging behind its other counterparts when it comes to its digitization levels (Agarwal, Chandrasekaran and Sridhar, 2016; Motawa et al., 2007; Edirisinghe, 2019; Bosch, 2020).

Still, "digitization is placing unprecedented pressure on organizations to evolve" (Loonam et al., 2018, p.102) and meanwhile, reports and statements, notably from Gartner (Hippold, 2019; Pettey, 2017; Panetta, 2017, Costello, 2020) or McKinsey & Company (Agarwal, Chandrasekaran and Sridhar, 2016), have established both cloud technologies and AI as the utmost importance for technological strategy investments and development. It is true that in considering on the one hand, for large projects, 20% of them run overtime and 80% are overbudget and on the other hand there is a net waning in productivity since 1990s (Agarwal, Chandrasekaran and Sridhar, 2016) and these technologies could bring about viable solutions. Additionally, it is noteworthy to point out that according to McKinsey, the whole construction industry currently invests less than 3% of its revenue on various forms of AI experiments and development (McKinsey, 2016) which is extremely low, and it can be claimed that construction is playing it safe. Nevertheless, in the case of AI, the Gartner report (Costello, 2020) expects leading organizations "to double the number of AI projects in place within the next year, and over 40% of them plan to actually deploy AI solutions by the end of 2020".

Accordingly, it is safe to deduct that the construction industry as a whole is "ripe for disruption" (Agarwal, Chandrasekaran and Sridhar, 2016). An array of reports and articles have demonstrated the advantages brought about by a successful implementation and application of AI more specifically in terms creating a competitive advantage (Alsheiabni, Cheung and Messom, 2019), labor productivity growth, reduction of production and prime costs (Polyanin et al., 2019) as well as a clear-cut increase in logistics efficiency (Lu, Chen and Zheng, 2012).

1.2 BACKGROUND

The concept of Artificial Intelligence (AI) has long existed in myths and stories and yet the term AI was first used in the mid-twentieth century (Eber, 2019). AI has been received differently over the course of time. Starting around the 1950s with Alan Turing, developing his deciphering machine called The Bombe while simultaneously in another part of the world Marvin Minsky started uniting interested scientists from different fields, aiming for a human-level intelligent machine, Artificial

Intelligence underwent a golden age with significant progress until the 1970s when it began to widely receive criticism which consequently eliminated funding for AI projects in both UK and USA (Haenlein and Kaplan, 2019).

After the AI winter, which was associated with lesser if not no funding on AI projects and infamy of anything related to AI, the enthusiasts of the field arose to continue on exploring the field (Haenlein, and Kaplan, 2019), this time with more support from available technology (Taulli, 2019). Advances on technology such as increase of dataset, improved infrastructure and invention of GPU accelerated the growth of AI research and implementation (Taulli, 2019).

Developing and applying revolutionary technologies to those industries such as construction which are anchored in their old habits (Kothman and Faber, 2016) is no easy deed. Certain theoretical and pilot study characteristics will likely apply to the recent attempts of AI application in specific fields of the construction industry such as the prediction of self-compacting concrete compressive strength, in assessing slope failure or dry density in cement stabilized soil (Lu, Chen, and Zheng, 2012) as well as a few numbers of pilot or experimental cases within certain areas, namely, project schedule optimization or analytical platforms which uses the data to help dealing with risks, cutting costs and reassuring the on-time delivery of the project (McKinsey, 2018). Albeit, for the scope of this paper we will be framing the scope of AI developments and application to that of Occupational Safety management applications for the construction industry.

It is worth mentioning that the implementation of technology needs to be justified and acclimatized to certain needs and characteristics of any organization such as its business value and business model, in order to create a successful transition to the future (Koscheyev, Rapgof, and Vinogradova, 2019).

1.3 AIMS/PURPOSE OF THE STUDY

As the introduction briefly presents, the main purpose of this paper is to first, analyze current theoretical approaches and trends towards the organizational digital transformation of the construction industry incurred by AI (machine learning) and more specifically for the management of occupational safety. Considering the burst of Machine Learning deployment in different industries, including construction, the near future seems to be widely and deeply affected by new tools that AI is putting at disposal. As future construction managers, it comes as a necessity to understand, prepare, or be prepared for the possible outcomes and challenges brought forth by the construction industry, i.e., how to understand the evolution of jobs, the meaning of safety performance and safety solutions, the implications of collaborative dynamics.

1.3.1 Research question:

The digital transformation of the construction worksite: how much added value can AI bring for worker and work environment safety?

a. Sub-question: What opportunities and costs does this represent to the following characteristics?
    i. Safety performance
    ii. Safety roles
b. Sub-question: How can the following concepts impact and get affected under a digital transformation?
    iii. Jobs
    iv. Collaborative dynamics

2 SECTION II – METHODOLOGY

2.1 INTRODUCTION

This section of the paper aims to demonstrate the meticulous process of data collection and its various sources with regards to the deployment of Artificial Intelligence in safety management. Given the brief introduction in previous section, the thesis researches the added value of AI for worker and work environment safety, and for this the abduction method is applied. That is the study's aim is to provide a reasonably sound inference and exploration on the concepts from the pre-established research question and sub-questions. In other words, in starting with research questions the study sought to acquire secondary and primary data for abductive reasoning.

Finally, it is important to point out a specific set of key methodological change. First, the layout of the methodology follows the chronological steps of the thesis rather than by order of importance. Second, the thesis study and scope were undertaken without the support of a company and the scope designed and finetuned by the author students. Lastly, the authors denote the shift of the methodological section prior to the theory after the unanimous opposition feedback concerning the importance of the following information towards grasping a better understanding of the theory and hence, the thesis in its whole.

2.2 RESEARCH APPROACH AND DATA COLLECTION

This part focuses on data collection methods and as mentioned above, it starts with secondary data collection for chronological reasons and later moves forward to primary data collection.

2.2.1 Secondary data collection

Saunders et al. (2007) define secondary data as data that was originally collected for some other purpose and can be further analyzed to provide additional or different knowledge, interpretations or conclusions. This particular form of data collection involves the process of assembling and analyzing data from various sources of raw and compiled data such as research articles, books, book reviews, dissertations, journals, and conference papers. It also represents a significant portion of the knowledge acquired and data analyzed for the purpose of this study.

'For many research questions and objectives, the main advantage of using secondary data is the enormous saving in resources, in particular time and money'.

In addition to the use of search engines such as EBSCO host, due to the pioneering characteristic of this thesis, authors would use other sources for secondary data collection namely, the websites of companies as well as visual sources such as videos and demo of products.

The approach decided upon for the collection of secondary relies mainly on, the closest collection of information to its original source at all times where possible so as to avoid hearsay and the importance of possessing the discipline to constantly re-read papers to gain fresh understanding (Silyn-roberts, 2000; Ghauri and Gronhaug, 2010).

Data collection for the research was sourced from two main sources: academic research articles (google scholar, Scopus, Chalmers online and physical library, EPFL search engine BEAST and EPFL physical library) and industry products and developments (web-based research and article founded organization examples).

The first round of secondary data collection was founded in and around that of Loonam et al. (2018)'s approach which consisted seeking a set of keywords to be found (i) in the title of the academic journal directly or (ii) in the abstract. The set of keywords was as follows: construction safety, AI, digital transformation, change, digital, construction organization, AI for safety.

All collected journals were then filed and archived in two large tables for each of the thesis authors on a drive where one's information was accessible by the other at any point in time. This was to better split the reading material but also to better find gaps and commonalities in the different fields of research as well as to avoid repetition in academic footwork. It is however important to mention that in consideration that the thesis spans over two independent areas of research this methodological approach was duplicated for the areas of interest, specifically, AI for construction safety and Digital transformation/change management of the construction industry. Thus, any documentation pertaining to pre- and post-construction phase was excluded from the scope of research. Similarly, AI related articles which were reviewed and released before 2015 as well as those after 2019 required to be considered with a pinch of salt. The former due to the significance of originality and trendiness of topic and latter due to the lack of sufficient feedback from academic society.

Following this, the second row of secondary data collection, a specific search was conducted for key journals in the field, namely: Automation in Construction and Safety Science. It is also worthy to point out that specific industry efforts in given areas of interest for this thesis were not fully available at times.

All in all, 77 sources of secondary data were reviewed: 55 academic articles and conferences, 13 websites, 9 Books.

2.2.2 Primary data collection

Primary data can be defined as the direct obtainment of the relevant data from a sample population (Creswell, 2003). This definition depicts two key points which are the direct obtaining of relevant data and the choosing of an appropriate sample population to provide the data. In regard to the direct obtaining of relevant data, this is achieved in the following of the ethics approval for the questionnaire. As for the choosing of an appropriate sample population, this is further discussed in the Sampling and Population Study sub section.

When assessing a research approach or strategy and the ways in which it can be tackled, there are three common ways: a qualitative, quantitative or mixed research strategy. Although certain academics are skeptical of the combination of both methods, a single method research design can limit a study's findings and prevent the acquisition of certain information (Gratton and Jones. 2004). Naoum (2013) defines qualitative research as 'subjective' by nature, it emphasizes meanings and experiences and thus provides rich and deep data, whereas quantitative research is defined as 'objective' by nature and provides hard and reliable data. This will be taken into account later on during the analytical steps of the research.

Using this specific approach permits the researcher(s) to constantly monitor and revise the survey based on the replies from interviewees and survey participants for primary data collection purposes. The procedure in place for the collection of primary data is as follows: semi-structured interviews (audio-video recorded) for the direct obtaining of qualitative data, followed by a web-based questionnaire survey method for the direct obtaining of quantitative data.

2.3 QUALITATIVE

The main objectives of the qualitative research are firstly, to diagnose the current state of the issues and developments with regards to occupational health and safety and AI. In keeping with Naoum (2013), the data gathered in qualitative research can be classified under two categories of research which are Attitudinal and Exploratory research.

As aforementioned, the collection of primary qualitative data will be achieved through the use of semi structured interviews. The reasoning behind the choice of a semi-structured interview is primarily due to its comprising of 'open-ended' and 'close-ended' questions which enable the researchers to undergo both attitudinal and exploratory researches on each of the interviewees. Secondarily, because the main strategy behind a semi-structured interview will be to build a rapport with the interviewee in order focus on the respondents' experiences regarding the situations under study (Merton and Kendal, 1946, cited in Naoum, 2007), which in consideration of the population sample and the primary data collection timeframe is of the essence to provision reliable data. The attitudinal research participant-focused questions in the interview will help establish hypotheses, hunches and relations between key issues/enablers present in the field of sustainable delivery of construction projects in developing countries. The exploratory research, however, enables the development of one – or two – specific theories based on the hypothesis and hunches established in the attitudinal research.

The 'open-ended' and participant-appropriate questions, synonymous of qualitative research do not have pre-determined answers and thus allow the participant to answer freely and consequently, represent the attitudinal research. Known disadvantages of open-ended questions include the difficulty and time required for the analysis process of the collected data. The more structured 'close-ended' questions of the interview offer respondent with pre-determined answers such as multiple-choice of Likert scale type question (Gray, 2014) will represent the exploratory research. contrary to open-ended answers the data collected is a rather straight-forward analysis process of the collected data. The proposed structure is a set of two grand tour questions respectively containing 1 to 4 questions.

The analysis of the qualitative data extracted from the interviews will be using one of the two main approaches to qualitative analysis - inductive and deductive -here deductive as allows to approach with a pre-determined pattern of categories and topics to map the data. This particular method enables the research to make surface to key themes essential to the research aim. The themes and topics by which the collected materials will be analyzed is one matching the questionnaire rationale below. Ultimately, the strength of this method is easy and effective toward the study but does not produce a rich new understanding to the topic. Finally, the study analysis will also make use of general sentiment analysis in that of tone and words to help sense make the overall perspectives on topics or better yet dichotomies in them. On a final side note pertaining to the analysis of the primary qualitative data, however the interview participants did not wish to be kept anonymous, the authors have chosen to give fictitious names to each participant for both clarity and comfort of writing.

2.4 STUDY TIMEFRAME

For this particular study timeframe, the researchers have agreed upon a cross-sectional study; it will represent a 'snapshot' of the events and current state of the field. A longitudinal study timeframe, while providing a more in-depth data collection for the formulation and development of theories and hypotheses will not be reasonable for this particular research paper considering the current timeline.

2.5 SAMPLING AND STUDY POPULATION

According to Robinson (2014), in a qualitative methodology sampling is an important step and should be accomplished considerately. A sample universe should be defined by common criteria found in the samples. By increasing the inclusion criteria, the sample universe delimits, and the homogeneity increases as well. In this thesis sample universe was primarily bounded to the actors in construction as well as the ones in the AI solution provider companies which are directly connected to construction industry. The chosen actors in the construction should have some experience within health and safety while the solution provider should have some clients in construction industry in order for the interviews to best serve the subject at hand. Due to novel nature of this thesis, the authors decided not to enclose the sample to geographical boundaries but to use the diversity to enrich the analysis. Keeping this in mind, this thesis benefits from the heterogeneity of the samples since the research question addresses a challenge in the industry at its very early stage.

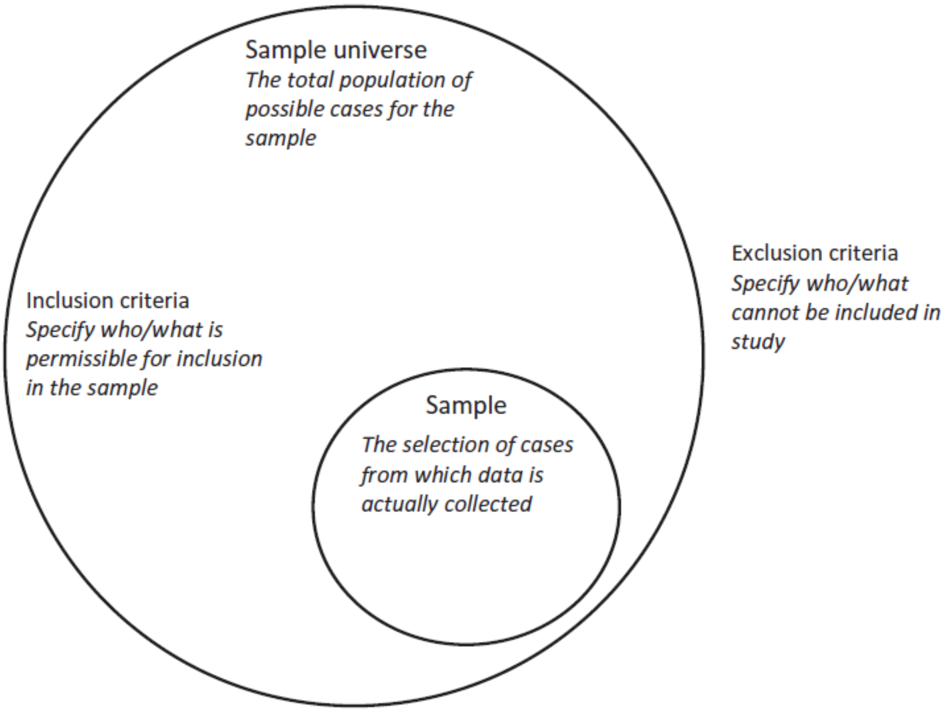

Figure 1 - Sample Universe and inclusion/exclusion criteria (Robinson, 2014)

Due to the level of the research (graduate), the accesses to a panel or a professional database are indubitably ruled out. The questionnaire sought out an audience definition chapter which defined relevant population variables (Dependent Variables) such as: country of origin, level of education (student/professional), years of experience for either the design or construction phase. In order to guarantee appropriate data collection for the qualitative research, the participants will be handpicked according to their respective involvement in safety management with based on the researchers' personal networks acquired during previous and current professional and academic experiences.

2.6 INTERVIEW STRUCTURE RATIONALE

Granted, this section might seem to be less clear to the audience as a result of the decision to shift the methodology before the theory. Nonetheless, the overall choice for its move remains justified as per the section’s introduction. If necessary, returning to this heading of the methodology ensuing the reading of the theory would help better understand the structure and intent of the interviews.

This being said, the interview structure is defined in two options and both options are divided into three parts. Option A is destined to interviewing a construction industry worker with AI for safety experience during the construction phase; Option B is aimed at construction workers involved in safety for the worksite with either AI experience pre/post construction phase or no AI experience altogether. At the start of the interview, the participants will be asked a series of 4 demographic questions (D1-D4) [Please refer to Appendix A for the interview template as well as the transcripts]. During this demographic conversing, the key areas to point are the provision of anonymity to the participant should they wish it, also a question pertaining to the extent of the working experience in the area of interest. This section helps first, break the ice, second, set out for comfort zones of improvised questions based on the participant’s knowledge pool and third, provides a sound background for analysis of the further data. Moving onwards, the interview rationale section will delve deeper into the questions and the sourcing, reasoning and predictive analytical intentions behind them.

Starting with Option A., the yellow section (See Appendix A) is centered in and around intra-organizational and the changes and challenges tackled or to be tackled which relates to hypothesis B. Question 1.1, seeks to directly assess what areas AI for construction site safety helps so to compare against both the literature and other types of interviewing. As for question 1.2, it seeks to retrieve direct case examples rather than secondary data case studies. Still, question 1.2 will be conditional on the availability and accessibility of information on the interviewee’s organization website. Should it be abundant, this question will be skipped. Then, 1.2 has a sub question which seeks to confirm whether organizations start AI deployment on small projects rather than large ones as per Costello (2020). This is rooted in the notion that if it is not true, the thesis could find a real dichotomy between deployment strategies currently in practice in the construction industry. Finally Question 1.3 pertains to the on-site end-users are too often omitted from the solution development. In considering the release date of the article in question in conjunction with the ever-growing daily rate of development in AI, the thesis will also seek whether this is still the case for the participants of the study.

Thereafter the interview moves on to the green section which covers inter-organizational collaboration in a sense to gauge how the two or more organization operate amongst each other. Question 2.1 delves directly into matters such as Knowledge management and trust as was covered earlier on in the thesis. As for 2.2 & 2.3 these are closely intertwined, such that 2.3 is conditional of 2.2 in that it identifies the tight or loose relationship adopted by the participant’s organization for the AI solution deployment. Finally, question 2.4 is a subsection open ended question on the matter of inter-organizational collaboration for AI solution implementation in the construction industry.

The third section, or blue section of the option 1 delves deeper into hypothesis B by covering B(i) and B(ii) which are the impact of AI on business as usual; more specifically, job evolution. The first question 3.1 investigates the performance and capability of safety on-site before and after AI deployment by attempting to acquire direct empirical information from the participant. Ensuing this, the blue section shifts to a “semi” open-ended question that is that they are still angled towards a specific set of information and theory discussed in the literature review. More specifically, 3.2 aims to acquire pure raw empirical data on the subject of new jobs, responsibilities and roles that are to come for safety on the construction with AI to make for a robust and interesting discussion. Also, it is in the interest of the thesis’s analysis to compare and contrast the thoughts of the participants on the upcoming jobs between option A and option B. Finally, the interview is put to an end with a grey section that are open ended conclusive question that are to be asked only if the above question weren't as fruitful as expected or if there is still time left in the allotted interview schedule.

Moving to option B, – the solution provider interview option- the yellow section (1.1 – 1.3) covers a purely external AI informed participant's view on the potential impacts of AI on business as usual (Hypothesis B). In essence, comparing a construction informed perspective (A) and AI informed perspective (B) on the costs and opportunities brought about by the deployment of AI for construction phase safety. Similarly, the entirety of the green section (2.1-2.4) for this final option will be directly compared to the green section from option A. Still, its intended to draw inferences with various answers from option A. Finally, the option B specific red section (B.1-B.2) is a section solely for AI solution providers. Its underlying goal is to confirm whether the gathered secondary data is still up-to-date and accurate – recalling on the ever-growing rate of development and research in the field of AI.

Lastly on each interview (Option A and B), based on the time spent with either of these options, the willingness of the interviewee and the among of useful data acquired by the interviewers, there are also a set of 3 purely open-ended questions for all interviewees to aid in gathering a more well-rounded understanding of the field and industry. Based on the results collected, an interesting rhetoric or further recommendations could be achieved in this thesis.

2.7 RELIABILITY, OBJECTIVITY AND VALIDITY

The methodological approach to the revision of the questionnaires based on the feedback from the participants imply the constant audience-focused development of the survey and henceforth, allowing the provision of optimal primary data. The raw data provided in the qualitative, specifically the exploratory research will be exactly what people have said (in interview or recorded conversation) or a description of what has been observed (Naoum, 2013).

With regards to the reliability of the information, a hypothesis will be considered reliable, tested and valid when a majority of the population sample (50%) agree upon the proposal.

3 SECTION III – THEORETICAL FRAMEWORK

3.1 INTRODUCTION

This section focuses on providing a theoretical framework on the relevant subjects in and around the research question. It comprises of three subsections to set a comprehensive ground for the later discussion as well as building the necessary basis for further structuring of the primary data collection. The first subsection in the following pages provides a basic understanding of the elementary concepts about new technologies (with a focus on Deep Learning in AI). It is, however, important to denote that this section serves mainly to address the technologies that have radically changed other industries as well construction. The aim behind this theoretical knowledge is to present notions that are not commonly understood in the construction sector but rather other sectors. The next subchapter focuses on safety management and the last subchapter digital transformation. Each of the latter two comprises of a brief comprehension on the matter as well as the conjunction of these topics with AI to show the integration and correlation between AI technology, safety management and change management/digital transformation. They focus on the enhancements or limitations AI carries forward to the safety management as well as a wider vision over how digital transformation and change management strategies has helped the process and finally an overview on current and future situation of AI deployment for construction safety management.

3.2 NEW TECHNOLOGIES – 3D-MODELLING (BIM), AND ARTIFICIAL INTELLIGENCE (AI)

Overall, automation for construction (safety) offers many similar benefits observed in the manufacturing and industrial sectors whereby these automations provide shorter construction processes (Kothman and Faber, 2016; Tajeen and Zhu, 2014), reliability in operations, new functionalities and personalization freedoms (Loonam et al., 2018). As per the introduction, authors Polyanin et al. (2019) have shown the student writers how human society is currently undergoing a digital industrial revolution. More to the point, these digital technologies enable a wider range of customization to the client's product and service (Loonam et al., 2018; Kothman and Faber, 1999) with such mass customization processes and procedures evolving to become business as usual and thus being offered at the same price. The rhetoric behind this argument is that of mass-customization anchoring itself into day to day customer expectation with the arrival of new technologies such as 3D modelling, additive manufacturing (3D printing) and artificial intelligence (AI).

These technologies have contributed to terms such as smart construction site, construction site of the future (Edirisinghe, 2019) and other declinations which are beginning to make an appearance in both the academic and practice fields as they pertain to the context-aware technologies (Edirisinghe et al., 2014a, Edirisinghe, 2019) that seek partial or full automation of certain tasks, activities and processes. Nevertheless, one must stay wary of outside industry technologies being pushed into other uses and functionalities. In some instances, these solutions do not aid in changing the root of the problem itself. Indeed, the fundamental objective of automation in construction is to enable resources to manage fully automated processes and operations (Edirisinghe, 2019) so to focus on the human quality that is creativity in this digital future (Polyanin et al., 2019).

In this sense, 3D Modelling sought to address the problem of the construction industry of tomorrow, namely collaboration and interoperability of software, trades and organizations (Weiming et al., 2010) all along the project lifecycle which according to Edirisinghe et al. (2014a), was the prevailing hindrance towards the successful shift from traditional manual processes to an interoperable and arguably automated process. The renewal of traditional construction design, method and process from technologies such as BIM, Digital twin and AI (Aouad et al., 1999; Agarwal, Chandrasekaran and Sridhar, 2016; Alsheiabni, Cheung and Messom, 2019; Tajeen and Zhu, 2014) imply that said technologies are of a disruptive nature and thus pose to improve performance that is greater if a disruption or change were to occur in any one of these areas (Kothman and Faber, 2016). A critical point in this disruption of traditional practices is the change management perspective adopted by the given managers of current leading organization to drive their habits away from business as usual with clearly communicated objectives, motivations and implications of structure and resources (Agarwal, Chandrasekaran and Sridhar, 2016; Panetta, 2017).

Research has routinely invoked the heterogeneous and dynamic nature of the construction worksite (Edirisinghe, 2019; Zhou, Goh, and Li, 2015; Agarwal, Chandrasekaran and Sridhar, 2016; Motawa et al., 2007, Lines et al., 2015; Brown, Hampson and Brandon, 2006; Dubois and Gadde, 2002) and thus infer the need for these new technologies to accommodate for geographically dispersed locations inter-organizational structure, single-project working relationships, relative short-time durations and competing stakeholder groups. These particular complexity factors in the set of relationships are most known as Weick's pattern of couplings (Dubois and Gadde, 2002) whereby projects are portrayed with tight couplings while the industry as a whole is loosely coupled system. This theoretical frame is further discussed in the next pages.

3.2.1 3D modelling - BIM

During the 1970s and 1980s many aerospace and aeronautical companies such as the French company Dassault Aviation with its original Dassault Systems modelling software for example pioneered Computer-aided Design (CAD) 3D modelling and improved their own productivity tenfold (Agarwal, Chandrasekaran and Sridhar, 2016). Although there has been many other software and companies e.g. ArchiCAD or Autodesk that have contributed to what is now known as CAD. Since then the automobile and healthcare industries have successfully adopted and applied CAD processes as well as its associated benefits even though this is the source of debates in the respective field of study which will not be addressed for this thesis. Yet only as recent as 2010s has 3D modelling – otherwise known as Building Information Modelling (BIM) – permeated through to the construction industry with the arrival of UK Publicly Available Standard (PAS) 1192-1 ... 1192-6. As introduced earlier, the construction industry is defined by a set of characteristics that play a key role in the slow adoption of new technologies, particularly those involving real-time sharing of information (Edirisinghe et al., 2014a). As a result of this digitization shortage, the construction industry has fallen subject to information sharing shortcomings for example still being heavily reliant on analog and paper forms of communication and reporting to manage its processes and deliverable (Agarwal, Chandrasekaran and Sridhar, 2016). Additionally, BIM provides a considerable amount of data which can serve to help the AI learn/train of which we will explain in the following subsection. Currently, the usage of real-time information systems, namely BIM (and more) have allowed for other technologies and developments to integrate themselves into construction procedures. The first of which is the use of the BIM model as well as other context-aware data sources (video, photo, sensors…etc.) to operate blind crane lifts (Edirisinghe, 2019) on the construction site. Another example includes the use of BIM for AR/VR applications (Edirisinghe, 2019; Panetta, 2016). Nevertheless, the thesis will not cover current VR/AR technologies development and deployment for construction safety as this falls short of the scope and the frame strived for. Overall, there is an explosion of data generation and collection throughout the construction industry in this era (CIOB, 2017b) which incurs a hefty potential for developments on the construction site of the future (Edirisinghe, 2019).

3.3 ARTIFICIAL INTELLIGENCE (AI)

AI's furthermost aim is to automate, mimic and even outmatch the natural intelligence (Hippold, 2019) which is already achieved to some levels in many logical fields, specifically with the use of machine learning (ML) and neural networks (NN) methods – two of more commonly used AI elements described in detail below – to enhance and empower tasks in different industries and even the construction (Eber, 2019). Although, as a part of Smarter with Gartner research, Hippold (2019) discarded the notion that AI operates alike a human brain as the first and foremost common myth associated with AI, arguing that albeit some forms of ML, more specifically image recognition, outperform most humans, in general they are not equivalent to a human brain performance just yet. This ability empowers AI to be used in improved and supported decision making (Costello, 2020), transform business models and shift the customer experience toward faster and more customized service (Duan, Edwards and Dwivedi, 2019; Loonam et al., 2018; Kothman and Faber, 1999). Fountaine, McCarthy, and Saleh (2019) in Harvard Business Review claim that an estimation of $13 trillion in the global economy would be increased as the consequence of AI implementation.

Though another perspective of common myths surrounding the arrival and adoption of AI in the field have led people to believe either: "AI will automate everything and put people out of work," "AI is a science-fiction technology" or even "Robots will take over the world" (Hippold, 2019). While the two latter myths obviously stem from fear and doubts as to the technologically induced change (Bosch, 2020), the former will be addressed in a later sub section of the thesis. Indeed, as with most disruptive technologies (Aouad et al., 1999; Panetta, 2017), there are those who perceive it as an inhibitor/barrier (Alsheiabni, Cheung and Messom, 2019) and others as an enabler/driver (Aouad et al., 1999) and it is most often the former who are reticent toward change and hinder its smooth and successful transition into common practice (Aouad et al., 1999; Bosch, 2020). In the same line of thought, Oesterreich and Teuteberg (2016) claim that construction industry was ranked as one of the lowest when it comes to investments in R&D based on the 2015 EU R&D Scoreboard.

3.3.1 Levels of AI implementation

Although AI is pushing the boundaries further day by day in several aspects of intelligence, such as emotion or creativity it still has some deficiency compared to human intelligence. In 1980s, Searle, a philosopher divided AI into two level: Strong AI and Weak AI. The first level which is also referred to as Artificial General Intelligence (AGI) performs a high degree of Artificial Intelligence which is closer to human intelligence in terms of perception over the environment. In the latter, the machine only perceives and perform in a narrow range of a task and is known also as Artificial Narrow Intelligence (ANI). Weak AI or ANI makes a wide range of commonly used applications nowadays, including Apple's Siri or Amazon's Alexa (Taulli, 2019, Kreutzer, and Sirrenberg, 2020).

3.3.2 Elements of AI

AI is implemented through various methods and techniques. According to Taulli (2019) (See Fig. 2) artificial intelligence is the superset for Machine Learning and ML is considered the superset of Deep Learning.

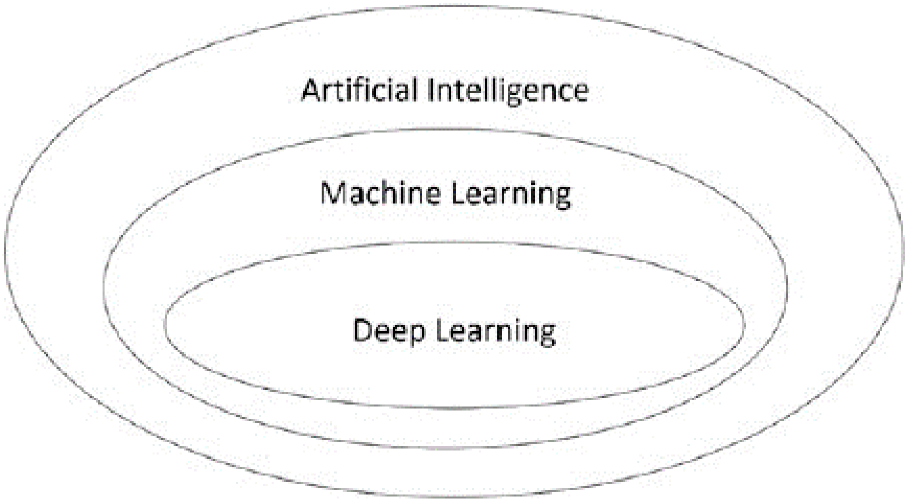

Figure 2 - High-level look at the main components of the AI world

3.3.2.1 Machine Learning (ML)

While in a consequential programming, a set of logical processes is defined by a programmer to be run (if-then relationship), the concept of AI brought another approach to creating software. In contrast to consequential programming, with the use of Machine Learning, the programmer provides the computer with data to be processed instead of lines of consequential programming. In this way the computer learns by analyzing the given data which is called the training or learning session which can be either supervised or unsupervised as will be discussed further. Later the computer is able to respond to requests by use of its analysis during the previous trainings (Taulli, 2019).

The learning process in the ML technique is run through various ways. According to (Monostori, 2003), these learning processes can be categorized into three different categories: supervised learning, reinforcement learning and unsupervised learning. In a supervised learning method, the data is labeled with the desired output or target, and the actual output is compared with the target to achieve the higher accuracy level in the model while in reinforcement learning feed-back is provided only in the form of evaluation of the output. The unsupervised method used a set of unlabeled data and the machine itself must make sense of it given an unspecified guideline (Munakata, 2008).

3.3.2.2 Deep Learning (DL)

As previously illustrated, deep learning is a subset of machine learning which can be explained as the process of learning by examples similar to human mind. Deep learning is used more in data sets which are not labeled but instead they share similarities (Taulli, 2019) which further infers to be able to classify certain types of data for sound, images or videos (Darko et al., 2020). One of the more commonly used methods of DL is neural networks which is the reason that these two words correlate intensively in literature, although NN is not the only component of DL.

Accordingly, as a part of the Gartner Report, Costello (2020) forecasts that by 2022, 75% of Deep Neural Networks (Deep Learning circle in Figure 2) will be used for cases that would achieve similar results with classical ML applications. They go further and stipulate that "simple machine learning techniques sometimes make the most sense" over other popular but intricate AI options.

3.3.2.3 Neural networks (NN)

According to Kreutzer and Sirrenberg (2020), Neural Network is an important component of Deep Learning, even though the term existed before coining the term DL. Artificial Neural Network is similarly defined to its to the neurobiological homonym. The artificial neural network is a simulation of human neural system and in a same way it builds an interconnection between neurons which is also known as nodes in data science. The construction of these interconnections is similar to the human brain, that is, based on experience and training with datasets (Kreutzer, and Sirrenberg, 2020; Munakata, 2008; Monostori, 2003). Within the training, different layers of connection build up, which means after a training session, a network is constructed which connects the input data to the output. The complexity and accuracy of the network can be determined by the number of existing layers as well as the number of nodes in each layer or in another term, how deep the network is (Kreutzer, and Sirrenberg, 2020). Figure 3 illustrates a simplified conceptualization of neural networks. As it is shown, the first layer is called inputs which is the data that is fed into the neural network while the last layer, output, labels the data based on the previous training sessions.

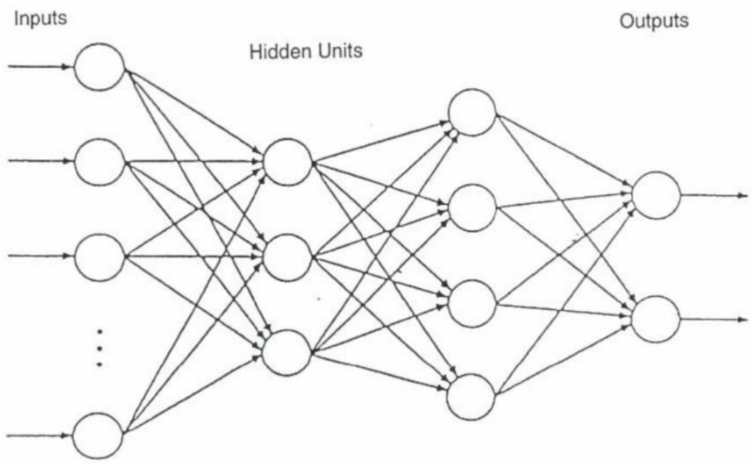

Figure 3 - Schematic view of the connection of neurons in a Neural Network (Kosiński and Kozlowski, 1988)

According to Darko et al. (2020) who undertook a scientometric study on the current situation of AI in AEC related researches, Neural Network has been one of the most frequent AI sub-techniques being explored by researchers in construction industry.

3.3.3 Construction and AI

In general, construction technologies and methods could be set-up and left alone for a rather long period of time without updates (Panetta, 2017). Yet, a key part of AI is its iterative learning process, that is that AI software routinely require refining/retraining parallelly to new data collection and acquisitions, only then will AI solutions retain their business value over the years and ensure high success rates (Costello, 2020). Parallelly, the BIM software and collaboration methods generate a considerable amount of centralized and verified data which can serve to standardize and stream the data acquisition channels to further enforce the endless retraining loop of the AI (Panetta, 2017).

With a focus onto the construction phase of building construction, Tajeen and Zhu (2014, p.10) argue this comes as a result of the "chaotic, dirty, untidy and cluttered with machines, tools, materials and debris" features of the construction site which make for example image recognition more complex due to the obstruction of view for objects and individuals.

Nevertheless, due to the exact same reasons inhibiting the wide deployment of AI in construction management, i.e. chaos, complexity and uniqueness of projects, AI is capable of benefiting the industry immensely by solving the "complicated, non-linear practical problems" and additionally by its high capacity for amount of data to be analyzed and further used in the industry (Darko et al., 2020; p.1). While the potential existing data in construction is vast, it can also be identified as heterogeneous in type; they comprise of images, videos, construction documents etc., yet in different research projects implementing AI in construction, more precisely computer visions and image recognition deployment, there is the issue of lack of enough data for training the model which could lead to false or inaccurate results. For instance, a research on the use of computer vision to recognize use of harness for safety compliance acquired less accuracy due to reasons such as limited amount of collectible data for trained model as well as false detection due to the color of the harness (Fang et al., 2018) or later in Nath et al.'s research on PPE detection, the result suffers the inability of the model in color recognition for equipment (Nath et al., 2020). On this note, it was a common denominator identified along the study is the lack of collaboration and collectivism in the gathering of data and model design. It can be argued that while some organizations utilize orange high viz vests and others yellow or also a brand recognition-based model is counterintuitive to pooling data.

To a certain extent, the marriage of AI technology and construction can be assimilated to Weick's coupling pattern (Weick, 1976; Dubois and Gadde, 2002). The particular coupling pattern present in the construction according to Weick is built upon two interdependent layers as a result of the construction industry's particular set of factors and uncertainties from the short-term collaboration of many organization sizes, skills, information and so forth. On the one hand there is the tightly coupled relationship during projects on the other hand there is a loosely coupled permanent network (Dubois and Gadde, 2002). From this perspective, Weick (1976) concludes that the specific pattern hinders innovation and long-term learning whilst facilitate short burst of productivity for the project's, hence, the collaboration's duration. Still, in adopting Weick's pattern of couplings there is the appearance of a paradigm in the industry. While the loosely coupled system is a potential reasoning for the technological and innovation lag present today in the industry, it also makes room for local adaptive solutions where any single tightly coupled local element can successfully adjust to the unique project factors without affecting or being dependent of the whole system. This means the very same pattern which allows so many localized innovations to bloom is also the very same which hinders their spread throughout the entire system. Dubois and Gadde (2002) denote that the individual organization’s role as well as the overall division of labor and responsibilities differ significantly from one instance to another; in turn, adding a supplementary layer of complexity and thus requiring a certain need for flexibility. Accordingly, contrary to what common logic delineates - namely that loose implies less connection between players thus less success – Weick ‘s (1976) opinion concedes on the lesser connection between players but deems this to create a lesser reliance and so a more flexible relationship in the sense that during shot-term bursts of innovation and problem-solving a higher flexibility equates to a higher success. In other words, the system-wide freedom brought about by the loosely coupled system purports an array of solutions to a one single problem thus pushing innovation in variety (Dubois and Gadde, 2002). As such, they continue by stating that novel adaptations can be hasty and cheaper as they are local. Similar to Weick, Dubois and Gadde (2002) found that a loosely coupled system on the industry scale is more beneficial to innovation that if it were tightly coupled – this comes as a result of the greater number of local mutations present in the system which favors efficiency. Still, it can be said this statement is somewhat unfounded because from Weick’s work in 1976 to Dubois and Gadde’s in 2002 there is still this dissonance between the system enabling vaster amounts of solutions while hindering their diffusion and adoption across the system itself. For instance, several viable local solutions to known industry problems could have been born and died on the one same tightly coupled project. This can be anchored to the learning and feedback nature of the construction industry (Weick, 1976). The absence of this knowledge sharing process – also referred to as ‘organizational memory’ - together with the pattern of coupling essentially results in each project becoming an experimental worksite (Dubois and Gadde, 2002, p.628).

3.4 SAFETY MANAGEMENT

Over decades, workplaces have been the ground for accidents leading to an injury or undermining a worker's safety whose cost not only is limited to economic costs but also social and human costs. Occupational health and safety or used interchangeably, Occupational Safety and Health (OSH) is defined by International Labour Organization (ILO) as follows: "...the science of the anticipation, recognition, evaluation and control of hazards arising in or from the workplace that could impair the health and well-being of workers, taking into account the possible impact on the surrounding communities and the general environment" (Alli, B., 2011, p.vii). According to International Labor Organization, aka ILO's illustration of risk, a potential hazard combined with exposure brings the risk. The objective of occupational safety and health (OSH) is "the management of the occupational risk" (OSH management system, 2011, p.1) which is achieved by a thorough risk assessment and preventive solution provision. An essential part of this process is to establish the occupational exposure limits (OEL) as well as possible occupational accidents. Occupational health and safety management system (OSHMS) was developed as an aiding method for OSH to be obtained in a work environment following the usual four-step system's theory: plan – do – check – act (OSH management system, 2011). In this system plan is the regulations and guidelines in OSH and implementing the guidelines or customized devised procedures and conditions to prevent the risks and injuries refers to do. Although the influence of OSH and OSHMS implementation in construction industry has been exposed to doubts and hasn't proved to be totally functional according to Goh and Chua, 2013 and Machfudiyanto et al., 2017. In spite of its limits, e.g. regional data based on a single large company's project, the research uses a novel method in 2013 to see to the co-dependency of elements of safety management. While for instance, in case of higher level of incident investigation and analysis or emergency preparedness, accidents occur less frequently or less sever, the increase in safety training affect the results negatively, i.e. increase of accident occurrence or severity (Goh and Chua, 2013). Moreover, Edirisinghe et al., (2014b) believes current methods of upkeeping workplace health and safety in construction are restricted and arguably faulty. Therefore, it may be more effective to promote guidelines and regulations that minimize impact of external market forces (cost cuts, time crunches, subcontracting…etc.) on site safety rather than simply increasing safety competency (Kerry and Brown, 2006). In essence, the influence of the internal executive carrot on safety culture is one part, nonetheless the legislative and regulatory stick should play a more essential role on adopting adequate safety behaviors.

Maintaining a safe workplace also contribute to the measures of sustainability in a company. Considering sustainability as a movement to "preserve the societal, economic and environmental systems" (p.3), it inherently includes the wellbeing of human beings which gets explicit in the UN sustainable goals; "decent work and economic growth" and accordingly, providing a safe workplace for workers. Contemplating on the notion of occupational safety composing a part of social aspect in sustainability, this could enhance the involvement two groups. On one side, it makes the sustainability-focused attempts to turn a head toward OSH and in the same manner, the involved people in occupational safety to take a step out of the traditional mindsets (OSHA, 2016).

It is important to point out here that the study will be placing the emphasis on the safety of the worker and thus the work environment and occupational safety rather than health variables. This therefore focuses on the construction site and the direct safe environment the worker is confronted too on a daily basis. This choice comes as a result of the more tangible and immediate factors that safety incidents possess when compared to long term health issues like chemical, socio-psychological, noise, light and so forth.

For the extent of this thesis the scope for safety regulations and standards is not narrowed to one nation but rather on the construction industry as a whole. This choice came as a result of the novelty represented by AI in construction safety currently in both academic research and in practice.

3.4.1 Safety management theories

Today, the managers have started a more inclusive attitude toward safety management to benefit the cooperation of different stakeholders including unions, labor force, and legislators in the field (Edirisinghe, 2019). Fig. 4 illustrates an overview of the change in organizational safety which is the superset to occupational safety (Lutchman, Maharaj, and Ghanem, 2012).

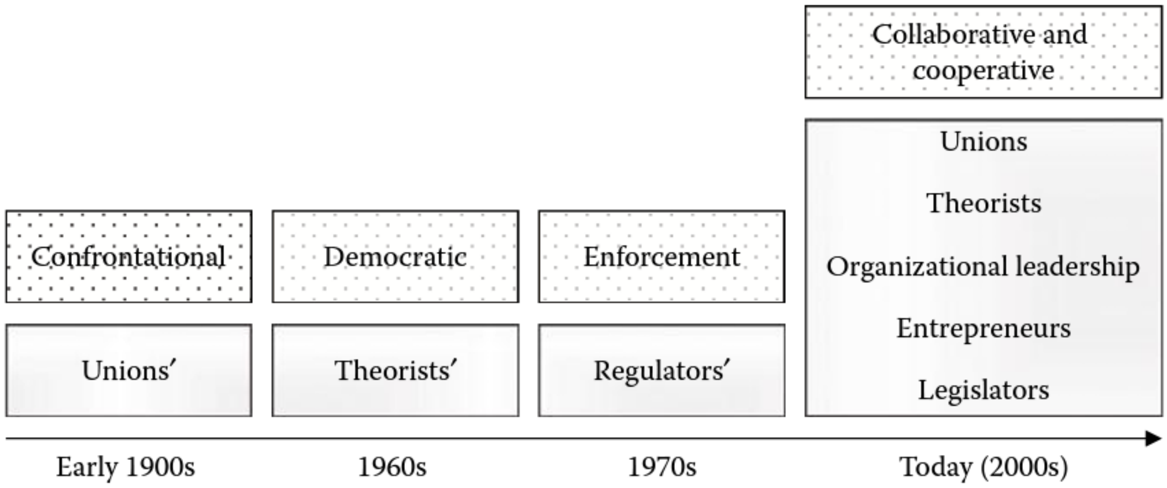

Figure 4 - Development of stakeholder involvement in organizational safety (Lutchman, Maharaj and Ghanem, 2012)

To further defining safety and more specifically construction safety, the heavy influence of organizational beliefs and values on the safety of their construction site is heavily established both in academia and practice. Kerry and Brown (2006) point out it is the nature of construction work, which is contrary to a proactive safety culture behavior, then turn the finger to those in decision-making positions to ensure a humanistic approach to actual safety on site. In keeping with the humanistic approach line of thought, relative to safety management, it can be categorized as a means and way to involve workers, share information, inciting workforce motivation, communication and so forth (Kerry and Brown, 2006); all in all, pushing toward the profound and correct knowledge for those in safety critical roles in the industry. In a different article from the collection of Kerry and Brown (2006) authors Biggs, Sheahan and Dingsdag (2006) found that safety culture was an organizationally based shared ideology whereby values, norms and behaviors and can be wildly heterogeneous as a result of that each company essentially managing its OHS regulations autonomously. Yet, to invest in the improvement of occupational safety management system is no longer considered as an expenditure but as an investment supported by different research and data (Lutchman, Maharaj, and Ghanem, 2012; Sutherland, Makin, and Cox, 2000). Still incorporating technology for safety in some industries can be more challenging. Aside from the difficulties of bringing the senior generation to technology front and facilitate their adaption to the new system (Lutchman, Maharaj, and Ghanem, 2012), in some industries such as construction, the cost of technological change is regarded as a barrier (Nnaji, and Karakhan, 2020).

According to (Lutchman, Maharaj, and Ghanem, 2012), Geller enlisted 6Es which are crucial elements of safety management while they add another E to the list based on their perspective on a newer and higher-performance model of safety management.

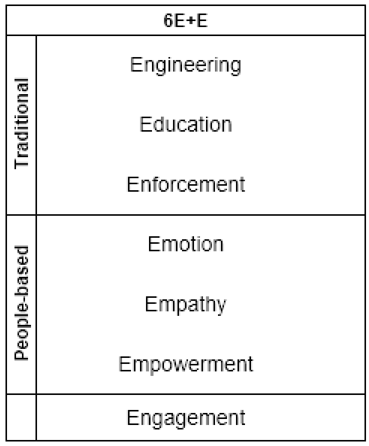

Figure 5 - 7Es of safety management according to Lutchman, Maharaj and Ghanem, 2012

Fig. 5 shows 7 elements which (Lutchman, Maharaj, and Ghanem, 2012) divide primarily into two sets of 3Es; the first set corresponds to the traditional perspective toward managing safety and comprises Engineering, Education and Enforcement. Engineering contributes to reduction of the safety risks by predicting risk in design phase and provide the proper solutions by equipment design and a safe environment (Geller, 2008) which leads to Education in which workers on site get trainings in accordance with their task and job and with Enforcement the safety manager makes sure that everyone is abiding by and following the rules. Geller (2008) suggests that the functionality of the traditional approach is not sufficient for a world class safety performance which can be achieved more effectively by inserting a more humanistic view to the matter of safety management. The second set of Es comprises of 3Es which Geller (2008) mentions and another E which (Lutchman, Maharaj, and Ghanem, 2012) add to his list in both they focus on a people-based consideration toward the matter. Based on what Geller discusses, since emotions are capable of invoking actions in people, they can be a good source of motivation. By explaining the consequences of neglecting safety rules and training from a personal and emotional point of view, the matter of safety becomes personal as well. Consequently, showing and promoting empathy helps further to build a coherent sense of responsibility in individuals for others. The sixth E, empowerment, as vague as it can be in organizational settings, in Geller's perspective, it should convey the sufficient authority for individuals to take action in the case of witnessing unsafe behavior (Geller, 2008). The last E, which is engagement, allows the workers to be part of the measures taken for safety design (Lutchman, Maharaj, and Ghanem, 2012). They recognize the role of a righteous leadership to be the solution for creation of a safe environment by influencing the behavior of the workers and align them with the safety vision of the organization. In the same way, Sutherland, Makin and Cox (2000) emphasize on the importance of focusing on behavior as the better alternative to attitude by realizing the motivation behind the action or "why people behave as they do" (Sutherland, Makin and Cox, 2000; p.17). Later they suggest avoidance of punishment for unsafe behavior by the managers and replacing it with appreciation for safe behavior. The role of a leader would also be discussed in change management as an important component for creating a keener reception toward adapting to changes, specifically new technologies (Walker and Lloyd-Walker, 2018).

While Geller depicts a general picture labelling the elements which play an important role in designing a safety management system, improving Occupational Health and Safety is examined from other perspectives as well. To look into the accidents and find the essential cause, attracted attentions of researchers for almost a decade, one of the debuts was the domino causation model of Heinrich (1931), revised by Bird (1974), later another linear model was introduced and developed by Reason, later developed to be known as Swiss cheese model in which holes in the cheese are metaphorically the flaws in safety management system which must be identified and covered. The Swiss cheese model covers a wide spectrum from organizational flaw to individual ones and proposes 3 elements that each play a role in accidents; the risks, defensive layers and losses (Suraji, Duff and Peckitt, 2001; Larouzee and Le Coze, 2020). The model was originally meant for a causal analysis yet the defensive layer could be interpreted as the barriers which can prevent an accident; such as supervision, regulations, PPE etc. Although this model has been criticized by other researchers, due to its clarity makes it comprehensible (Larouzee and Le Coze, 2020).

Pointing out to unsafe behavior as one of the main causes of accident such as Heinrich in 1930s who explains an accident by a series of events resulted by fault of a person (Suraji, Duff and Peckitt, 2001) is outdated now. Instead, analyzing the reasons behind an accident and learning from them, leads to a more proactive safety system by preventing the recurrence of the same chain of causal event. According to Geller a change from behavior-based safety to a people-based safety needs leadership as an essential element to enable everyone to turn to a self-initiative approach for safety measure. In another word, each workforce would take the responsibility for enhancing and maintaining a safety climate not only for themselves but also for the others with a strong emphasis on the role of leadership through which a work environment can improve in a more interactive and integrative way (Geller, 2008). Considering the concerns of the academics in the field, through a literature review ran by Zhou et al. (2015) on 439 papers, a gradual change in course of researches happened in safety in construction, standing on a statistics point of view in the beginning followed by calculations of costs and inducing injuries' factors and later moving to a more humanistic approach which focuses on workers and how to encourage them toward safe behavior (Zhou et al., 2015).

Overall, the humanistic approach, or humanistic psychology, is centered on allowing people to behave and act out of a sense of free will (Bosch and Gluch, 2020). It is an optimistic view of people whereby one seeks to find their inner strengths and capabilities in that sense allowing a worker to behave freely and it still be in a safety compliant manner (Bosch and Gluch, 2020) yet if a safety culture is overruling the whole organization, this becomes more probable that individuals follow the safe behavior (Sutherland, Makin and Cox, 2000) The humanistic approach inherently maximizes behavioral learning by necessitating the full emotional presence in the situation from the worker. It stresses the importance of subjective awareness as experienced by the individual, the importance of taking responsibility for one's situations and accepting the element of choice (Bosch and Gluch, 2020). In other words, it is referred to as a holistic approach in that we are not just how we feel, act and behave, we are that in a social and cultural context as previously explained.

3.4.2 Safety in the Construction industry

Research has routinely invoked that "throughout the world the construction industry is a hazardous industry" (WHSQ, 2013: p6 cited in Edirisinghe et al., 2014a; Edirisinghe et al., 2014b; Mneymneh, Abbas and Khoury, 2017). In spite of an array of safety management regulations, inspections and approved codes of practice the construction industry is still subject to a record high rates of workers fatal and non-fatal accidents when compared to other industries (Mneymneh, Abbas and Khoury, 2017; Edirisinghe et al., 2014a). Yet, Sweden has a lower number of accidents and death rate. In 2018 the rate was counted to around 6000 accidents with only 12 cases of death in all industries from which 8 cases belong to the construction industry according to Håll Nollan (Samuelson, 2019) demonstrating that even though the number is significantly lower than other regions and countries, construction industry accounts for two third of the total fatality cases.

Accordingly, the European Commission (2012, cited in Edirisinghe et al., 2014b) denotes as well that a quarter of all deaths at the workplace occurs in the construction sector, with other nations such as the US reporting a fifth (OSHA, 2018; Edirisinghe et al., 2014a). A construction worker is more prone to accidents such as OSHA's (2018) fatal four: slips, trips and falls, (34%) struck by an object (11%), electrocutions and fire (9%) and caught-in/caught-between (6%) and has a 1 in 200 chance of succumbing to a fatal accident in a 45-year career (Edirisinghe et al., 2014b). To illustrate, the subsequent table of activities and work environment conditions derived from Edirisinghe et al. (2014b), depicts the many reasons why the statistics for safety in the construction industry are so appalling:

Vehicle Traffic	Working below elevated surfaces	Working in confined spaces	Working under lifter load
Heavy vehicle traffic	Open holes, excavations and trenches	Unsafe scaffolds	Overload mobile equipment

Table 1 - Unsafe work environment conditions and activities as per (Edirisinghe et al., 2015 & Biggs et al., 2006)

Theoretically, safety related indicators can be derived, defined, and used as pre-emptive precursors to such conditions and accidents (Edirisinghe et al., 2014a, Halsam et al., 2003 cited in Edirisinghe et al., 2014a and cited in Winge, albrechtsen and Mostue, 2019; Motawa et al., 2007). Halsam et al. (2003), cited in Edirisinghe et al. (2014a), and cited in Winge, Albrechtsen and Mostue (2019), developed what is now referred to as the Construction Accident Causality (ConAC) framework wherein they categorize safety related indicators into three categories:

1. Originating influences: client requirements, permanent works set out, safety culture and risk management
2. Shaping factors: communication, collaboration, supervision, geographical restrictions, worker conditions
3. Immediate circumstances: usability, feasibility, weather, worker behavior, immediate site environment

There are few accident causation frameworks developed for on-site safety in the construction industry (Edirisinghe et al., 2014a) and with consideration to supervisors' ability decreasing by the larger the construction site and/or number of workers on site get (Mneymneh, Abbas and Khoury, 2017) as well as the high number of projects shouldered by a safety inspector (CIOB, 2017b) not unheard of.

All in all, the circumstances for measuring adequate PPE training, activities and site layout could use a hand in upkeeping and improving their performance (Mneymneh, Abbas and Khoury, 2017). This is where AI solutions development, deployment and implementation can play a role in the workplace health and safety execution thus bringing us to the following section.

3.4.3 Safety and AI

The vast amounts of safety data produced by each project in construction industry, is too grand for any individual to analyze on their own – let alone given the fact that a safety inspector can have up to 10 construction projects simultaneously (CIOB, 2017b). This is where AI can come into play and shoulder the analytical and process role (Panetta, 2017). As AI delivers the potential to disrupt business as usual, organizations are turning more attention to it (Panetta, 2017; Costello, 2020; Agarwal, Chandrasekaran and Sridhar, 2016).

As introduced above construction industry is known to be the main responsible sector for work environment injuries and accidents notably in USA (OSHA, 2018) and Europe (EU-OSHA, 2019; European Commission, 2012). The number of fatal accidents in construction surpasses the rate in other industries. According to (Mahalingam and Levitt, 2007, OSHA, 2018, European Commission, 2012 cited in Edirisinghe et al., 2014a), while only 7% of workforce in the world are employed in construction sector, yet the fatality rate is one third of the whole fatal injury in all industries. Bearing the mentioned numbers and ratio in mind, the construction industry calls for a more effective safety management practice which can help reducing the statistics (Winge, Albrechtsen, and Arnesen, 2019). An increased consideration about the accidents resulted in an increasing number of researches forming around the concept of health and safety management in construction.

3.4.4 Trends and early stage examples

As per what was mentioned earlier, in AEC industry, the pace of change toward adaptation of innovative technology is sluggish yet the increasing awareness of its benefits (Zhou et al., 2015) and the swarming influence of these new technologies on other industries, constantly pushes the industry forward to more deployment of them. An overview on research carried out in safety management in construction industry (until 2013) shows a quadrupled number of researches on innovative technology applied on safety in construction industry under a 3-year period between 2008-2010 compared to the 2002-2004 period. The number from the 2008 to 2010 period doubles in the next three years (Zhou et al., 2015). Although one must be aware of the management fashion concept – namely the swing in popularity of certain management techniques and best sellers as well as software and consulting solutions which promote one best way theories (Bosch and Gluch, 2020). Management fashions differ from other management theories as they are pseudo-scientific concepts and solutions promoted by buzzwords from a powerful network of gurus, consultancies, software firms and business schools (Bosch and Gluch, 2020).

Past developments in the field of AI for Construction workplace safety sought out to process real-time information from construction operations and processes to track and analyze data related to material, people and equipment (Weiming et al., 2010). According to Nath, Behzadan and Paal (2020), while computer vision and deep learning techniques enabled opportunities for tracking PPE on site, most cases only focused on detecting hardhats. Although there are very few examples in which the detection goes beyond hardhats, such as Smartvid which provide a software for safety vests, goggles and gloves aside from the hardhat (Nath, Behzadan and Paal, 2020). The need for this data processing to be streamlined is ever more present in light of the above-mentioned numbers but also because sites are gradually getting more crowded, where many different activities are undertaken simultaneously. The immense data generation incurred by construction site not always captured let alone processed (Agarwal, Chandrasekaran and Sridhar, 2016). This is in part because sheer quantity of data is too grand for any individual to analyze on their own (Pannetta, 2017) and it is not unheard of to have on safety manager active on 5-10 projects (CIOB, 2017b). Still a prevalent area of debate in the field relates to the 'real-time factor' of the AI solution a wide variety of the safety data gathered requires to be processed immediately to be of any performative and pre-emptive use (Edirisinghe et al., 2014a; Tajeen and Zhu, 2014; Nath, Behzadan and Paal, 2020). This is otherwise referred to as the time-sensitivity issue of AI for H&S (Edirisinghe et al., 2014a).

All in all, sites are getting denser in equipment, materials and resources (Agarwal, Chandrasekaran and Sridhar, 2016). In this light, it is safe to claim that AI for construction safety implies a change in responsibilities and reach for the H&S roles in construction today.

3.5 DIGITAL TRANSFORMATION (DT)

The rise of the digitization era driven by a widespread of methods and tools, such as AI which instigated a digital transformation (DT), turned around most of the industries (Alsheiabni, Cheung and Messom, 2019). In the midst of this era, it could be argued that the construction industry has no choice but to undergo a transformational change (Loonam et al., 2018) for which improved automated evolutions become the norm and the associated processes are fundamentally transformed (Bosch, 2020). Authors (Koscheyev, Rapgof and Vinogradova, 2019; Loonam et al., 2018) surmise that DT is a key success factor towards delivering organizational competitiveness and development. On this matter, a study conducted by Loonam et al. (2018) found that a given number of critical success factors were pivotal to safeguard a successful digital transformation (DT) including but not limited to a focus on change management (Motawa et al., 2007) and effective leadership (Alsheiabni, Cheung and Messom, 2019; Fountaine, McCarthy and Saleh, 2019; Bosch and Gluch, 2020). With regards to the latter, a survey conducted by the Gartner Report (Moore, 2019) found that nearly half of CEOs had no metrics for digital business transformation – and even though this study was cross industrial it leaves one to suspect that proportions would be lower for construction industry CEOs than that of the ICT industry.

3.5.1 Levels of Digital Transformation (DT)

In light of this, research has invoked different levels of digital transformation notably the stages and decisions one implements, changes, and finally enacts (Koscheyev, Rapgof and Vinogradova, 2019). As previously explained, change management has an array of definitions and as such so does digital transformation. Moving forward, digital transformation is not only considered a goal to interlink machines and IT infrastructure with people (Bosch and Gluch, 2020) but doing so in a way to necessitates a complete review of business model in some branches of an industry (Koscheyev, Rapgof and Vinogradova, 2019); more specifically, an initiative brining about a change to the flexibility of otherwise very 'centralized and standardized operational processes' (Loonam et al., 2018, p 102).

Recalling upon earlier words, this digital revolution process is commonly associated with BIM and the newly found information system functionalities. Nevertheless, from a purely theoretical standpoint, in the categorization for theoretical models for change by Van de Ven and Poole (1996, cited in Bosch and Gluch, 2020) the thesis will adopt a constructed rather than a predetermined trajectory. In other words, the dialectical and teleological theorists believe change is a goal set out and in control by those in charge, thus favoring human agency in the digitization process (Bosch and Gluch, 2020). Contrary to this, evolutionary predetermined theorists believe that change is issued from a predictable incremental adaptation of a process in specified direction whereby change is just a step in a sequence or cycle that is identifiable.

While the definition of digital transformation's change management is vague (Moran and Brightman, 2001; Agarwal, Chandrasekaran and Sridhar, 2016), for the extent of this report it will be considered as the "renewal of an organization's direction, structure" and service to clients (Moran and Brightman, 2001; Motawa et al., 2007). Although project management is the process of leading a team through construction tasks to a clear goal and target date, change management has for intent to adapt internal processes to external demands (Bosch and Gluch, 2020). The academia in this field can be categorized into two theorist groups when it comes to change: planned change and emergent change theorists; and also into four schools of thoughts: teleological, lifecycle, dialectical and evolutionary theories (Bosch, 2020). More generally though, the common features amongst all theories' intake on change management is that it involved a series of events, decisions and adaptations to an either constructed or predetermined directions albeit they debate over the degree and extent to which executives play a role in the change in and of itself.

3.5.2 Implications for organizations

With the increasing rate of "projectification" in various organizations, the role of project management is not totally limited to project-centered companies namely construction, thus the importance of project management theories is on the rise. Even though there is a decent literature database on project management, the new technology and its exponentially rapid pace is severely missed or ignored in comparison to its significance (Walker and et al., 2018). While there is a general concern on the future of technology and the impacts of Industry 4.0 on humans' life, in project management career there is the more specific concern of how the interface between human employees and the intelligent systems would look like. In this context, different issues must be addressed. One of them is the continuous dilemma that if it's ethical in case advances on technology comes at high price of workers losing their job. Although the same concern existed during the third industrial revolution, the criticality wasn't as of today's (Walker et al., 2018). Fountaine, McCarthy and Saleh (2019) explain that the organizations in which a process of AI deployment is undergoing, expect resistance due to different reasons such as outdated workers' skillsets or company's culture. Currently, the emergence of new intelligent systems or AI techniques is shifting the way the organizations are functioning. Certain methods of AI now undertake an increasing number of tasks which were used to be manual such as automated customer service (Fountaine, McCarthy, and Saleh, 2019).

Pertaining to the implications for organization brought about AI adoption and deployment the first relates to above mentioned effective leadership (Alsheiabni, Cheung and Messom, 2019). In their study, Loonam et al. (2018) reviewed 10 DT cases and proceeded onwards to develop a conceptual framework to support others whether academic or in practice albeit, limited to a lack of empirical data for the scope and level of this paper should suffice. This being said, they proposed that with due consideration given to the disruptive nature (Kothman and Faber, 2016; Loonam et al., 2018) of AI, and in parallel with Schein's model for transformative change (Bosch and Gluch, 2020), it requires a flexible bottom-up managerial approach to best convey the emergent technological demands in line with the newly adapted business model. Furthermore, they recommend giving careful attention to the alignment of new business needs and models with the intentioned best-fit breed of AI technology uses to ensure competitive success (Loonam et al., 2018; Pettey, 2017). Panetta (2019) offers an interesting standpoint on the topic opted by declaring one should replace "*technology-literate people with people-literate technology*".

The second implication for organizations, similar to the previous one, correlates back to what was introduced earlier on from Alsheiabni, Cheung and Messom's (2019) study wherein "*organization that does not invest in change management will face the same resistance encountered during previous waves of technology deployment and are more likely to fail*" (Agarwal, Chandrasekaran and Sridhar, 2016: p.28). Still, at this point in time organizations are cautiously delving into AI applications with a learning and experimental perspective rather than rushing their way through the digital transformation change (Pettey, 2017). Indeed, it is often best to begin AI deployment on small to mid-size pilot projects before megaproject applications (Agarwal, Chandrasekaran and Sridhar, 2016). In conjunction with what we have learned regarding the recent technological revolution, 3D modelling and more specifically the ways in which the construction industry tentatively approached these technologies and learnt from its counterparts infers a slow but perhaps enhanced success rate.

The third implication for construction organizations is the iterative honing of the AI model and process to best match the desired business model and needs and ensure high success rates (Costello, 2020). In other terms, it is crucial to safeguard a standardized data pipelines (Agarwal, Chandrasekaran and Sridhar, 2016; Costello, 2020) and established a controlled data flow (Jiang et al., 2010). Plus, it is common for the construction to sit on old technologies for several years or even decades, but AI requires a regular updating and training.

3.5.3 Sensemaking

When it comes to making change and moving toward transformative technology, depending on the level of change it can be crucial to justify and reason the change to lay a smoother ground for stakeholders and involved actors to follow (Fountaine, McCarthy, and Saleh, 2019). This applies to transforming to an AI-empowered management system. As it was explained before, AI brings myths with itself. According to Walker et al. (2018), increasing use of AI can raise the question of what will happen to previously human-owned jobs.

Another consideration about making changes can be the return of investment. To quote Fountaine, McCarthy, and Saleh, (2019), “one of the biggest mistake leaders make is to view AI as a plug-and-play technology...” (Fountaine, McCarthy, and Saleh, 2019, p.1) which refer to a common doubt about investing on new technologies. This can be explained by the type of change (Motawa et al., 2007) and the reason behind it. For instance, Walker et al., (2018) suggests that emphasizing on “taking control” could be useful in order to deliver the sense of significance in individuals within the organization. In another level, according to (Fountaine, McCarthy, and Saleh, 2019) illustrating a vision of the future for stakeholders – including workers – can help with acceptance.

All in all, the reality is that commercial uses and pilots AI are complicated to scale up to an enterprise-wide application thereby diminishing the potential financial returns and general business value (Agarwal, Chandrasekaran and Sridhar, 2016; Costello, 2020). In effect, said large scale integrations force organizations to re-evaluate their competitive position in their respective market share (Koscheyev, Rapgof and Vinogradova, 2019; Alsheiabni, Cheung and Messom, 2019). The interesting notion that arise from the “re-balancing” of market positions is the ways in which company will address the complexity of AI data requirement and analytical power implementation through collaboration. An interesting school of thoughts is that of (Costello, 2020) who coins this as an “infrastructure led disruption” in regard to the partnerships and collaborative work between business and IT organizations required to successfully deploy AI tools and techniques.

In accordance with the work of Loonam et al. (2018), technology-centric and organization-centric actions are a best-fit to the subject at hand. Whilst the latter are indirectly covered above, this hereafter subsection will best attempt to cover the former. With regards to the former, the construction organization should seek out a horizontally integrated approach to systems “where digital technologies can seamlessly interact with one another” (Loonam et al., 2018: p107). In considering Gersick’s (1991: cited in Bosch and Gluch, 2020) punctuated equilibrium and gradualist paradigms we can begin to understand the ways in which organizations can take actions upon the required AI relative changes and transformations. In the building industry context, it is the punctuated equilibrium paradigm which best applies and describes the organizations’ actions (Bosch and Gluch, 2020). In this sense, the paradigm assumes either long periods of equilibrium in which persistent “deep structures” only permit limited incremental change or short periods of revolution wherein these deep structures are altered by bursts of radical discontinuous changes from the external environment. Within the context of AI for construction work-site well-being, one can safely presume the external pressures and market demand changes induced by AI on the industry’s working field.

3.5.4 Task/job reinvention and upcoming required skill set

As key part of disruptive technologies (Loonam et al., 2018; Panetta, 2017), and as believed by common AI myths (Hippold, 2019; Kothman and Faber, 2016), a key part of its successful deployment and implementation is the reinvention of job roles and responsibilities. In light of AI higher accuracy for prediction, clustering and processual based decision-making it is believed AI will only replace mundane jobs whose activities can be easily automated (Polyanin, et al., 2019). Albeit be categorized as a myth, many authors have gathered around the same school of thoughts the matter of the effect of AI on upcoming required skills and jobs. Authors Polyanin et al., (2019) and Kothman and Faber (2016) believe that there will be structural unemployment proportion increase for the medium to low skilled -people without secondary special education [SSE] (Polyanin et al., 2019)- jobs which therefore feeds into the fear and threat induced by deploying AI technologies in the construction industry (Bosch and Gluch, 2020; Kothman and Faber, 2016). The proportion increase in structural unemployment will only be greater in considering the fact that while the low and medium skilled workers will potentially lose a job, there is an expected shortage in supervisory resources to arise all the like (Agarwal, Chandrasekaran and Sridhar, 2016). Nowadays the eventuality of our work environment being untouched by digital transformation is very improbable; the change brought forth will result in the retention of certain skills, the creation and liquidation of various jobs and the appearance of digital company champions like Smartvid (Polyanin et al., 2019). They claim to be developing solutions to supplement the workplace health and safety team and not replace it (CIOB, 2017b), therein pointing one towards the realization that people define the goals and technologies only execute them (Pettey, 2017). The fear of change can really prove to be a hindrance to its implementation, and ironically implementing it in these conditions can contribute to exercising the negative impact one originally feared would happen (Bosch, 2020), yet according to Kagermann et al. (2013; cited in Walker and Lloyd-walker, 2018), the change evolved from technological advance enhances the opportunity of rather more responsive career path.

3.5.5 Knowledge management (knowledge sharing)

Clegg, Pitsis, and Kornberger, (2005) identify two types of knowledge: tacit and explicit. Tacit knowledge is the type of knowledge which is not easily described in instructions and processes for example the grammatical knowledge. But the explicit knowledge is the type of knowledge that can be learnt through reading and as its name shows it can explicitly be described. Tacit knowledge due to its characteristic is more valuable than explicit knowledge which is why most of organizations devote much credit on this type of knowledge and consider it as an asset and according to authors, the tacit data converted into explicit data, leads to a facilitated process of change. Based on Clegg, Pitsis, and Kornberger, (2005), Levit and March (1998) define organizational learning as a response to changes brought by organization's environment. Categorization of learning procedure into single-loop learning and double-loop learning dates back to Argyris and Schön in 1978 while the former indicates a straight-forward instructional approach aiming to obtain knowledge, the latter describe a more analytical approach toward what that has been obtained before and challenge what is implemented. According to Bhatt and Zaveri (2002), organizations cannot evade the need to learn as long as they interact not only within but also with the outer system or otherwise, they will be found incompetent as the environment changes while they remain still. Moreover, Clegg, Pitsis, and Kornberger, (2005) outlines that in a static environment single-loop leaning is the best and most efficient practice yet when the environment is changing, a critical overview on the guidelines and assumptions is more fruitful.

The process of learning in an organization can be challenging as it is not an individual achievement of knowledge but more of sharing the knowledge thoroughly among different levels and individuals in the organization (Bhatt and Zaveri, 2002). Likewise, Clegg, Pitsis and Kornberger, (2005) suggests what Wenger (2002) believed as the rewarding way of organizational learning which is not only by a number of sessions of trainings or scarcely happening seminars but through a more inclusive process called social learning system. In social learning system, knowledge gets shared among people with different fields and level of experience and knowledge through working on a problem of interest.

Digital transformation imposes changes to organizations which consequently force the technologically adapting organizations to go through a double-loop learning process. What new technology empower the companies with is the boosted collaborative nature of undertaking the tasks due to digitalized means of communication. This collaboration is primarily considered between people but it is not limited to that. In another perspective, to succeed in the era of digital transformation, the ideal workforce needs different type of knowledge, namely, cross-discipline knowledge as well as the ability to share individual situational knowledge with others in a collaborative workplace (Walker and Lloyd-Walker, 2018). With all being said, the challenge in this system of knowledge management which involves sharing the acquired knowledge with outer system environment needs trust.

Earlier on, we established that the literature found the construction industry lags behind others in terms of transformational change, more specifically digital transformation (Agarwal, Chandrasekaran and Sridhar, 2016; Motawa et al., 2007; Edirisinghe, 2019; Bosch, 2020). This is because traditionally, construction has opted for incremental, necessary changes associated to unique and temporal projects (Agarwal, Chandrasekaran and Sridhar, 2016). The scaling up and institutionalization of new technologies, methods and processes is believed to be difficult due to already evoked construction characteristics. Still, the literature established to vital aspect of workplace health and safety in the above sections where we discussed the high accident/incident rates and the conditions in which they occur.

3.6 DIGITAL TRANSFORMATION OF SAFETY MANAGEMENT IN THE CONSTRUCTION INDUSTRY

Living in an age of digitalization makes it inevitable for companies, organizations and industries to change (Guo et al., 2017), yet the construction industry has proved to be less adoptive or inclined toward change. This could be a result of its "unstructured and changing environment" (Zhou, Goh and Li, 2015, p.343/7) which consequently brings difficulties for implementing a new technology in the exact same conditions for two projects (Zhou, Goh and Li, 2015).

3.6.1 History

According to the literature overview carried out by (Guo et al., 2017) on digital technologies in construction safety management, there are several fields of technologies being used in safety management in construction. He recognized 15 technologies, including BIM, augmented reality (AR), virtual reality (VR), game technology (GT) and real-time hazard management. It is worth mentioning that the literature review is done regarding the published literature between 2002 to 2015 which considering the continuously increasing pace of technology advancements, a different rate in use of these methods are expected as well as the emergence of newer technologies (Guo et al., 2017, Winge, Albrechtsen, and Arnesen, 2019). In the same way, (Zhou et al., 2015) undertook an analysis review on the safety management in the construction industry in 2015 in which a result in the use of innovative technologies in construction industry was analysed. They mention technologies such as BIM, GPS, AR, VR and CAD among others, to enhance and improve the safety in the work environment while it is also common to combine more than one technology due to their distinctive potentials and possibilities.

Mentioning them as the state of the art, Carbonari, Giretti and Naticchia (2011) name real-time tracking technologies as tested and implemented in risk management and a proactive approach to construction health and safety in 2011.

3.6.2 Current situation

The above-mentioned technologies increase the efficiency and effectiveness of different safety management systems. For instance, BIM, VR and AR enhance the safety planning by analyzing and determining the expected risks even before the construction starts, i.e. during the design phase which facilitates avoiding the possible safety-related issues less costly (Zhou et al., 2015).

Another example on current use of digital technologies lies in applying a real-time hazard management (Carbonari, Giretti and Naticchia, 2011). According to Guo et al., (2017) in this method which uses location recognition and proximity warning proved to be extremely beneficial for enhancement of safety on construction sites since it enables the safety manager to track not only the trucks but also materials and workers. With a hindsight to the compelling and unstable situations on-site, this method comes to help worker to grasp a better awareness in real-time and be noticed by different means in a shorter period in contrast to potentially limited knowledge based on their experience and estimations or the stationary training sessions (Guo et al., 2017; Edirisinghe et al., 2014a).

Construction sites are by nature complex, volatile and "nomadic and custom-designed" (Poh, Ubeynarayana, and Goh, 2018, p.1; Lines et al., 2015; Brown, Hampson and Brandon, 2006) as it was already brought up. These characteristics accordingly imply the importance of agility in safety management on-site and even with the most capable health and safety coordinator, pursuing the ongoing situation on multiple locations simultaneously is not possible (Poh, Ubeynarayana, and Goh, 2018). Alternatively, technologies can respond to the shortcoming in this scope by taking a proactive attitude toward the surrounding environment's safety as well as improving worker's awareness on the possible risks and incidents (Fang et al., 2020).

Even though the definition and concept the word real-time carried a decade ago pointed mainly to the use of location tracking technologies in construction (Carbonari, Giretti and Naticchia, 2011), today it indicates wider range of technologies (Fang et al., 2020).

3.6.3 Prospective uses / pilot projects the ("future")

With the arrival of the construction site of the future, wearable smart textiles, or e-textiles, have made for strong developments in the field recently (Edirisinghe, 2017). Current (pilots) and prospective uses of technologies developed for construction workplace safety deployment which do not necessarily involve AI today but could most likely call for it as a part of their role for the construction site of the future are listed and discussed hereafter.

In general, there are several applications of wearable bands/terminals (Agarwal, Chandrasekaran and Sridhar, 2016) on the forearm notably (CIOB, 2017a) which serve to automate alerts such as when operators fall asleep, idle time on the managerial side (Fig. 6). Still, these technologies seek a bidirectional communication and information sharing system whereby the "online operator" (CIOB, 2017a) will be given in real-time guidance, information and help (Edirisinghe, 2019) as a part of the hands-free communication system developed by SUEZ and Bouygues Construction (CIOB, 2017a). Notably, this last example has successfully passed the pilot phase and is not being spread across several other projects of the respective two companies. Other examples include but are not limited to wearable high viz vest with integrated sensors such as: thermal abnormalities sensors; air analysing sensors; Smart glasses with access to the BIM model and location tracking safety boots (Edirisinghe, 2019; CIOB, 2017a; Edirisinghe and Blismas, 2015).

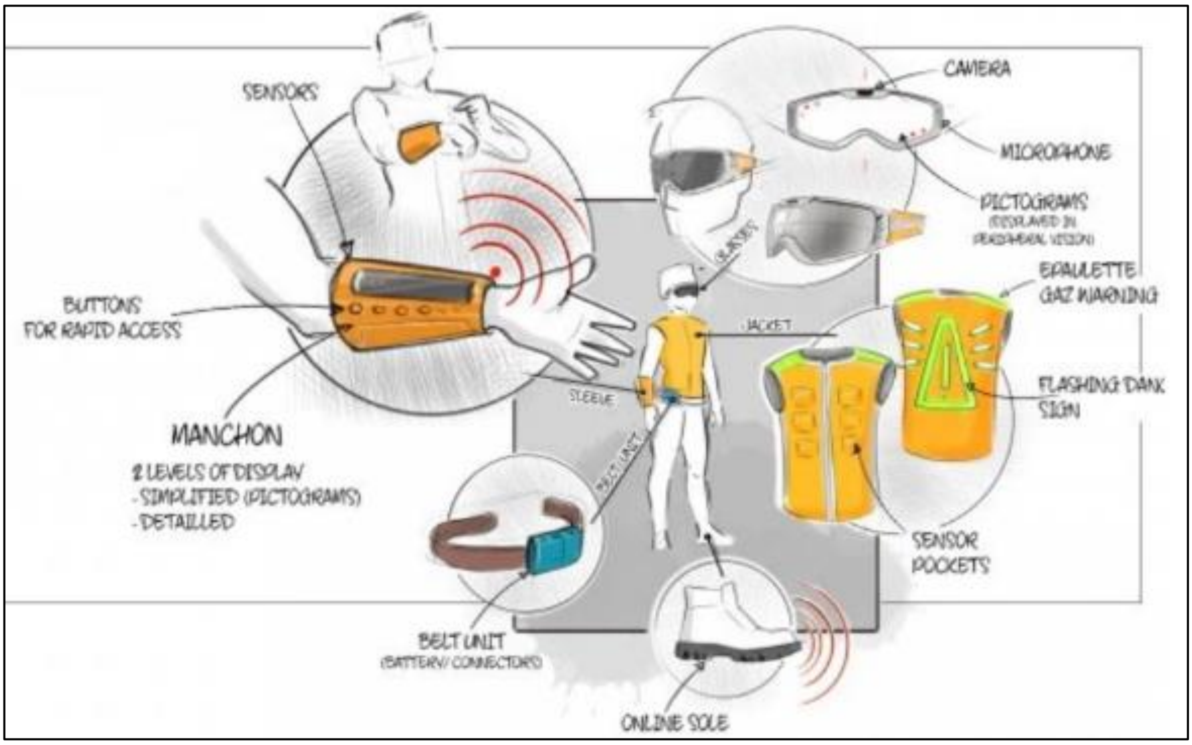

Figure 6 - 'The online operative' Image courtesy of Bouygues (CIOB, 2017a)

On a final note, author Costello (2020) stipulates that “launching pilots is deceptively easy but deploying them into production is notoriously challenging” which should be bearing in mind when considering these future technological applications for construction safety. Parallelly, while there is an array of academic research and content on the developments of future technologies for the construction site, very few consider the human viewpoint these entail, that is to include those concerned in the development and application of said technologies (Edirisinghe, 2017) which is a point the thesis will look into for the empirical data collection.

4 SECTION IV – ANALYSIS

4.1 INTRODUCTION

This section moves forward to the findings and thus analytical part of the thesis where the verbatim qualitative data from the interviews executed for the research. As per the methodology above, the interview participants fell into two general categories and two subcategories: academic & professional and construction & AI experience and/or knowledge (See Figure 7). Although the interview participants did not wish to be kept anonymous, they will still be given fictitious names for the entirety of this analysis and discussion albeit their information and details figure in their respective appendices.

In this sense, Helena (Appendix C) and Richard (Appendix E) are both construction academics and while they both have knowledge in the construction and AI fields their perspectives differ in the sense that they do not belong to the same institutional fields (Swedish and English universities). To explain more in details, Helena is a PhD student working on a research project which is a collaborative study on a machine learning model for the causality of on-site risks embedded in accident occurrence. Richard on the other hand, works both as an AI consultant in construction industry and also as an academic researcher in UK with over 20 years of experience.

On the professional side, we have Anna (Appendix D) and John (Appendix B) who are disassociated in this study by their relative knowledge to their own industry and the others. John is a lead computer engineer in a company called Smartvid for two years who is involved mostly with R&D, machine learning, computer vision and deep learning. He also has a couple of years of experience in video analysis. The company, Smartvid, provides intelligent video analysis solutions in first place for its client. Using the techniques such as image recognition, deep learning and computer vision, it is able to help the customers to track PPE as well as checking the construction progress and scheduling. Anna is a strategic program manager working in big project called Smart Built Environment, based in Sweden and comprised of multiple projects with a large number of companies involved in it to some extent. She has over 15 years of experience in construction. Anna has over 15 years of construction experience and works for the Smart Built Environment Innovation Program and John a Lead Machine Learning Engineer at company Smartvid, a key player in the area.

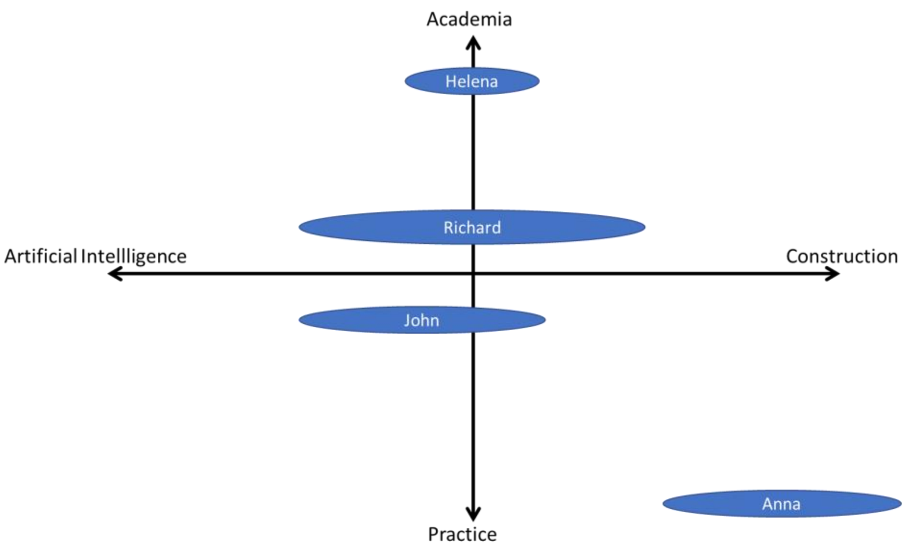

Figure 7 – Interviewee knowledge and expertise repartition

The interview rationale divided the interview questions into sections that enable the authors to facilitate the cross examination of different participant categories against interview sections. Although the agility and degree of improvisation of the interview flow into each interviewee's knowledge pool makes for a handful of stand-alone verbatim data which are considered into the study to push further the argumentation and discussion. Once more referring back to the methodology the analysis of the empirical data will be done in a deductive manner in accordance with topic categorized questions as well as make use of the sentiment analysis of the participants' answer.

4.2 QUALITATIVE RESULTS

The results in this section is divided into two sections; first part is the results acquired from the academic sub-group and the second one is focused on the results from the professional group. Bearing in mind that the interviews started with the demographic questions which has been brought up in the previous section as a preview to the interviewees.

- <u>Yellow</u>

This part starts with a question about the project they are involved with and its contributions. Richard is knowledgeable in the available AI applications and software developed and its use for safety and as a part of his consultancy job. Helena is in rather starting phase of her research which evolves to be a machine learning model which can identify risks corresponding to accidents. She claims that she attempts to involve safety engineers to work with finding and evaluating a solution for risk identification.

Anna answers to the same question by introducing the Smart Built Environment program extensively, mentioning that the program is aiming to provide more sustainable ways in construction by examining the processes, methods and technologies. The borders of the project start from design phase and even before; the construction permissions and stretches further to construction site and they are looking more into technology recently, more precisely, discussing the innovative uses of AI within construction with AI Innovation of Sweden. John who is the Machine Learning engineer explains about their project as one of the pioneers in this area. Smartvid, based in Boston, USA, provides construction companies with a web-based and mobile-based app which analyze the visual data sent from construction sites. The app is used for health and safety as well as monitoring the progress of the project.

Next question is asking for more details or examples. Richard explains that in the projects on which he is consulted with, aside from suggestions for implementing an AI solution for H&S, he also suggests software or application to improve the progress and cost-efficiency of the project. He mentions that the H&S AI models they implement into some projects are to recognize and identify PPE compliance among workers and set and alarm in case of dissonance. Helena is not entirely sure about the exact solution which she would come up with, yet set she states that the final goal is to have a classification solution which can benefit the occupational safety engineers (arbetsmiljö ingenjör) by offering more capabilities with AI identifying the contributing risks for accidents in any severity.

Anna explains that what they are working with is rather the use of AI in the design phase while she believes that looking into the data from earlier stage let the decision to count in more aspects. Later she points out to a common issue which is ending the project right after it's handed in and not looking back into the problems and their roots. John gives a more precise example on tracking workers and their safety equipment. According to him, they train a model based on gathered data from the customer in form of images of PPE compliance as well as cases in which workers don't follow the rule. Later they test the model with a large amount of data in different situations and if the model passes the test successfully the deliver it to the client. The client would have access to the analysis right after uploading an image, informing the client in case of discordance with the PPE compliance on-site. He confirms that the data is given from the client company so that the final solution is customized to their own need and their own safety requirements. He also mentions that some clients ask for real-time while most of them prefer rather a daily/weekly upload of their data which is unusual considering the possibility of opting for real-time service.

As an answer to the size of the projects which they are involved with, Richard explained most of the projects in which he plays the role of consultant for AI deployment are large-scale projects with commercial purpose. On the other hand, since in Helena's project the progress hasn't reach the point of an actual and ready-to-use model which can be tested and evaluated, no data exist in terms of the size of project yet she claimed that the model is going to be tested in three different project with different size to evaluate its effectiveness on various type of projects in term of size.

Anna explains that Smart Built Environment is a 12-year program comprised of about 100 projects although the subject of them is not exclusively AI and construction safety.

Later on with the question about dynamic and collaboration among the internal actors in the project during implementation, Richard answered the main actors involved are H&S managers who decide and apply the AI model to the project and the workers on the site are mainly involved during training for H&S and they are only informed of the solution being used, for instance the cameras collecting data from the site. He further states that they may later get feedback in case that hazardous situations happen but in general he finds it unconventional to talk about it with the lower part of hierarchy. In case for Helena, as she mentioned under previous answers, they involve the safety engineers in the company from the beginning to the prototype and until the final product, but the involved actors' dynamic and presence goes further to an AI specialist, a head of AI division in a university, who in collaborating during the meetings with companies who has taken interest in the project. She mentions a co-supervisor as well who is specialist in machine learning. The two AI specialists, she mentions had previous interdisciplinary experience yet not in the construction industry, but they are helping with development of the model as well as choosing the algorithm and other technical aspects. It seems that there are two type of actors involved, the ones in closer and constant connection such as the AI developer or the strategic health and safety developer in the main company, as opposed to those with biannual meetings which includes the representatives from other interested companies.

Anna says that the internal collaborative relationship is working really well even though she then refers briefly that sometimes it happens that things don't work among some partners. She further explains that involving actors are from different companies, authorities and academia and this leads to increased communication between people who are working in the same sector but surprisingly never met before and communicated before to see challenges.

- <u>Green</u>

When questioned about the knowledge sharing and collaborating, the participants were all using a negative perspective and turn of words. Still, it is Richard and Helena who were most adamant about the ‘difficulty’ surrounding this topic. Helena argues in her case that the data in itself was very unstructured and difficult to work with. On the other hand, Richard (Appendix E) certifies organizations have no incentive to share their information with others. Despite the added complications of getting all identifiable filmed or photographed people’s authorization no one is willing to take the risk of divulging such information he states. Ironically, he also concludes his thought by claiming an organization would benefit from a system with other willing organizations’ shared knowledge.

On the other hand, Anna is the least negative amongst the participants to discuss the topic of knowledge sharing. As a program director which is involved with more than 200 companies her primary challenge to tackle is the unheard voice of all small trades and entrepreneurs that are a part of the program. Pointing the finger directly to the resource availability and capacity differences big and small organizations have and how this impedes every stakeholder’s interest in the program goals. Pleasantly, Anna says that it is too often as such and the larger leading players of the industry end up tailoring the innovation program to their needs and goals thus dissatisfying the smaller organizations kept unheard in the problem solving. In this line of thought Anna shows the modern management style she and thus the program as well nurture thus safeguarding its long term and depth of impact on the industry.

As a part of it being the writing authors’ first interview and the associated level of flexibility between script and participant needed finetuning, John’s answer for this topic seems insufficient.

Nonetheless, immediately ensuing to this question and within the same topic is the notion of one-time perhaps pilot projects or long-term relationships being established between the two involved organizations. John, at Smartvid says they have many different types of relationships ranging from short to long with their clients but that predominantly their relationships were long. Hence, presuming the success of their model and product or for the least its business value being met on the construction worksite. Richard’s answer for this topic is unfortunately very biased towards his current personal experiences with the two organizations he consults for where he states it is a onetime fully implemented (non-pilot project) and that he isn’t aware of their strategy for AI in the future.

Nonetheless, both the practice and academic sides concur on the relationship being initiated by the construction organizations. Anna says this is perhaps because they are more established and have a development manager or such roles in the small flexible organization structures. This comes of interest when juxtaposed with Richard’s rather descriptive comment regarding how some technologies are just ‘smart people trying to shove it down the throat of construction people; ”you got to use this it’s going to help” (Appendix E). Thus, implying these external solutions to internal problems seem to just look for the problem rather than solve it.

Finally, this topic concludes with an open-ended question asking the participant to surface any problematics with today’s current operations and methods between construction and AI organizations. Richard, with 20+ years of research in construction innovation stamps construction as being very stagnant and then there is a sudden burst of technologies – drones, AI, BIM. Many are struggling to adapt to all these newfound technologies, worse is some are acquiring some technologies. This is interesting because as a part of her program Anna wants to drive forward the behavior, working methods and organization change brought about by the use of AI rather than the technology in and of itself.

- <u>Blue</u>

Moving onwards, the blue section concerns the job and performance evolutions section. As per the interview rationale, the very first question of this section attempts to acquire some raw, almost of quantitative nature, data from this question. From Helena's research perspective, she claims it hard to identify such results and numbers, as accidents often happen in cycles, plus there is commonly instances with false positive and false negative incidents identified by the already established unstructured data. As for Richard, he didn't have any numbers or results off the top if his head but questioned whether these results we sought for were numerical in terms of life or in terms of value which is very interesting, humanistic thought process toward the question.

The second question referred back to the second hypothesis of the study (ii) pertaining to the evolution and shift of jobs brought about by the greater digitalization of the construction but most specifically in the scenario of AI implementation for occupational health and safety. When asked this question the participants all concurred on the coming of new jobs and rendering of other jobs useless by AI's potential for automation – more specifically some aspects of supervision (Richard in Appendix E). While some jobs may be replaced by robots as common knowledge prescribes to believe, the robot is just the hardware, the AI is the model and software which drives the hardware. In his eyes, this is inevitable, as AI/robots have no lunch break, they don't go on strike, don't join unions, don't require pays raises. There is already so much automation present in the safety day to day going on that has not fully replaced anyone's job but has shouldered specific responsibilities such as dust detection, sound detection and other aspects. These values have standards and regulations that affect the worker health and safety on the worksite should they exceed them. The AI detector in this sense are completing the safety manager role by continuously feeding them the data to enact and decide upon it. The decision-making will always stay in the hands of the human not the machine. Still, a key common denominator for several of the study's participants is the unstructured data collection. Once more from Richard's perspective, construction organizations today collect and gather massive amounts of data and in observing what competitive advantage other industries are getting from all this data we keep it to ourselves. Except today we have too much data and do not know what to do with it (Helena, Appendix C and Richard, Appendix E) thus the need for an AI model to make sense, help structure or exploit this data – and each of these three functionalities could have many more applications. Returning to the topic at hand, the evolution of jobs and performance, the analysis saw earlier that Anna identified the difference in organization structure and power it exerts on innovation programs with the presence of a development manager and how other smaller organization are excluded because they do not have one. This problem is reiterated in the sense that both Richard and Helena believe the use and integration of a data scientist, preferably one with interdisciplinary experience is going to arise from this technological implementation. Does this mean that all smaller organizations are going to be left behind when it comes to fast paced change in the construction industry? First with BIM and BIM managers, operators, then with development manager for innovation programs and lastly with data scientist/engineer for AI implementation. Smaller scale contractors can't embrace the innovation or even comprehend it from this angle. Finally, a concluding thought brought up by Richard was that today Health is a much costlier factor than Safety to the industry. It seems as when a worker dies at home 10+ years later or when a worker is crushed or perishes on site, the latte one is mediatized and incurs a heavier reputation loss on behalf of the company. However, the former tis the one which occurs more often and can result in life-long claims and lawsuits.

- <u>Grey</u>

The last part of the interview was dedicated to the open-ended question about the unnoticed AI deployment possibilities in the field of construction safety. Richard believes that in health and safety, health is somewhat neglected due to the reason that it is not considered commonly as important as safety. He further suggests that the real-time solutions could be improved in terms of speed in feedback so that if for instance there is someone not wearing the hardhat, he would be reminded immediately to avoid possible consequences instead of using the data acquired from the construction site only as the mean to analyze the safety performance. Helena finds a more fundamental issue concerning the data while developing an AI model. She states that data, which is available as of today, is dispersed and unintegrated all the while, the key to get a better insight and results is that the data from the project and data from the accident get combined. She also mentions other methods of AI which are less explored and might prove to be more functional. Anna has a different perspective, suggesting a clearer connection being established between the construction process and the early planning. She explains further that there should be a better way to strengthen the motivation rather than just a technical solution. She emphasizes that the solution for part of the problems in health and safety lies with the understanding about “why do people do what they do” (Appendix E) and align it with technical tools.

With regards to the interview rationale, John wasn’t asked the question since his area of expertise is mainly machine learning and computer engineer. Although another question was called; the reason why AI adaptation in construction lags behind compared to other industries. John believed that privacy issues with having a camera on-site and an old-school dominance in the industry toward new technologies which slows down the process.

The next open-ended question and the last one asks the interviewees about the possible future plans related to AI and construction. Richard gives a brief suggestion to use AI for productivity and efficiency improvement. Considering Anna’s project as an actual on-going program, she claimed that they have a number of new pilot projects starting in autumn which comprise of attempts to find the need in certain fields to be improved. Additionally, she talks about plans on establishing meeting places for actors in different fields so that the ones with a problem could get connection with the ones who provide AI solutions. She also mentions another idea of a project which can boost the communication and integration between designer and contractor, a solution which is more behavior/organizational centered rather than merely a technical solution.

- <u>Extra non-categorizable line of thoughts:</u>

In this part of the analysis, the investigation will be turned toward all, ‘improvise’ conversations and notions discussed with the interview participants. In a sense this is a rich pool of data as it extracts the deepest knowledge of each participant and enables their gathering to enrich the ensuing discussion. Granted that this part is unfortunately heavily biased toward Richard, however in data terms he possessed the most knowledge and methodologically this was the study's final interview and off script improvisation skills was at its easiest. This being said, Richard began an in-depth conversation about the meaning of AI for safety which was truly enlightening. In simple terms it is that identifying that someone is not wearing the hardhat does not equate solving the problem. 'Anybody who decides to be unsafe will be unsafe' (Appendix E), just because one reminds them to behave safely doesn't mean they are going to start to change their behavior. This is where both Anna and Richard agree in saying that safety is a 'culture, habit behavior' (Appendix E) and it should be linked more to motivation (Appendix D) more specifically intrinsic motivation (Appendix E). 'You can identify problems every single day without running a safe site' he stated. Thus, bringing the argument back toward technologies which seek only to identify problems rather than help solve them. Perhaps this can be correlated to the Gartner report statement (Appendix E) and other industries pushing 'technologies not driven by construction people' unto them. Thereby inferring the new job arrival mentioned above where Helena thought interdisciplinary skills would be a key requirement. Richard confirms this in stating that 'if you have never driven a forklift, dug a foundation' then you do not utterly understand the problems and the works of the construction industry. It was also very interesting to grasp an understanding at the greater picture in that if one were able to manage all the data and not just that of a site or an organization, patterns and commonalities would most certainly arise on a much larger scale. This is where the tools would help us point towards the core problems of the industry.

4.3 CONCLUSION

Our four interviewees brought in different perspectives and interesting insights with their answers. There are highlights from each conversation and questions which evoked other questions.

The strengths of this empirical information however was the richness of the interview participants, the study interviewed a lead engineer for a prominent construction AI company – Smartvid.io who had previous construction working experience and an innovation program manager for a 10+ years and 200+ partners national program. It also had two academics which a foot in each camp in the sense that one was collaborating with other construction organizations for her PhD and the other has consultancy partnership with AI using companies.

As mentioned in the methodology, the interviews were held while Corona crisis resulted in lots of uncertainty leading to fewer number of interviewees than what was planned. Despite our attempt to get into touch with one of the main actors in safety management (a health and safety engineer) with or without AI experience, it was failed due to time shortage of the person among other reasons such as reluctance to answer.

5 SECTION V – DISCUSSION

5.1 INTRODUCTION

In this section, the thesis seeks to explore and interpret the bridging of the previous theoretical and empirical chapters. The structure adopted reflects that of the latter two parts of the literature review and the overall study research questions. The first section of this discussion considers Safety in construction more specifically into the safety roles and the associated performance. Following this is an understanding of how construction safety jobs and the implicit collaborative dynamics are affected during a digital transformation. It is given that the extents of impartiality of the interviewees due to their profession is considered as well as the overall generalization of rhetoric from the relatively small population sample for the empirical data.

5.2 SAFETY IN CONSTRUCTION

As introduced in accordance with the second part of the literature covering - safety management theories, safety in construction, safety and AI and finally current trends and pilot projects for construction safety – as well as the first sub-research question– into a nuanced interpretation of facts, theories, and line of thoughts from the interview participants.

5.2.1 Safety roles

The first sub-research question seeks out the safety roles and the questioned impact exerted from all of the above material. Before all it must be pointed out that the population sample and juxtaposing of thoughts and arguments did not fully enable a constructive discussion.

In general, it does seem confirmed that safety supervisory and managerial roles would be affected with AI solutions and on-site IoT detectors. As per Walker and Lloyd-Walker (2018), automation is followed by a reduction in mundane tasks and subsequently, provide the opportunity for the role to focus on the creative part of the job. Similarly, this can be applied to safety managerial roles after implementation of AI applications. Additionally, Helena emphasizes the need for a supervisor of the collected data, someone accountable for its structure. This is further discussed below; but all in all, it points out to the need for new responsibilities or even an entire new role according to some of our participants such as Anna – once more this is discussed in the later jobs section of the discussion. Realistically, it is safe to say that safety supervisory and managerial roles will not be displaced but facilitated by extended processing power for more information at the right time.

5.2.2 Safety performance

As for the second concept relating back to sub-research question (a), namely safety performance, it was established that the fatal four (OSHA, 2018, European Commission, 2012) and the sheer statistics behind the construction's industry current safety performance (Mahalingam and Levitt, 2007; Edirisinghe et al., 2014a and Winge, Albrechtsen, and Arnesen, 2019) places it in a position where disruptive digital technologies such as AI can only procure a decrease in some of these safety incidents rates. Meanwhile, the empirical data helped the study to understand that helping the construction safety performance problems comes about by affecting safety culture, thus safety behavior and consequently impacting performance rates not the other way around. In focusing on the rates and statistics, AI solutions will not suffice in successfully tackling the true problematic at hand. Indeed, the call for a behavior-based approach (Zhou et al., 2015; Bosch and Gluch, 2020; Kelly and Brown, 2006; and Geller, 2008) infers the need for a behavioral learning to occur, hence requiring behavioral solutions and behavioral technologies. This can be related to where Richard insinuated that this is because the tools for problem-solving can only be found internally to the industry and not pushed from external digital and technological organizations. Stressing the importance of notably the 'what' of the problem which can only be understood if you have been personally involved in construction undertakings.

In moving away from safety behavior and towards safety culture, Geller (2008) established that in order to instigate a self-initiative approach, leadership is required that helps with creating a more overruling safety ambience. The empirical evidence points in the same direction whereby most agree on the need for a fuller understanding of the problem before adopting the solution. In full, this confers with the teleological standpoint (Van de Ven and Poole, 1996, cited in Bosch and Gluch 2020) developed and suggested in the literature review. Confirming the role of those in charge affecting the overall outcome and continuity of the change trajectory. In tying back to the essentiality of leadership skills during these digitally transformed times is the need for more specific critical success factors (Koscheyev, Rapgof and Vinogradova, 201; Loonam et al., 2018) when it comes to the adoption and implementation of a new technology - it would be interesting to see some pertaining to workforce motivation (Kelly and Brown, 2006) as well as improving methods or exploring new ones on safety performance measurements.

5.3 DIGITAL TRANSFORMATION

Moving forwards, the final part of the literature review covers digital transformations – levels of digital transformation, implications for organizations, sensemaking, task/job reinvention, knowledge sharing. Running parallel to the literature review and the sub research question (b). This latter part of the discussion delves into the inferences for jobs and the correlated collaborative dynamics

5.3.1 Jobs

When it comes to roles and career, various academic literature suggests that there would be elimination on certain jobs (Polyanin et al., 2019; Walker and Lloyd-walker, 2020; Kothman and Faber, 2016) yet the interviewees did not regard it as a negative issue. Richard mentions the upskilling of workers not only as a solution but as an imminent procedure to adopt to the more digitalized future of sector. Helena and John had rather actual examples on how new roles are at the moment; an interdisciplinary knowledgeable person who works as an intermediary, connecting the construction safety side to the AI solution providers either in a permanent or temporary role. Meanwhile, Anna, identified the gap in possibilities and reach for smaller and larger organizations with regards to integrating this newfound role. Discerning the notion of task elimination and joblessness is important for employees of a company to follow the digital transformation. Aside from that, the existing roles such as safety-supervisor, more likely undergo an alteration rather than elimination by taking up novel and creative tasks. Finally, regarding the well-known fear of human jobs being replaced by machines as per Pettey (2017) and Hippold (2019), it seems AI supervision solutions will be covering variables that weren't previously routinely undertaken by humans (dust, heat, vibration, sound…etc.). Thus, the argument that mainly supervisory roles will be replaced from the theory remains unfounded on the basis of our empirical data which results in a more constructive and overall humanistic approach.

5.3.2 Collaborative dynamics

Almost all interviewees were involved in collaborative projects; even John working at Smartvid stated that there are companies who are taking part in collaborative innovative projects with the company. Considering the unique data available in a company deemed as knowledgeable; managing, and sharing it plays a vital role in machine learning projects, yet the distinctive perspectives of the interviewees were noticed. While Anna was positive about the increasing zest on running collaborative projects and sharing knowledge according to her experience, Richard doubted the sufficiency of incentive among managers to share their data, not only due to competitiveness but also for the exposure to critics and the fear of judgement. Reflecting on different nature of their project, it is observable that in a collaborative project that encompasses a larger group's benefit, for instance the whole sector's, the sharing of the knowledge and data which was formerly exclusive to each company happens more willingly. This aligns with Walker and Lloyd-Walker (2018) statement that digital transformation needs the knowledge to be shared among collaborators but also can illustrate that having a common vision and benefit to achieve makes it easier for companies and stakeholders to take part and bring in their unique knowledge to the stage.

In a connected notion, as much as the amount of data aggregated helps a ML model significantly, the available data could be troublesome as mentioned by Helena in the case of construction occupational safety due to subjective records of data, i.e. not maintaining a structured and fully objective dataset acquiring system. As suggested by Clegg, Pitsis and Kornberger (2015) turning the tacit data into explicit help with the transformation procedure; this could be applied in a narrower sense that the explicit data is more accurate to be interpreted or analyzed in a ML model. Following this, it is essential that the data is well-structured, and this only capture more notice when it comes to intra-organizational collaborative projects. While according to interviewees, specially Anna and Helena, accessing data is a major focus, sharing the problem is of significance as well. Anna explained how their collaboration project aims to be inclusive, giving an example on how they define common problems among actors in the sector who never contacted each other.

The theory recognized Weick's (1976) pattern of couplings as potentially mirroring the relationship between construction organizations in the industry. In a sense, the unwillingness to share between one another and considering only the project at hand when implementing the solution goes to show, first, the confirmed state of 'projectification' and them acting as individual experiments and second, the knowledge sharing dynamics between construction organizations. In spite of GDPR and anonymity of image proving constraining for such actions, it appears to be no incentive from organizations to do so in understanding Richard's rhetoric. While one could benefit from others taking the risk, one will not carry that risk to help others. The loose coupling can be flagged here in that the industry operates in a panoply of individual heterogeneous tightly coupled cells as opposed to a whole (Dubois and Gadde, 2002). From this, the discussion confers with eh notion that while this heterogeneity and inter-independency allows for organizations to take risks and innovate on a small scale, it prevents them from sharing the innovation knowledge appropriately.

On a different note, Agarwal, Chandrasekaran and Sridhar (2016, p 23) established that these types of solutions were hard to upscale and it was often recommended to start on larger projects rather than small ones. Along with Richard consultant work and experience in the field this is also his opinion on the matter.

5.4 SUGGESTIONS

Overall, it is safe to say that on-site safety has yet a relatively long journey to reach to a game-changing point on deployment of ML, as stated in literature and supported by primary data connoting that the range of AI applications being used in on-site safety barely reach beyond monitoring. Yet according to what has been discussed above, there are potential actions which could be suggested to which this part of the text is allocated.

With regard to safety, it is worth mentioning again that creating a strong safety culture can benefit more than focusing on tools and mere safety performance measurements. This is a role for the leader to take up while automation of part of the routine tasks such as mere monitoring as well as improved processing and analytical capabilities, both brought upon by AI, would make room for probing the possibilities on that front.

In addition, it was observed under the primary data collection that occupational accidents data interpretation can be challenging for two reasons: one is due to the qualitative nature of this type of data and secondly, accidents record can be affected by subjectivity of the person who register those data. Keeping in mind the enabling role of data in ML or DL, it might be beneficial to investigate and explore possibilities of improving the data registration for accidents more systematically.

From the other standpoint and looking closer to the digital transformation, first issue that comes into mind as a consequence of automation imposed by AI is the loss of jobs. As discussed before, the obsolescence of some tasks and roles is inevitable and yet the jobs would rather be altered and tailored to the new situation. The alertness of companies on upskilling workers as well as assigning new tasks in place of the discarded ones is of significance to be prepared for digital transformation.

Furthermore, the companies interested in implementing an AI solution should be wary of the possibility of the pitfalls in which they only adopt the ready-made solutions and applications without contemplating over the problem. The primary data pointed out that solutions evolved out of the defined problem and not merely applied to it are more effective.

And lastly, it has been pointed out that in various degrees of digital transformation, the collaborative relationships would play an essential and significant role. The importance of it is enhanced when the development of the desired solution is carried out external to the company and more specifically external to the sector or when there are more companies in one sector involved. As much as assembling the companies of the sector to identify the problem and work toward the solution is advantageous to inclusiveness of the final application, it brings challenges as well namely, the reluctance toward sharing their experience and data. Respectively, a possible solution to that would be a common project between the companies and perhaps a third-party to facilitate the development of solution while the data could be aggregated in anonymity to avoid the fear of judgement.

6 SECTION VI – CONCLUSION

First and foremost, the conclusion will cover a quick recap of both the literature review and results and findings' main points. Concerning the former, the first section of the literature review was undertaken with an educational and research driven focus, while the second and third sections do as well, they also highlight various theoretical and academic viewpoints. In the respective order, the key points brought forward are that in general AI is currently revolutionizing all industries including construction. The notion at hand was to establish how permeable and deep could this change go for worksite safety in construction. The scope of the study converged on the more tangible consequences of safety rather than health and focuses on the impact on safety roles and performance as well as implications for jobs and collaborative dynamics between construction organizations on the basis of AI implementation. Understandably, the methodology section covers the data collection process and targeting approach for the duration of the study. The qualitative data acquired from four interview participants divided into four parts in accordance with interview rationale whilst remaining the in the fields of construction/AI/safety. The interview and analysis structure considered first, a deeper look into the in the interviewees' roles and projects, second, to examine the collaborative relations in each project illustrating different experience in terms of sharing data and collaboration. Lastly, the discussion above enabled an array of strong theoretical viewpoints to be confirmed such as on the one hand the teleological view on the trajectory of change and agency role the leadership concerned plays. On the other hand, the humanistic approach to safety performance was sought out in research and found similar results empirically.

Here we will address the research questions and sub question individually to assess the extent to which the research enabled the study to answer them. The first sub research question pertained to the opportunity-cost of AI for (i) existing safety roles and (ii) safety performance. From all of the above materials, it appears that safety roles will remain, as the supervisory responsibilities shouldered by AI solutions currently go hand in hand with IoT solutions and measure variables that were not previously covered. Thus, enabling the safety worker further, facilitating and not replacing the job. Concerning (ii) safety performance, the study found that a safety culture which promotes safe behavior and behavior-based learning and performance evaluations could successfully tackle the current worksite safety challenges faced by the construction industry. Nevertheless, it is noteworthy that more experience direct qualitative data or perhaps even quantitative data on the subject would have enabled the study the further anchor in these findings.

As for the second research sub question, this last one delved into how (i) jobs and (ii) collaborative dynamics affect and are affected by digital transformation in the construction worksite safety field. It was found that the coming about of a new job role was essentially inevitable as there is the need to hold someone accountable for the structure and exchanging of this data. This newfound role requires interdisciplinary skills; some suggest the upskilling of the workforce while others believe in job losses. All in all, the robust and well-rounded panel of participants made for a rich interpretations and argumentation on this topic. Finally, it is expected that providing a safe collaborative dynamics ambience would promote other actors and stakeholders to take part in the more practical solution findings to current challenges. The arrival of a new job and associated structure could enable more organizations to further share and exchange their data and knowledge.

6.1 LIMITS OF THE STUDY AND FURTHER RECOMMENDATIONS

The thesis attempted to achieve an understanding and new thoughts on the relatively new subject of machine learning deployment in occupational safety for construction. Naturally, there has been limits and obstacles on the path.

Primarily, what the authors of the thesis consider as a limit is the number of interviewees taking part in the primary data collection. Due to different reasons such as novelty of the topic, the limited timespan and influenced circumstances by COVID-19, it remained a challenge to find enthusiastic interviewee with relevant background.

As further recommendations, it is suggested to cast interview over a larger group of actors in the field. This can be improved additionally by conducting a survey as complementary to the interviews in order to grasp a more general insight to the subject.

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8 APPENDIX

9 APPENDIX A – INTERVIEW TEMPLATE

Interview Template	
Demographics	
#	QUESTIONS
D1	What is your role within the *"organization name"*?
D2	How long have you been working with H&S/AI?
D3	What are your experiences with the use of AI in construction projects?
D4	Which phase of the project is it typically used for?

Option A: Construction - AI experienced interviewee	
1,1	How does it work? In what area does it help with?
1,2	Can you name us direct examples? *What is the size of the project/projects? (area, type of construction)*
1,3	How does it work internally between the involved actors ? (are the on-site end users involved in the solution development)
2,1	What has been done in terms of knowledge management for ordering such services (data exchange, collaboration process....etc)
2,2	Is it a one-time project or a long-term innovation plan?
2,3	*Who initiated it?*
2,4	Do you see any problematics with today's current development methods between construction and AI fields/organization?
3,1	Do you have any statistics that show the relevance AI for safety performance?
3,2	What are your thoughts about the jobs which will come about by the deployment of AI?
4,1	To your belief, which areas remain unnoticed as of today? How can this be improved?

Option B: AI solution provider	
1,1	How does it work? In what area does it help with?
1,2	Can you name us direct examples?
1,3	Please explain about the projects you have been involved with?
B1	*How many construction companies do you collaborate or run a project with?*
B2	What techniques or element of AI do you use for these types of projects?
2,1	Who (construction company of other source) provides the required data for the training of the software? How is the collaboration with the development's involved parties?
2,2	Is it a one-off project or a long-term innovation project?
2,3	Who are the intermediary roles in the development of the solution? Which side of the collaboration are they on?
2,4	What can be problematic with collaborating/providing this service to a construction company as opposed to other industries?

Open-ended conclusive questions	
*	Why do you think the construction industry lacks behind others in term of AI experience altogether?
**	Based on what we talked about throughout the interview, to your belief is there anything we didn't cover that you would have appreciated to talk about?
***	Similarly, do you have any contacts, colleagues or friends with whom we could conduct further interviews

Legend	
D1	Demographics
1	Intra organization
2	Inter organization
3	Performance and job evolution
4	Open-ended questions
B	AI solution provider specific questions

10 APPENDIX B – INTERVIEW: SAJJAD (JOHN), LEAD COMPUTER ENGINEER @SMARTVID.IO

Date: 02/05/2020

Sara: So, let's start with the most common question, what is your role within Smartvid.io

Participant: So, I'm lead computer engineer. So, I lead the computer division at smartvid. Mostly involving R&D of ML, CV, Deep learning models here from the research to the product. Bringing in new models, proving existing one, adding research to the product in an R&D manner.

Sara: So just to be clear, smartvid is involved in the fields of construction AI for health and safety.

Participant: Yes

Sara: Thank you. How long have you been working with this health and safety work with AI at smartvid?

Participant: Two years. A couple of weeks over two years actually. In general, for AI and computer engineering and that SMART background, I would say 6-7 years. Before joining smartvid I did video analysis mostly for safety and security of airports. But the same type of safety scenarios can be applied to jobsites and construction sites. From 2 years ago I have been mostly focused on the use of AI and safety proactivity on the construction and making sure workers are safe and they have their safety prerequisites for working.

Sara: can you explain a bit more what exactly is your experience with the use of AI for construction safety?

Participant: Ok yeah so what we do basically is using computer vision models to detect specific object or features for example hard hats, high viz, gloves, glasses or in this situation if workers have masks for corona situation. If they are in close distance for example again for COVID 19 they need to be at least 6ft. apart so we make sure that they have the distance needed. Besides doing these object detections and image analysis we also do video analysis leaning detecting and analyzing workers that are in the videos. We have access to many jobsites cameras that are recording any activity on the jobsite, so we want to make sure - we obviously do the same image analysis on frame by frame analysis – But this is linked to detect specific types of behaviors that workers are supposed to do/not to do – if they are productive, if the phase of construction or the progress is going the way its planned. Everything is on time; equipment is taking care of and people are safe.

Sara: Ok which phase would you say your solution is usually used for?

Participant: I'm sorry I do not understand.

Sara: Is it only onsite while the construction is ongoing or is it also about preconstruction and after?

Participant: So mostly I would say its during construction. Preconstruction if you mean for example like architecture design and things like that that happen before the construction site, we do less of those. Mostly we are interested in cameras and real-world scenarios like video recordings and also using mobile application the safety laagers would use on the jobsite. So, there should be a jobsite which means basically during construction. And after construction until its delivered to owners or residents we track that and for example when all details are finished and before if there's furniture going into the building – before that so it's until the end of construction. Then we also have the construction company remove their cameras they are done with their job and we do not have access anymore.

Sara: as I understood the cameras are sort of connected probably some server in your company and that's where the data gets analyzed and the results are sent back, is it right? how does it exactly work?

Participant: Yeah so, the main product is a web app and mobile app where safety and construction managers can upload their images and video while we can also provide solutions with direct access to cameras. Most of the companies are providing us with the photos and images so we do not have access to their cameras plus there are some privacy issues and such. So, we mostly can the data by asking customers to upload their data. So they put in on our cloud based system, It's like a data inventory for them so if they want to look back and see what happened a month ago a year ago in this project what happen that's an application they can use it for as well and we do an analysis on the content on top of that.

Seb: And how real-time is this communication/upload to your web app?

Participant: Well image by image is real time but some of our customers upload like a month at a time so they upload terabytes of data and it takes longer because it is a huge data set. Those who upload everyday they will get their analysis in a couple of seconds. This is like the AI analysis there is also like a monthly or weekly analysis that we will do, like a summary of what has happened in this month: how many cases without hardhats, how many incidents did we have. That is like a couple seconds as the images are uploaded.

Seb: Would you say demand is more real time or periodical offline uploads.

Participant: Most of our clients opt for offline uploads based on their needs. So, they do not have the data you know their machines are not connected sometime so they have to take the hard drive connect it to another machine and upload them. If they do, some of our customers they do have their cameras connected to internet those are connected to our servers and everything is running real-time.

Seb: Ok thank you

Sara: So basically, it's the choice of the customer whether its real time or not. And real time helps onsite to provide more safety but the non-real time is more of an analytical tool just to see which subcontractor did what, because I think I saw also that as a report each subcontractor gets a grading or score.

Participant: Yes, basically yes. But just to give you a sense of what is not real-time. Usually they upload daily or weekly, so we get back to them daily or weekly, so they get their reports regularly.

Sara: could you give us one of the exact projects that you have been involved with, the process that you have been through for one of them?

Participant: Sure, for example let us say the tracking of workers and their safety requirements. So, what we do we collect data from our customers where they have both cases of workers having hardhats and cases that they do not follow the rules. What we do we takes those and start labeling them in house and we do the analyzing of data, cleaning of data for training purposes. , then training a model that aims to classify a person image if they have the hard hat or not. After training we evaluate our model and say ok now that we learn this from the sub set of our data, now let's test on wild data that comes in any day could be from any region, any time of day, any company. So, we test our data and make sure its makes a good job with everyday data. Once we make sure the performance of the model is good, we basically ship it to the client. We have and engineering team that takes care of the product. So we basically give them access to this model so they can call on the model from the product or web app. Every time they upload an image to the product it sends it to the model and sends back results if there are any without hardhats. On the development application there some glow that going the show up, it will draw a boundary box around the person and draw an alarm to the safety manager saying look at this person who doesn't have a hard hat.

Sara: How many construction companies would you say you are collaborating with or have a project with.

Participant: I do not know exactly, but the public ones you can see at the bottom of our website page. They are the biggest ones.

Sara: not sure if it has one answer or not, but what type of techniques do you use in AI for these projects, is it ML for image recognition or something else?

Participant: In general, I do not how much in detail I can go. DL for image analysis, so image classification, object detection, video analysis are deep learning and also traditional computer vision.

Sara: Who provides the data for the models to be trained?

Participant: Its mostly from our customers. So, its data provided from the site.

Sara: so, its personalized for each company or is just some companies that contribute to your dataset and then it can be used for all companies.

Participant: So basically, depending on the solution that we provide, some of the features are universal so hardhat for example is everywhere. A good example for them High viz or safety, that is depending on the company it can change. So, we have to learn from their own data. So, then its specialized on their needs. It depends on the features for some of them its data from all around the world sometimes it is just their data.

Sara: it is the company who provides the regulations and which regulations should be used on site. Ok. How is the collaboration within the involved partners and companies?

Participant: I think, that will be a question for our sales part. As far as I know they are in close contact with our customer's they make sure we have delivered our outputs and reports to them on time. They also take requests and make sure in a couple of sprints they get access to the leave us feedbacks, we need this model to be upgraded or this model to be improved.

Seb: What you describe is typically for once it's in use. But let us picture a first-time client approaching and they are interested in implementing AI on their construction site, what type of collaboration occurs there? You send one of yours there they send on of theirs here, the deployment phase how does it happen then?

Participant: Mainly clients start with trial solution, so they have a sense of how good our product is. Usually we start with video conference and we give access to trial with limited number of managers and specific amount of data that they can upload, and we analyze. Since we are a software company, we don't provide hardware for them. Our product is compatible with any sort of hardware camera there is. We also partner with their camera providers (some of them) so we have a platform to work with any camera and also any cloud system that they use. If they need in person or instruction or tutorial, we send one of our own to teach them and help them.

Seb: one last further question, how extensive is your relationship with their cameras/hardware provider? Is it one-time thing or over the duration of the project?

Participant: Its dependent on the type of product that they need. One thing is we are mostly in contact with video provider companies. Since they provide us with 24/7 video analysis content. We also take video from GoPro, android, ios product. The reason we work with video cameras is basically we want to make sure we get the best video sequences. Also work with them because they can change FOV, they also have APIs we can work with to capture images that we need. So, depending on the camera and the customer some of them is more extensive with camera provider.

Seb: Perfect thank you.

Sara: Now that they gather all content, they are sending to smartvid, how is the privacy and access to this data? I know that smartvid is following GDPR but how is it going with your customers?

Participant: With European companies we make sure we are following GDPR for example we do our own analysis with blurring of the faces coming from Europe. Some of them we do not even post the data, they send us bit images so we cannot decode it and then send back the report. So, its secure and privacy is secured. Others in Us we host the data and analyze. With their permission if they do not want, we do not with all NDAs taken care of.

Sara: the next question would be your projects with your customers is it a one-off project or is more long term?

Participant: Its long term, because the nature of this industry, it takes a couple of years or at least a couple of months.

Seb: but is it long term because of the project duration or over the span of multiple projects?

Participant: Some companies have multiple projects and have been here since the beginning others are one-off projects.

Seb: if you would have to say which on represents the bigger share?

Participant: Long term yeah, they are like the companies who have several projects and are happy with the product and any new products.

Sara: Does that contribute to your system and model as well is a double way innovative relationship?

Participant: Yes, that is a good point. Our product is constantly learning, so the more data we have in CV the more we learn in an active manner where we give our product data and get the feedback let us say 99% was correct. Take the 1% retrain and make sure it is not repeated. We constantly learn in what we call active learning.

Sara: how trustworthy is the product in terms of accuracy? are there different accuracies based on the type of projects?

Participant: I would say it's the state of the art in the world, make sure we are the best product with best performance since we don't want to ruin the reputation of our product, it not doing good performance on some images. We do not release anything until its state of the art. Some of our models are actually better than other products such as google or apple. Some of our models in that sense are not delivered yet because they are not as accurate as we want them to be. We do not want to sale something that is not fully functional.

Sara: before you give the answers to the customer. After the customer is using, do they give feedback about the accuracy?

Participant: Yes, definitely, the customer success team have weekly meeting with every customer to see about errors, failures in our analysis and report it back to us. Which is the learning dimension of our models, so we train again and ensure it does not happen again.

Sara: what can be problematic within this collaboration between SaaS with a construction company compared to other industries.

Participant: Challenging I would say, is the huge amount of data. The challenge is always data cleaning and transferring the data. It's like terabytes of data they have to take the time, assign a person. Data transfer and management are a challenge since we have over 10M images in our dataset. Besides that, I would say, mostly it's like technical challenges not collaboration. Obviously during this COVID 19 there are a lot of jobsites stopped so no data is provided. There are challenges obviously in computer visions.

Seb: that is remarkably interesting that you say there is a person assigned on the construction company side, is this a one-time job or is the creation of a new job/new skill?

Participant: If it is a new customer, they have never used AI or anything of the sort. They hire someone to make sure no corruption or missing data is transferred. It's usually the first time only.

Seb: do they shift responsibilities onto an existing role, or do they open a new post for a short duration?

Participant: Most companies are hiring a data engineer or something that is charged to communicate with our model.

Sara: Do they get trained by your company?

Participant: For our product yes, they get trained.

Sara: And is it a continuous or one-time training?

Participant: Continuous because we always release new features and parts of our product so always need for new training.

Seb: One question relating to back in the beginning about COVID-19, you mention the safety distance and masks on site, has that already been implementing and deployed on site.

Participant: Yes, a couple of our customers have that for a couple weeks now. We released it in mid-April. The next feature will be mask detection. Also, around next month it should be available.

Seb: Thank you that is really impressive.

Participant: We have a fast pace that allows this.

Seb: yes, but I would not have though companies that reactive

Participant: There were also news agencies that covered this like the times and others will provide you.

Sara: So, these are our last questions and the first one is why do you think that construction industry is lacking a bit behind other industries in terms of employing and implementing AI?

Participant: Good question. I think there's a couple reasons, one of them is the privacy issues that some of the countries or companies have on using the cameras on the jobsite. Some are concerned about privacy of workers; some unions are against being recorded during work. Second reason is that they have not been exposed to AI in general, most of the construction companies are old school in terms of the technological work. There has not been many robots or AI in general, I think they are getting more opened to this. I can see it with our company there were very few of them at the beginning but now there a very few that are not using it. But I would say it's just the nature of the industry to be afraid of AI is going to be used against them, for instance if an accident happens because a worker didn't have the helmet on than the reputation of the company can be tarnished. On the positive side, the whole idea here is to save a life not the reputation, make sure workers are safe. Which is also good for construction, if they get a complaint about what is happening on a worksite for an accident then they will be more responsible for that next time. Next time it will not happen or at least know what happened last time, and also, they save a lot of money in terms of insurance, reputation. We also had a couple of insurance companies pitch their customers to us to make sure their workers are safe. I would say cost-saving for them as well.

Sara: And would you say that most of your customers are from US?

Participant: I have not done any statistics, but I do know we have customers from Europe, china, japan, middle east, south a middle America they are worldwide. But in terms of percentages I do not know. We do work with everybody around the world. Obviously, it started in the US, in Boston actually.

Sara: alright thank you. Do you think that there is something we did not over in this interview that you want to add?

Participant: No, I think that should be all, so the only thing is the new stuff coming out for COVID 19 support from our company.

11 APPENDIX C – INTERVIEW: MAY (HELENA), PHD STUDY ON MACHINE LEARNING MODEL FOR THE CAUSALITY OF ON-SITE RISKS EMBEDDED IN ACCIDENT OCCURRENCE @ CHALMERS UNIVERSITY OF TECHNOLOGY

Date: 13/05/2020

TECHNICAL RECORDING PROBLEM for first 1'.30"

Participant: ...is happening in one company but there are also other people from other companies that joined us in a reference group, so they also have their input because they are also keen to improve their safety situation as well

Seb: Could you name us some specialties and skills that are part of this – reference group?

Participant: Yes, in Swedish I'm not sure if I'm saying this correctly, it's called arbetsmiljö ingenjör, like safety engineer or work environment engineer that are involved in the reference group from both [maybe... I don't know if I want to name them] but the biggest three contractors in Sweden, they are involved. There is also involvement from people from unions, work environment unions so they are also within the reference group.

Seb: Okay, are there any people from outside the construction industry and inside the AI industry?

Participant: Yes, there are... I have like sort of a co-supervisor that is a specialist in machine learning but in the reference group there is also someone from another university who is like the head of AI division in another university. So, they also joined the reference group because we also need -the other- insights on the technical AI part.

Seb: And final question with regards to the head of AI and specialist in machine learning, do they have an affiliation with construction, do they specify construction or do [are] they purely AI experts?

Participant: no, they work with the machine learning and artificial intelligence, not connected to construction.

Seb: okay, so now that we got more or less in both ways an understanding of each other's topics of research, we delve into further questions...

Sara: Can I ask one thing; I want a little bit clearer. clarification on if it's one project that you're doing between several companies and like. is it like a project that is defined or is it more like a research on one company or? how is it working? Because you said biggest construction companies in Sweden? How does it work?

Participant: Basically the project that I'm involved with, my PhD, is only in one company so we have the data from one company and we are working only with these but the other participants are there because the way we..., we first applied to fund this project , the funding organization required us to involve the industry so the info actually benefit to not only one company but to also have been a bit that is distributed basically it's a requirement that we involve other actors as well so that's why they are involved and the other reason is that because they are interested so that's basically what is happening but my project in specific it's within one company and the reference groups meetings happens like every six month or something so they are updated about what's happening, they know the results and they also contribute with their input.

Sara: thank you

Seb: and just one final general question, which phase of the project do you focus on?

Participant: basically, it's the construction because that is influenced by multiple factors, first is that accidents mostly happen in construction maybe there are accidents that happen elsewhere, maybe driving into the construction site or outside work, there are also injuries related to illnesses that are caused by maybe working in construction but maybe something that doesn't happen during work but what we are focusing on is that... on accidents that happen during work so occupational accidents basically, in specific

Seb: okay

Participant: yeah, we are not focusing on other things like illness for example.

Seb: and would you have direct examples on the ways which you focus on occupational accidents like how you go about to perhaps prevent them or to report them –faster- or what solutions are you trying to deploy to address these hazards?

Participant: right now this is not entirely clear for me because I'm still exploring the solutions but basically we want to involve like work environment engineers and other people who are responsible about that so we understand exactly what kind of solution can benefit them so this is the plan to actually have them involved in creating the solution and also have them involved after creating the solution to evaluate if they actually find this helpful and in the technical part we are striving to identify risks that can contribute to accident regardless of their severity because also accidents have like... they could be minor or they could be major and very unfortunate so our aim is to focus on risks that contribute to the accident regardless of what is the outcome of that.

Seb: and so... would this solution in essence– I know you don't have one answer to it yet – but does it aim to perhaps solve directly sort of the conditions that result in accidents or help the safety engineers to identify them? Does it enhance their role or does it kind of reduce their responsibility?

Participant: In my view, it should enhance their role

Seb okay, so the responsibility still lies with them, they just have further capabilities

Participant: yes, they would have further capabilities maybe and further access of important information so maybe they process less but they influence more. hopefully

Seb: okay that's really good... alright then also. are you doing this on a project? kind of a project-applied case? and if so, how big would you qualify the project?

Participant: Well that's part of our... like method design, the initial plan is to actually try this out in three projects, we didn't specify how big or small or what kind of project they are, I think it also depend on the availability also which we actually find then but we have a plan to actually try this out if we manage to create a prototype to try it out and see how it works and if it actually works

Seb: okay great, we covered it a little bit above but for the sake of Sara's note and the recording, I will ask you again in a different turn of words: how does it typically work between the involved actors so you mentioned that you really involve the safety engineers both at the beginning and at the end to evaluate but how does this go about for example with the machine learning specialist and the head of AI? Do they have for example training toward health and safety to further understand or how do these two worlds meet to develop the best solution possible >>> internal or external?

Participant: well the two of them, the AI external specialists they both worked with another type of safety which is road safety, cars, so basically I think they are used to work in different domains but it is still critical that their understating of the building is mainly important but they can contribute more with technical solutions related to the modeling of the machine learning model, the choice of algorithm, how we can evaluate methodologies that we can follow, so this is the type of input that they are best to contribute with and otherwise, other domain-related issues that are very specific to the construction an very specific to occupational safety in construction sites we try to discuss them during meeting and explain as much as possible and then maybe find a meeting point

Seb: that's very interesting, now that we touched a bit to the actual... so they are being responsible for the algorithm and the modeling of the machine learning how typically does it go in terms of, so, what we qualify as knowledge management but where does the data come from, who provides them? are there any specialists.... because working with/for one organization even though multiple organizations are involved, how does it go about to feed the information to the machine learning model? who contributes what? are there any rights? Are there any issues with privacy and such?

Participant: Yes of course, the data is coming from the. I actually don't know exactly where it's stored but it's coming from the contracting company, they have it stored somewhere, so they provided a backup for the data and this was challenging because the data is not structured in a way that is easy to use. Basically the database that I got contained a lot of information related or not to accidents that I want to look at, contain other kinds of reporting, like near-miss, which is like an almost accident, positive observations, negative observations... I think many construction companies in Sweden are doing that right now that they use this type of software that has like this similar way of reporting, so the data was a really difficult part and I'm still struggling with that because it wasn't structured so it was very difficult actually to work with it. In that regard, we also tried to contact the software supplier but I think they also didn't have much to contribute to, so I think basically now I like speaking only about safety reporting data, we need to work with what we have but I think there is a lot of improvement that could be done to work with the database, to organize it, structure it, understand it, know what is inside. So, I think there is a lot of potential to be improved in that regard.

Seb: So, you mention that most of it comes from one organization, does that mean that in the end how applicable and viable is the solution – the end product- for the other organizations that are involved?

Participant: well that is also a challenge. It might be applicable only for the one company, it might be beneficial for the other, there could be maybe trials to evaluate if it's actually applicable, like we create a model for one company and we test it on another, but right now we don't have a plan for that. But this could be possible to check if it's applicable and then if it seems that is not applicable, that also say something that maybe it is very specific with the one company and there are probably factors that play a role in one company that are not existing in another because finally we have to live with that the accident reporting reports only specific type of information, not everything. So, we also need to acknowledge that there are lot of things that we don't know.

Seb: Okay... Then ...

Sara: Sorry Bastian, I want to ask something before we go further about if the outcome of this program would be the risk situations or the circumstances that lead to accidents. Is that what you're trying to develop with this data or is it something else like a training program for the workers or...? I mean where is the outcome... where does it lie in health and safety management?

Participant: Yeah well it depends actually on the results but our goal is to actually identify risks but if we find that one of the risks is that people are not knowledgeable enough then maybe the solution is to actually train them more but in principle it's not a training or education for workers or people. It's more like risk identification system probably, it's something like that.

Sara: And it focuses on verification and not prediction of accidents, right? as I understood.

Participant: Yeah right now I would say like we don't aim at predicting the accident but we actually work with their risk factors more than predicting the accident because it's still not entirely clear but that's what we discussed so far.

Seb: With regards to this collaboration and the aim of the whole project, who initiated it? Is it the organization, is it the university? Is it a third party we haven't heard of? Who initiated this group and this project?

Participant: The group or the idea?

Seb: both if they are not the same answer.

Participant: Well that idea is like a collaboration basically so we started with a proposal and then the proposal started to develop, we started talking to the company and then they came up with the ideas so it was a collaboration between both the researchers and the company and afterwards the group, the reference group was like collected, people were contacted and then there were showing interest and then they approved and then they acknowledged participation on the project and so on. But in ... so the idea was a collaboration, the group we sought (sort) the out as researchers and then they joined and so on...

Seb: ... contributed their ideas. Okay, thank you. And then, so once this collaborative group came into existence, were there any temporary or not intermediary roles which in other words are for example sending a person from the organization to the AI solution provider to train them about health and safety or vice versa sending someone to shadow a safety engineer for a week to understand like how did people get to understand the other's day to day business as usual? Were there any rolls created, full-time part-time temporary?

Participant: No not really the empirical study part is something that I should do. I need to go out and talk to people asking questions what do they really want, what they think about that, how do they go about their reporting, what kind of risks they from their experience identify so that role is the one I (have) (19'36") otherwise we rely on the regular meetings to discuss and so on. There is a contact person in the company that I can contact. So I have created some contacts within the company now and both the safety engineer and the safety development manager something like that I can check the position correctly but basically I talk with this person, because she is knowledgeable about the data, she knows about the software, the system, the data, how to extract it, work with it what each entry means because they have like different meanings of the terms that are used on the reporting and what does that mean and later on I think that I also need to talk to more people that are involved with the reporting to understand how they do that, what kind of information they actually value, why do they write the causes the way they do, how do they describe the accident and things like that so the roles that are being... or the network that I'm initiating now is this one. I can check the position of the people that I talk to and...

Seb: and this safety development officer so we call it now, so did her job exist prior to this reference group? Was she hired for the sake of AI appointments?

Participant: Yes, her role exists before because they also tried to use the data every year, they initiate... they create a report with the information that they have because the data still exist and it is easier to get charts and... yeah like charts and information that are related to the most frequent accidents, where they are happening, the most report cause, things like that. So, they actually use this so they can identify high risk like activities and things like this so they can learn from that. And so, she is involved with using the data on that level before.

Seb: And then Sara I'll tell you this, just for note taking to take a very slight outside question from option 3. Yes. So, you talked earlier about the training of the machine learning model. Do you know more about which techniques or elements of AI are used or most suitable towards this specific project?

Participant: It's just she is a strategic health and safety developer. So, you're asking me about what is acceptable...

Seb: Which elements of AI, which did you find? Well, which one is used? Which one is most suitable? What can you say about this?

Participant: Well, basically, we did the literature review to see other people who have worked with the same problem. And so, what we found is that most of the literature is dealing with this problem as a classification problem. And this is in machine learning when the algorithm classifies if this is A or B, so accident, not accident, but in reality, there's no no-accident situation. There is the accident and levels of severity. So, the literature that we find was trying to predict the severity or the level of the accident. And from our view, this was not very helpful because there isn't a clear prototype or clear model, and the use case also is not clear. How can these results be used? This is something that we haven't seen so far. And so, I think that so far, the literature is not dealing with the problem in the best possible way, especially that there are less serious accidents and much more less serious ones. So, when they are trying to work with this as a classification problem and then the major accidents... or the accidents that that lead to death, for example, are very less represented. And therefore, it's very less... it's very difficult for the algorithm to learn from those. So maybe I would also treat it as a classification problem. But this is still not clear for me as well.

Seb: And do you know, currently the AI experts and the head of division, what type of like, you know, is in machine learning is a deep learning. Is it supervised? Do they recommend a certain type for the information that they have been provided for this project of AI training?

Participant: For now, I would say machine learning. And we didn't discuss deep learning. So now I think it's still machine learning and. I don't know what algorithm we would use.

Seb: Okay.

Participant: OK, but mostly machine learning and if I have to say it should be most likely classification or clustering. Clustering is when the algorithm can group different features together in one group where they are similar to each other. So, it could be this could be that most likely I don't see other way right now, you know...

Seb: Sara do you have anything to add before I go back to the original.

Sara: So, I don't know. Just out of curiosity, do you label the data with the risks before you feed it to your model, or do you just like give the input and then regulate the output sort of to identify the risks afterward? I mean, are the risks labeled with the accidents and their severity or not?

Participant: I think they are. I haven't I didn't start working with that yet. Right now, I am extracting and working with the data, just exploring what it has. But I think it's labeled because there are categories that are already defined in the reporting form. So, there is like a form that that there is like a drop list where people can choose from already made lists. So, this is very helpful in that sense. But there are also other elements that probably could need to be worked with. But I think that it's already labeled and then I can use those as they are. Yeah. But this is something that other literature that I've seen struggled with. There were more available data that is unlabeled. And so instead of like analyzing sixteen thousand accidents, they could only analyze one thousand because that's the ones that are labeled that they could find. But I think that I don't have that I will not struggle with that as much because it's the report that they are working with their work usually text. So, I think it's going to be different for me.

Sara: In the sense that it's easier with the label and. ...

Participant: Yeah, yeah.

Sara: So, it's not part of that structural problem that you mentioned before.

Participant: No, not entirely, because, as I said, that database, the way it was, it wasn't helpful because it contained a lot of more information and it was like scattered in different tables and so on. So now we are going around another solution to actually extract it in a different way. But, yeah, that maybe it is part of the structure, but not really. The problem was that the organization was it was not easy to deal with to actually find what you're looking for within this very large database.

Sara: Yeah. Ok interesting.

Seb: Ok, so now we move on to the final section before the open questions. Now here, I know that you're still at an early point in your project, so perhaps either you don't know the answer or perhaps you take an expectation perspective of these questions. So, would you predict and expect any statistics that show the relevance for AI safety performance? So how it would affect the statistics? Typically, what would it change if the solution is deployed on-site?

Participant: It's hard to know, actually, even if we try to track this down. I think it's hard to know because accidents sometimes happen in a strange way. They happen like in cycles. And another thing is that sometimes risks are taken like there are risky situations where an accident doesn't happen, for example. So, it's really hard to track down the numbers and that's part of the problem. And so even the reported accidents actually tell a lot. There are a lot of situations where the accident doesn't happen, but a deviation or violation is happening. And these are hard to add to find it could be something good that people now try to report positive and negative observations, like if they see something risky on site, that they report that even if nothing's happening, really. But I still think that I don't know how much these are reported, but I just assume that they are not reported as much.

Seb: You would overall say that the statistics on the performance would be difficult to qualify because not everything is reported from the site. And in that sense, we don't know how much effect the solution has.

Participant: Yeah, yeah. And the mechanism of the accidents happening is sometimes or seems sometimes to be random. So, I wouldn't say it's random and I wouldn't say it's not. I would, I would say I am not sure. But the thing that I know is that it's not always an accident when there's a risky situation. So therefore, why the accident happened in this particular time, this is something that I think it's a bit hard to know. And so probably on the on the long run, statistics could show an improvement maybe for a couple of projects, a couple of years. But an immediate evaluation, I would say that this is going to be challenging. But I still also think that the perspective of people is important, so the way they feel, if they are using a new system, the way they think, this is helpful. This is also, I think, an indicator. And so probably we can rely on that before we make, like, hard statistics judgement.

Seb: There are very good, very good points. And then the final two questions are tricky, given the timing. But you mentioned earlier that after the solution would be deployed, the safety engineer who is there to help develop it but also reevaluate it to check the performance...

Participant: Maybe, maybe more than one....

Seb: Yeah, but the role...

Participant: Yeah

Seb: Okay, then the following question, you cannot answer, but if we move forward, we have. So,

what are your thoughts in the long run or short run regarding the types of jobs that will come about by AI?

Participant: Specifically, in safety?

Seb: Yes, for the construction side, the AI side perhaps there will be a construction specialist, specifically for our industry?

Participant: I would say that a data scientist would definitely enter the picture in their future and maybe a data scientist who's also knowledgeable in construction, like maybe someone with my type of experience, experience like interdisciplinary, that is where I have the basic construction and education and experience, but also is knowledgeable with the machine learning and the solution development. Probably not very technical but understand how the solution is made and deployed and that's maybe the role that will come up in the future. But I still also think that of like data scientists that are from outside the construction can also have a big part to play, because basically they this is their entire profession. And so, they their skills might be very popular in the future. Another type of work that I see, I see that that this is important, and I think that probably specially like large contracting companies, they might also start to work on their database. And so, this also might be a type of work that could be popular in the future. Yeah, because right now, I mean, that's like only from hearing. I hear this, that we have a lot of data, but we don't know what to do with it. We have a lot of data, but we don't really know how to find what we really want to look at. And so this is something that I come on to be heard in the sector, especially now with the boom of artificial intelligence and machine learning and the value of data that we see other industries are working with and how competitive it is now. So, I think that that this is something that might come up.

Seb: Sara, if you don't have any final comments, rebounds or anything before we go into the open-end section...

Sara: I want to know if or what is your opinion on this A.I. Solutions for Health and Safety on site, like the companies, like, for example, INDUS or smartvid, which are working with this, and some of them are only in the identification phase and some of them are also going to prediction phase. So, what do you think about those? What is your or like how close, how different and how useful you see them?

Participant: I see that they are useful, but, um, in a way that they have the live tracking the like, real-time tracking and because let's say that there's a safety engineer, site manager, whoever is involved in checking people are really safe and it's really hard to cover everything at once. So, I think the solutions are really helpful in that regard. But at the same time, since we don't understand exactly the mechanism of why an accident happen, there are maybe situations that there will be too late. So even real-time will not solve the problem. It should be something that has been thought of before. Planned before, managed before. So, they are helpful, but I'm not sure if they are really helpful in every situation. Also, I think they are very good in tracking the safety equipment use, for example, gloves, helmets, vests, harness and the such. So I think that that could be really helpful and probably also if they are connected to reminders or warnings or alarms, that could actually do something like, yeah, maybe if there's a worker that is not wearing a harness on a roof, there's something that is going to happen immediately. So, it also depends on the intervention time when an intervention is going to happen if something wrong was spotted. So, I think that's also something that is interesting. Uh. What did you also ask me?

Sara: Like, how much different is that work from yours, which I think I got almost the answer like you are trying to see a bigger picture, like try to see one step before the accident and they are working in real time. But what about their predicting system which they are developing? Is that do you think that's close to what you are working on or is it different in some senses?

Participant: I don't know much about that, actually. I only know about the real-time recognition. But the prediction, I don't know about that. I don't know what they do, actually.

Sara: I also haven’t found data, like detailed data. I guess they are just developing it.

Participant: You know, maybe, um, probably I don't know, actually.

Sara: Yeah, well... Do you want to move to the last question?

Seb: So, if you're done with your... OK, perfect. So, the final two open ended questions to discuss about, to your belief, which areas as of today remain unnoticed in the field and what can be improved? Aside from what you brought up, with your classification, what big areas remain unnoticed that should be talked through or discussed or ...

Participant: Like you mean AI technology that is not being exploited now...?

Seb: Or the other way around, it could be AI not meeting H&S or H&S not meeting AI. Where do you think that there's something that's unnoticed that could prove to be truly beneficial, primarily for the construction, but for both parties.

Participant: Yeah, well, in terms of health and safety, I would say that the data is key and integration of data. So, the more information about everything that we have connected together is the better, at least in this stage where we don't know much, we don't know a lot. So, if we can combine project related information with the accident information, maybe we will have much more insight. But right now, this is really difficult to happen. It's really hard to find this data to put them together. And they are not put in a system that they can be found together. So, the more that we have data right now, the more potentials we might achieve. On the side of... on the other way around, I think there are also techniques that could be employed. But right now, I don't see exactly how. But since they have a lot of potential, I think that there could be something beneficial, like the reinforcement, for example, where the AI system and the AI algorithm learn by itself based on some sort of penalty function, like they use this reinforcement learning to train an algorithm to play Mario. So, when they go to some laws, they know that they lost and therefore play again and again, and then they learn to play very well, that and that so that they don't lose, for example. So, this type of algorithms, I think, could be something to explore further.

Seb: Yeah and final question, in your opinion, are there any unanticipated consequences of AI's implementation in the construction sites.

Participant: Yes, ...

Seb: Now that we can see the good outcomes, are there any consequences considered or that are not talked about?

Participant: Yes, I think that there are definitely consequences, especially that like I mean, we know a lot, but our understanding is still modest. We have worked a little bit with identifying that like what kind of decision-making problems we might have using AI and machine learning models. And basically, the accountability of decision making, responsibility, are something to worry about, because let's say that we have a machine learning model that predicts something and would the responsible person still take responsibility or who's responsible, for example? That is a very important question. So, what would there be an overreliance on the recommendations of the model or not? And also, there are problems with the evaluation of the model itself. So, like we discussed earlier, we want to try this in three projects. But does this really saying that the model is working or not? And so there should be more robust methods to actually evaluate and best the modeling results. These are, I think, very much valid concerns. And right now, there are no... there aren't good answers for that, but not on the machine learning the experts, not in our field as well. So, this is something I think, that a lot of people need to work with.

Seb: That's a very interesting train of thoughts for me, one of my favorite questions of the interview as well.

Participant: Well, I have also one thing to add that in accidents, it's a costly problem. You know, it's very responsible if the model predicts something and finally someone gets hurt, that's very... that's a very costly mistake. you know. And there is other type of maybe machine learning applications that this is also something that there are costly predictions like in bankruptcy and like very like major things, like in cancer prediction, like, then the machine learning also is used into diagnostics where they look at images of these scans that the machine learning models should say if this person is sick or not, and then it is really sensitive. And so therefore, it is really important to understand how the algorithm works. What are the parameters? How can this be evaluated, and should we use it or not? You know, so these things are something to worry about and these things are things that we are thinking about when at least not only me, actually everyone in the project is thinking about these things.

Seb: Thank you, and if you have anything to add, now is the time, otherwise, thank you so much for your time.

Participant: You're welcome.

12 APPENDIX D – KRISTINA (ANNA), INNOVATION PROGRAM DIRECTOR @ SMART BUILT ENVIRONMENT (SBE)

Date: 25/05/2020

Seb: I am going to start the recording. Could you tell us about “Smart Built environment” and your role within that?

Participant: Yes, I am a program manager. This is a strategic innovation program 1/17 in Sweden, so the scope for Smart built is to create a more sustainable Built environment and the areas we are looking into is the processes and the working methods and technologies etc. in the whole Built environment process. By that we mean both the project process that is what is happening on the constructions site and in the design phase but also the earlier phases with the most areas where the municipalities are responsible for the permission to build and so on and also there early planning phases. The scope concerns quite a lot of people in the Built environment sector, we have goals to have more effective processes, quicker processes, to be able to build in shorter times not just on the constructions site but also in the other processes. It is about 8 to 10 years from the early idea until you have developed and built an area in Sweden and then we also look into better environment and also for the working environment, for instance lowering the impact on the climate and this is actually one of our mission, lowering the climate impact but we also of course other environmental aspects. So we are really connecting the program to the agenda and sustainable goals. Today, we are quite focusing a lot of technical issues, what is the software we use, how can we use it in the design phase. Just recently we started looking into: how could AI be tool in the different phases to make us work more effectively and for instance you can use it in the design phase to analyze much more parameters when you are choosing the right structure, but this is not used to much extent today there are some small research projects where you can analyze both technical issues and also for maintenance to be more “right activities in the right time to save money which is rather interesting because you have risks in the sector”. The program is not only about AI but also digitalization, industrial processes, and working in a way. We have a vision where processes must not be like those we have today, because the processes will be different after you made the digitalization transformation. We will see how far we will reach. As for the AI part we are recently done a pre-study that has put what is important for us in the program, we have discussion with AI innovation in Sweden which are situated in Lindholmen in Gothenburg. We are also starting smaller projects to a straight a platform to work together, one important thing is that “ to be able to use AI in a very good way you need to have a lot of data, we talked about this during the lecture, we are aware that a lot of innovation programs talk about “looking into the data” but if you should visualize the data then we think we need to work together, because you need a lot of data for the work to be meaningful. So that is where proximately we are today. So it’s in the beginning and we work together with skilled people in this area, however our program is quite new in this area.

Seb: Thank you, really quick on the overall general questions before we dive into the specifics of the interview, When you say it is fairly new, how old more or less would you say the Smart Built environment, and your role within that institution is?

Participant: We are in the 5th year, we have been working for 4 years, after 3 years we have been evaluated and the program is supposed to be 12 years long, it is quite a long term commitment from both and all partners in the program and the authorities who are financing 50% of the program. This is really unique, when it started this long term commitment was quite important and unique. As partners in the program we have municipalities, authorities, “Lantmatreri” who is responsible for all the data, large and small companies, large universities in Sweden so yes this is a national program.

Sara: May I ask, This Smart Built is not only this program, but this program is part of the activities going through Smart Built, or is Smart Built based on this program?

Participant: Well the Smart Built environment is the name of the program. But within the program there is approximately 100 projects going on. So we finance projects that can be granted money from open calls, so we have just an open call which result will be on the 27/05 from the budgets come from the authorities. We also have strategic projects from the program managers, we are a group of people....And then there are other 16 strategic innovation projects, one that is very close to ours is “InfraSweden” 2030 but they focus on the transport infrastructure but not the transportation in itself but the built environment for transportation such as roads, bridges, railway. But we work quite a lot together and there are also several programs “Viable cities”, more about the development of the cities not the processes in the building. Is it clear?

Seb: Yeah, we can sense that it is a super broad strategic approach that goes hand in hand with the amount of actors and their interests and needs from this collaboration but to your knowledge do you have any subjects which “relate to AI for construction worksite” has there been any people from any of these collaborators and part of these program demanding specific direct applications?

Participant: I would say what has been on our discussion among our partners is more using AI in the design phase to be able to investigate a lot of different aspects and to be able to actually take more aspects into account before you make a decision. That is mostly what has been discussed and when talking to people in other sectors that when we work with a name guy named (inaudible) living in the US and working all over the world, he is a Swedish guy and he has worked a lot with the health sector. When discussing in groups with people that has come a little further than the building sector, we can identify that it could be used to minimize risks at any sort. But if you connect this to the constructions site would be probably possible to identify for instance, we know rather what is the most common incident, what causes the different problems at the site but they see something that you often work with in your company. I believe that if you analyze the data and not looking only at your site maybe you could see patterns to be able to take actions to minimize the accidents. To minimize problems, we have another problem we have quite a lot of things that we rebuild rather soon after been built because there has been something wrong. And if you could gather the data from this situation when you go through the project and “end audition”. If you gather data from this kind of activities, you could probably see more easy patterns when there is something wrong and we can adjust it in another way. To be better to take knowledge from early projects back into the process if you analyze them, there AI can be very helpful. Often, there are different problems. We have a project define process that means that, when you end one project you go to a new one and maybe it may be different and there is no incentives for taking the knowledge loop back but I think if you sort of make the data more general and not pointed out well this was wrong. For instance, “in 10/12 of our projects we have this problem, forget the guilt and blaming - “this is the problem we had in other projects we need to do something about it”. One problem is to define process that does not give incentives to improvements, the other problem is so much work to gather and analyze data.

Seb: It is interesting that earlier on, right here a few minutes ago you brought up that, perhaps for constructions site safety will be internal to an organization when at the beginning you were saying something that for Sara as well was music to our ears - from the get go you adapted not a collaborative as it is too broad but more a partner approach to the use and collection of the data for AI. The more info you have the better performance it can exert. It was quite interesting that you bring up that as a strategy overall you have that thought process but when it has to be applied on the construction site it is an internal to an organization.

Participant: It is today. The work environment is something that is kept quiet. If you go 5 years back, I was working with the largest construction corporate groups, all these big construction companies in Sweden they were not keen to work with other contractors, if they had a good idea they wanted to keep it for themselves. During last 5 years there has been a change there is a little more interest from those companies to solve problems together. This is what I see, we need to come to in the working environment area. We are not yet so open. I think the sector is going in that direction, you realize that there are some issues that you don’t or not competitive to solve them by yourself. It is easier in some areas such as digital data we need to have standardized format on the data and have an agreement “data from product” and in Sweden we do not have that kind until Smart Built started. But we did not have really the agreement that we have with this standard. It doesn’t matter what tool you have that can be made standardized for this format. Today, all the actors in the building sector, we need to agree on what standards we should use and this a process called (inaudible).

There is a lot of work going on, we didn't come that far in sheltering data in a lot of areas not only constructions. Therefore, it is better to work on a higher level to analyze the data not connected to the specific accident or activities but to check patterns and see where there are the most problems and how should we tackle them. But there is a way to go before we reach this.

Seb: It is very interesting that the thought process to take a step back, overall it is not a project applied application of why this accident happened and how we can prevent this from happening, but taking a step back and look overall at the industry and check which type of problematic we have to then address them as a group and as an industry. Perhaps it is very framed to the Swedish industry, I am French in France it is impossible, two branches of the same organization compete in terms of technology and other processes so they can't work together. But this being sad, I had one question regarding about the amount collaborators, who initiated this plan and how does it work internally?

Participant: You mean who initiated the program?

Seb: Yes, and how does it work internally between the people in the program.

Participant: it works really good, we have some problems also where it doesn't work between the partners. The start was to gather private and public companies and authorities and academia to really increase the intervention in the Built environment because we are a sector not known to be innovative. We are mostly innovative when there is a problem. In Sweden this has been up for years on how you work; it is also about your people liking the problem-solving environment. There were 3 agendas at the beginning, the first organization was working with BIM, the second was centered around GIS and making geographical data digitally available and the third agenda organization was focused on industrial processes. When these 3 groups started to talk to each other they realized there were a lot of common things between our different scopes why don't we make a large program that covers all the three areas. The overall aim of the program is to gather the sector to push forward areas in Sweden where were strong such as, quite early in adopting, building information models in design we still do not use them in large scale in the process that much. The aim of this innovation program should contribute to strengthen Sweden's' competitiveness in Europe and globally. This was from the authorities' goal. For the Built environment sector the first step is to get the actors to talk and cooperate, coordinate because you had very much these designers, you have the contractor on one side, architects, real estate manager etc. What did not contribute, cooperation between parties that have never met before and both have worked in the Build environment sector. This is really an ambition to get some common goals. What does needs to be done in this sector and should we do it. We are not halfway through the program time. So far we gathered the sector and now we need to consolidate, to address policies and regulations that are stopping the development.

Sara: They can also accelerate the process rather than stopping it.

Seb: This last comment that you brought up. It actually segways to the next question. Who are the intermediaries' roles in the development of this program, strategies and solutions? Who coordinates and processes all this information so that everyone achieves their interests?

Participant: All partners in the program?

Seb: Who makes sure that all the interests are met, is it an intermediary role, is it someone from within the organization, does it create a new job to manage all this information and that all the stakeholders get their aims? Do you see any problematics with the current partnerships?

Participant: This is very interesting because I think my nearest colleagues our main work is to collect the information about our partners (100-200 partners). We had processes to gather ideas, thoughts from everybody who is interested in our meetings. Anyone can join the meeting and affect the program and how we are working. We have a management board that follow our guidelines that are representatives for the sector actors. We have municipalities, Swedish transport sector, Academy. This is quite a good spread. As program managers we are the ones that need to get things going. Everyone who is willing to put their own effort and time is very welcome to join us. We have a problem because if we look in our partners we have some really large organizations (contractors, municipalities) and then we also have members that are really small they are less than 4 employees, to me this is something that I lifted up to the board because 75% of all the things are built in Sweden are built by small and medium contractors and a lot of the housing and office building are owned by small companies. This is a group that is harder to reach because they can be interested in what we do but they don't have the resources to work in development and innovation projects. This is interesting in respect to your question because we try to address these groups by addressing maybe some smaller scopes that might interest them. We want to cooperate with other organizations and have more contact with smaller organizations. We have a problem if we do not have these companies as partners. If we only have large companies pointing out how we should work is not fitting all the sectors. It is the same if you just work with large universities than the smaller universities do not get as much out of the program. How do we make sure that they get out of the program this is what you asked? Who those who are active in the program, for instance in our board hopefully they feel quite confident that get something from their development, however how we secure that also those who are not active in the program, which is harder because if you are active you get more out of it rather than if you are not active. The program wants to satisfy all the sector not only the one active in it. We are searching networks and platform where we have more small and midsized companies. We want to work with start-ups, we have some but we want more.

Sara: When you mentioned the limited resources of the small and medium actors, was it implying the financial resources or because there aren't enough actors that can be active in the board in the program, with their time for the meetings?

Participant: I do not think is the financial issue, the small companies it is more they are more into the day to day business and they do not have development manager or search manager. Big companies they have people appointed to work with the development and work with digitalization. When you have a contractor that has 20 employees, you don't have a person that is dedicated to work with these things because they don't have this type of organization. Actually, there is one interesting thing, the professor from Chalmers said "in another meeting it was an innovation group she gave a presentation why it is quite hard for large organization to work with start-up. An organization that is large is very organized and has processes for repeating every activity 100, 1000 times, but a small company or start-up are organized to do the things for the first time. They don't have the same type of organization, same mission, so it is very hard to find ways to cooperate. This is something we really need to develop further in the future.

Seb: Do you have the name of the theory, perhaps?

Participant: Camille Rodbelly, she is a journalist. I thought it was very interesting because it explains on a large scale why we can't work with small, large and start-ups for innovative teams.

Seb: Sara, perhaps in question 1.3 do you have any questions you want to ask? Or can we move to the grey section.

Sara: We can move forwards.

Seb: To your belief there are any areas today that remain unnoticed in practice or academic and how can this be improved?

Participant: I am not sure got your question.

Seb: In terms of digitalization for construction safety there are any areas that remain unnoticed that should be brought up and improved?

Participant: There are a lot of areas which should be improved, I am not sure there are a lot of areas unnoticed. The different companies know quite a lot about the working environment they really work a lot with safety for the people on site. But if you could make the connection clearer between the safety, the resources efficiency, connected to the design phase and early planning. I don't think this new information, but we don't seem to be very good at doing something about it. I work for the sector for 30 years and there are reports pointing our problems such as leadership, short term economic goals and not long-term ones. I think if you connect more motivation, behavior and so on to the problem that we still have we are good at creating rules, guidelines and having working descriptions and so on. So it's not the more technical problems I think we know how to make for a safe environment, but you need to look what motivates managers, why should they sort of live the way they want their employees to live. We are not very good at working with academic skills in other areas connected to motivation or behavior. Leadership is an area that the sector has worked quite a lot but it is not enough. Companies know what they should do but they do not really do it anyway, the sector is lazy. As long as you do not connect "why do people what they do together with technical tools and results, why do we have a lot of accidents on site from low heights and not from high heights like roof. Is more when you stumble and fall on the ground the main accidents. There should be simple activities to avoid those but maybe there is a connection between different areas where the technologies is one part of it, they could do more work. Cross-disciplinary, research to understand what motivates people to work in a safe way.

Seb: What is your plan to implement AI for future applications, future piloted projects. Anything down the pipe? AI regards to constructions.

Participant: I quite interesting and it is connected to what we talked about. We have some piloted projects that will start this autumn. Where we tried to find the needs for a certain area and make a test project, gather data and analyze it. In that way that can show what we are able to do with AI. Also we hope we can create also find platforms and meeting places where people have a problem where there are people with AI that can solve that problem, with other programs not only the strategic program. However, when we were talking about different competences areas more connected to the behavior field there is a risk in this project we are planning right now that is rather technical. For me is quite interesting to think about that we use AI in the right manner, we use it to analyze data until you have a lot of input. For instance, it would be interesting having pilot projects in areas where the design is going into the production or construction phase. There is time where we have a lot of problems, misunderstanding and if you could analyze results from these data then we could a get a result that we know what we do. Like a designer never designed in details because the contractor knows what to do. This can be avoided. We expect that the contractor knows what the designer has thought, but he doesn't he can only know what is on the design not in his mind. Maybe our pilot project connecting to AI is more connected to behavior, working methods, organization rather than technology which is something I would like to drive forward.

Seb: This concludes our interview with the final 2 question. Everyone can attend events for the SP, when you mean anyone is part of the partnerships or future actors or really anybody.

Participant: It is really anybody.

Seb: Is there an agenda or news releases that could point us to events that we could participate?

Participant: You can find it and sign for it with your email address. That is one of the most important part of the program. All our events that will become digital now in order to be more international. We had physical events in Stockholm which are difficult to be attended by everyone. Some events are meetings for new projects that have been granted money and those meetings will happen in September and are for these people to meet each other and about the projects. Otherwise when we have our meetings for input we really want to reach out different new networks such as colleagues, students from universities, LinkedIn. The easiest way is to register to our newsletter.

Seb: Thank you very much for that, we will have a look to the newsletter. I will add you on LinkedIn.

13 APPENDIX E – ZULFIKAR (RICHARD), PHD CIVIL ENGINEERING, PROFESSOR OF STRATEGIC IT IN CONSTRUCTION, AND CONSULTANCY WORK

Date: 18/06/2020

Seb: So first and foremost, what is your experience in the use of AI for construction projects in construction organizations?

Participant: My experience, its two-fold. On the research, I do some research as an academic. And I Also do some consulting in the industry for AI related stuff.

Seb: Could you develop a bit on which phase and what type of projects this consulting and research work is done?

Participant: Mostly commercial projects – large scale commercial projects. We look into AI in terms of for example things like H&S, also being able to extract some value from data, how to make projects faster or cheaper based on the data that has been collected with historical records of other similar projects or about ongoing projects that are being collected. It's all about algorithms that can help improve the process.

Seb: Thank you for your answer. Now we will move away from the demographics section and into the first section of our interview. So, what type of AI do you typically use, how does it work and in which area does it help with?

Participant: Well like I said, a lot of the work I do has to do with health and safety. Look at apps and technologies that can help identify hazards on site for example when construction workers are not wearing har hats or high viz jackets or just hazardous situations they engage in some activities that are hazardous or dangerous or have some kind of cameras that capture some of these things and automatically flag a hazardous situation based on what is perceived.

Seb: Ok Thank you. And so, for this which type of AI do you use to train the software? Maybe Sara you can help on the key terminology here.

Sara: I would like to know if you are involved in the process of developing the model or if its more the consultation part of it.

Participant: No, I do not necessary develop the models themselves – scripts no. But I am aware of some of those models that can be useful for machine learning. Pattern recognition and the rest of that but I do not go into that level we just apply already existing tools and customize them to our needs.

Sara: I was wondering if it's possible to give us an example on one of these projects, just so that we understand with better details what is going on?

Participant: What do you mean?

Sara: for example, how does it work, you already have a database of some applications that are useful in this area and you recommend them based on the needs of your client or how does it work?

Participant: Well, we have a database of some of the things we train the AI to work with, to recognize hard hats, recognize high viz, recognize a dangerous activity going on, a risky situation. On that basis we have live camera feeds that capture images and process them and alert the workers/managers if there is any worker who is not complying in a situation dubbed dangerous. So, we use quite a few tools but one of the ones we use is something called "smartvid.io". Have you heard of it?

Seb: yes, we interviewed them a few weeks ago.

Participant: Yeah so, we deployed that to health and safety. So, a ready-made solution really. Its not as if we are developing it from scratch.

Seb: and in this sense, since you mention that you customize the already existing tools. To which extent is this customization adapted or involving with the actual people in the field who are the people that are going to be analyzed in video recognition and such.

Participant: Sorry can you repeat that.

Seb: Yes, are the people who wear the high viz and hats, who are in the hazardous situations. Are they involved in the customizations?

Participant: No, they are not. The end workers are just doing their thing. They are aware that we are collecting data for AI purposes whatever. But they are not involved with the H&S managers on the customization.

Seb: Ok, could you perhaps without putting yourself in a sensitive position, tell us why they are not involved other than they do their job on a day to day basis?

Participant: Well because at the end of the AI is helping us to analyze and identify hazards and dangers and those sorts of things. We don't necessarily involve them in the sense that – of course they get training and know what to do (whether to wear their hard hats and such) where they forget to put it on or put themselves in a dangerous situation – the AI's job is to alert us or the safety Managers who will assess them. But they do not have to come to the dashboard all the time and ask questions, they have work to do, their purpose is not to contribute to AI, their purpose is to construct the building. AI is just something that management can use to improve and make life easier. There is no point in engaging their view. We inform them of these tools we are using will capture them in images recorded for nefarious reasons. So, we just let them know what is going on, but they are not involved in day to day running of AI, they are busy laying brick and driving cranes – they do what they do. Involving them is almost pointless. Every now and again we can give them feedback, especially if they are in a hazardous situation where not wearing the hard hat that's where you involve them and tell them you need to wear your high viz or such but other than that they are not involved with AI development. They are not there to do AI they are there to construct.

Seb: Of course. What I meant by that is in the moment AI is decided to be used and implemented on site, for the workers that have been working several decades they are informed of their uses.

Participant: Of course, you have to warn them – you cannot collect data like that.

Seb: Ok so for GDPR then.

Participant: Yes.

Seb: Ok perfect thank you so much. Next section Sara – the green one. What has been done in the knowledge management area. You mentioned that you worked with "smartvid" and we are interested in the fact that knowledge sharing is not that common yet in construction as a whole. So, are you allowed to use their image sets? are you sharing your own with them? Is it private?

Participant: No. We do lots of work with them that is private. We do not share it outside the organization.

Seb: ok so the training of the software is based solely on the data from the org. was this a decision from top management? Is this an institutionalized practice?

Participant: I mean they have no incentive to want to share data with anyone. That will also mean getting the approval of all the people that have been captured. I do not think anyone would take that kind of risk and start sharing images of their workers or scenarios to others. It may happen but for now no I have not had the situation where it happens. I do not know if they asked but if they did, I doubt they would have been given access. Maybe one day it will be centralized but for now I do not see the incentive for anyone to share their data. I am sure they would be happy to receive and it would improve them.

Seb: yes, that is what we discussed with smartvid – is that in sharing you also get the access to other orgs sharing which makes your recognition pattern that much stronger because it fed by many more.

Participant: That can be done but on a centralized database. But no on a company to company level.

Seb: ok, thank you. Yes, so you mentioned that you are working on a large commercial project. Is this a one-time project for AI implementation? is this a pilot project or are they doing on several projects? What the timeline and scale of the implementation?

Participant: The projects that I have been involved are a one project, but they are not a pilot project – they are fully implemented. Whether they are going to use it for future projects I cannot tell.

Seb: ok so its fully implement into the projects that they are currently taking on. And are you working with one or multiple organization.

Participant: Two organizations.

Seb: and these two organization do you know if this a one off partnering or do; they have a more long-term collaboration strategy in mind?

Participant: Well I was not involved in the licensing agreement so I would not know what king of strategy they have. But I think they get value from this, they like what they see. There is no reason why they will not involve them again in similar projects. Because using smartvid is not cost effective if your project is not of a certain value. Small projects are pointless – so for the large projects that I work with why not I do not see why not if you reap the benefits of it.

Seb: Thank you for that. Well if we move on. Yes, this also relates to your previous answer so perhaps you were not involved but still, who initiated the collaboration? was it a consultant such as yourself? Did it come from inside the organization? Where did the idea to work with smartvid and AI H&S come from?

Participant: No, the company themselves wanted to use smartvid.

Seb: Internal ok. Then causally relating to this. We look into the intermediary's roles which if I'm not mistaken would be, your role as a consultant which is a semi-permanent intermediary role. As such which side do predominantly fall under? Organization side or is it also solution provider being actively in the industry?

Participant: Well I cannot say for sure. But I know some people who work for smartvid. But also, a lot of people who work for contractors who just use smartvid.

Seb: ok. Do you see any problematics with today's development methods between the construction health and safety and AI fields /organization?

Participant: Problems. Well yes, I will say there are some challenges here a there. One of them being of course data privacy being an issue for people. People are not used to being recorded so it is a new way of thinking and working. Working when you know you are being recorded in video that affects you – even if it's to help you for H&S you get the feeling someone is observing you. If you are a brick layer and someone is watching, you will not be comfortable doing your work. If all of us are being watched – so there is a feeling that someone is watching might affect the quality of work that you do. The comfort zone relating to data privacy.

Another thing is that the industry as a whole – this whole use of AI is a challenge in many ways because we are not used to this sort of innovative solutions. The industry is very stagnant. And all of a sudden, within the last 5–10 years there is this sudden burst of technologies – drones, AI, BIM, and this and that. And many are struggling to cope with it, sometimes people are subscribing to some of these things without realizing the benefits or the value. They just feel they should use it. There is some time some problems are that some of these technologies they are just solutions looking for problems they are not born out of the industry's needs to solve its own problems. It's just some smart people coming up with some technologies trying to shove it down the throat of construction people "you got to use this it's going to help" – yes its going to help but you better use the solutions that came from genuine problems that evolved into that solutions.

Seb: that is an interesting point.

Participant: Yeah, we have problems of productivity and H&S. Solutions should be drawn from these problems not by somebody that came up with a wonderful technology that uses drones or 360 cameras. You cannot look on the other side to solve all your problems.

Sara: Do you have any experience on some problems like this, as in the solution is unnecessary but because the technology for the sake of technology is being used.

Participant: Well I will say quite a lot of technologies eventually start up like that. I think with time they get better and end up becoming construction industry focused. Just because you have a technology that can identify hard hats and high viz it does not necessarily mean it will be effective in helping the H&S problem. If you have a site without anybody in it, you will not have H&S problems – you will just have a blank canvas. H&S starts when you have people involved, when you have all those things it's what creates or mitigates hazards and risks, so I think that not all of these technologies need to be…. I think what I am trying to say is that these technologies are not driven by construction people. They are driven by IT people who may have good intentions, but they may not necessarily the core of the problem. If you are not a construction person – if you have never driven a forklift, dug a foundation, you don't what a slab is or how a column is like that or why people do this and that. I am not sure you will appreciate how people work and why they work the way they work. I tend to see a lot of technologies. If you look at the Gartner hype cycle- something I think you should be familiar with. You see that many of these technologies you find them on the peak of their inflated expectation. Someone with think that by implementing smartvid "oh my H&S problems will go away". Anybody who decides to be unsafe will continue to be unsafe – just because you have smartvid does not mean that that guy from yesterday will wear his high viz. If he does not take H&S seriously, he does not take it seriously it is a s simple as that. So, I think that technology that does not lead to behavioral change, technology that does not make people to improve then it's not really solving the problem. It's not enough to identify someone who is not wearing the hardhat, what if we have to remind him every day to wear the hardhat, because what if we fail to identify and remind him to wear it if he's where the camera is not there. In the end it is not meant to be a reactive solution. I think that some of these technologies could identify problems but are not necessarily good at changing the behavior and making them safer.

Sara: maybe I'm going too much into details, but have you tried any of the proactive approaches because for example smartvid I know that they are working to instead of just identify the safety hazards they want to prevent it. I want to know if you have experienced something similar to this that helps for prevention instead of just identifying.

Participant: I am talking in general – not necessarily about smartvid. But let us take smartvid as an example if you implement smartvid on a site today you can easily identify problems or hazards or risks and those sorts of things. But like I said if you identify 3 or 5 workers who did not wear hard hats and you alert them to wear them, now you have reminded them. Tomorrow you light have to remind them or maybe next week. What I am saying is H&S is a cultural thing, it is a habit a behavior. People need to understand why they need to become safe they do not need a technology to remind them they need to be safe – it's helpful if the technology can remind them. But if you don't have that mindset then you will find yourself have to be reminded every day and you won't appreciate the benefit of wearing the hard hat, so if someone tells you to wear it and you put it on. You will not respect it as something that saves your life – do you see my point. Technology has to help people close the loop, there needs to be learning from it, not just reacting. I do not know what they have to do – I mean if you can tie it to a system of carrots and stick where you reward good behavior and punish bad behavior it may help sink in. People will do what you tell them to do because you told them to do it, but if they know the reason why they are doing it then you won't even have to tell them to do it. And that is how you can change the H&S and other aspects of construction. Similarly, with productivity. Let us take a bricklayer for example, how to improve the speed of the bricklaying or to minimize waste in the mortar. So, what you identify this guy is doing things faster but if you are not training him to do it in an a safe, fast, and effective way then …. what I'm trying to say is identifying problems is one thing, but you can identify problems every single day on a site without necessarily changing behavior and the technology should be helpful to change behavior so that I can improve.

Sara: that a very humanistic approach to all the technological trends that the industry is going through.

Participant: Well I am a technology person. But at the end of the day I realize that technology is there to help people. Like I said sometimes solutions are there just looking for problems. If you asked a bunch of bricklayers – maybe 200 of them or 1000 of them – and asked how I can help your productivity with technology. I am sure they would come up with some ideas that are interesting. That is how you can develop technology that can actually help them be more productive. But if you develop cameras that observes them and flags numbers of bricks – oh you only laid 200 when you could have done 250 in this and that way. You will not understand why he only laid only 200. Maybe one of them is left-handed, maybe he is lefthanded, maybe he does not like waling facing east because of the sun shining in his face. All you see is that he is not laying the 250 bricks you want him to lay. And you complain because you want him to do better.

Seb: And I actually had two points on this amazing answer that you just... so not just the answer, but conversation that you just sparked. The first was regarding the very first point, the..., the challenges with GDPR and how the people are not really used to being observed all the time and it affects their behavior. So, Sara brought up the key term of the humanistic approach from the humanistic approach, it is you know, this anxiety and, and such that provides it to the person. But then I saw in a course last year on the behavior that it could actually increase performance because of the feeling of being watched, they take less breaks and they feel they need to perform because they feel their supervisor is directly watching them. So, while performance and feeling are linked and somewhat independent from the professional perspective, would you say that their performance is increased when they have the feeling of being observed or not?

Participant: There's no doubt that when you watch someone, and you know they are watching; his behavior will change. OK, so if you look at productivity, for example, somebody knows that his boss is watching him, even if he is not recording, if his boss is watching him with a camera, with binoculars or watch face to face he would probably want to do a better job than if his boss was not watching them. But when it comes things like health and safety or even for the productivity of rate, at the end of the day, you want it to be intrinsic. You want it to be from the inside. You want someone to behave in safety because he knows the value of this, not because he is afraid, you see. Let me put this analogy. You want people to change because they believe in change, not because they are afraid of the consequences of the change. That is how you can get the real benefit from these sorts of systems; people should be safe because they value safety. If the technology can help them to be safe, that is fine, it is always welcome. But they should, first of all, have a technology that helps them to know the value of safety, not a technology that just simply playing good cop, bad cop, identifying them when they are not safe and criminalizing them for, you know, or exposing them, you know, if they feel that the technology is only there to just point fingers at them for not being productive or not being safe, whatever, then they just feel like this is kind of Big Brother telling us, just been monitoring us, which is OK because we normally have this monitoring anyway. But think about it this way, before technology, it was human beings that went around supervising and making sure people are safe, making sure people are productive, a good worker will be productive with or without his boss around, he'll be safe because he knows the value of safety. So now we are replacing the surveillance with technology. And this technology is even more ubiquitous. It is more detailed than surveillance is, never goes on lunch break. It never goes on strike. It does not matter whether it is rainy or snowy, it is technology. It is always there. So and I'm just trying to say that the technology is helpful, is always welcome, but we should not forget that, we want people to be productive and to be safe because it's the right thing to do to be productive, not that they are doing it because of the consequences. When you get to traffic lights, do you stop because the law says we should stop because it is the right thing to say, to stop when it is red? Or are you stopping because you see traffic policeman? and you are afraid that if you cross the red light, he is going to arrest you. If you are doing it because you are afraid of the traffic police, one day you are going to get hit by a car coming from the left or right. If you cross a red light, you are going to die. Because you are only doing it because you have fatal consequences. But if you are doing it because you believe it's the right thing to do when the light is red, well, I have to stop even if I'm the only person and it's 2a.m., It is a red light. I should stop. It is the right thing to do that. It is built in as a behavior. Then you do this no matter where you are, no matter where you are no matter the circumstances, you always stop at a red light. What I am saying that sometimes these technologies might make people do things because they are afraid of the consequences of being caught, not because they have the belief in doing the right thing. So, there's always room for people, there's always room to supervise people and make them, we will give them a one finger, whatever, there's always room to make people who go astray. But in general, technology, AI, should help people improve behavior. AI would do things that what is AI? It is just a machine or a computerized way of processing information and getting intelligence much faster, more effectively than the human being can ever do that. What AI can do in ten minutes, the human being will take months to be able to analyze, come up with intelligence. You know what I mean? We want to also improve people; we want improved productivity. We are not using AI to criminalize people, to punish people. If the smartvid is only identifying people who do not wear hats only so they can give them a warning or deduct them some pay, then is not successful. But if you are going to be successful, people would be like, wow, I did not take my hard hat but nowadays and actually I do not need to be told. I know I feel uncomfortable without my hardhat because, you know, this AI has helped me in a way.

Seb: And thank you, thank you once again for the that, Sara do you have anything to add before we move on to the next session?

Sara: I want to say that that is a particularly good intro to the section. Yeah, yeah.

Seb: So, in this next and final session, since the final one is the opening, two questions. We dive into really the statistics and quantitative parts of AI's implementation for health and safety. And in that sense, the first question goes straight to the middle, which is do you perhaps off the top of your head or under your hand have any statistics to show the relevance of AI's performance for safety? Is it minus 10 percent accidents? Do you have any numbers perhaps?

Participant: No, I do not have any number. I do know from what I've seen that, yes, once you have something like smartvid and it's able to identify workers who are not doing certain things or do what they're not supposed to do whatever, certainly you can tell that without these, these people will have gone all day doing something wrong. So, but if I can give you the statistics. No, I do not have that high-level summary of how much I saved in terms of what our lives have been saved, our lives have been saved from being broken or whatever. I do not have that.

Seb: No problem, we know it is a long shot, that that is why we try to aim straight for the bull's eye from the get-go. But then on a semi qualitative, do you have any not statistics, but information and thoughts on the ways in which AI impacts today's safety management roles? So, does it take away some of their responsibilities? Does it require them to have more skills? What is the impact on the traditional safety roles?

Participant: I think for safety managers, for health and safety people in general. It is an immensely powerful tool, is an especially useful tool to have. AI, it does not have to be smartvid, it could be any other one. There are some sensors for example, that detects dust, exposure to dust and they alert the worker or the managers. Some of them detect sound level, you know, to expose to tell you whether a worker has been exposed to too much noise of a certain frequency by a long time. And they obviously have to take a break. I mean, there are all kinds of things that AI can do, that is doing so. And without these things there are some of them that for example, dust sensors and whatever that would be difficult for any safety manager to be able to detect, you see my point. Some of them like I told you. Yes. you can tell this guy has been exposed to a vibrator for the past six hours. He should take a break because there are some guidelines and policies about noise level exposure, time weighted, average exposure of acoustic noise over a certain duration. We know that workers should not be exposed for more than a certain number of hours. But if you don't have the AI, you won't be able to detect, you have to manually monitor people or they have to have some watch or someone who will remind them you need to take a break every six hours from using a vibrator or whatever. But AI can automate that process, make it faster so that you do not forget, so that you are not overdoing it or underdoing whatever. So, I think in many ways AI is extremely helpful and powerful, especially when it comes to where I see potential is where it comes to the health side of things. Now, when we talk about health and safety, but I think people forget that there are actually two different things. Yeah. Not only things that we talk about that you see smartvid doing is actually mostly safety. It is not health. Safety. Why? Because these are things like easy to see. You have a guy not wearing a hardhat, something could fall on his head and it could break it, not wearing high-vis jacket. This is all about safety. Safety are the things that happen to us, safety issues are things that happen at site, like we get to hear about this, a worker breaks his leg you get to hear about it, isn't it? A worker falls on a day to get to hear about it. A fire. These are all safety issues. But when it comes to health, you are talking about things like vibration, like silicosis, people exposure, such as to cement, inhaling dust that can be carcinogenic. Health issues actually cost the industry more. But the problem is that they are not instant. We do not get to know about health issues until maybe many years. You do not find out oh I have cancer, but I have never smoked. Yes, but you worked in a cement project or whatever, where you are inhaling smoke dust, or you have skin problems because of silicosis or you lost your hearing of a certain frequency because you've been exposed to some level of noise, which on a normal day will not be harmful. But because of being exposed to this machine or this equipment for 20 years, then you lose your hearing for such frequency. These are health issues that cause the industry much, much, much more. But they do not get to hear about it until many years, often when people have retired. So unfortunately, AI is not able to -so far, to the best of my knowledge, I do not see how it has necessarily been used in tackling health issues. Most times people look at safety because that is one that is marketable. That is one that gets into the news when a worker falls down and breaks his neck, is in the news. You do not get to hear about the worker who has cancer because he has been doing some work over the last 20 years, who is not taking treatment. And you do not get to hear about that, do you? You do not unless he goes to sue his employer, maybe he and his colleagues to the employer by a class action, which would be very difficult to prove, would take a long time to go to a court case. Think about it. A worker who is exposed to vibration today, and a worker who breaks his leg, who, which one will get into the front news.

Seb: Worker who breaks his leg cause ...

Participant: Right, exactly.

Seb: ... he is most likely to...

Participant: Exactly, so we worry more about safety because that is instantly visual, we can see it, we can feel it, it is more impactful, it is more has more immediate consequences. But I would like to see AI help more also, you know, that case we're looking at using the Internet of Things and sensors to be able to detect it, sort of things that even normal human beings will not be able to detect on time. You know, like you have sensors that can detect the level of particles and cement dust and some things that can harm your lungs. This can alert you by raising an alarm. You know what I mean? Exposing yourself to certain vibration or noise, it can raise an alarm after a certain number of hours, I say you need to get away from this environment because you have overexposed yourself. If you are allowing yourself to remember or there is a device to tell you to leave the place because it is just too much noise or vibration. What if they forget?

Seb: No yeah that is remarkably interesting, especially I mean, I personally did not know that because I knew the fact that most health issues were not found until years and years later. I did not personally know that it costs more to the industry than safety. And this is ...

Participant: It costs more to the industry, to individuals, to the society, to the health care sector. It cost more. Like I said before, the problem is that it is safety issues that are more recognized, safety issues that are more seen. And you can tell when you go to sites, someone is not wearing hardhats, or did you know whether he is inhaling some bad smoke from the equipment on the truck or whatever he is driving? You do not know that he may be getting some poisonous gases in the equipment he is using gradually and then retires and he starts having lung problems. You do not notice it immediately, that is a problem.

Seb: Yeah. That was actually something that I found during our readings for this thesis is that I don't remember the exact percentage, but I think it was close to one third of all these health issues don't even see the light of day. They do not even enter the statistics because they happened so long after that even the worker himself does not realize it was because, you know, half a century ago he worked on this site.

Participant: Yeah, there is some that would be recognized that is what will be at the point of retirement by diagnosis for some silicosis, skin disease or some cancer or something like that. Some of them do get or some of them disappear, you never recall it. Because the link is not extraordinarily strong. People do not realize it and sometimes it is not the health issue and site that itself might be the problem. It may just put images interior to a health condition to the extent that it makes it easy for you to now catch some other disease or get some other problems. I do not know if you understand what I am saying by that.

Seb: Yeah.

Participant: The work that you do affects your health in such a way that that work itself is not the disease itself, but it exposes your body, it weakens your body or your immunity or whatever so that later on, you know, you become vulnerable to other illnesses.

Seb: You're more prone to have them there.

Participant: Yes because that mean your body has been undergoing such an iteration gradually over time.

Seb: OK. I mean, unfortunately, as much as you know, the two topics are extremely interesting, we at first chose health and safety and we narrowed down onto the safety side because there is more academic material to research on for the same reason that safety is more in the media than health. So, we focus on that side. But it is terribly interesting what you are saying. And I do want to read more about how much it costs the system.

Participant: I think I think safety, at least in the UK, about not taking, I think safety... when I say cost, I am talking about financial not the human cost. Yeah, I think safety accounts for about 70 percent sorry, health accounts for 70 percent, safety 30 percent.

Seb: Okay

Participant: You go to health and safety executive for the UK, for example. A lot of the things you see, almost all are the safety. Moving objects, falling from heights, tripping hazards, all those things. They are safety issues. Very few of them have to do with health, but people assume that is the same thing or they do not know how to draw the line. But it is not. You can be safe, but not healthy. You see my point? You can be safe in says that I am climbing a scaffold. I am safe, nobody falls down. I have in my hands. Nothing is going to happen to me. But I am breathing in something. Which is affecting my health. So health is usually passive, it's not something that you can easily notice or observe, you know, it does affect your inner body, while with safety you can get blood coming out because you cut yourself or you tripped and fell down, scratch or broke your leg, you know, or you know, you get hit by an object and die, these are all safety issues. But health, you know, you look OK, but deep down, no, you are not.

Seb: But in returning to the final set of questions for our interview, what are your thoughts about the jobs that will come about with the hopefully... well hopefully or not wide scale deployment of AI? Are there going to be new jobs? Are there going to be a shift in skills of the existing jobs? What are your thoughts on this topic?

Participant: Of course, there will be new jobs, some jobs will have to go because they are outdated and no longer required. We have technology, we have advanced. That is how we have always been. People will look at it and say, oh, technology is going to displace us. Technology always displaced us. Maybe not digital technology. That is different because, again, I show you the first time the computer was invented, some people lost their jobs. That has always been technology coming up, but it is just that we live in an age where technology is so fast, so digital, and so much more efficient than we ever had. The input we made in the last 20, 30 years is massive. So, jobs will have to go, but new jobs will be created. You know, some jobs will never recover. They will never come back again because there is no point using them for example some aspect of supervision might be taken over completely by AI some aspects might be completed by robots. Because AI is not necessarily robotic. Robots are just the hardware. The main patrol, for example, all these robotic dogs you see in the USA being piloted by many companies that can walk around and do carry tasks and carry objects. AI is not robot, AI is just the script that is the most important thing about AI, but it can be... the script can run in a hardware, which is what makes a robot. A robot without a script is just junk, a metallic junk. So what I'm saying is that even the job that human beings do whether to visit people or claim certain locations are, confirm certain things, inspection and the rest of that, robotics and drones and all those things, the hardware available to be able to do some things even better. You know, like I said, when you use AI robotics, you have so many benefits because they are very efficient. They do not go on lunch breaks. They do not go on strike. They do not ask for a pay raise. Yeah. And they do not join unions and go on strike. So, there are many reasons why technology and robots are helpful, but also that some things are always you want to be involved in for many reasons. Why? One, because there is a human side of things. Secondly, because we cannot just replace, my opinion, we cannot just replace every job. If you were to replace every job in construction, I mean, what will be a society? This is something people want as believed. Assuming we have these robots now, we have some kind of automated robots laying bricks, if we can really automatically lay bricks for all the houses in the world, automatically spray paint, automatically install everything, robots. What will we do? Because a job occupation is not just for income, it gives you something to do. OK? so I think that in a way, to ensure that we see going on has some social angle to it, some societal angle to it, that people have not necessarily taken, but I think those in the construction industry need to be very careful about it, because if you were to have a system with technology that now replaces, let's say, for example, all the bricklayers in the UK, where do you think all those bricklayers will go to, they have to be retrained, OK, and but the process should be gradual, should be gentle, such that, you know, you can upskill them, somebody might end up going to work in IT themselves. Somebody might end up being people who help maintain that equipment that replace them. Imagine you being a bricklayer, end up going to retrain as a software engineer or retraining as a hardware and whatever to fix a robot, the same robot that made you jobless. I mean whatever you have to do, you have to do it. If you look at, I think it was in Detroit, in the US, we should be a center of car manufacturing over the last two decades or so. The city was... it lost a lot of jobs because you know the car manufacturing things went to Asia, Mexico, and other parts of the world. And some of those workers in those car factories were retrained to go into things like software development or some other IT related things. You have to just find a way to retrain people. In the construction industry, it means we have to think about what will the next supervisor of the 21st century look like in the next 50 to 100 years? You know, what will the bricklayer of the future look like? Would we need him to be a bricklayer or will be just someone who just changes the oil in a bricklayer machine? See my point, but we cannot stop the progress, that is a problem. We cannot. We just need to make sure that as we're making progress, as we are replacing, automating more and more, we take care of the people that are being replaced because it means more and more people might be jobless if we don't find them something to do.

Seb: Yeah, well this concludes our interview, thank you for helping us finish on a very interesting note. Thank you for your time Zulfikar.

Participant: Thank you. Goodbye.

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