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Envisioning a Human Centric Approach to C4.0 Technologies

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Abstract

Question: Q1) What are the social impacts of C4.0 technologies on people in the construction industry? Q2) How is the industry coping with this digital shift?

Purpose: This purpose of this paper is to explore the literature on the social impacts of C4.0 technologies. It compares different findings, analyzes them, and reflects on how practitioners need to consider a more humane approach when implementing new technologies. Artificial intelligence was used as a case study in this research.

Research Method: The authors conducted a synthetic literature review to project a critical view on the literature findings, identify trends and patterns, and reflect on them. Reflections were in form of statements and questions that would trigger more thought on how to approach this digital shift.

Findings: The findings shows that the industry's approach to adopt C4.0 technologies overlooks the social factor and social impacts of their adoption. Also, the paper highlights the need for a human-centric approach, such as Lean Construction 4.0, to preserve the social aspect amidst this revolution.

Limitations: The study only covers a part of the body of knowledge found in the literature. Moreover, the research tackled artificial intelligence as a specific case and can be extended to cover a wider range of technologies.

Implications: The paper highlighted the importance and the need of using a human-centric framework in the shift toward digitalization. It also raises a set of questions that address the subtle impacts that C4.0 technologies impose on people in the industry.

Value for authors: This study will give companies and practitioners a new perspective on how to plan for adopting technologies in our industry. It will help them ask the right questions focusing on the social and human factors in their assessment.

Keywords: Construction 4.0, human-centric, social impacts, Lean Construction, artificial intelligence

Paper type: Full paper.

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Introduction

Over the course of history, humans managed to disruptively innovate and evolve throughout different industries, improving their overall wellbeing and the lives of their succeeding generations. In the first industrial revolution, production became mechanized using water and steam. The second revolution included mass production using electrical energy. The third revolution was about production automation using information technology and electronics (Majumdar et al., 2018). The fourth revolution, Industry 4.0, includes the use of cyber-physical systems and advanced digital technologies (Sawhney et al., 2020). Culot et al. (2020) stated that Industry 4.0 is an "announced revolution". It is an encompassing concept for a list of technologies and applications applied in different contexts. Embarking on this fourth revolution, the potentiality is not yet actualized. In the context of construction, the term Construction 4.0 (C4.0) is used. Sawhney et al. (2020) described C4.0 as a paradigm that uses cyber-physical systems (such as robots, actuators, and drones), industrial production (such as 3D printing and off-site manufacture), and digital technologies (such as BIM, internet of things, and artificial intelligence). As defined by the authors: "Construction 4.0 aims to create interconnected environment integrating organizations, processes, and information to efficiently design, construct and operate assets."

An overlooked aspect amidst this revolution is the social aspect. Scholars addressed the impact of several C4.0 technologies on humans as individuals and the social structure in the industry. Studies categorize C4.0 technologies differently based on their application and level of digitalization and innovation. However, most studies tend to generalize and deduce impacts, influences, and implications of specific technologies among others under the umbrella of Construction 4.0. Many researchers shed light on the negative impact, while others showed the bright side that came with the implementations. This indicates the potential benefits that can be harvested from implementing these technologies, as well as the collateral damage that may be left behind.

This paper explores the literature found on the social impacts of C4.0 and how the industry is coping and approaching this inevitable shift to address the following research questions: (1) What are the social impacts of C4.0 technologies on people in the construction industry? (2) How is the industry coping with this digital shift? The paper explores these impacts under the title of "C4.0 technologies" and investigates artificial intelligence in more details. The study aims to provoke discussion and reflection on the impact of existing and promising technologies on humans. It also emphasizes the need for a human-centric approach for their adoption. The paper is divided into the following sections: Research methodology, social impacts of C4.0, Hansei, investigating AI, different approaches to C4.0 adoption, the need for a novel human-centric approach, and conclusion.

Research Methodology

Due to the controversial and abstractive nature of the topic, a synthetic literature review was used. A synthetic literature review is a methodology used to critically analyze a specific topic to identify trends and patterns in the literature, analyze and

pinpoint discrepancies in the body of knowledge, and propose recommendations and next steps for future research (Schirmer, 2018).

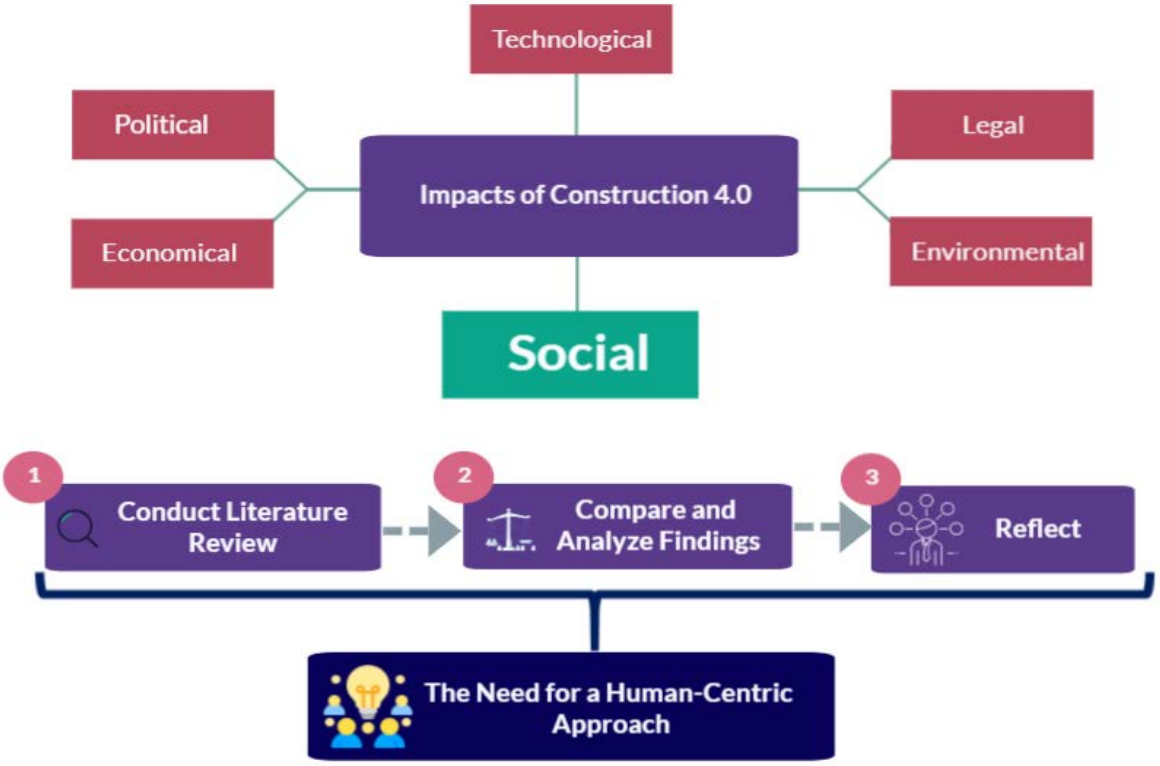

Figure 1: Research Methodology

As shown in Figure 1, the social impact was the focus in this study among other types of impacts (political, technological, legal, environmental, and economical). The first step was conducting a literature review to understand the state of the knowledge in terms of what the social impacts of Construction 4.0 technologies on people are, and how they are being addressed. The review process is linked to the research questions stated in the introduction, with the aim to highlight different views on the social impact of C4.0 and the industry's approach to adopt C4.0. The next step was conducting a comparative analysis between different views on the topic to capture any specific trend in the impacts and the current methodologies carried out to address them. This sparked reflection that was expressed after the analysis; reflections were in the form of statements and questions that would trigger more thought on the topic. Moreover, the findings were linked to studies and theories in other fields and sciences, such as psychology and neuroscience. The same steps were followed to address artificial intelligence as a specific case of C4.0 technologies. This paved the way for expressing the need for a more humane approach for embracing C4.0.

Social Impacts of C4.0

Socially, C4.0 has impacts on organizational structures and companies as a whole as well as impacts on people and individuals. Table 1 summarizes the findings on the social impacts and considerations of adopting C4.0 based on literature.

Table 1: Summary of C4.0 Social Impacts

Authors	Main Findings
Balasubramanian et al. (2021)	C4.0 might lead to small and medium-sized enterprises (SME) running out of business due to the monopolization of technologies by bigger companies
	Cyber-Physical Systems (CPS) may reduce employees' creativity, professional autonomy, self-worth, and morale
Lokovitis (2021) Sherratt et al. (2020)	C4.0 does not support the nature of architects' work (art and culture) and might cause disruption
Ness (2009) Forcael et al. (2020)	C4.0 imposes the risk of automating and replacing the jobs of blue-collar workers
Chan (2020) Balasubramanian et al. (2021)	C4.0 technologies lead to safer environments
	Companies can upskill their workers
Oesterreich & Teuteberg (2016) Alaloul et al. (2020)	Most companies adopt a techno-centric approach for adopting C4,0
	The social and ethical factors are barely addressed in the adoption of I4.0 technologies in construction
	Social and technical factors are the most critical in delaying the implementation of C4.0 technologies.

Balasubramanian et al. (2021) studied the current and future state of C4.0 technologies in the industry and how they are disrupting the sector. The authors used extensive literature review and surveys to assess different technologies. They reflected on the social, economic, and environmental sustainability impact. With respect to the social impacts, organizational structures are expected to radically change, where big companies will monopolize the market and SMEs are at risk of being left out of the game. Moreover, the impacts were also expressed at the level of individuals. For example, the study showed that Cyber-Physical Systems may reduce the creativity of employees. Also, AI and machine learning were indicated to negatively affect professional autonomy and creativity of employees. From the interviews conducted in the study, the interviewees voiced the concern that technologies are truly shaping and limiting free thinking, creativity, and skill utilization. Furthermore, C4.0 technologies were viewed to affect employee's perceived self-worth and morale. These alarming issues are hard to detect as they are abstract and subjective; however, their repercussions may ripple from individual performance to an entire organization's existence. The subtlety of the problem is a much bigger problem.

Lokovitis (2021) investigated the integration of C4.0 in the Greek AEC industry using interviews with experts from the architecture, engineering, and construction field. Interestingly, experts with an architectural background reflected that C4.0 innovative technologies do not align with the nature of their work. They opined that architectural work still focuses on creativity and brainstorming which are not yet

supported by these technologies. The interviewees stressed aspects such as art and culture, which cannot be reshaped by C4.0 technologies.

Sherratt et al. (2020) used the term technocratic optimism to describe the negligence and passivity in accepting technologies without any consideration of their social impacts. In their study, the authors argued how C4.0 technologies are close to reshaping the whole workforce by eliminating the people who actually build projects in real life. Moreover, the authors expressed concerns regarding the impacts of C4.0 technologies on reshaping the work of architects. This digital shift was said to lead to projects being built to meet and fit technological advancements in the industry, rather than being a product of creativity, humanity, and imagination of architects. Besides reshaping the nature of jobs, some are risked being replaced or even lost. Whether due to industry 4.0 technologies (Morrar et al. 2017; Berriman 2017) or construction 4.0 technologies, jobs of manual workers and blue collars are anticipated to become redundant and automated (Ness, 2009; Forcael et al., 2020; Chan, 2020; Balasubramanian et al. 2021).

Other studies reflect optimism regarding the impact on jobs. During the interviews conducted by Balasubramanian et al. (2021), some interviewees mentioned initiatives in their companies to upskill blue collar workers to knowledge workers, where their jobs will not be as physically intensive as before. Blue collar workers would shift from an unsafe and harsh environment to a safer and more controlled one. They would supervise and transfer their experience to robotic systems. Robots and automation are predicted to produce new roles and opportunities (Garcia de soto et al., 2019). Although these contradicting views may both be true, what is most important is the need for proactive measures.

Oesterreich & Teuteberg (2016) conducted a systematic literature review (SLR) and multiple case analysis to explore the benefits, challenges, and state of Industry 4.0 technologies in the construction industry. The authors used PESTEL framework to aggregate findings (benefits and challenges) and categorize them as political, economic, social, technological, environmental, and legal. From the 9 case studies conducted (each case study addressed a different construction company), only one showed a human-centric approach to the adoption of technology. The company explained that innovation and work environment redesign springs from their own workforce, fitting technologies adopted to what people saw helpful and healthy. This is what deemed the approach human-centric; innovation and change come from people who are doing the work to fit their needs.From the SLR conducted, the authors found that the analyzed articles mostly address technical aspects of I4.0 technologies adoption in the construction industry. The social and ethical aspects were barely addressed.

A comprehensive literature review was performed by Alaloul et al. (2020) to identify causes of delay in implementing I4.0 technologies in the construction industry. The findings of the study state that social and technical factors were the most critical factors in delaying the implementation of these technologies. This highlights a paradoxical trend, where social factors are considered as hindrance for C4.0 technologies on the one hand, and on the other hand are barely addressed in adoption frameworks, models, and methodologies.

Hansei

Kaizen and Hansei are principles from the Toyota Way model that describe how organizations can become learning organizations that always strive to continuously improve (Liker, 2004). Hansei means reflection on mistakes or weaknesses and developing ways to improve; it is similar to the "check" step of the Plan-Do-Check-Act (PDCA) cycle in quality control (Gao & Low, 2013). Tying this concept to this topic, this "check" step is missing, and we can't move forward without reflecting on the situation and asking considerate questions on how we are impacted and what a better approach would be. The questions derived throughout the study are summarized in table 2 below.

Table 2: Questions raised

	Questions
Q1	Is there a standardized method for organizations to assess the impact of these technologies on their employees?
Q2	How is this radical change managed?
Q3	Is it too late to track these impacts?
Q4	Is it a positive thing to automate or delegate creativity, brainstorming, intuition, and other humane tasks to machines?
Q5	What would be the consequences of achieving that?
Q6	Which jobs are compromised?
Q7	What jobs are created?
Q8	How can the affected people fill the gap in the new opportunities that technology create?
Q9	What is the strategy to upskill people?
Q10	What if companies start with the root cause, the social factor, and address it as a basis for their approach to digitalization?

These are few preliminary questions that should be raised, and more effort should be put to address them. These questions are applicable to any technology and do not have universal answers. Among different C4.0 technologies breaking through the industry, artificial intelligence (AI) is one of the quickest in reaching maturity. A significant number of studies focused on the current state of this technology, its prospective benefits and challenges, and its impact on humans. Therefore, it is chosen to be discussed as a specific case in the following section.

Investigating AI

Technology has different levels of disruption depending on what the technology is able to offer, and how drastic its impact is on the latest practice. Clerck (2017) explained the difference between digitization, digitalization, and digital transformation. Digitization is the move from paper to digital data. It is the creation of digital version of physical things. Digitalization is the automation of processes where machines replace human labor. Digital transformation is the integration of different digital technologies leading to radical change across industries, organizations, and people. It is considered to be beyond a technological phenomenon.

Artificial intelligence is a branch of science and technology that creates intelligent machines and computer programs to perform various tasks which requires human intelligence (PK, 1984). AI is one of the most influencing digital transformations disrupting almost all industries. With respect to construction, the technology can potentially infiltrate any aspect of the industry and is addressed in particular by many scholars and researchers. Arroyo et al. (2021) discussed the uses of AI in the industry and the ethical and social dilemmas that arise from using it. The authors highlighted provoking questions that spark reflection and thought about how impactful AI is on industry practitioners. For example, if AI would take over, how would team structure and collaboration look like? A construction project binds effort of various trades. Project success is highly related to how harmonized the trades are with each other. Can AI algorithms come up with decisions that take social context into the equation? Would it compromise these bonds that tie people in a construction project?

McAleenan (2020) tackled moral issues and considerations of the use of AI in construction. The author stated that transparency is crucial for human liberty and well-being. However, the AI systems designed are still far from being transparent to both creators and users. The AI could be several AIs within an AI, obscuring transparency further and leading to more difficulty in finding the root causes of distrust and mistrust between the human and the machine (Abbas, 2019). Taking the best-case scenario, where the intentions of inventors are noble in trying to improve construction productivity, there are unintended consequences of these inventions (Arroyo et al., 2021; McAleenan, 2020).

Schia (2019) explored the impact of AI on human behavior in the construction industry. The study included interviews with people from contracting and subcontracting companies to discuss the digital shift and its impact on the human behavior. ALICE, which is an AI-powered construction scheduling application, is one of the technologies that the interviewees assessed. The assessment was based on technology, process, and culture. It was evident that there was no clear strategy of how ALICE should be implemented (process). Moreover, the cultural aspect (visibility of the utility, willingness to use, sense of achievement, and ownership) is missing. It is difficult for a worker to understand the output coming out of the application, let alone trusting it. Klien et al. (2004) reflected on the challenges for making automation a "team player". Even today, nearly 18 years after publishing the paper, challenges such as the ability to negotiate, ability to interpret signal of status and intentions, ability to reach mutual predictability, and ability to collaborate are far from reached. This gap is both exciting and scary; if not closed, it can lead to a lot of conflict between human and machine.

Wang and Siau (2018) categorized AI as being either weak or strong. Weak AI performs specific tasks with high involvement of human in terms of decision making and supervision. While strong AI is the performance of tasks with human-like intelligence and decision-making abilities. In 2014, Google Deepmind developed AlphaGo, an AI algorithm that competes in the world's oldest board game developed in China: Go. Go is an abstract strategy board game with simple rules; however, the possible configurations of the Go board are more than the number of atoms in the universe. Therefore, it is impossible for any existing computer to compute all possible variations. Thus, as described by Go players, most of the times intuition drives their decisions to move the

stones on the board. This challenge of mimicking human intuition using AI was picked up by the researchers and developers of Deepmind. In 2016, AlphaGo won 4 out of 5 games against 18-time world champion Lee Sedol. The caveat lies in analysis of AlphaGo's moves as the games were progressing. A lot of moves were judged as unreasonable and stupid but turned out to be genius as the game unfolded. However, other moves were also judged as unreasonable and stupid and turned out to be so. In 2017, a newer version of AlphaGo defeated its predecessor 100 times (Du Sautoy, 2019). The technology is maturing faster than what we can comprehend, making the adaptation process more challenging and threatening in terms of disruption. As these decisions might be unreasonable for human brains, how can we judge a decision made by algorithm as right or wrong? Developing human-like autonomous AI applications like AlphaGo in the construction industry is not far from possible; how can users ensure transparency and develop trust with such a technology?

Construction projects can be viewed as a network of commitments where reliable promising is at the heart of project success (Howell & Macomber, 2006). In his theory of Multiple Intelligences, psychologist Howard Gardner defined 8 types of intelligence (Gardner, 2011). With an artificial intelligence depicting one (Logical-Mathematical intelligence) out of 8 types of intelligence and disregarding all intrinsically human views of intelligence, how can rapport be built and decisions be agreed on when dealing with a strong AI? How can reliable *promising* be made with no emotional connection? How can trust be developed facing an emotionless machine? Who will be making the promise and based on what? Technology can be supplementary in a sense that it doesn't overtake what humans are meant to do but rather support it. Delegating tasks that are cognitive and humane to an algorithm sets the limit of what humans can achieve. Explainable AI is a new enhancement on AI systems where algorithms are able to explain the results of the solution to be understood by humans. This is both alarming and exciting; it indicates that the "black box" problem of AI is a serious one and not only a pessimistic speculation, and it indicates that the solution for that problem is possible and actionable.

Different Approaches for C4.0 Adoption

Goodrum et al. (2011) developed a predictive model to assess and estimate the potential impact of a technology on construction productivity. The authors used analytical hierarchy process (AHP) to weigh the input of experts on 4 main categories: strategic economic analysis, technical feasibility, technology usage issues, and technical impact (attributes that have been found to directly influence construction productivity). The model built was successfully validated based on the preset criteria. However, social factors were not mentioned or used in the model. Hossain & Nadeem (2019) developed a framework describing steps to adopt the concept of C4.0 among construction companies. Although the authors stated that "digital culture" and training are the major hindrances in the adoption of C4.0 technologies, the framework did not include any measure of assessment on human impact. The framework is considered to lead to positive increase in productivity, quality, efficiency, and process integration. The factors used are critical in assessing a technology; however, they are incomplete. If socio-cultural and human factors are usually considered an impedance on the adoption,

what is the solution? What if this "hindrance" is the solution for a successful and healthy adoption?

Simon Sinek, a well-known entrepreneur, inspirational speaker, and author, tackles a well-known phenomenon in business which highly relates to construction. He explains the relationship between performance and trust, and how organizations measure success (Sinek, 2019). He highlights that performance metrics are not wrong; however, they are incomplete. If an organization hits a financial goal by the end of a year, people in the organization get incentivized without knowing how they got there. Meaning, even if team members kept quitting and their morale kept fluctuating abruptly, as long as the goal is met, people (whoever is remaining of the team) would get a bonus. Sinek discusses that on the long run, measuring performance leads to diminishing returns because metrics such as momentum, trust, and morale are out of the equation of success. Tying this back to construction, whether measuring project performance, or assessing impact of C4.0 technologies, the metrics are lopsided. There are uncountable metrics to measure performance, but negligible to zero metrics to measure elusive yet highly critical human factors such as trustworthiness and morale. The focus on potential benefits in terms of productivity and profit reaped from adoption of C4.0 technologies may lead to the inconsideration of any social, human, and ethical consequences (Sherratt et al., 2020). If only monetary metrics are used to assess the implementation of a technology (productivity, profit, cost, time, etc..), then this would be similar to the attempt to optimize the parts of a system rather than the whole.

Hatoum et al. (2021) proposed a framework to assist companies in reengineering their processes with construction 4.0 technologies. The framework integrates Lean Construction and Construction 4.0 transformations. People-process-technology triad is used as a basis; the assessment of current state, vision of a future state, and the implementation are all based on the triad. Moreover, the authors leveraged lean principles to describe the philosophy and motivation behind the steps presented in the framework. The framework encompasses both sides of the equation: human and technology. Overlooking one and emphasizing the other gives false hopes and incomplete information about what the technology is expected to achieve. Does lean construction bridge this gap? Is it a healthy methodology that balances all factors?

The Need for a Novel Human-centric Approach

The comparison between different point of views indicates an inevitable trade-off of gains and losses from adopting C4.0 technologies. The vocal concerns about technological dominancy are not an attempt to run away from it, but rather an urge to embrace it in a healthy fashion preserving both: control and humanity. Control is an external factor, meaning that humans should have the predictability and control of the physical output of any technology. Technology should serve what the human wants and not the opposite. Humanity is an internal factor, meaning that humans must flourish and succeed, not only projects. Technology are means of support, not dominancy.

The study of qualitative, subjective, and abstract factors such as motivation, collaboration, satisfaction, or any human related factor is very challenging. Assessing such factors in the construction industry makes it even harder and appeared to be limited in the literature as this study was conducted. However, the impact of

digitalization on our brain is highly discussed in neuroscience, psychology, and sociology. Brain coach Jim Kwik elaborated in his book Limitless (Kwik, 2021) on what he named "digital villains": digital dementia (coined by neuroscientist Manfred Spitzer), digital deluge, digital distraction, and digital deduction. The most relevant to the impacts of C4.0 technologies are digital dementia and digital deduction. Digital dementia is the breakdown of cognitive abilities (such as planning, reasoning, critical thinking, etc..) due to the overuse of technology. Just as people's route processing abilities diminish with the reliance on GPS, the ability to do proper project planning (which is an art), scheduling, and control will wane if these technologies take over.

This also relates to digital deduction, which is the automation of deduction. With a matured technology, such as AI in planning and scheduling, one click would solve almost every question a practitioner might have. There would be no deduction made on how the technology arrived at the solution and why it is the right one. This means that critical faculties such as problem solving and creativity are now delegated to a machine. How can the industry innovate, evolve, create, and thrive when such skills are being automated? Wouldn't that limit our abilities? What is more alarming is the direct exposure of these technologies to the new generation. People with previous actual practical experience have the potential to judge a decision made by a technology; they have the "hunch". This privilege is not available for the upcoming generations, meaning that a gradual extinction of such knowledge is occurring without us being aware.

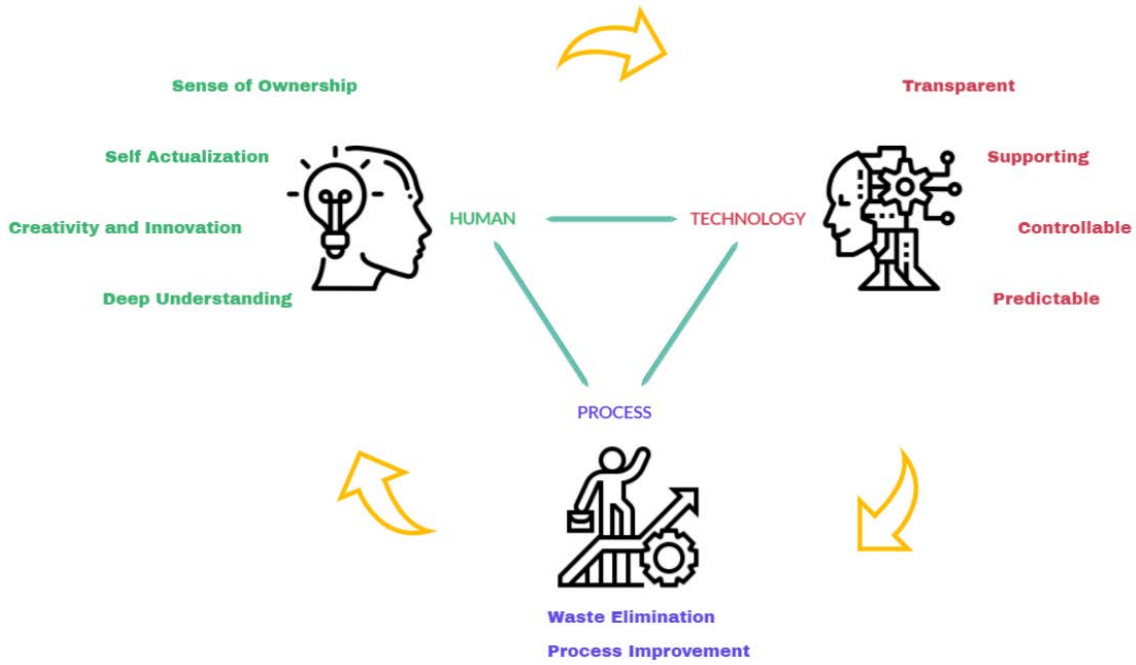

Figure 2: Human-centric Approach

The "bigger, faster, stronger" mentality in disrupting construction with no proactive measures may backfire. Albert Einstein once said, "It has become appallingly obvious that our technology has exceeded our humanity." As scholars and professionals in construction, we owe ourselves to raise the concern of preserving humanity in face of everything, not just technology. Lean construction, in its essence, bridges the gap between technology and people. Hamzeh et al. (2021) introduced Lean Construction 4.0 which embraces the shift toward digitalization maintaining the people-process-

technology triad as a foundation, as shown in Figure 2. The philosophy behind Lean Construction 4.0 is human-centered rather than being technologically-centered, where process improvements and technology applications are designed to the convenience and benefits of the individuals using them and directly impacted by them.

There are different approaches to human-centered design including empathetic design (IDEO, 2011), participatory design (Kensing and Blomberg 1998), contextual design (Beyer & Holtzblatt, 1998), and inclusive design (Keates & Clarkson, 2003) as shown in Figure 3 below. This ties also to the human element in the Lean Construction 4.0 triad; both white- and blue-collar people drive the design and implementation of these technologies in any organization, making sure these technologies fit their needs and preserve their rights of performing their work freely, efficiently, and humanely.

"Industry 5.0", coined by the European Commission, is starting to gain momentum. This new industrial revolution is considered to be "value-driven" compared to the 4th industrial revolution which is technology-driven. Its core values center around human-centricity, sustainability, and resilience. The reason behind introducing a new industrial revolution is the assumption that I4.0 overlooks sustainability and social fairness, and focuses on digitalization for production improvement (Xu et al., 2021).

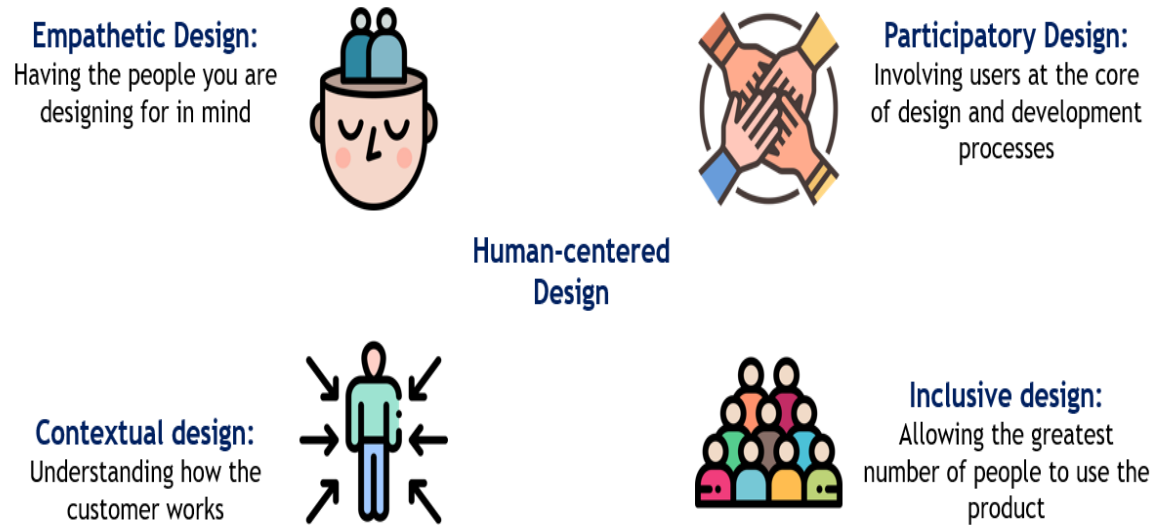

Figure 3: Human-centered design approaches

Industry 5.0 is considered a shift in perspective, where the same technology used in I4.0 is now designed and used to serve people and societies meeting the needs of industry workers. Industry workers are considered "investments" rather than "costs" (Lu et al, 2021). Lean construction encircles similar principles and core values. Besides maximizing value and minimizing waste in production, Lean Construction puts people first and safeguards their autonomy and privacy. The Last Planner System® (LPS®) (Ballard, 2000) serves the best example of the beforementioned statement. With the goal of reducing variability and uncertainty in construction operations, successful implementation of LPS in any organization cannot happen without the embracement of "lean" philosophy by all stakeholders involved (Hamzeh, 2011).

Liker (2004) emphasizes the importance of people and culture over technologies and methods in implementing any lean tool. Principle 8 in the Toyota way states that technology is to support people and not to replace them (Liker, 2004). This mindset brings to surface any hidden harm a technology can bring on both people and processes. It regulates current and future applications of any technology and preserves the human element. Therefore, it can be said that Lean Construction 4.0 is a masked expression of a newly announced industrial revolution 5.0 in the context of construction. They are similar means to the same end. The key is to believe in these values and transform them into actions.

Conclusion

The shift to digitalization promises a lot of benefits such as improvements in productivity, safety, quality, just to name a few. However, even if the benefits are actualized, the social impacts of Construction 4.0 technologies are overlooked in the pre-adoption and post-adoption phases of these technologies. Like fire, technology changed our lives, but a fire can cook your food or burn your home down. The light side of technology empowers practitioners and organizations, supports them, and helps them to thrive. However, unconscious consumption and disruption of such technologies may backfire and lead to permanent consequences that would degrade our industry further.

The paper aimed to explore the literature on that subject, compare and analyze different findings, and reflect on the endeavors made to adopt C4.0 technologies. The paper also addressed artificial intelligence as a specific case. The findings showed that the industry's approach to adopt C4.0 technologies overlooks the social factor and social impacts of their adoption The paper projects reflections made as statements and questions to provoke questions and thoughts on this topic. Moreover, the paper highlights the need for a human-centric approach, such as Lean Construction 4.0, to preserve the social aspect amidst this revolution. With respect to the research limitations, the authors acknowledge that the study only covers a part of the body of knowledge found in the literature. Moreover, the research tackled AI as a specific case and can be extended to cover a wider range of technologies. This paper calls for future research to investigate the social impacts of the latest technologies in the construction industry. Also, research should be done to assess and compare frameworks and methodologies used to adopt different C4.0 technologies.

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