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LEAN CONSTRUCTION 4.0 AND SOCIETY 5.0, HOW CLOSE ARE THEY?

Eric Forcael¹

ABSTRACT

The rapid advent of technological progress has triggered many industries to modify how they perform their tasks. The construction industry has not been immune to this reality. In this sense, Lean Construction 4.0 was recently born from the fusion of Lean principles and Construction 4.0. Similarly, concepts such as Industry 5.0 and Society 5.0 have also emerged in recent years, intending to put human beings at the center of companies' work. Thus, this article addresses how close Lean Construction 4.0 and Society 5.0 are. After analyzing both approaches, it is feasible to say that the relationship between both views is sensitively close, specifically under a human-centered approach and, therefore, it cannot be ignored as a process that also deals with the transformation of society through technology.

KEYWORDS

Lean Construction 4.0, Society 5.0, Human-centered approach, People-Process-Technology.

INTRODUCTION

According to Hamzeh *et al.* (2021) and González *et al.* (2023), Lean Construction 4.0 can be defined as the necessary combination of Lean principles and the implementation of technologies that make up Industry 4.0 in the construction industry, also known as Construction 4.0. In this sense, Lean Construction is inspired by the postulates originally proposed by Lauri Koskela (1992), aimed to meet customer needs better while using less of everything, based on production management principles, and resulting in a new project delivery system that can be applied to any construction but particularly suited for complex, uncertain, and quick projects (Aziz & Hafez, 2013; Howell, 1999). Similarly, based on Industry 4.0, the concept of Construction 4.0 was born, essentially made up of the digitization of the construction industry and industrialization of construction processes (Forcael *et al.*, 2020), and characterized by robotics, Internet of Things, digital twins, 4D printing, cloud augmented and virtual reality, blockchain, artificial intelligence, machine learning, and deep learning (Baduge *et al.*, 2022).

On the other hand, Society 5.0 is a model to spread to industry and the general public how governments envision a society in the future, based on a people-centric society founded on merging cyberspace and physical space (Deguchi *et al.*, 2020) to balance economic advancement with the solution of social problems (Huang *et al.*, 2022). In other words, Society 5.0 states a system of systems connected to mitigate both local and global major social problems (productivity, competitiveness, networking, and well-being), focused on humans to balance the growth of Big Data, Internet of Things, and Artificial Intelligence, and maximize human use of the current and future technological transformation and digitization (Narvaez Rojas *et al.*, 2021).

¹ Professor, College of Engineering, Architecture and Design, Universidad San Sebastián, Concepción, Chile, eric.forcael@uss.cl, orcid.org/0000-0002-3036-4329

Thus, on the one hand, a new perspective arises that connects Lean Construction with the technologies of Construction 4.0, while another perspective known as Society 5.0 seeks to put people at the center in the face of deploying those technologies typical of Industry 4.0. This paper tries to answer the question of how close both views are. Regarding the rules of exclusion or inclusion of dimensions for the critical and comparative analysis between Lean Construction 4.0 and Society 5.0, the main criterion was to consider some of the most cited bibliographical sources related to both topics, accordingly included in the present research.

LEAN CONSTRUCTION 4.0

LEAN CONSTRUCTION

According to Koskela *et al.* (2019), from an epistemological point of view, there can be two interpretations of Lean Construction: a Platonic one that considers a static body of knowledge applied to practical situations or an Aristotelian one that contemplates a dynamic body of knowledge that is born from discoveries that come from practical situations. As a consequence of this reflection, Lean Construction could be defined as a combination of a circumstantial production model arising from trying to solve specific issues in the construction industry by implementing generic lean production principles, tools, and methods from the automobile manufacturing industry (Koskela, 2020).

In this sense, authors such as Womack & Jones (2003) and Pessôa & Trabasso (2017) have established that the Lean principles correspond to specifying value, identifying the stream value, guaranteeing the flow, pulling the value, and seeking perfection. According to Aziz & Hafez (2013), lean thinking can be summarized into eleven principles: reduce the share of non-value-adding activities (waste); reduce variability; minimize the number of steps, parts, and linkages; increase process transparency; focus control on the complete process; balance flow improvement with conversion improvement, to mention a few (Koskela, 1992), while the Construction Industry Institute (Ballard *et al.*, 2007) considers fourteen principles organized in four categories (4P of the lean way): Philosophy, Process, People and Partners, and Problem-Solving, including decisions based on long-term philosophy even over short-term financial objectives, developing extraordinary work teams committed to the enterprise philosophy, going through a company that learns from deep and continuous cogitation and improvement.

On the other hand, from a lean perspective, Dave *et al.* (2008) state that people, process, and technology—essential aspects of Lean Construction—can be summarized as a) People: the core driving force behind the process and technology, where a poorly implemented information system may jeopardize to reach a higher efficiency; b) Process: a task-based approach where variability is inherent within the processes and wastes have to be eliminated or reduced; c) Technology: including information and communication technology (ICT) systems such as CAD, estimating, scheduling and productivity software, 3D modeling, and BIM, among other tools. Accordingly, the TFV theory establishes that Transformation (T), Flow (F), and Value (V) influence People, Processes, and Information Systems (Dave *et al.*, 2008; Koskela, 2000), including the problem-solving ambit from the 4P of the lean way (Ballard *et al.*, 2007).

Thus, the last 30 years have brought with them a series of advances in rethinking the construction industry based on technology, processes, and people interaction, integrating partnering practices, databases, new construction methods, new financial and cost models, and quality management practices, helping practitioners to think about construction as a manufacturing process (Tzortzopoulos *et al.*, 2020).

CONSTRUCTION 4.0

During this first quarter of the 21st Century, significant technological and scientific progress has been evidenced in terms of Industry 4.0, which mainly focuses on computer and cyber-

physical systems (Boyes *et al.*, 2018). On the other hand, the construction industry has also taken advantage of these advances, converging in what is known as Construction 4.0, a term first mentioned in 2016 by Roland Berger, which emphasizes that the digitization of the construction industry, encompassing digital data, automation, connectivity, and digital access (Roland Berger, 2016). Accordingly, Sawhney *et al.* (2020) establish that Construction 4.0 is a framework where industrial production and construction, cyber-physical systems, and digital technologies occur. Forcael *et al.* (2020) mention some technologies of Construction 4.0, such as BIM, drones, virtual and augmented reality, new materials, cloud-based project management, blockchain and cybersecurity, artificial intelligence, Big data, laser scanners, robotics and automation, wearable sensors, Internet of Things, actuators, additive manufacturing, offsite and on-site construction; technologies that may help define Construction 4.0 as the industrialization of the construction processes and digitalization of the construction industry.

Recent investigations also establish that Construction 4.0 has diverse variants focused on the broader ambit of the asset/product/property of the realm of construction and going beyond the general concepts of Industry 4.0, including but not limited to lean construction, digital building ecosystems, Internet of Things, and smart cities (Siriwardhana & Moehler, 2023). Similarly, according to Muñoz-La Rivera *et al.* (2021), Construction 4.0 can be categorized into (a) Automation (to integrate digital end-to-end engineering based on technologies to automate the physical manufacturing environment), (b) Simulations and Modelling (implements to design, build, and operate infrastructures and buildings through simulation and modeling), and (c) Digitalization and Virtualization (implements for products and industrial processes, digitally and virtually). In other words, Construction 4.0 is an extension of Industry 4.0 that focuses specifically on the construction industry, emphasizing automation, dematerialization of buildings (usually linked to “smart” homes), and the interdisciplinary nature of new construction (Forcael *et al.*, 2020).

LEAN CONSTRUCTION 4.0 FUNDAMENTALS

Essentially, the concept of Lean Construction 4.0 is a framework that integrates the principles of Lean Construction and the technologies associated with Industry 4.0 (Hatoum & Nassereddine, 2023). Accordingly, Hamzeh *et al.* (2021) suggest that Lean Construction has to seize the changes triggered by Industry 4.0 while keeping the people-processes-technology in the center, where a turnaround to Lean Construction 4.0 requires focusing on the combined benefits between digital/smart technologies and production management theory. On the other hand, based on the three crucial aspects of Lean Construction: people, process, and technology (Dave *et al.*, 2008; Koskela, 2000), there is an inherent connection between technology and Industry 4.0, or even more specifically, Construction 4.0. Nevertheless, given that Lean Construction 4.0 focuses on integrating ICT into the construction industry, it will not be easy to transform the current construction business model if all construction participants do not incorporate innovative technologies and techniques (Musa *et al.*, 2023).

Notwithstanding the relevance of the previously emphasized relationship between Lean principles and Construction 4.0, it is crucial to consider the power of people as the foundations needed to successfully attain the Lean Construction 4.0 vision of the Architecture, Engineering, and Construction (AEC) Industry (Hatoum & Nassereddine, 2023). In other words, since the resistance of a chain is given by the resistance of its weakest link, it is not possible to talk about process and technology leaving people behind, especially when one expects to have a robust chain made of people-process-technology.

In terms of applications, despite the incipient nature of the concept, some initiatives of Lean Construction 4.0 are already evidenced, such as the feasibility of implementing it in multi-family projects to improve the decision-making experience using digital twins of building works (Lara Ramirez *et al.*, 2022). Another example concerns evaluating the usability of a

cloud-based tool called LeanBuild after the design stage and assessing the exhaustiveness of the software design flow, showing that considering data privacy and security, modules for designing and tracking offsite construction, sustainability tools, and artificial intelligence enhance its use and bring more value to end-users (Musa *et al.*, 2023).

In summary, Lean Construction 4.0 can be graphically represented through Figure 1, adapted from González *et al.* (2023) and Forcael *et al.* (2020).

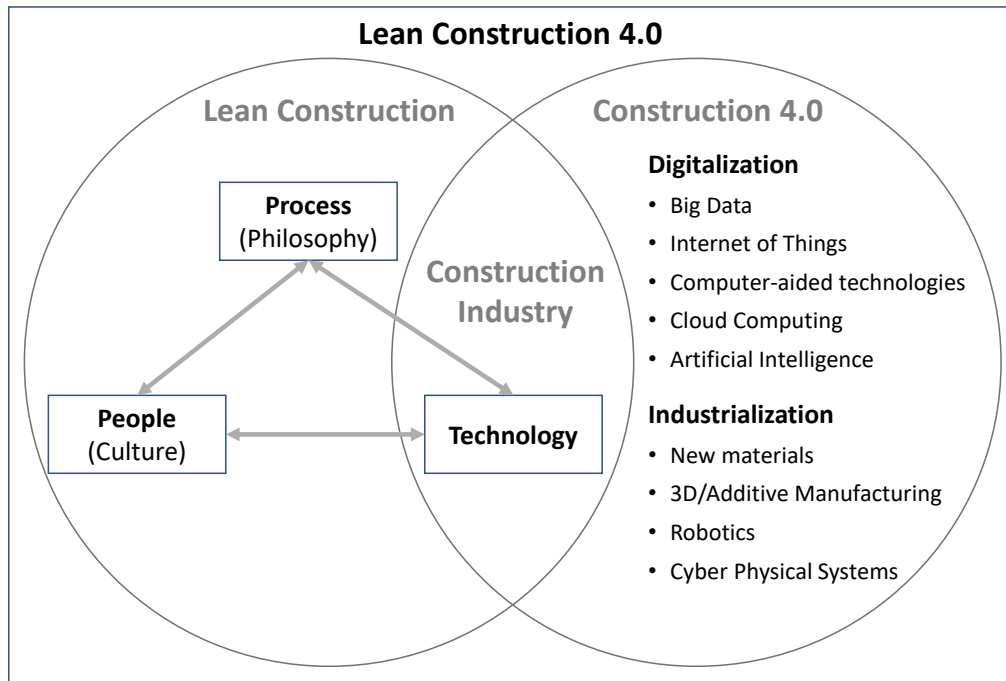


Figure 1: Lean Construction 4.0 (adapted from González *et al.* (2023) and Forcael *et al.* (2020))

SOCIETY 5.0

The term “Society 5.0” was proposed in January 2016 by the Japanese government as part of the 2016-2020 Fifth Basic Plan for Science and Technology, aimed at merging the physical space (real world) and cyberspace by fully leveraging ICT, based on a “super smart society” that brings wealth to the people (Council for Science Technology and Innovation Cabinet Office Government of Japan, 2015). From a chronological point of view, Society 1.0 corresponds to the hunter-gatherer human, Society 2.0 is related to the agrarian human, Society 3.0 is centered on an industrial human, Society 4.0 regards an information-based human, and finally, it is found to a superintelligent society known as Society 5.0 (Deguchi *et al.*, 2020).

According to Narvaez-Rojas *et al.* (2021), Society 5.0, as a Japanese concept for a “superintelligent society,” is focused on human beings at the core of transformations, economic growth, technological development, and sustainability, allowing for the development of sustainable technology without restricting prosperity. In other words, Society 5.0 consists of finding solutions for the current society’s obstacles based on a modern super-smart society, where people may benefit from a high-quality and enjoyable life by amalgamating cyberspace and physical space through fully utilizing ICT (Huang *et al.*, 2022).

Also, taking into account the relevance of placing the human being at the center of the work of every company, Industry 5.0 came up as a vision from a technological Industry 4.0 to an industry centered on people and the workers’ well-being but keeping up productive performance (Alves *et al.*, 2023). Comparatively speaking, Industry 5.0 was launched by the European Commission looking for a sustainable, human-centric, and resilient European

industry, while Japan suggested Society 5.0 to equilibrate economic progress and social issues solutions within the Japanese society (Huang *et al.*, 2022).

Thus, Society 5.0 should be sustainable and resilient against threats and unpredictable and uncertain conditions, ensuring people's safety, security, and well-being (Council for Science Technology and Innovation Cabinet Office Government of Japan, 2021). This vision toward a people-centric society, which looks to merge cyberspace with physical space, based on a knowledge-intensive and data-driven society, can be schematically summarized in Figure 2.

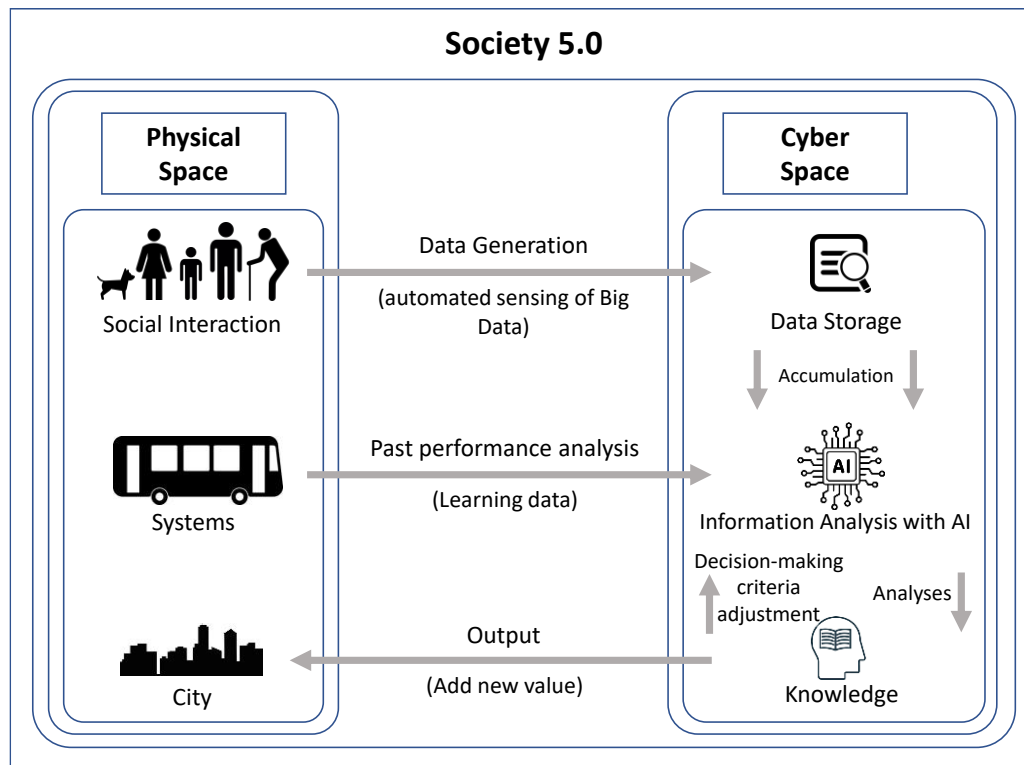


Figure 2: Society 5.0 (adapted from Deguchi *et al.* (2020))

RELATIONSHIP BETWEEN LEAN CONSTRUCTION 4.0 AND SOCIETY 5.0

Based on all of the above, it will be increasingly necessary to consider those aspects behind the technologies associated with Lean Construction 4.0 and Society 5.0, such as digital manufacturing, Internet of Things, cybersecurity, artificial intelligence, big data, cyber-physical systems, maker culture, among others, but also those topics related to professional ethics, environmental and social sustainability, decision-making under challenging situations, and the promotion of creative problem solving, thereby focusing on people. To achieve this, it would be good, for example, to look back to the model of the ancient engineers, who built fortifications and ports, channeled rivers, designed machines, and traveled to discover the world to successfully face and solve the increasingly demanding needs of a society that was becoming increasingly globalized (Cámara & Revuelta, 2016).

Tomorrow then involves implementing the technologies behind Lean Construction 4.0 but properly managing humanity's most precious resource, people; also worrying about their comprehensive training, including professionals not only from the AEC but also talent from diverse fields of knowledge: philosophers, sociologists, linguists, biologists, economists, jurists, scientists from various areas and even politicians. All of this, along with a more accentuated role of people, will provide the flexibility, plurality of approaches, and dynamism necessary to face the dizzying technological changes that the future holds for the construction industry.

In this way, it is interesting to consider how Lean Construction 4.0 principles and Society 5.0 are connected, as schematically shown in Figure 3 and discussed in the following section.

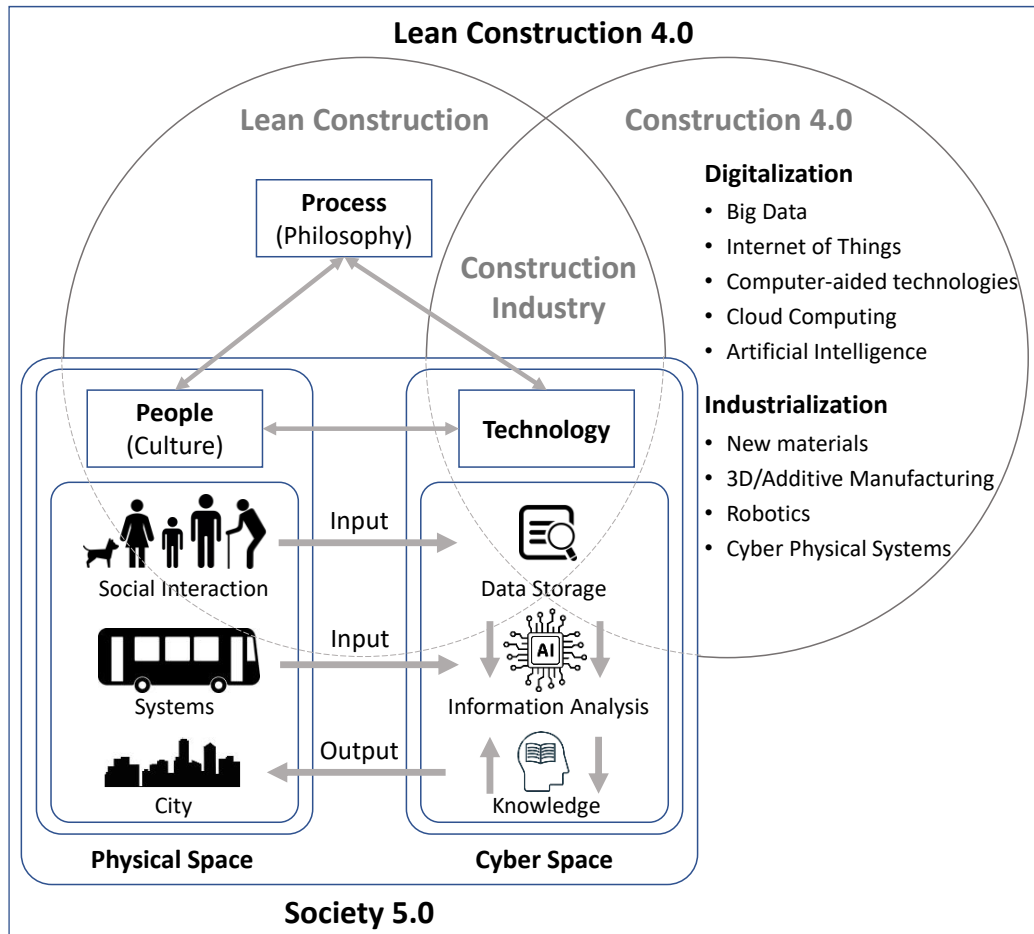


Figure 3: Lean Construction 4.0 and Society 5.0.

DISCUSSION

NEW CHALLENGES FOR A LEAN CONSTRUCTION 4.0 BASED ON SOCIETY' NEEDS

Due to the extensive scientific-technological growth, construction professionals could easily take on the legacy of the ancient engineers, characterized by their ability to face the most varied intellectual, productive, and even artistic challenges, always considering the technical aspects of their tasks but without leaving behind the human perspective in their performance (Cámara & Revuelta, 2016), capable of learning and reinventing themselves throughout life, with global projection and vocation, aware of the challenges of working with professionals from other countries and cultures, to deal with the challenges for sustainable growth of society.

These construction professionals, with solid technical and technological knowledge, are called to build a new humanism for the 21st Century (Bokova, 2014), given that they occupy positions of responsibility in all areas of the construction industry; therefore, with the ability to make decisions based on the Lean Construction 4.0 view but in total harmony with Society 5.0.

In this sense, this new approach of Lean Construction 4.0 must also be involved in the decision-making processes that affect society since the construction industry is linked primarily to technical or technological problems and overlooks its impact outside its immediate operational environment. In developing any construction project, considering environmental and social aspects is essential to the change and must be motivated by academia and industry.

It is for all these reasons that the path to the future requires a construction industry better prepared to continue developing and guiding the technological advances that are rewriting the present and that include the development of supermaterials, global communication networks, the widespread use of nanotechnology, and the exponential growth of artificial intelligence, among others. New Lean Construction 4.0 development schemes are necessary to combine the fundamentals of construction and new technological challenges, becoming more stable, specialized, and dynamic, thus aligning the performance of the construction industry with the needs of this new paradigm of Society 5.0.

The construction industry of the future must be able to learn along its way and adapt to today's rapid technological changes, continually preparing to reinvent its professional work, assuming the possibility that certain construction areas or constructive processes will disappear—the disuse of formworks with the advent of 3D concrete printing methods (Forcael *et al.*, 2021), or drones replacing people in the structural inspection of bridges (Jeong *et al.*, 2020)—, bringing the challenge of defining and linking to new business sectors.

PREPARING THE CONSTRUCTION INDUSTRY FOR THIS NEW PARADIGM THAT COMBINES LEAN CONSTRUCTION 4.0 AND SOCIETY 5.0

The ability to learn and adapt during the life of a company is a crucial competence for its survival, where conventional practices in the construction industry will require to be redesigned to adapt to the new changes brought by Industry 4.0 and boost growth successfully (Alaloul *et al.*, 2020). In this sense, taking into account that technological revolutions occur without pause and that these will affect the role of any company in society, learning to learn and adapt over time is increasingly necessary. This adaptative skill must be actively promoted within the construction industry through strategies that include increasing collaboration between academia and industry (Falcone *et al.*, 2019), establishing research and training collaborations between higher education institutions and local communities, developing continuing training programs for construction professionals, and creating mechanisms for the increment of significant learning in diverse contexts (cultural, social, technological).

Thus, the solution to different social challenges and the adaptation to the radical changes that are coming will require a more complex construction industry, which transcends traditional practices, including aspects such as the ability to implement and work in multidisciplinary and international teams, an interest in delving into cultural, social, political, and historical aspects, as a complement to purely scientific-technological ones, and a basis for mutual understanding between countries and cultures, and awareness of globalization as a fundamental key towards the new perspective of Lean Construction 4.0 and Society 5.0, which improves social cohesion and access to opportunities.

On the other hand, an adequate adaptation of the construction industry is necessary to solve the needs demanded by Lean Construction 4.0 in a dynamic and personalized way based on greater legislative dynamism and simplifying procedures and bureaucracies focused on data, moving towards human-centered systems. In this sense, it is also crucial that the construction industry assumes the role of accompanying its workers to turn them into the leaders of the future, with adequate training in aspects related to personal and professional growth, the management of technological, economic, and human resources, further promoting graduate training in construction. In other words, the industrial revolutions in which society is involved demand the attention of organizations to develop and train human resources for the future growth of the nations (Man, 2020). Lean Construction 4.0 and Society 5.0 cannot be absent in this challenge.

Finally, in terms of competitiveness in the era of Industry 4.0 and Society 5.0, it will be required to count on sensitive human resources who are fervent to find opportunities and dare to produce changes to stay in the game against competitors (Ellitan, 2020).

MERGING OF LEAN CONSTRUCTION 4.0 AND SOCIETY 5.0

As known, Industry 4.0 was defined more than ten years ago, mainly driven by a comprehensive set of interconnected innovative technologies (intelligent factories, artificial intelligence, rapid prototyping, additive manufacturing, big data, cloud computing, and robotics, among others), moving from the third to a cyber-systems-based industrial revolution (Kagermann *et al.*, 2011). Although the topics belonging to Industry 4.0 have been a matter of permanent interest, the number “5.0” has been more related to research and development of processes, products, and systems performed as “4.0 Technologies,” which have been moving towards Society 5.0 (Cabinet Office of the Government of Japan, 2024). Consequently, “Industry 5.0” has been born as the effect of implementing the technologies from Industry 4.0 and their diverse derivations into the “Society 5.0” approach (Gürdür Broo *et al.*, 2022; Habash, 2022).

Thus, “5.0” will be significant in the future construction industry since its fundamental mission is to generate and apply innovative knowledge in traditional construction. In this sense, if society moves towards Industry 4.0, the construction industry must advance even faster, not only thinking about current challenges but also implementing new technological advances that allow it to reach the productivity levels of other industries. Consequently, Lean Construction 4.0 and Society 5.0 should converge on systems and methodologies beyond conventional construction’s current and already obsolete models.

Ethical and Social Aspects Behind Lean Construction 4.0 and Society 5.0

As the construction industry is considered unethical, including but not limited to nepotism, interest conflicts, bribes, or contract awarding for political reasons (Owusu *et al.*, 2019), there is a challenge to meet the conduct codes and avoid corrupt practices within the construction industry (Amoah & Steyn, 2023). Therefore, based on the people-process-technology triad, it becomes essential to motivate the construction industry to be ethical when developing construction projects, going beyond the purely procedural or technological aspects (process-technology) and considering the harmful effects of unethical practices on the social fabric (people). In this sense, the construction industry must encourage reliable and committed behavior in its professionals to work under high ethical standards, understand the social responsibility of their actions, and incorporate an attitude of service towards people in each constructive project they carry out (Forcael *et al.*, 2013; Rupnow *et al.*, 2018).

In this sense, it becomes very relevant to understand the construction industry as a social activity that must reach the highest ethical standards. This principle implies that the construction industry must realize that it does not only work with equipment and machinery but also with people fundamentally. Therefore, it has to be prepared to face its work’s potential ethical and social impacts. Consequently, the merging of Lean Construction 4.0 and Society 5.0 will require each construction project throughout its entire life cycle to contemplate the study of the social effects and ethical challenges present in the industry. Fortunately, professional ethics and social responsibility have been systematically incorporated into the construction industry.

Despite the previous facts and the complex societal and technological challenges that are coming, this industry’s future is promising and full of opportunities, where the accomplishment of the highest ethical standards by the construction industry will be more effortless after materializing a mutually beneficial merging of Lean Construction 4.0 and Society 5.0.

A reframing view of Lean Construction 4.0 and Society 5.0

The rapid and constant transformations in the construction industry will demand less dogmatism, open-mindedness, dynamism, foresight, the ability to adapt to vertiginous changes, and the capability to face new scenarios with humbleness. This new perspective will give the modern construction industry—which will successfully implement technological advances in

its work—, a relevant role in reshaping society towards a less threatening future based on the quality of life through technology.

From this perspective, a Lean Construction 4.0 vision without strong moral and scientific postulates that put society at the center is doomed. The traditional ways of the construction industry will no longer be a rigid dogma; they must be adjusted to include the contemporary and ongoing technological revolutions from Industry 4.0, primarily related to the Construction 4.0 technologies, but without ignoring the human factor. However, disruptive technologies, such as artificial intelligence or humanoid robots, may bring uncertainty to people due to the recurrent fear that machines will replace humans sooner or later. Therefore, a Lean Construction 4.0 vision that strongly emphasizes the role of people by merging with the Society 5.0 approach will play a fundamental role in the modern construction industry.

Thus, the vision of a construction industry that strives to incorporate technology and innovation into its processes to bring comfort, well-being, and economic growth without harming the environment and respecting people is more significant than ever.

IMPLICATIONS FOR LEAN PRACTITIONERS

Below are some recommended practices for Lean practitioners that can help jointly implement Lean Construction 4.0 and Society 5.0, as a way to impact society through this integration:

It is unnecessary to look for intricate definitions of these two concepts. Lean Construction 4.0 combines Lean principles and technologies from Construction 4.0, while Society 5.0 is essentially a model to publicly spread how governments envision a future based on a human-centered view that balances new technologies and solutions to social problems.

After the discussion, there might be the feeling that using ICT is the end goal, but it is not. Although supporting effective practices via software raises the value of technological outputs rapidly, “waiting for Superman” is a recurrent problem of technology—the next iteration or version will be the response—. However, the reality is that today’s generation has more software than ever, and productivity remains at a standstill. The solution is not technology itself but people driving technology to improve society.

Construction professionals must strengthen their ability to face broader intellectual, constructive, technological, social, and cultural demands without leaving behind the people-centric view. They must be capable of learning and reinventing themselves throughout life, with a worldwide vision for working with people from other countries and cultures through making decisions based on the Lean Construction 4.0 principles and Society 5.0.

The construction industry must actively promote learning to learn and adapt faster than ever, including research and training collaborations with higher education institutions. This action will increase significant learning in diverse contexts (cultural, social, technological, political, and historical), facilitating access to opportunities and cultivating social cohesion.

Construction has to solve the needs demanded by Lean Construction 4.0 in a flexible way challenged by greater legislative vigor and streamlining procedures and bureaucracy, moving on the road to people-centric systems through leaders with appropriate training in aspects related to personal and professional growth, the management of financial, technological, and human resources, based on sensitive people who are fervent to dare to produce changes.

Finally, merging Lean Construction 4.0 and Society 5.0 will require each construction project’s development to contemplate studying the industry’s social effects and ethical challenges throughout its life cycle.

CONCLUSIONS

The present research was focused on the merging of Lean Construction and Society 5.0, based on the construction industry’s role in using new technologies to face increasingly complex

construction projects and their impact on people. In this context, the construction industry needs to be closely connected with people looking to impact society by using technology and information analyses that provide a quality life for all.

This new perspective requires highlighting the relevance of counting on an updated construction industry capable of gathering the best technological aspects from Construction 4.0, including how the incorporation and implementation of technology into constructive processes emphasize the privileged position of human beings and ethical principles as crucial elements of the modern construction industry. To put it differently, new ways of envisioning a construction sector that considers the best of technological advances and people's perspectives but takes into account multiple social contexts and interactions today.

Finally, the current Society 5.0 approach, based on social interaction with systems that generate valuable data to be analyzed by different means (e.g., AI), has to merge into a new technological vision that leverages the best of the Lean Construction 4.0 emphasizing the need for linking the physical and digital worlds and the relevance of human's role in technology utilization (González *et al.*, 2023). Thus, after analyzing both views, while Lean Construction 4.0 needs to develop its processes through technology and considering people, and Society 5.0 searches for the better use of technology to improve the human's physical world, it is feasible to say that the relationship between both paradigms is sensitively close, specifically under a human-centered approach and, therefore, it cannot be ignored as a process that also deals with the transformation of society through technology, a phenomenon that the human race has been facing from its origins but today more than ever.

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