Tech enablers to the EU Renovation Wave: Framework-based on the Communication (2020) 662

Diego Calvetti, diego.calvetti@prodyoup.com
CONSTRUCT/GEQUALTEC, Faculty of Engineering, Porto University, Portugal

Pedro Mêda, pmeda@fe.up.pt
Construction Institute, CONSTRUCT/GEQUALTEC, Faculty of Engineering, Porto University, Portugal

Hipólito de Sousa, hipolito@fe.up.pt
CONSTRUCT/GEQUALTEC, Faculty of Engineering, Porto University, Portugal

Abstract

The construction industry in Europe is being called to renovate 35 million building units until 2030. This must be done following several requirements and principles that constitute innovation imperatives. The construction value-chain is composed of many stakeholders that work together to deliver the goal; renovated building unit. Each one of them has a positioning in terms of innovation. Some are more ahead than others and their objectives differ depending on their role. Despite that, the interconnection between construction phases and inherent processes impacts or conditions issues outside their specific boundaries. The present research works renovation wave principles and technological trends merging all aspects on a conceptual framework to provide strategic guidance for stakeholders and evaluation tools facing specific construction processes. IDDS imperatives are used as metrics balancing people, processes and technology. This framework is focused on providing clarity regarding stakeholders positioning and strategic challenges to better accomplish construction industry challenges.

Keywords: Renovation Wave, People, Process, Technology

1 Introduction

European Union' (EU) Renovation Wave is an initiative to mobilise actions to renovate 35 million building units by 2030 (European Union 2020). The Construction Industry (CI) will be demanded on many levels/chains (e.g., construction products, design and construction, facility management). More than 85% of the existing buildings will still be standing in 2050 (European Union 2020). Low energy-efficiency buildings are an unsuitable reality. The requested processes to achieve that ambition plan are complex. Efforts should integrate innovation and the fundamental principles that support this EU initiative. The key strategic principles for building renovation concern to:

- Energy efficiency first;
- Affordability;
- Decarbonisation and integration of renewables;
- Life-cycle thinking and circularity;
- High health and environment standards;
- Tackling the twin challenges of the green and digital transitions together;
- Respect for aesthetics and architectural quality.

The Construction industry digitalisation era will influence new building projects as well as the renovation of the existing ones. The application of innovations into renovation projects is a challenge, as these types of projects have more heterogeneous work process and fragmented service providers. CI players' are achieving higher levels of operational efficiency due to the implementation of digital construction tools (McKinsey 2020).

Data exchange across all construction life-cycle phases will enforce traceability and provide a solid foundation to smart buildings. Buildings automation is increasing as the IoT (Internet of Things) is more affordable and also because consumers are demanding greater energy efficiency and connectivity (McKinsey 2020). Sustainability knowledge should be shared with building owners through a multi-platform. Feedback over users' experience (UX) can root lessons learned to allow a continuous improvement process.

People, Process and Technology (PPT) are innovation vectors that must be strategically considered. Routing the ideal balance between these three elements is vital to innovative projects' feasibility. CIB Integrated Design and Delivery Solutions (IDDS) priority research theme overlaps these three imperatives centring IDDS in: Collaborating People, Integrated Process, and Interoperable Technologies (CIB-Publication-370 2013).

This paper aims to provide a conceptual framework for integrating the cited technologies/methodologies and the EU Renovation Wave key principles, pursuing this initiative' outcomes. As well, by identifying stakeholders PPT awareness, this works allows an innovation path visualisation. Experts' focus group and stakeholder's survey will allow the framework conceptualisation and knowledge awareness identification. The discussions and conclusions highlight the technologies/methodologies maturity level assessment, providing a real visualisation of the possible flow that connects the Renovation Wave fundamental actions with the respective innovation opportunities.

2 Method

A conceptual paper is set to deliver awareness regarding the challenge of the EU Renovation Wave initiative and the trends technologies/methodologies connected that will increase the CI capacity of achievement. The main technologies and methodologies identified in the EU document for Renovation Wave (European Union 2020), where:

- BIM - Building Information Modelling;
- DDT/DBL - Digital Data Templates and Digital Building Logbooks;
- GIS - Geographic Information System;
- IoT - Internet of Things;
- AI - Artificial Intelligence;
- Blockchain;
- Digital Twins;
- AR/VR/MR - Augmented/Virtual/Mixed -Realities;
- APPs - Applications (UX).

The paper method consists in first to assess, via a survey Delphi-based, the technologies awareness related to the EU Renovation Wave. To achieve an organized and compiled data the identified technologies were transposed to a survey. The purposive sampling of respondents was composed of (15) fifteen active researchers in the field of civil engineering with knowledge of both technologies and management of renovation projects. Although the sample of researchers may bring a bias to the results, it is most useful to the purposes of the research, because such a perception of solutions can be better acquired than over the general public. Mainly in the dimension of the buildings' rehabilitation projects.

In the survey, the respondents select for each technology, above listed, at "People", "Process" and "Technology" dimensions the maturity in accordance with a four-scale option [1- Emerging; 2-Sedimented; 3-Generalized; 4-Consolidated] (Mêda Magalhães et al 2020). This provides the maturity levels for each technology in each dimension. Also, three other questions were presented to evaluate CI digitalisation maturity:

- "Give us your opinion regarding the level of readiness of different construction sector agents [Construction Products Manufacturers; Construction Products Traders; Design

Companies (Architecture); Design Companies (Engineering); Contractors; Construction Surveyors; Public Owners; Private Owners; Real Estate; Facility Management], in relation to Digitisation processes [1- Emerging; 2-Sedimented; 3-Generalized; 4-Consolidated].";

- "Highlight a factor that acts as ENABLER to the Construction Industry digitalisation:";
- "Highlight a factor that acts as a BARRIER to the Construction Industry digitalisation:".

Authors' formed the focus group to discuss the results and to develop the framework. After the conceptual framework first draft some researchers that responded the survey were invited to participate in a discussion concerning those technologies (content in the survey) and the actions and outcomes connected to the key principles for building renovation (European Union 2020), concerning:

- Energy-efficiency;
- Smart buildings;
- SRI (EPBD);
- Life-cycle and circularity;
- Teleworking suitable (pandemic COVID-19);
- Data information (logbooks, passports, levels);
- Smart finance (funding, mortgage, credit);
- Smart public procurement;
- Green supply chain;
- Green Jobs (technical assistance);
- Craftsmanship green skills, plus safety/health;
- Local sources;
- End-users awareness and engagement;
- Neighbourhood-based transformation;
- Buildings high health and environment standards;
- New European Bauhaus.

After a focus group meeting, with the researches contribution, a final framework connecting the technologies/methodologies and the "Renovation Wave" actions/outcomes was conceptualized. Finally, addressing the IDDS analysis approach, that framework was discussed (by a final Authors' focus group meeting) highlighting the: Drivers for change, Enablers, Barriers and, Opportunities of each Technology and the connected group of actions/outcomes (CIB-Publication-370 2013). Figure 1 illustrate the method detailed above.

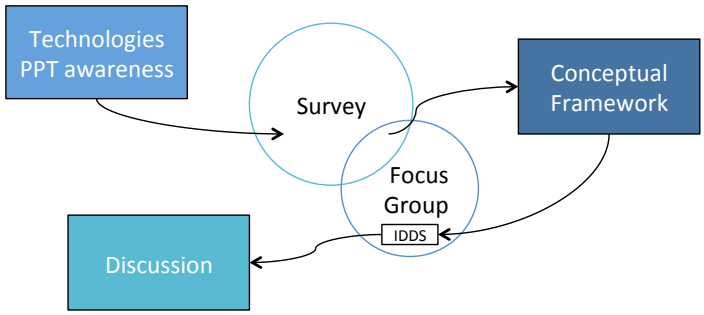

Figure 1. Research method.

3 Results and Discussions

3.1 Technologies/methodologies awareness and CI digitalisation

To successfully implement an innovation, it is necessary to find an appropriate balance between the PPT imperatives. Although some technologies are already widely known and accessible, it is necessary that people are able to use them, and even more relevant is the need for this innovation

to be incorporated into the companies/businesses processes. Figure 2 shows the results of the highlighted technologies in the three-abovementioned dimensions (PPT). It is seen in the graphical representation that the closer the lines get to the centre of the figure, the greater is the maturity. The results are indicative in that, the great part of technologies/methodologies lacks research and development for application in CI. However, the results presented guide the future development and application of these technologies/methodologies in the CI market.

It can be observed that the maturity of the technologies/methodologies is mainly related to two factors, the time (degree of penetration) of application and the level of complexity of the

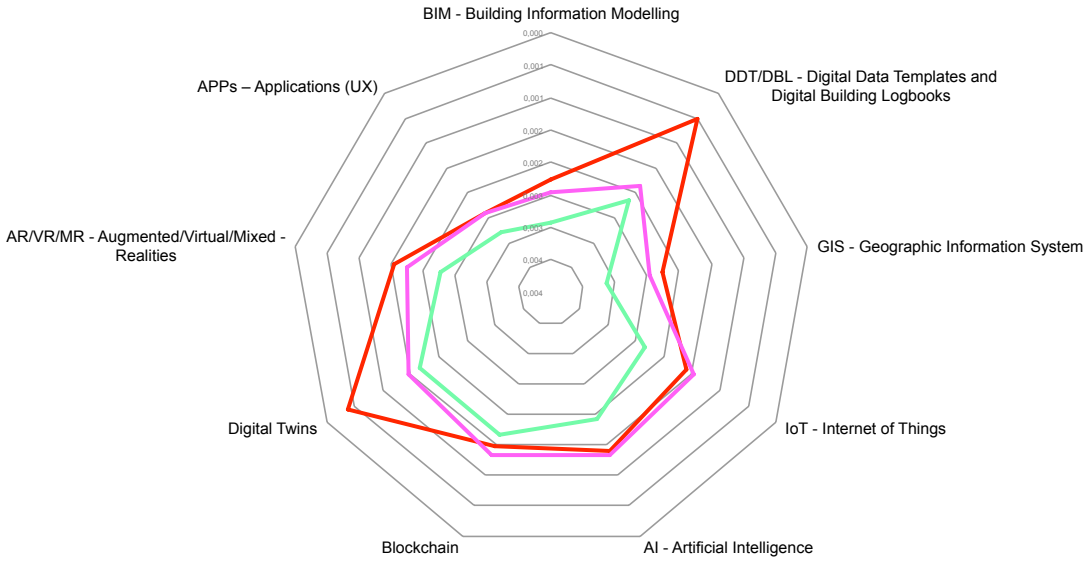

Figure 2. Technologies/methodologies into maturity PPT dimensions.

same. In this context, GIS, BIM and APPs stand out. On the other hand, latest solutions as Blockchain, DDT/DBL and Digital Twin, have reached a lower maturity. Still, on average, there are AR/VR/MR, IoT, AI, which are solutions with extensive knowledge and wide application, where a greater maturity of the technological dimension stands out. In Figure 3, each technologies/methodologies is presented following a maturity sequence (the larger the central image, the greater is the maturity). In addition and following the same order, each one of them is highlighted and analysed as follows:

- **GIS - Geographic Information System.** The application of GIS methodologies, both for geolocation and for analysis of information in databases, is already consolidated in technological terms. As well, it evidences an interesting development in terms of processes and people. In addition, GIS integrates with other methodologies/systems and provides wide use and high knowledge. CI application example: GIS and BIM as integrated digital environments for modelling and monitoring of historic buildings (Tsilimantou et al 2020).
- **BIM - Building Information Modelling.** The use of BIM has been encouraged and widely sponsored within CI at several levels. Notwithstanding, there is some noise around the understandings and the real potential application of such a methodology (Hjelseth 2017). Frequently, 3D modelling stands out due to the imperious relevance of the information that permeates it. In the construction sector, there is an established knowledge of BIM, both in terms of technology, processes and people. CI application example: BIM for FM, Developing information requirements to support facilities management systems (Matarneh et al 2019).
- **APPs - Applications (UX).** Both web applications and smartphones are widely used by people on a daily basis. Within CI, professionals already perform many of their work routines through computer systems. Every day platforms are developed to integrate all

stakeholders in engineering projects, from professionals to end-users. CI application example: A big data-based workers behaviour observation in China metro construction (Guo et al 2015).

- **AR/VR/MR - Augmented/Virtual/Mixed -Realities.** The growing development of technologies supporting the visualization of modified realities fostered its dissemination and use outside the world of games. Such ways of presenting the virtual world enhance, from an anticipated view, the customer's final product, as well as the use of mixed reality on-site (e.g., equipment location). CI application example: Augmented reality system for facility management using image-based indoor localization (Baek et al 2019).
- **IoT - Internet of Things.** In terms of technological evolution, the devices and networks that will support the implementation of the IoT are already well known. Nevertheless, people's awareness and the integration of processes still lack practical experimentation. As a result, there is a great deal to evolve towards a broad application in CI, mainly on-site. CI application example: An IoT-based autonomous system for workers' safety in construction sites with real-time alarming, monitoring, and positioning strategies (Kanan et al 2018).
- **AI - Artificial Intelligence.** Artificial Intelligence applied to data processing permeates all technologies/methodologies. Although there is a perception of its use and its need to speed up the processing of large amounts of data, the high complexity of the methods inhibits an understanding of their application. A vision with a focus on process outputs/deliveries can enhance people's awareness. CI application example: Building Information Modelling, Artificial Intelligence and Construction Tech (Sacks et al 2020).
- **Blockchain.** People already have knowledge of blockchain due to crypto-currencies. The applications in CI go further, as examples, the smart contracts and the validation of information between different stakeholders. An agile financing process for rehabilitation works can facilitate access to resources and speed up business. Transparency and security for the use of technology is essential to guarantee processes and people's confidence. CI application example: Exploring applicability, interoperability and integrability of Blockchain-based digital twins for asset life cycle management (Götz et al 2020).
- **DDT/DBL - Digital Data Templates and Digital Building Logbooks.** Digital Data Templates are standardised and interoperable metadata structures that support construction products information related data (ISO-23387 2020). A Digital Building Logbook is a dynamic tool/platform that organises under specific categories a variety of data, information and documents concerning all projects life-cycle (European Union 2021). Both DDT and DBL are very recent concepts and have been few explored even in academia. Due to this their awareness in all dimensions is still limited. It is evident the perception of very little knowledge of these concepts in the dimension of people. CI application example: Data Templates—Product Information Management Across Project Life-Cycle (Mêda et al 2020).
- **Digital Twins**. Although Digital Twins is the pertussis concept at CI (the new trend), there are still no practical applications. This indicates that being a concept that is still abstract, it is very little perceived in the dimension of people. At the same time, it is necessary to increase awareness of the dimensions of processes and technology. CI application example: Construction with digital twin information systems (Sacks et al 2020).

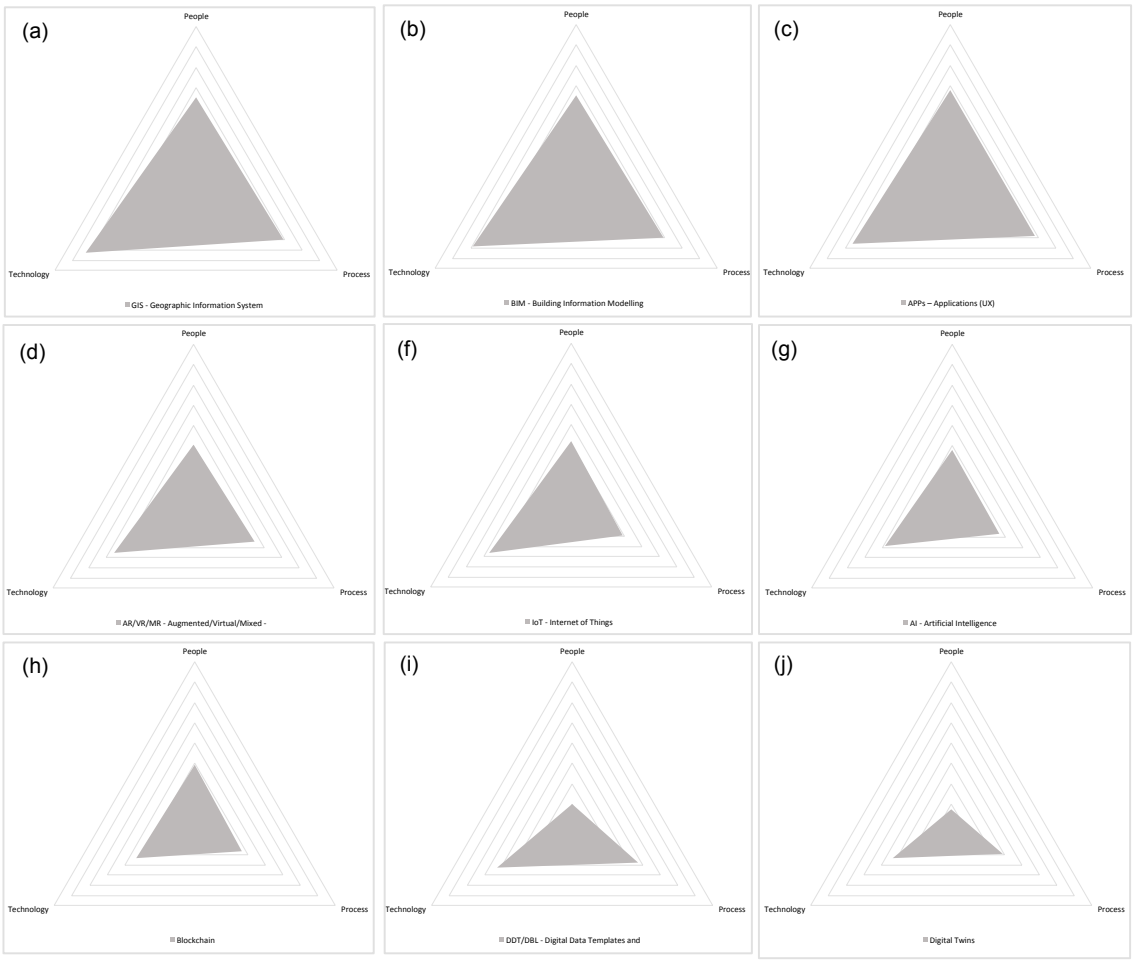

Figure 3. Individualized results for technologies/methodologies following the sequence of the achieved maturity

Respondents indicated, following their knowledge, the level that they view each entity in the CI production chain. In this view, design companies with a higher perceived digitisation level stand out. Bearing in mind that currently the projects are developed using digital systems, this idea seems to be correct. It can also be identified that, in the view of the respondents, the digitisation of the CI moves from the design offices to the factory environments, with the real estate market and private works owners in the middle. Finally, it moves to the on-site and the lowest level of digitisation is found on the public agents.

a. Design Companies (Architecture);
b. Design Companies (Engineering);
c. Construction Products Manufacturers;
d. Facility Management;
e. Real Estate;
f. Private Owners;
g. Contractors;
h. Construction Surveyors;
i. Construction Products Traders;
j. Public Owners.

3.2 Conceptual Framework

The conceptualised framework was designed to allow an integrated visualization between the different core actions of the Renovation Wave and the technologies/methodologies that will enhance the development of these actions. The framework does not provide exhaustive interconnection between all elements (action-tech; action-action; tech-tech). As previously

exemplified and as an example, AI would be connected to all other technologies/methodologies. This view seeks to highlight that a weak maturity in a technologies/methodologies can put in question the full execution of an action/outcome.

Figure 4 integrated the PPT maturity into the technologies/methodologies connected to the most related actions/outcomes and combines the interconnected actions/outcomes. Cluster 1 is highlighted in orange and Cluster 2 in blue, being painted in green the touching points between them.

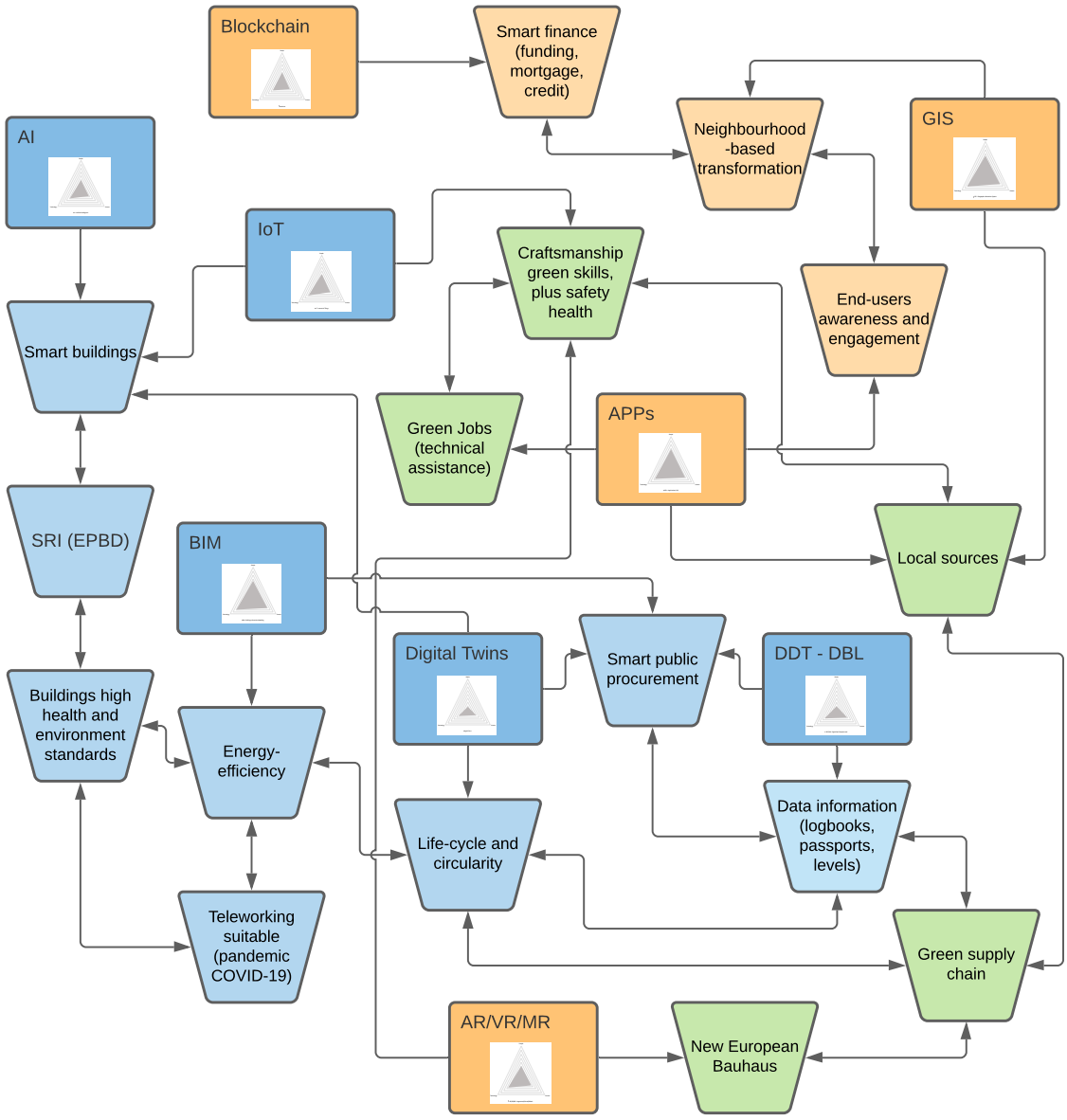

Figure 4. Tech enablers to the EU Renovation Wave: Conceptual framework.

From this highlights that there are two clusters of technologies/methodologies and actions/outcomes most interconnected. These are:

- Cluster 1 [Blockchain + GIS + APPs + AR/VR/MR] connected to [Smart finance (funding, mortgage, credit); Neighbourhood-based transformation; End-users awareness and engagement; Local sources; Green supply chain; New European Bauhaus; Green Jobs (technical assistance); Craftsmanship green skills, plus safety/health]. This cluster evidences a particular feature; the focus on local resources (from people, to products, and even into a finance dimension). Therefore, georeferencing and user interface applications

are the main technologies/methodologies. Also, the flow of financing opportunities for local actions is evidenced, which take advance on human resources with skills to use local products within an aesthetic concept of reference, which, however, perceives the characteristics of the neighbourhood.

- Cluster 2 [DDT/DBL + BIM + DT + IoT + AI] connected to [Data information (logbooks, passports, Level(s)); Green supply chain; New European Bauhaus; Local sources; Craftsmanship green skills, plus safety/health; Smart public procurement; Life-cycle and circularity; Energy-efficiency; Buildings high health and environment standards; Teleworking suitable (pandemic COVID-19); SRI (EPBD); Smart buildings]. Within this cluster, the buildings are more evident. The entire supply chain focuses on energy efficiency and circular construction. The intelligent buildings are sensored and allow the monitoring of environmental comfort conditions and lead to the development of digital twins. Data traceability through DDT/DBL adoption and implementation have impacts on the entire construction value chain due to the systematization that it introduces in the information management process (BIM).

Finally, Table 1 highlights the Drivers for change, Enablers, Barriers and, Opportunities (CIB-Publication-370 2013) of each Technology and the connected group of actions/outcomes.

Table 1. Tech enablers to the EU Renovation Wave: challenges evaluation.

Technologies	Actions Outcomes	Drivers for change	Enablers	Barriers	Opportunities
Blockchain	- Smart finance (funding, mortgage, credit) - Neighbourhood-based transformation - End-users awareness and engagement	- Governmental funding - Technology higher maturity - UX friendly - Regulation requirements	- Platform to connect Institutions and People - Agreements	- Specialised resources demanded - Trust - Technology assess for People	- Open platforms sponsored by Government - Streamlined bureaucracy - Processes follow-up
GIS	- Local sources - Neighbourhood-based transformation - Green supply chain - New European Bauhaus	- Local sources availability/ database to connect projects and stakeholders	- Web and APPs interoperable platforms -Standards	- Personal identification (GDPR -General Data Protection Regulation)	- Provide local sources fitted to an EU aesthetic concept of reference
APPs	- End-users awareness and engagement - Green Jobs (technical assistance) - Local sources	- Governmental funding - Developing a value chain to attract investors	- Interope-rable tools -User interfaces	- Personal identification (GDPR)	- Engage people - Share costs
AR/VR/MR	- New European Bauhaus - Craftsmanship green skills, plus safety health	- UX friendly - Smartphones to incorporate functions	- Visual systems to simulate the real situations	- Specialised resources demanded - Technology assess for People	- Open platforms sponsored by Government
DDT/DBL	- Data information (logbooks, passports, levels) - Smart public procurement - Green supply chain - Life-cycle and circularity	- Governmental funding and standardisation - Technology higher maturity - Regulations	- Interope-rable tools	- Personal identification (GDPR) - Data ownership - Lack of awareness	- Data-driven construction -Circular construction process

(Continued)

Table 1. Continued

BIM	- Energy- efficiency - Buildings high health and environment standards - Teleworking suitable (pandemic COVID-19)	- Innovation imperatives - Competitive-ness	- Contract agreements - Guidelines - Interope-rable tools	- Misunderstan-ding of the concepts real dimension - Resistance to innovation	- High-performance buildings - Suit for purpose constructions - FM on time
Digital Twins	- Smart buildings - SRI (EPBD) - Buildings high health and environment standards - Life-cycle and circularity - Smart public procurement	- Owner's requirements - Competitive-ness - Market opportunities for difference	- Interope-rable tools - Life-cycle vision	- Specialized resources - Data ownership	- Improved industry - Prescriptive maintenance
IoT	- Craftsmanship green skills, plus safety health - Smart buildings - SRI (EPBD)	- Market opportunities for difference - Owner's requirements	- Agreements - Training	- Personal identification (GDPR) - Data ownership - Awareness	- Engage people - Processes follow-up - Productivity - Health and safety
AI	- Smart buildings - Support to all Technologies/ Actions	- Market opportunities for difference - Innovation imperatives	- Decision support tools - Biases proof	- Personal identification (GDPR) - Agreements setup - Awareness	- Improved outcomes - New processes and metrics

Finally, the findings suggest that it is necessary to increase the maturity of technologies/methodologies in the PPT dimensions. The different results should point to specific actions to overcome the gaps. The integration of technologies and the digitalisation of the CI are key elements to achieve the Renovation Wave objectives and goals. It is key to understand that there is not a single technology with the capacity to support all actions/outcomes. There is a lack of understanding that inhibits the integration of actions and this impacts on the achievement and delivery of the outcomes.

4 Conclusions

Construction works under the renovation wave strategy must attend several requirements defined not only in this document but also in other that are setting the industry trends. Many of the aimed outcomes are influenced by technological changes and new analysis and validations across the construction process value-chain.

All these have impacts on the processes and mostly on the stakeholder's relations. The presented framework aims to support stakeholders within these processes to best define their strategies and to evaluate their positioning in relation to the different technologies and strategic principles applied to specific construction processes.

One of the future research headings is to validate the framework and to develop practical evaluations in real-case situations. Likewise, these will also be used to calibrate the IDDS dimensions and confirm the Drivers for Change, Enablers, Barriers and Opportunities for each one of the technologies presented in Table 1.

Construction is being confronted with a lot of trends and in addition to the challenge of fulfilling their specific goals, there is the need to identify the overlaps, the gaps and define strategic roadmaps based on each entity positioning and priorities. This must be done at the same time the industry is responding to market needs. The margin for error is limited and therefore all strategies and tools to support innovation decisions must be used. A construction process is composed by a multiplicity of processes and people that belong to different stakeholders.

Technologies are key to support their actions and to achieve improved outcomes. Yet, for this to happen those two dimensions must be suited and aware of the different implications, challenges and benefits.

Acknowledgements

This work was financially supported by: Base Funding UIDB/04708/2020 of the CONSTRUCT Instituto de I&D em Estruturas e Construções - funded by national funds through the FCT/MCTES (PIDDAC).

References

Baek, F., Ha, I. & Kim, H. (2019). Augmented reality system for facility management using image-based indoor localization. *Automation in Construction*. 99(August 2018). pp. 18–26. doi: 10.1016/j.autcon.2018.11.034.

CIB-Publication-370 (2013). CIB Priority Theme: IDDS - Integrated Design and Delivery Solutions.

European Union (2020). A Renovation Wave for Europe - greening our buildings, creating jobs, improving lives, pp. 1–26.

European Union (2021). Study on the Development of a European Union Framework for Digital Building Logbook - Final Report.

Götz, C. S., Karlsson, P. & Yitmen, I. (2020). Exploring applicability, interoperability and integrability of Blockchain-based digital twins for asset life cycle management. *Smart and Sustainable Built Environment*. doi: 10.1108/SASBE-08-2020-0115.

Guo, S., Luo, H. & Yong, L. (2015). A Big Data-based Workers Behavior Observation in China Metro Construction. *Procedia Engineering*. 123. pp. 190–197. doi: 10.1016/j.proeng.2015.10.077.

Hjelseth, E. (2017). BIM understanding and activities. *WIT Transactions on The Built Environment*. 169, pp. 3–14.

ISO-23387 (2020). Building information modelling (BIM) — Data templates for construction objects used in the life cycle of built assets — Concepts and principles. p. 17.

Kanan, R., Elhassan, O. & Bensalem, R. (2018). An IoT-based autonomous system for workers' safety in construction sites with real-time alarming, monitoring, and positioning strategies. *Automation in Construction*. 88(November 2016). pp. 73–86. doi: 10.1016/j.autcon.2017.12.033.

Matarneh, S. T., Danso-Amoako, M., Al-Bizri, S., Gaterell, M. & Matarneh, R. T. (2019). BIM for FM: Developing information requirements to support facilities management systems. *Facilities*. 38(5–6). pp. 378–394. doi: 10.1108/F-07-2018-0084.

McKinsey (2020). Construction and Building Technology – poised for a breakthrough?

Mêda Magalhães, P. N., de Sousa, H. J. C., Gonçalves, M. C., Calvetti, D., Camargo, F. & Dias, P. (2020). People, Process, Technology in Construction 4.0 - Balancing knowledge, distrust and motivations. *In Toledo Santos, Eduardo; Scheer, S. (ed.) 18th International Conference on Computing in Civil and Building Engineering / 37th International CIB W78 Conference.* São Paulo: CIB W78. pp. 218–231. doi: http://dx.doi.org/10.46421/2706-6568.37.2020.paper016.

Mêda, P., Sousa, H. & Hjelseth, E. (2020). Data Templates—Product Information Management Across Project Life-Cycle. *In Sustainable Materials in Building Construction, Building Pathology and Rehabilitation 11*. Springer International Publishing. pp. 117–133. doi: 10.1007/978-3-030-46800-2_5.

Sacks, R., Brilakis, I., Pikas, E., Xie, H. S. & Girolami, M. (2020). Construction with digital twin information systems. *Data-Centric Engineering*. 1. doi: 10.1017/dce.2020.16.

Sacks, R., Girolami, M. & Brilakis, I. (2020). Building Information Modelling, Artificial Intelligence and Construction Tech. *Developments in the Built Environment*. p. 100011. doi: 10.1016/j.dibe.2020.100011.

Tsilimantou, E., Delegou, E. T., Nikitakos, I. A., Ioannidis, C. & Moropoulou, A. (2020) GIS and BIM as integrated digital environments for modeling and monitoring of historic buildings. *Applied Sciences (Switzerland)*. 10(3). doi: 10.3390/app10031078.