2021 European Conference on Computing in Construction
Online eConference
July 26-28, 2021

HUMAN DATA INTERACTION IN SENSORED SITES, CHALLENGES OF THE CRAFT WORKFORCE DIMENSION

Diego Calvetti[1], Pedro Mêda[2], Hipólito Sousa[1], Miguel Chichorro Gonçalves[1]
[1] CONSTRUCT/GEQUALTEC, Faculty of Engineering, Porto University, Portugal
[2] CONSTRUCT/GEQUALTEC, Construction Institute, Faculty of Engineering, Porto University

ABSTRACT

Construction Industry (CI) is moving towards digitalisation. Yet, craft workforce is still the primary vector of on-site performance, accounting more than 50% of sector's employment. Construction sites sensing should concentrate on workforce' performance monitoring. An in-depth understanding of the data process and the stakeholders' interaction is more important than ever. A Human Data Interaction (HDI) vision implies the evaluation of the collected data implications in the CI, glimpsing paradigms and regulations. This work presents new use cases and frameworks to reflect data interactions into sensored sites regarding the craft workforce performance and delivering a detailed analysis to GDPR' compliance.

INTRODUCTION

EC3 established the Human Data Interaction (HDI) Committee in July 2019. HDI approach is a game-changer. The status quo HCI (Human-Computer Interaction) concerns humans and computers interactions, emphasising software and hardware systems (HDI Committee, 2020). HDI foster's and leads to the interaction of humans and data. The HDI Committee mission is to oversee the use of technologies and understand users' behaviours. Facilitate the development of infrastructure and providing a solid foundation for construction industry innovation revolution. Nowadays, construction sites are being populated by new technologies. Due to this, data can be more available and should be used to drive construction management.

Sensored construction sites materialization relies in many different types of sensors (e.g., Vision, Imaging, Noise, Temperature, Proximity, Pressure, Position, Photoelectric, Motion, Humidity, Force, Contact and Non-Contact Sensors). A specific hardware device/equipment can have embedded more than one sensing technology (e.g., smartphone, drone, inertial measure unit). The data can flow between devices, for example, through Wi-Fi, Bluetooth and, Ethernet. Different systems are needed to store and process data, such as, operating systems and databases. Throughout the process of implementing the devices, their use, data collecting and processing, various actors/knowledge will be required.

The CI is a labour intensive sector. Focusing on the construction sites dimension, the craft workforce is the main vector of the tasks outcomes, having direct influence on the projects' performance. In this context, craft workers are found to be the most valuable assets to apply electronic performance monitoring (EPM).

The General Data Protection Regulation (GDPR) compliance is a primary concern in the employees/employers data exchange relationship. Yet, GDPR is a new regulation and concerning electronic monitoring of workers, there are no case law records nor established agreements what, in practice, generates a gap. There is still a lack of detailed diagnosis of what data should be collected about the craft workforce and mainly the one related with performance. Nor is there a clear vision of the data flow that ranges from the on-site collection to the companies' management systems. As worksite-sensing monitoring is a new and complex scenario, it is necessary to broaden stakeholders' awareness, in order to allow the test and implementation of these kind of projects.

RESEARCH AIM AND METHOD

The research aims to deliver detailed HDI models focusing on craft workforce data (on-site EPM) and the employers' management systems (GDPR compliant). HDI Use Case Diagram provides an exhaustive visualisation of employees/employers information interaction and relationship. HDI Information process provides a systemic view of the data flows through the systems necessary to deliver useful information.

Qualitative research is inductive, heterogeneous (Maxwell, 2004) and interpretative (Denzin and Lincoln, 1994). Semi-structured interviews are a form of qualitative research used to gather subjective data to form analysis and further understanding (Kimmance, 2002). In this paper's scheme, the interviews were used to conceptualise the HDI approach and identify the main challenges using the interviewee's intuition and experience. Focus groups provide stakeholders with' interactive discussions.

An iterative process was carried out to improve and validate the models and concepts presented, according to the following steps (i) author's group meeting discussion was managed for HDI models and concepts development, (ii) experts' semi-structured interviews were conducted based on the conceptualised models presentation, (iii) a

second group meeting discussion was performed to consolidate the experts' answers and establish the final models.

The respondents had experience and practical knowledge in law/academic research in the CI, construction management and information technology. Table 1 shows the participants involved in the study. The interviewed were from 3 different countries (Portugal, Italy and Brazil).

Table 1: Experts interviewed

Participant number	Participant Role	Country
#1	CI Legal/Academic (Researcher)	i
#2	CI Business (Senior Executive)	ii
#3	Information Technology (Senior Professor)	iii
#4	CI Business (Executive)	iii
#5	CI Business (Project Manager)	ii
#6	Information Technology (Project Manager)	ii
#7	CI Legal/Academic (Senior Consultant)	ii

The approach in the semi-structured interviews was centered on the proposed models. The interviews introduction addressed the explanation of the purpose of the diagram and the data process, asking open questions about their perceptions regarding the possibility of Sensored Construction Sites and HDI. These questions surrounded the following: (i) Benefits and challenges of Sensored Construction Sites, (ii) Ways the data could be used to improve productivity, safety, quality etc., (iii) Ways the data can be utilised in contractual agreements supported by blockchain, (iv) The way the use of technology can be applied, (v) Employee reaction to sensored construction sites, (vi) Impact and challenges to the employer, (vii) Views of Sensors and Artificial Intelligence (AI) in the construction industry, (viii) Effect of GDPR on the use of Sensors and AI-based decision-making, (ix) Current legislation on the use of Sensors and AI, (x) Way ethical and moral challenges can be minimised, (xi) The possible influence of algorithm bias on the framework.

DISCUSSION AND RESULT ANALYSIS

The semi-structured interviews range several topics within the central theme over the conceptualised HDI use case diagram and information process. Depending on the interviewees' role and background, specific discussions on "topics of expertise" were raised, leading to the following presented contributions.

HDI Use Case Diagram

It was a consensus in the group meeting discussion and confirmed by the experts' that the HDI Use Case Diagram developed should not be totally attached to the IT terminology UML (Unified Modelling Language). The conceptual diagram aims to achieve a broad public of readers' by being user-friendly and from a visual perspective delivering all the HDI piece of information reviewed. Figure 1 presents a full view of HDI into the craft workforce dimension on sensored construction sites. As a behavioural diagram, the concept presented the data interaction between the actors' craft workers and employers (visually represented by the dolls). The ellipses representations are the use case that brings different pieces of information as actors' actions, systems, conditions, features, processes, and devices, among others. Lines that connected the actor to the use cases represent communication links. The verb inside the stereotype "<< … >>" identifies the primary relationship between actors and the boundary of uses cases. Finally, the perimeter of the square cluster's uses cases with similar aspects.

Sensing Technologies will be applied at construction sites to monitor the environment conditions and the workforce performance (Calvetti, Mêda, *et al.*, 2020). It is necessary to manage those devices to collect data, as example, embedding customised software or setting permissions. Firstly, it is envisaged that employers must provide the devices to workers, or that at least the workers are able to use their own devices.

More important are the actions among the actors at the figure center. A transparent relationship between workers and companies is mandatory. Prior knowledge is required, and it must be clearly stated what data will be collected and what will be its uses and sharing. Different levels of information can be delimited. As well, it must be authorized which actors will have access to which data. Information may be shared between different actors or platforms. It is essential to define the level of access to information and also the data ownership. For example, it is necessary to delimit for workers what information about their own performance can they share without disclosing sensitive/strategic data from companies. Likewise, companies can disclose information about their projects without characterizing/individualizing the performance of its workforce. Data sharing and the use of information can, and should, be monetized. In this sense, both employees and employers will have real gains with the application of these technologies. As a result, GDPR compliant agreements should be celebrated between employees and employers.

Many Conditions (Features) can be observed/collected from craft workers and from the construction site environment (Calvetti, Mêda, *et al.*, 2020). That data should be managed to be sent/shared. Finally, the processed information about human factors (e.g. motivation, fatigue, skills and others) may reflect performance evaluation and can finally be stored/used by different information systems. Given the complexity and

also the operational cost of these systems, it is natural that employers support such investments. However, workers should not be just a passive source of data. The more the craft workforce interacts with their own performance results the better they will understand its usefulness. It is necessary to create a virtuous interaction process, where the performance' knowledge/improvement is beneficial for all parties. Let's consider a hypothetic situation, where the employer supplies a wearable device with sensors embedded to measure the craft workers' heart rate and location path. The craft workforce is first informed about which data is to be collected and processed. Awareness and discussion should be made leading to a conscious agreement. The electronic monitoring goal is in assessing the workers' heart rate and location path to identify extreme efforts to avoid health issues. The company system can cross the workforce data with on-site conditions (e.g., temperature and humidity). After data analysis, it comes up that the auxiliary craft workforce was more exposed to be fatigued because of outside tasks (picking up products for far storage). To act on this issue, micro storage areas near the service front were arranged. By performing this the fatigue risk decreased and increased task outcomes was achieved.

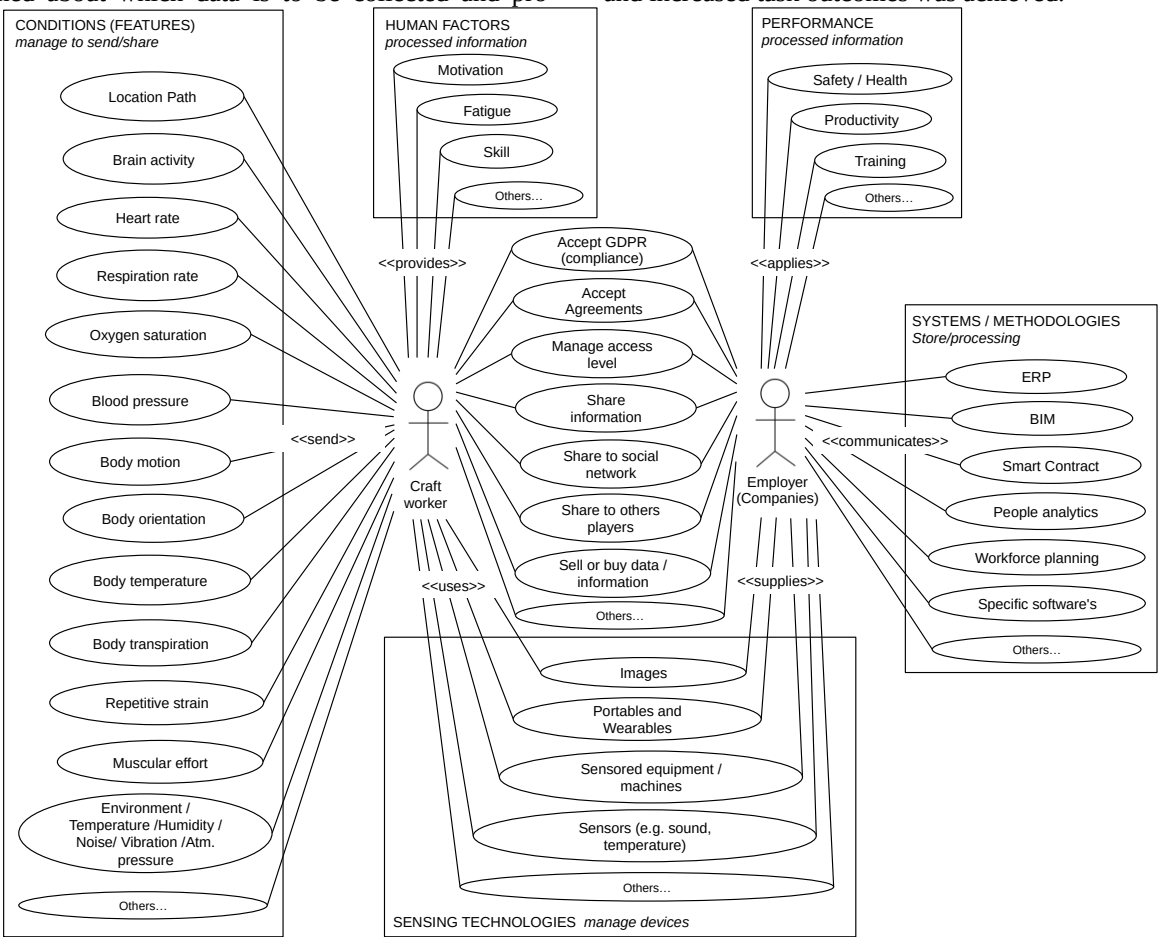

Figure 1: HDI Use Case Diagram (version 1.1)

HDI Information Process

The HDI information process represents the data path starting by on-site collection through systems/processes until the workforce management (Figure 2). The process designed is attached to Business Process Model and Notation (BPMN). It aims to indicate the data path thought different process/systems. The processes colours indicate a stronger connection with the innovation vector PPT People (red), Process (magenta), Technology (green). People are the foundation and source of knowledge of any process. The clusters of elements to create knowledge are connected to the Processes. Technology is the systematics (e.g. hardware, software, methodologies) to delivery the established outcomes.

The designed flow starts by implementing a sensored construction site (1) to collect data; forward, that data will be transmitted and stored (2) processing is the next step (3). This last is pertinent to the future information application. At the same time, the desired outcomes will guide the sensors type choice. As seen before, many sensing technologies are prone to monitor on-site/workforce conditions and features.

Two paths can be used. Initially, the information may populate BIM and be useful for construction contracts performing. Furthermore, the information can lead to AI decision-making. The data may be general, only reporting site conditions or the number of workers presented each day. However, if the intention is to manage personal information (e.g. pay each worker based on-site presence) profiling is needed.

BIM-COBie is prone to catalogue the human data collection and after that the information may be shared through different formats (e.g. IFC, JSON, SQL, XML). In this schema, Blockchain may support the validation of the information content and foster a smart contract process. A smart contract ecosystem is possible by sharing information from the BIM to the Blockchain ledger between the different stakeholders (e.g., client, contractor, subcontractor, insurance, bank) (Calvetti et al., 2019). Subsequently, the pre-defined clauses/rules are automatically played, based on specific routines developed (Nawari and Ravindran, 2019).

AI decision-making to manage workforce will demand profiling and a series of concerns, mainly regarding transparency and cross-validations. Therefore, a human must validate any AI decision, as well. The workforce must always have the right to contest the AI decisions.

GDPR compliance focusing on each process is presented next.

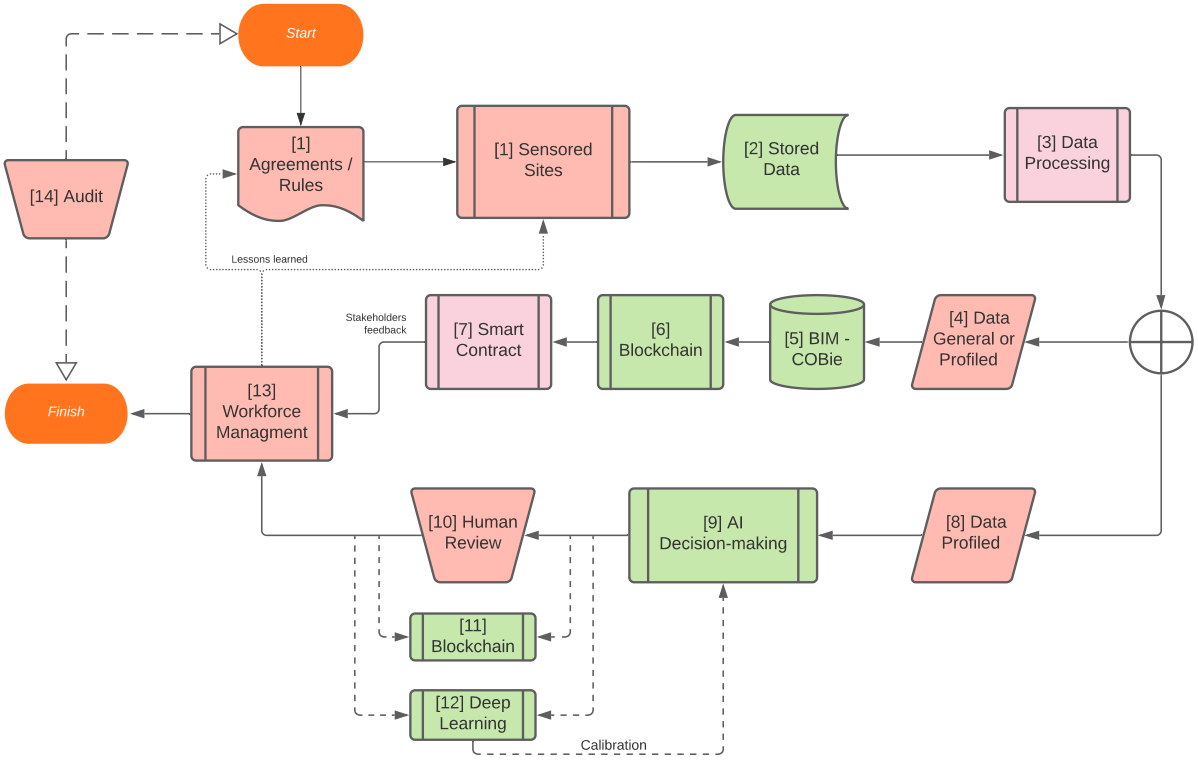

Figure 2: HDI Information Process (version 3.0)

Agreements/Rules and Sensored Sites (1). Implementation and monitoring: Agreements/Rules; Structure for EPM; Collecting data.

The company's higher-level management should commit, authorize and sponsor the innovation project, setting the requirements and boundaries for the implementation of a sensored site (Calvetti, Magalhães, et al., 2020). First, it is necessary an ‘Employee Privacy Notice’ that explains how the company is going to process employees general and personal data (GDPR Art. 12-13-14) (European Union - GDPR, 2019). The Worker Explicitly Consent is expressed on GDPR Art. 7, where "the request for consent shall be presented in a manner which is clearly distinguishable from the other matters, in an intelligible and easily accessible form, using clear and plain language. ..."; and "The data subject shall have the right to withdraw his or her consent at any time." (European Union - GDPR, 2019). Next, it is necessary to implement on-site infrastructure (hardware and software) to support the sensors devices (Calvetti, Magalhães, et al., 2020). When the systems are operational and the workforce informed and in accordance signed a agreement consent, the data collection may begins on-site (Calvetti, Magalhães, et al., 2020).

Data Transmission and Storage (2). Strongly cryptography.

GDPR establishes on Art. 5 - 1. e, f: "personal data may be stored for longer periods insofar as the personal data will be processed solely for archiving purposes in the public interest, scientific or historical research purposes, or statistical purposes in accordance with Article 89 (1)" (European Union - GDPR, 2019). Besides, the data/information should be "processed in a manner that ensures appropriate security of the personal data, including protection against unauthorised or unlawful processing and against accidental loss, destruction or damage, using appropriate technical or organisational measures (‘integrity and confidentiality’)" (European Union - GDPR, 2019). Further, GDPR (Rec. 83) point that “the controller or processor should evaluate the risks inherent in the processing and implement measures to mitigate those risks, such as encryption...” (European Union - GDPR, 2019).

Data Processing (3). Keywords are Data analyses and Classification; Visual, Statistical; Artificial Intelligence.

GDPR establishes on Rec. 33 "It is often not possible to fully identify the purpose of personal data processing for scientific research purposes at the time of data collection. .... Data subjects should have the opportunity to give their consent only to certain areas of research or parts of research projects to the extent allowed by the intended purpose." (European Union - GDPR, 2019). Beyond, algorithmic bias considerations should be analysed and avoided (e.g. IEEE P 7003) (Calvetti, Magalhães, et al., 2020).

Data: general or profile (4). Path to store and share processed information could be general data (e.g. on-site temperatures, number of workers on-site), or profiled (e.g. which worker was on-site, personal performance).

The workforce must consent data collecting, GDPR Art. 7 and 9 (most important it for profiled purposes) (European Union - GDPR, 2019). In most cases, can be assumed that sensoring sites are a form of profiling the workers, see WP251 Guidelines on Automated individual decision-making and Profiling (WP29: Independent European advisory body on data protection and privacy, 2018). The data collected may be useful for several purposes, either related to the workforce or the on-site environment. The workforce profiling occurs when the biometric data collected has the purpose of uniquely identifying a natural person for assessing different aspects, such as how a task is performed, safety behaviours, quality of work, absenteeism, effort, and fatigue (Calvetti, Magalhães, et al., 2020). Based on that, it is mandatory to inform in a clear and simple base, which aspects are to be evaluated, and when the data will be collected. Most important, when it concern workers' profiling that should be put in agreement.

BIM -COBie (5). Database for information standardisation and storage.

The data collected and stored on the construction base of information (BIM), may be shared data with third parties (Calvetti, Magalhães, et al., 2020). Consequently, GDPR on Rec. 69 emphasises that "on grounds of the legitimate interests of a controller or a third party, a data subject should, nevertheless, be entitled to object to the processing of any personal data relating to his or her particular situation. It should be for the controller to demonstrate that its compelling legitimate interest overrides the interests or the fundamental rights and freedoms of the data subject." (European Union - GDPR, 2019).

Blockchain (6). Data shared across stakeholders with the same piece of information.

Transparency is a GDPR prerogative (see WP260 Guidelines on transparency), and a Blockchain system, in a private network, can provide the data/information blocks validation between the subjects. Forward that data will establish a Smart Contract flow.

Smart Contract (7). Automated process for Information sharing; Monitoring KPIs and project constraints; Contract automated execution.

As stated before, the data storage on BIM and shared through smart contracts can either be general (e.g. overall workforce worked-hours for paying a subcontractor) or each worker's hours to individual payment (Calvetti et al., 2019). The smart contracts flow must be very transparent and clarify which rules will be automated and played in as well as the rights of the party/subject to review that process (Calvetti et al., 2019).

Data: profile (8). Path to use data to manage workers' based on AI decision-making, been profiling intrinsically because of that.

The workers must explicitly consent their profiles to manage specific actions. A "data for good" view is enhanced, hoping that new technologies/processes will bring benefits for both employees and employers. That view remains attached in the legitimate interest principle, not confronting employees' fundamental rights and having presented an effective communication to provide transparency (Calvetti, Magalhães, et al., 2020). The concept of data protection by design should present all-time starting with the implementation of the sensors (hardware and software) through the processing, until the use of the information (WP29: Independent European advisory body on data protection and privacy, 2017, 2018).

AI Decision-making, (9). Workforce' recruitment, training, bonus, reward, and punishment, among other actions.

It is fundamental as the WP251 Guidelines on automated individual decision-making and profiling (WP29: Independent European advisory body on data protection and privacy, 2018) state in section IV, plus specific provisions on solely automated decision-making, page 23 (based on Article 22 from GDPR, page 46 (European Union - GDPR, 2019)): "The controller must be able to show that this type of processing is necessary, taking into account if other effective and less intrusive whether could adopt a less privacy-intrusive method means to achieve the same goal exist, then it would not be 'necessary'.".

Human Review, (10). Validation of the AI outcomes.

Based on GDPR Art. 22 and Recital 77 A human review process is required "The data subject shall have the right not to be subject to a decision based solely on automated processing" (European Union - GDPR, 2019). The AI decision-making process should be consented to by the employees.

Blockchain, (11). Data shared across stakeholders with the same piece of information.

Similar to the previous Blockchain process, it will provide the data/information blocks historical record. What will register both information about AI outcomes and Human revision/confirmation to guarantee the transparency of the process.

Deep Learning, (12). AI to improve decision-making algorithms.

A Deep learning calibration process is recommended to allow the human review's perception as to improve the AI outputs.

Workforce Management (13). Workforce' recruitment, training, bonus, reward, and punishment, among other actions.

Workers' management is the final goal of the flow. Through the data collection and processing, and based on pre-established rules, the legally/morally permitted actions are performed. Any segregation bias will be detected if the entire process is compliant with the GDPR.

Audit (14). Keywords are Controller and DPO; Internal and external; Board.

It is fundamental to establish a system of control/audits throughout the flow (Calvetti, Magalhães, et al., 2020). For GDPR compliance, it is necessary to have a data controller and DPO (European Union - GDPR, 2019). GDPR rules that organisations that process/store large amounts of personal data must appoint a DPO (Data Protection Officers) to oversee the processes. Multidisciplinary teams should provide internal and even external controls. Most importantly, this process should evaluate the sensored sites' impact and pursue the GDPR principles as values, wellbeing, fairness, equality, transparency, and consent (European Union - GDPR, 2019).

Challenges identified

Concerning the HDI in sensored sites into the craft workforce dimension, different topics were collected from the interviews. These were grouped and are next presented. The stereotype (#) and numbers represent codes that correlate to each interviewee in Table 1.

Data Ownership. In the context of data ownership when targeting human data, there are many controversies. Corporations seek profit and seek to improve the performance of workers. When a dimension of analysis of this performance is envisaged at a nanoscope level (e.g., movements, gestures, bodily activities). There is a fine line between the analysis of the task and the analysis of the human himself who performs this action. It is very complex to define which data is related to the project task that the company develops, and for which it pays the worker's to perform. And what data is properly referring to human beings (workers) that in addition to performance reflect their physical and motor skills.

#1 The data ownership is quite an issue! It could be the owner, the public administration (for example, when building a hospital) or the contractor. If data becomes public, that can be strategic damage for the company that developed the structure.

#2 The companies are the natural owner of the collected data. In the future, with improved awareness of the data value, Clients will request the data ownership, and it could be a big challenge.

#3 The Companies are the owners of data and sharing it will depend on the regulation (GDPR).

#4 The data ownership will be a challenge/fight, but it should provide/share benefits for all stakeholders (workers, construction companies, clients).

#5 The data ownership is to the company that pays the workers.

GDPR compliance and Law. GDPR is a driver. As well, it is a bottleneck. Because it is a new regulation without jurisprudence established in practical cases. In addition, GDPR brings broad concepts and indicates/grants to Member States the specific regulation of acts. In the specific case of workers' monitoring, this prerogative is governed by collective agreements for each workers category in each Member State. However, although GDPR brings fundamental precepts, it ends up not presenting specific regulations. With this, GDPR is always remembered and cited as a source of concern, however, in itself, it does not bring any solution to make the practice feasible.

#1 A framework focused on workers is a relevant topic. It can constitute a reason to start a strategic discussion within the European Commission in terms of policy development and practical case of enablers and barriers.

#1 As long data is not directly targeting the workforce's profiling, such as measuring the construction process as a role or improving planning accuracy, the GDPR should not be a problem.

#2 The GDPR will be a challenge for the implementation of EPM and AI systems.

#5 During the pandemic (COVID-19), checking the temperature of workers was discussed, which generated controversies regarding GDPR.

#6 Based on the GDPR, pre-authorisation of the workforce is necessary to collect the data and assure the data treatment (what for).

#7 For implementing sensored sites the compliance with GDPR and countries legislation (labour legislation and collective agreements) is mandatory.

#7 The Estate Member construction collective agreement does not regulate any form of workforce performance monitoring, and it should be handled.

#7 The workforce must explicitly consent to their data collection.

ROI (Return on investment). This nature projects give rise to high investments in both human resources and equipment. Also, by being a highly innovative approach, there are still no off-the-shelf solutions. For this reason, most of the time it concerns custom projects. Despite the investigative nature of these projects, the time to reach the payback can be quite extended and even uncertain.

#4 It will be a challenge to quantify the real benefits for the companies (buyers of these technologies), how they will have the ROI.

#4 This system/framework can provide claim mitigation and bring adequate transparency in Construction Companies and Clients' relationships.

#4 The most prominent benefit in the field of data information is the ability to collect a tremendous amount of data (collected for a long time) without human interfer-

ence/appropriation. This is due to the human observation that introduces noise and strain to the assessment.

#5 The technology has many potentials, and it is a challenge to solve even a less advanced feature, for example, workers entrance on-site (which implies profiling).

Do profiling or do not profile? The collection of general data, for example, related to environmental factors is still an important analysis tool. However, failure to personify performance analysis inhibits a better understanding of the production processes. In addition, without identifying each individual, it becomes impossible to deliver specific actions, e.g., training, rewards.

#3 Individual monitoring will bring as a benefit the unique opportunity of learning.

Technological and Specialised Human Resource demands. At the same time, specialists in specific areas of information technology are needed, e.g., AI, Blockchain, Hardware. Human resources are also needed for many different actions, to analyse CI processes, to deal with human resources management, and to assure compliance with the legislation.

#3 The significant amount of data and the traffic band are technical challenges.

#4 There is no tool/product or service ready to use for this proposed framework. Customised system needs to be developed embedding all rules, processes and expertise. Given the range of the topics, the development team must be multidisciplinary, constituting an even more significant challenge.

#6 The use of Blockchain gates increase transparency in the framework. It will be informing the data sets and the algorithm's code.

Equity and Design Bias. The development of systems and algorithms are fundamental and require maximum care to mitigate bias and promote actions without discriminatory nature. The entire process must be audited by internal and external entities with a view to transparency.

#3 The ethics of design is more dangerous than the algorithms bias because the algorithms bias are already widely known and easier controlled.

#4 The AI (decision-making) must be an auxiliary decision-making tool, meaning that humans should do all the decision-making.

#5 An outside company must conduct the AI (decision-making) process to maintain the system's transparency/trust.

#6 A heterogenic stakeholder involvement (business managers, developers, HR people, etc.) as a co-creation of the system rules is crucial to prevent the algorithms bias and have the ethics in the system design.

Productivity approach. Undoubtedly, the evaluation of health and safety performance is extremely important. However, it is the improvement in productivity that most enhances the return of investments. With this, it is necessary to confront this reality and in a transparent and fair way to seek the analysis and improvement of productivity.

#2 Sensored sites main goal should be the ability to assess the construction work performance rather than the detailed assessment of the tasks (equipment and workers). It is evident that to achieve it is required to evaluate the different parts that constitute the construction work.

#2 The safety concerns should be the driver to demonstrate the value of workforce EPM. Following this, there are important gains in terms of how stakeholders can use data to boost productivity.

#4 Productivity is the goal that supports the investment. Safety and quality are added value sub-products.

#5 After the production workforce's measurement, it is vital to assess the quality of the tasks outcomes (quality).

#5 Sensored sites implementation should be gradual, and following the lessons learned, as previous initiatives on safety issues. This strategic approach will streamline the sensing technologies introduction in the construction industry.

Human barriers. Certainly barriers will exist and resistance to change is inherent to humans. Nevertheless, the workers' fear of possible misuse of information is just and valid. In order to break such paradigms, it is necessary to trust systems and especially in people.

#2 As all humans, the workforce is resistant to changes. In addition, workers do not like to be monitored.

#2 Electronic devices should be embedded in the personal protection equipment or in the tools/equipment to avoid additional workforce resistance to use.

#3 In order to break the technological paradigm of these types of innovation, benefits should be delivered for the workforce.

#4 The ethical challenge. Workers' feelings. Labour unions authorisation/interest.

#5 It can be seen that in this pandemic moment that workers are averse to wearing masks and maintaining adequate social distance (when possible), while technology could assist in this monitoring, workers' reaction may be contrary to use.

CONCLUSIONS

The proposed HDI use case diagram and information process concerning craft workforce into sensored sites were validated and improved by the involved Construction Industry Experts. The semi-structured interviews provided an in-depth discussion about the theme. Since HDI and sensing technologies are cutting-edge themes, it is not easy to find expert people in these fields of knowledge. Specialists' identification was challenging, and the short sample may not satisfy a generalization of the results. However, it seeks to shed light on the discussion.

Based on the HDI use case, it is concluded that the purpose of monitoring must be clear. That is, among the

countless human conditions that can be monitored, it is necessary to identify and indicate exactly what data will be collected and what the expected outputs are. The general knowledge delivered in this scheme will provide opportunities for specific use cases (analysis of some human conditions to evaluate a given performance) to be detailed with a focus on the visualization of constraints and actors.

Furthermore, the analysis of the HDI information process indicated that it should be continually reassessed and audited. At the same time, all management decisions/actions indicated by the systems must be disclosed to the parties involved and always supported by human evaluation. The visualization of the information process flow, containing the connection between each process and the GDPR, will allow the processing of specific data in compliance with the regulations, and more importantly, raising the standards of transparency.

GDPR is both an enabler and a bottleneck for the implementation of sensored construction sites. Data ownership should be vastly discussed in a way that is a monetary asset. Employees and Employers may share the financial results from data use. Experts also raised challenges in different subjects, as example, profiling and human barriers. There was a consensus that a gradual and people-centred approach is prone to introduce a higher success rate into sensored sites implementation.

Further research should be done to quantify the sensored construction sites benefits, identification of initiatives implemented during COVID-19 and impressions on their role, possible ROI measurement and human-centric studies confronting craft workers with real returns observing their behaviours.

ACKNOWLEDGMENTS

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).
Our deepest thanks to the experts who contributed to this work.

REFERENCES

Calvetti, D. *et al.* (2019) 'Sensing technologies embedding construction workers outcomes / key performance indicators', in Kumar, B. et al. (eds) *In Proceedings of the 36th CIB W78 2019 Conference: Advances in ICT in Design, Construction and Management in Architecture, Engineering, Construction and Operations (AECO)*. Newcastle, UK, UK: ISBN (Print) 9781861354877, ISBN (eBook) 9781861354860, pp. 890–900.

Calvetti, D., Magalhães, P. N. M., *et al.* (2020) 'Challenges of Upgrading Craft Workforce into Construction 4.0 – Framework and Agreements', *Proceedings of the Institution of Civil Engineers - Management, Procurement and Law*, pp. 1–7. doi: 10.1680/jmapl.20.00004.

Calvetti, D., Mêda, P., *et al.* (2020) 'Worker 4.0: the Future of Sensored Construction Sites', *Buildings*, 10(169), pp. 1–23. doi: 10.3390/buildings10100169.

Denzin, N. K. and Lincoln, Y. S. (1994) *Introduction: entering the field of qualitative research*. Thousand Oaks, CA: Sage.

European Union - GDPR (2019) *GDPR: Guidelines, Recommendations, Best Practices, European Data Protection Board*. Available at: https://edpb.europa.eu/our-work-tools/general-guidance/gdpr-guidelines-recommendations-best-practices_en (Accessed: 10 October 2019).

HDI Committee (2020) 'Human Data Interaction (HDI): Committee Annual Workshop'. European Council on Computing in Construction (EC3), pp. 1–31.

Kimmance, A. G. (2002) *An integrated product and process information modelling system for on-site construction*. Loughborough University. Available at: https://repository.lboro.ac.uk/articles/An_integrated_product_and_process_information_modelling_system_for_on-site_construction/9454796.

Maxwell, J. A. (2004) 'Reemergent scientism, postmodernism, and dialogue across differences', *Qualitative Inquiry*, 10(1), pp. 35–41.

Nawari, N. O. and Ravindran, S. (2019) 'Blockchain and the built environment: Potentials and limitations', *Journal of Building Engineering*, 25(June). doi: 10.1016/j.jobe.2019.100832.

WP29: Independent European advisory body on data protection and privacy (2017) 'Article 29 Data Protection Working Party. Opinion 2/2017 on data processing at work (WP 249)'. Directorate C (Fundamental rights and rule of law) of the European Commission, Directorate General Justice and Consumers, B-1049 Brussels, Belgium, Office No MO59 05/35, pp. 1–24. doi: 10.2139/ssrn.2972855.

WP29: Independent European advisory body on data protection and privacy (2018) 'Article 29 Data Protection Working Party. Guidelines on Automated individual decision-making and Profiling for the purposes of Regulation 2016/679 (WP 251 rev.01)'. Directorate C (Fundamental Rights and Union Citizenship) of the European Commission, Directorate General Justice, B-1049 Brussels, Belgium, Office No MO-59 02/013, pp. 1–37.