Learnings from User Digital Trail Post-Occupancy Evaluation before COVID-19 for Future Workplace Analysis and Design

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Abstract: Data are required for optimizing workplace design, assessing user experience, and ensuring wellbeing. This research focuses on the benefits of incorporating post-occupancy evaluation (POE) data analysis by studying the digital trail of employees generated by the existing Wi-Fi infrastructure of the office. The objective is to enable a safe return to offices through compliance with COVID-19 space-capacity regulations and in consideration of the health and wellbeing of employees. Workplaces, teams, and people have become more digitalized and therefore more mobile due to the globalization of knowledge and cutting-edge technological innovations, a process that has been accelerated by the COVID-19 crisis. Now, hybrid work and fully remote working routines are increasing in a significant number of companies. Nevertheless, with the return to the office, understanding how to calibrate spatial capacity is now key for workplaces and companies. Traditional assessment methods are obsolete; new methods that respond to mobility, changing occupancy rates, and comfort are essential. This paper analyzes, through the case study of a pre-COVID-19 activity-based office, the advantages of using digital indoor-location techniques (such as Wi-Fi networks, which additionally have the advantage of being previously installed in the majority of these spaces). The paper demonstrates that the incorporation of digital POE of user trends enabled a more seamless, accurate, and scalable return to a new normal office work scenario and an improved post-COVID-19 design of workplaces.

Keywords: human-centered design; post-occupancy evaluation; data analysis; workplace; indoor location; digital trail

1. Introduction

1.1. Workplace

The workplace is undergoing a dramatic transformation in its transition from the industrial age towards the knowledge age [1]. The requirement to anticipate and predict change is crucial to making the most of the transition and remaining sustainable [2,3]. Market changes have led to the growth of new types of offices: open-plan, activity-based offices, multitenant offices, and new ways of working [4]. To understand how the workplace is developing, it is necessary to understand new work styles, patterns, and locations that will ensure organizations stay effective in the long term [2].

Several factors have driven the transformation in workspaces: the sharing economy [5], the need for flexibility [6,7], the increase in self-employed workers, and the use of mobile technology, making it possible to work anywhere at any time [6,8].
1.2. Work Dynamics and Coronavirus Disease 2019 (COVID-19)

However, it is the COVID-19 crisis that has established an unprecedented global situation where millions of people in countries around the world have been subjected to staying at home for long periods of time, with remote working becoming the only option [9,10]. This has clearly demonstrated that after the pandemic, workplaces need to adapt quickly to new environments where digitalization, flexibility, and health and safety are essential [11–16].

To achieve this, the understanding of human work dynamics [17,18] and new ways of working [4] and the ability to predict the spread of viruses and diseases in the office [19] and adapt quickly to changes [20] have become key to success in envisioning the future world of work. After COVID-19, this has accelerated [16]; remote working has become a necessity for companies to keep their businesses operating, setting a precedent for flexibility at work [15,21]. The pandemic has made commonplace what was already a reality in the most advanced, digital workplaces; white-collar workers could already work without a fixed workstation through online connected communities [22], proving that virtual space is not location-specific [23], but goal-driven. White-collar workers, dismissed from their fixed workstations, were able to use their mobile devices to move and work freely within a wider variety of spaces, inside and outside the office [24]. Nevertheless, they still seek work environments that stimulate networking and collaborative possibilities [25], which has led to the growing popularity of coworking spaces [6,24,26], known to enhance performance and social networks [27].

1.3. Post-Occupy Evaluation (POE)

Within this changing paradigm, there is a need for more advanced, digital methods to understand the use of space and improve its design [27,28]; post-occupancy evaluation (POE) and other methods [29,30] are becoming essential in analyzing the current use of workspaces and predicting workspace occupancy, use, and working dynamics.

Innovation and new technology enable a faster and more accurate understanding of the occupancy of and the interaction with space [24,31]. The Internet of Things (IoT) integrates entities of the physical world by making them addressable through the Internet and making the Internet accessible through physical objects [32]. Today, new ways of monitoring and data analysis can provide almost real-time feedback [28,33]. The workplace is not an exception to this; current studies incorporate new technology to understand smart dynamics, workplace optimization, productivity, and user patterns [20,34]. Occupancy information and prediction can help architects to improve space efficiency and workplace design [35].

1.4. Smart Cities, Smart Buildings, and Human-Centered Design (HCD)

A smart city is “a community that systematically promotes the overall wellbeing for all of its members and is flexible enough to proactively and sustainably become an increasingly better place to live, work and play” [36]. The inclusion of digital devices, technology, and data analysis from IoT devices promotes the transformation of cities, buildings, and spaces towards more sustainable, efficient, and optimized spaces, but it must start with the people, their needs, and ways of living, current and future [37–39]. There is a need to include users in participatory design processes, learn from their use of spaces and occupancy. The current study relies on POE indoor location techniques to understand smart workspaces with the objective of designing more human-centered smart buildings and cities [6,29].

1.5. Indoor Location Techniques

Traditional analog space-planning and occupancy studies are not functional anymore due to new dynamics of flexibility and collaboration between users [18,40,41]. Due to increased mobility in their day-to-day work [40] collaborative workers today interact in a wide variety of working environments [1,42]. Location tracking systems such as sensors, Wi-Fi, or facial recognition are currently used to understand space dynamics [17,18,43],
user behavior [44,45], and energy consumption [46]. Other buildings such as malls or outdoor spaces often use location and occupancy analytics for security or understanding behavioral patterns [27,45,47].

This case study analyzes how a wireless local area network (Wi-Fi) can be used as an effective indoor positioning system. It is competitive in terms of both accuracy and cost compared to similar systems and due to the following factors:

1. Seamlessness: nonintrusive for employees using the existing technology at the office.
2. Affordability: included in the communications infrastructure, no added budget.
3. Accuracy for indoor navigation: more accurate than Global Positioning System (GPS) or Bluetooth [48,49].
4. Durability: regular maintenance is included in the regular workspace Wi-Fi network maintenance.

The Wi-Fi access points are proposed as a proxy to represent the virtual dimension and to integrate both virtual and physical dimensions [50]. The user location information represents a core dimension as understanding user context is a prerequisite for providing human-centered services that generally improve quality of life [51–53].

The objective of this paper is to evaluate the improvements of using digital infrastructure already in place at an office as a post-occupancy evaluation (POE) tool (see Table 1) to gain input on the employees’ use of space. New flexible workspaces will require indoor positioning methods such as Wi-Fi to facilitate POE. The purpose of this paper is to demonstrate the improvement of the workplace by the assessment of user experience, operations, and health and wellbeing through indoor data-driven analysis [28].

Table 1. Conceptual analysis assessment framework development for the methodology.

| Methods | Parameters (What We Measure) | Metrics | Measurement Standards | Assessment Framework |
|---------|------------------------------|---------|-----------------------|----------------------|
| QMv: Quantitative manual (viewers) | A. Presence | - Occupancy and density rates [35,44,45] | User satisfaction survey | User experience (user satisfaction) |
| QMs: Quantitative manual (self-assessment) | B. Occupancy of space | - Time and duration of stay [44] | Workplace designer interview | |
| QD: Quantitative digital (Wi-Fi location) | C. Duration of stay | - Occupancy reiteration [44,45] | | |
| | D. Reiteration | - Diversity of users [6] | | |
| | E. Proximity between users | - Team working patterns [44–46] | | |
| | | - User mobility and silos [44–46] | | |
| | | - User spatial preferences [46] | | |
| | | - Occupancy and density rates [35,44,45] | Workplace optimization ratios | Operations (occupancy and cost efficiency) |
| | | - Time and duration of stay [44] | Design standards | |

2. Materials and Methods

In this investigation, the presence, length of stay and choice of the users, and proximity among users were analyzed through 3 different methods developed by the authors as part of the Business Innovation Consulting Group (BICG), two analog and one digital. The studies took place in parallel during the same time frame and in the same space to realize a comparative and complementary analysis.

- Method 1: The quantitative digital (QD) method is an indoor location method based on using the Wi-Fi network signal to identify the position of the employees by locating the position of their digital devices (laptop, mobile phone signal). The devices do not need to be connected to the office Wi-Fi network; the Wi-Fi has an automatic process to constantly see device traces within its radius of influence. These traces are linked to
real spaces similar to a fingerprint; each real space of the office has a digital fingerprint assigned, and the trail is referred to as a digital trail. The QD method was used to collect data inputs from devices 24 h a day for the 5 days of study. These raw data were later anonymized, cleaned, filtered, and aggregated to show patterns of use of spaces. These data were processed through a digital platform of own generation and then visualized with Tableau.

- **Method 2:** The quantitative manual “viewers” (QMv) method is a method of tracking employee location by external professionals, called “viewers”; these viewers were trained to do regular walkthroughs of all the office spaces following a map of the office and writing down the occupied or empty spots of the office every time they pass by. Walkthroughs registering the different locations of employees were done every 30 min from 9:00 a.m. to 6:00 p.m. for the 5 days of the study. These data were later transcribed to Excel and then visualized with Tableau, a business analytics service by Microsoft to provide interactive visualizations.

- **Method 3:** The quantitative manual “self-register” (QMs) method is a method of tracking employee location by self-registering. Employees signed in on a paper at their location every time they sat at a workstation and signed out every time they left a spot. The rule was to sign in every time they would sit for more than 5 min during the 5 days of study. During the cleaning of these data, entries shorter than 10 min were erased. There was a lack of accuracy because the employees sometimes forgot to sign out after a short stay. These data were later transcribed to Excel and visualized with Tableau.

By generating a tool to monitor these metrics, it is possible to improve the user experience, occupancy, cost optimization, and wellbeing, which can directly impact business performance and talent attraction and retention [54].

Table 1 shows the POE spatial assessment tool generated to assess the data inputs through the 3 data collection methods (QD, QMv, and QMs). This analysis tool is a methodology to provide a framework that structures the dataset obtained from the different methods. The process of the study is as follows: the data collection methods assess certain identified parameters, providing metrics that will answer the required measurement standards that will finally provide inputs to the global analysis framework.

2.1. Research Design

The pilot study was designed as part of BICG research and innovation team to enable the measurement of the use and occupancy of the spaces through a mixed-methods [55] study composed of both quantitative manual and digital methods. The relevance of the current study for post-COVID-19 assessment is related to the opportunity to learn from offices that, before COVID-19, had already implemented a mobility strategy for employees and were using data analysis to assess occupancy and use of spaces.

At the analyzed office, the headquarters of BICG, employees were not assigned to workstations even before COVID-19; the company had an innovative way of working that they developed and implemented in office spaces. BICG provided with mobile working devices (laptop/tablet/phone) to all the employees and they were free to choose their location inside or outside the workspace, they were typified as “mobile employees”. The space that enables such mobility is referred to as “flexible workspace”; after the pandemic, offices started making spaces more flexible and employees became more mobile due to changing regulations on space capacity to respond to COVID-19.

The current study was divided into 5 stages as shown in Figure 1.
At the analyzed office, the headquarters of BICG, employees were not assigned to workstations even before COVID-19; the company had an innovative way of working that they developed and implemented in office spaces. BICG provided with mobile working devices (laptop/tablet/phone) to all the employees and they were free to choose their location inside or outside the workspace, they were typified as “mobile employees”. The space that enables such mobility is referred to as “flexible workspace”; after the pandemic, offices started making spaces more flexible and employees became more mobile due to changing regulations on space capacity to respond to COVID-19.

2.2. Pilot Study

The pilot study of the “flexible workspace” intelligence was carried out at the headquarters of a medium-size international company based in Madrid. The office gross leasable area (GLA) is 469 m² and has a capacity of 48 people (Figure 2). The pilot study was undertaken for a total of 5 working days, 13–17 May 2019, pre-COVID-19, and in normal conditions in an office where employees could work from home or from the office, the most similar environment to a place with full mobility; the aim is to study the applicability of this research for post-COVID-19 spaces.

Figure 2. Interior photographs of the office space analyzed: (a) Entrance; (b) Pradera; (c) Jardín; (d) Altar.
The data collection methods did not make a distinction between permanent employees, visiting employees, and occasional external visitors. In the data cleaning phase, the different data registers were classified and categorized or dismissed.

Regarding the QMv study, the first limitation is that the inputs are collected through “viewers” that count the number of employees in space; as these numbers are not tagged to a person and data are anonymized, the QMv does not identify individual employee locations or timespans, whereas the information of QD and QMs is also anonymized but processed before to identify timespans. The research was undertaken to understand the dynamics of the employees at the office. The data were aggregated and anonymized in compliance with the principles outlined in the GDPR regulations, and the study was performed in accordance with the principles outlined in the Declaration of Helsinki; all participants gave written informed consent [56–58].

To comply with GDPR regulations, the data were encrypted, codified, anonymized, and aggregated. We based our study on the current European regulations and previous research on GDPR-compliant Wi-Fi indoor location techniques to ensure data compliance [56–58].

The data encryption was performed encrypting the raw data with a unidirectional code function that substitutes the MAC number of the devices for a unique random code using a #+Alt function that makes the original anonymous MAC number unretrievable. Afterward, the data were always treated aggregated.

The data collection schedule of the parts of the study that were undertaken is shown in Figure 3. Employees had a flexible schedule; despite this, the reception counter was open for external visits from 9:00 a.m. to 7:00 p.m. Monday to Thursday and from 9:00 a.m. to 3:00 p.m. on Fridays.

An initial analysis of data collection methods regarding schedule showed that QD was the most complete, collecting rigorous and continuous data 24 h a day. QMs and QMv were more irregular and required additional training of the viewers (QMv) or the employees themselves (QMs), which meant they required a greater investment of time and were less scalable, as well as introducing the possibility of human error.

2.2.1. Stage 1: Spatial Assessment. Enclosed Laboratory Definition

The space within the office first needed to be classified to be measured: if you cannot measure it, you cannot prove it [59]. The granularity will differ with each collection method. For this study, for the QMv and QMs methods, the information of the occupancy was collected distinguishing each workstation individually, while for the QD method the data were classified through DARs as a minimum space unit. A DAR is the minimum measurable area space distinguished by the measurement tool (in this case, Wi-Fi). The DARs were manually defined to integrate workstation clusters or areas with the same function. The “flexible workspace” is understood as a combination of DARs. DARs will be classified according to their typologies as workstation, meeting, informal, and value-added spaces as shown in Figure 4.
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Figure 3. Data collection schedule for the 3 data collection methods: QMv, punctual data collection through walkthroughs; QMs, continuous data collection while employees are present; QD, continuous data collection 24 h.

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Figure 4. Office space classification.

Each DAR was coded and categorized given the following features and as shown in Figure 5:

- Floor, type (letter that represents the typology, e.g., W = workshop);
- Category (classification of the space in relation to an activity-based working (ABW) office);
- Typology (subclassification of the category in relation to the activities developed), capacity, and area in m² [54].

Following the classification of Figure 5, the different DARs were tagged in layouts (Figure 6) to enable data collection methods for QMv and further data processing for QMs and QD. Figure 6 also tags the access points (APs) available at the office for the QD study. A walkthrough path (Figure 7a) sheet of each floor was also designed and printed for the QMv; the “viewers” used this sheet to mark the occupancy of each space every half hour.

| CATEGORY            | TYPOLOGY               | DESCRIPTION                                                                 |
|---------------------|------------------------|------------------------------------------------------------------------------|
| WORKSTATION         | STANDARD               | Spaces designed to work individually for extended periods of time.           |
|                     | ANCHOR POINT           |                                                                               |
|                     | THINK TANK             |                                                                               |
| MEETING             | MEETING ROOM           | Spaces designed specifically for team work, meetings or presentations.      |
| INFORMAL            | WORKSHOP               | Informal areas or collaboration spots where employees can maintain an informal meeting, casual encounter or develop temporary tasks. |
|                     | BENCH                  |                                                                               |
|                     | OPEN COLLABORATION     |                                                                               |
|                     | LOUNGE                 |                                                                               |
| VALUE ADDED SERVICE | GRAVITY                | Value Added Services, Other services that cover functions to the employees external for what they strictly need to cover their work functions and add value to the Company Experience⁶. |

Figure 5. Office spaces per category, indicating floor, code, name capacity, number of seats, category typology, and total area in m².

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- Category (classification of the space in relation to an activity-based working (ABW) office);
- Typology (subclassification of the category in relation to the activities developed), capacity, and area in m² [54].
Figure 6. Example of workplace area layout tagged by DARs identified by colors. APs are also tagged and named. (a) Ground Floor (spaces: Workshop, Kitchen, Flower, Altar, Clients, and Reception); (b) First Floor (spaces: Jardín, Salon, Pradera, Video, Green, Orange, and Red); (c) Second Floor (spaces: Dungeons, Imperial, and Grey).
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Figure 7. (a) Example of the walkthrough path sheet. (b) Blank register sheets from the QMs.
2.2.2. Stage 2: Data Collection (QMs, QMv, and QD)

The quantitative manual “self-registering” (QMs) study took place organically as the members registered during their working hours and every time they moved until they left the space. The transition times and other activities that are not strictly working, such as informal chats or phone calls in other spaces apart from the workstations, were not collected. The QMs self-register sheets (Figure 7b) were attached to the different tables or walls at the space and completed by the employees; each day, the data were collected and filled into the databases to be prepared for the next phase, data cleaning.

The quantitative manual “viewers” (QMv) study was organized to take place between 9:00 a.m. and 6:00 p.m. The viewers walked through the spaces collecting information every 30 min. The viewers recorded the occupancy of the different areas without identifying the users or the technology they were using in each area (mobile phone, laptop, or screen in the meeting spaces).

The data were recorded on the walkthrough path sheets (Figure 7a) and transferred to the working databases every day to be cleaned.

The quantitative digital (QD) study registered employee data trails 24 h a day and stored them in a data warehouse on the cloud. The study registered all the digital trails generated by the users while they had their devices (mobile, laptop, table) on in the office space, even if they did not have the Wi-Fi enabled.

“For these studies the data collection through Wi-Fi systems relied on the fingerprinting technique. Every time user devices (laptop, mobile phone...) conduct a scan of nearby access points (looking for Wi-Fi), all access points in range receive a message containing the unique identifier of the device and a signal strength corresponding to the distance to the access point. The combination of signals received by each access point is called a fingerprint” [19,48,49,60,61].

The IT network was built using Cloudtrax software and devices. The network was a combination of 7 APs distributed around the 3 floors of space: 2 on the ground floor, 4 on the first floor, and 1 on the upper floor. The location of the APs was not planned or modified for this study; future lines of research on planned locations of the AP devices will be suggested to optimize the location tracking grid.

The Wi-Fi digital trail works as if it was a digital fingerprint of the presence of a device in the space (Figure 8). The model was trained throughout the algorithm to identify the digital prints emitted by the devices with the digital fingerprints that identify each space. If the digital print matched one of the recorded reference fingerprints, then the device was allocated to that specific space; if it did not meet the requirements of any space, the devices were not considered as being in one of the measurable areas. This operation was repeated every time the device sent a signal transferring the digital print.

2.2.3. Stage 3: Data Cleaning and Clustering

The data cleaning phase was essential to be able to compare and assess the results. Meanwhile, the QMv and QMs were cleaned manually by dismissing any invalid results and classifying the data from the different databases with the office categories (Figure 5).

The QD study conducted a deeper analysis that included data science analysis and corroboration of the triangulation methods to generate a quantitative sum of registers. The APs collected numerous registers of location per minute; to be able to assess and lower the uncertainty, the data collected were clustered in 3 min periods, which means that records from the same device in the same position with a shorter timespan than 3 min were considered as one; in addition, isolated registers were dismissed to lower uncertainty. Figure 9 shows a representation of the record count of signals received from each AP for every DAR.
Figure 8. Data collection schedule for the 3 data collection methods: QMv, punctual data collection through walkthroughs; QMs, continuous data collection while employees are present; QD, continuous data collection 24 h.

Figure 9. Access points and record count from each space (digital platform visualizations are shown with black background). Once the data were cleaned, they were classified and analyzed through the categories.

After being processed, the data were imported to the software Tableau (https://www.tableau.com/, accessed on 1 January 2019) to merge and filter the data, and an in-house digital platform was created to visualize different dashboards with the data and enable easy decision-making processes. Figures in this paper that come from the digital platform have a black background and color-coding.

The process of data cleaning was as follows:

- **Data selection and storage.** The data selection was only applied for QD, selecting data only during office working hours to avoid including data from the cleaning service team or maintenance done during night shifts.
- **Data segmentation and cleaning.** Data cleaning was executed for inaccurate data or incomplete data for QMv and QMs methods and for any register of a stay under 10 minutes in any of the methods.
- **Data labeling.** Data were labeled according to time of the register and spatial location of the stays to classify per spatial occupancy; data were also automatically tagged according to the team or department of each employee.
- **Data assessing.** Aggregated data were analyzed and visualized in the metrics identified to understand patterns of presence, occupancy of space, duration of stay, reiteration, and proximity.

The data collected through the different data collection methods (QMs, QMv, QD) were classified according to the parameters developed in the POE spatial assessment tool. Table 2 analyzes how each data collection method can provide information on the different parameters requested.

| Method | Presence | Occupancy of space | Duration of stay | Reiteration |
|--------|----------|--------------------|-----------------|-------------|
| QMs    | ✔        | ✔                  | ✔               | ✔           |
| QMv    | ✔        | ✔                  | ✔               | ✔           |
| QD     | ✔        | ✔                  | ✔               | ✔           |
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| Presence | Occupancy of space | Duration of stay | Reiteration | Proximity between users |
|----------|--------------------|-----------------|-------------|------------------------|
|          | ✓                  | ✓               |             | ✓                      |
| QMs      | ✓                  | ✓               | ✓           |                        |
| QMv      | ✓                  | ✓               | ✓           | ✓                      |
| QD       | ✓                  | ✓               | ✓           |                        |

1. Presence tables: Analyze the signs of present users at the office or at the different DARs identified.
2. Occupancy of space: Correlates the presence of tables with the capacity of the different spaces.
3. Duration of stay: Studies the duration of employee presence at a certain space.
4. Reiteration of stay: Analyzes the frequency of use of the spaces by the different users.
5. Proximity between users: Analyzes the relationship between users by understanding their occupancy of spaces at the same time.

**3. Results**

The results are structured according to the parameters developed in the POE spatial assessment tool.

QMs analysis could only provide insights on occupancy of the DAR because the data collected could not be labeled and followed. QMs provided very complete information but was not very accurate on duration of stay because employees in 17% of the cases forgot to sign out of the place they were situated at or forgot to sign in when they sat down. The quantitative digital method was the most accurate data collection method: it could assess data 24 h and in a noninvasive way seamlessly. Data extraction and storage could also be automated for longer periods and therefore broader, scalable, and more extensive analysis.

The data from the QD were automatically extracted from Wi-Fi, stored in what is called a data lake (an online data warehouse that stores data 24 h a day automatically), encrypted, and anonymized. This specific study programmed the data extraction and storage of 5 days of data. If programmed for future research, the automatic data extraction could be programmed for a long and continuous period. Data would then be automatically extracted and stored in the digital warehouse. Data could be extracted the same day for analysis, or past data from previous days, months, or years (retroactive data) could be extracted for analysis at users’ convenience. This is only possible with digital analysis and automatization of data extraction from Wi-Fi networks.
3.1. Presence Results

The three data collection methods provide insights on presence. The Wi-Fi location methods enable the full-time collection and storage of data in a nonintrusive way and retroactively. The QMv and QMs studies achieved the same results but required forward planning, and data could not be obtained retroactively for dates different than those considered for the study.

The study demonstrates that the presence of users in the different spaces was very uneven. Table 3 shows the employee presence in the different DARs or areas of the office by time of day. Pradera, Jardín, and Workshop were identified as the most popular areas chosen by users, occupied by five or more people during the study.

Table 3. Presence per DAR (quantitative manual data). Numbers indicate the number of employees present at each spaces per hour. Dark colors highlight the areas with more users present at a time.

| Floor | DAR Code | DAR | 09:00 | 09:30 | 10:00 | 10:30 | 11:00 | 11:30 | 12:00 | 12:30 | 13:00 | 13:30 | 14:00 | 14:30 | 15:00 | 15:30 | 16:00 | 16:30 | 17:00 | 17:30 | 18:00 |
|-------|----------|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 0     | A        | Altar | 2     | 1     | 1     |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | C        | Clients | 1   | 2     | 2     | 2     | 2     | 2     | 3     | 2     | 2     | 1     | 2     | 2     | 2     | 3     | 2     | 2     | 3     | 2     | 3     |
|       | F        | Flower | 1   | 3     | 4     | 4     | 4     | 4     | 4     | 4     | 4     | 4     | 3     | 4     | 4     | 2     | 3     |       |       |       |       |       |
|       | K        | Kitchen | 1   | 1     | 1     | 2     | 1     | 2     | 2     | 1     | 1     | 1     | 5     | 4     | 4     | 2     | 3     | 2     | 2     |       |       |       |
|       | R        | Reception | 1   | 1     | 2     | 2     | 2     | 2     | 2     | 2     | 2     | 2     | 2     | 2     | 2     | 2     | 1     | 1     | 1     | 1     | 2     | 2     |
|       | W        | Workshop | 1   | 1     | 3     | 4     | 5     | 5     | 5     | 6     | 6     | 5     | 4     | 4     | 4     | 4     | 6     | 4     | 5     | 5     |       |       |
| 1     | FP       | Fix Position | 0   | 2     | 3     | 4     | 4     | 4     | 4     | 5     | 5     | 4     | 4     | 6     | 6     | 4     | 4     | 3     | 3     | 3     | 3     |       |
|       | G        | Green | 1   | 1     | 1     | 1     | 1     | 1     | 1     | 2     | 2     | 2     | 2     | 2     | 2     | 2     | 1     | 2     | 2     | 2     | 1     |       |
|       | J        | Garden | 1   | 2     | 4     | 5     | 6     | 6     | 6     | 6     | 6     | 6     | 6     | 6     | 5     | 4     | 3     |       |       |       |       |       |
|       | O        | Orange | 1   | 4     | 2     | 2     | 3     | 2     | 2     | 3     |       |       |       |       |       |       |       |       |       |       |       |       |
|       | P        | Pradera | 1   | 2     | 6     | 8     | 7     | 7     | 7     | 9     | 8     | 7     | 7     | 6     | 6     | 6     | 6     | 5     | 5     |       |       |
|       | RR       | Red | 1   | 1     | 1     | 2     | 2     | 3     | 2     | 3     | 1     | 2     | 2     | 3     | 2     | 2     | 3     | 2     | 3     | 4     |       |
|       | S        | Salon | 1   | 1     | 3     | 1     | 1     | 2     | 2     | 2     | 4     | 5     |       |       |       |       |       |       |       |       |       |       |
|       | V        | Video | 2   | 2     | 2     | 2     | 2     | 2     | 2     | 2     | 2     | 2     | 2     | 2     | 2     | 2     | 2     | 2     | 2     | 2     |       |
| 2     | D        | Dungeons | 1   | 2     | 2     | 2     | 2     | 2     | 2     | 2     | 2     | 2     | 2     | 2     | 2     | 2     | 2     | 2     | 2     | 2     |       |
|       | GG       | Grey | 1   |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | I        | Imperial | 1   | 2     | 3     | 2     | 2     | 2     | 2     | 2     | 1     | 2     | 3     | 2     | 2     | 2     | 2     | 2     | 2     | 2     | 1     |
|       | TOTAL    |       | 9   | 21    | 33    | 43    | 42    | 42    | 45    | 50    | 49    | 49    | 47    | 51    | 41    | 45    | 43    | 43    | 44    | 41    | 42    |

The study demonstrates that the presence of users in the different spaces was very uneven. Table 3 shows the employees present in the different DARs or areas of the office by the time of day. Table 4 describes the most popular spaces, with higher rates of presence, among employees (Pradera, Jardín, and Workshop), with higher presence across the study according to Table 3, and crosses these results with additional feedback from employees to understand the positive aspects of the spaces and why they were the most popular among employees.
Table 4. Spaces with positive performance and relevant employee feedback.

| DAR Code | Space Name   | Positive Performance                                      | Employees ’ Feedback (Categorized through Global Analysis Framework) | Global Analysis Framework |
|----------|--------------|----------------------------------------------------------|---------------------------------------------------------------------|---------------------------|
| 1P       | Pradera      | Overoccupied, high density of employees                  | Close to the employees that are not “mobile” (B)                     | B. Operations             |
|          |              |                                                         | Chosen as a permanent area to work for a low mobility and big size team (A) | A. User experience        |
|          |              |                                                         | Ergonomic chairs, double screens (C)                                 | C. Health and wellbeing  |
| 1J       | Jardin       | High density                                           | Biophilic design, good light, temperature, and views to the park (C) | B. Operations             |
|          |              | Longest stays                                          | Quiet space, good for concentration (A)                               | A. User experience        |
|          |              | Popular among C-suite and management team               |                                                                      |                           |
|          |              | High occupancy                                         |                                                                      |                           |
|          |              | High churn rate, used by different users               |                                                                      |                           |
|          |              | Popular among junior employees and new employees       |                                                                      |                           |

Table 5 describes the spaces with negative performance, with very low presence across the study according to Table 3 and crosses these results with additional feedback from employees to understand negative aspects of the spaces, why they were not chosen by employees, and how they can be improved. All the spaces categorized as underperforming had in common “user experience factors” as shown in the table.

Table 5. Spaces with negative performance and relevant employee feedback.

| DAR Code | Space Name   | Negative Performance | Employees ’ Feedback (Categorized through Global Analysis Framework) | Global Analysis Framework |
|----------|--------------|-----------------------|---------------------------------------------------------------------|---------------------------|
| 2GG      | Grey Room    | Very low presence     | Lack of natural light (C)                                           | C. Health and wellbeing   |
|          |              |                       | Artificial light is inadequate for working (C)                      | A. User experience        |
|          |              |                       | Difficult access through another meeting room (A)                   |                           |
| 2I       | Imperial Room| Low presence          | Smaller meeting rooms were occupied (B)                              | B. Operations             |
|          |              |                       | Need of other space for concentration (A)                            | A. User experience        |
|          |              |                       | Not designed with functional furniture to work (A)                   |                           |
| 0A       | Altar        | Very low presence     | Too noisy (C)                                                        | A. User experience        |
|          |              |                       | Space for events or presentations too exposed (A)                    | C. Health and wellbeing   |

Table 6 shows the occupancy of spaces regarding the specific users of a team; their presence was highly concentrated in the Pradera space. This was because of the presence of screens and the proximity to meeting rooms and other members of their team and the teams they work with.

3.2. Occupancy Results

Correlating the presence data with the capacity of each space enables the understanding of the occupancy of each DAR (Table 7). The research shows a disparity in occupancy of spaces; when understanding workplace occupancy, the targeted occupancy for the current study is to be between 70 and 90% of the capacity of the space.

**Occupancy per DAR = Number of users/Capacity of the DAR**
### Table 6. Design team presence per DAR. Numbers indicate the number of employees from design team present at each spaces per hour. Dark colors highlight the areas with more users present at a time.

| Floor | DAR Code | DAR | 09:00 | 09:30 | 10:00 | 10:30 | 11:00 | 11:30 | 12:00 | 12:30 | 13:00 | 13:30 | 14:00 | 14:30 | 15:00 | 15:30 | 16:00 | 16:30 | 17:00 | 17:30 | 18:00 |
|-------|----------|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 0     | A        | Altar |       | 1     |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | C        | Clients |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | F        | Flower |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | K        | Kitchen |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | R        | Reception |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | W        | Workshop |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | FP       | Fix Position | 0 | 1 |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | G        | Grey |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| 1     | J        | Garden |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | O        | Orange |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | P        | Pradera |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | RR       | Red |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | S        | Salon |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | V        | Video |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | D        | Dungeons |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | GG       | Grey |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | I        | Imperial |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | TOTAL    |       | 2 | 3 | 7 | 8 | 10 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 |

### Table 7. Occupancy/capacity per DAR (measured in %). Numbers indicate the number of employees occupying each space divided by the capacity of the space, expressed as a percentage. The number of employees present at each space per hour. Dark colors highlight the areas with more users present at a time.

| Floor | DAR Code | DAR | 09:00 | 09:30 | 10:00 | 10:30 | 11:00 | 11:30 | 12:00 | 12:30 | 13:00 | 13:30 | 14:00 | 14:30 | 15:00 | 15:30 | 16:00 | 16:30 | 17:00 | 17:30 | 18:00 |
|-------|----------|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 0     | A        | Altar |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | C        | Clients |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | F        | Flower |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | K        | Kitchen |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | R        | Reception |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | W        | Workshop |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | FP       | Fix Position |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | G        | Grey |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
| 1     | J        | Garden |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | O        | Orange |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | P        | Pradera |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | RR       | Red |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | S        | Salon |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | V        | Video |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | D        | Dungeons |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | GG       | Grey |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | I        | Imperial |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|       | TOTAL    |       | 17 | 40 | 62 | 81 | 79 | 79 | 85 | 94 | 92 | 92 | 89 | 96 | 77 | 85 | 81 | 81 | 83 | 77 |       |       |

Regarding I, the Imperial meeting room, it can be observed that it was under capacity for most of the time, or being used by 1 or 2 employees, whereas R, GG, and OO were well sized. Informal Areas are designed to be used occasionally.

Valued-added spaces are designed for specific moments of the day or events; rather than recording the average occupancy during the day, the occupancy check should be done
at these specific moments of time during peak occupancy. In this study, the value-added space is the kitchen, and the lunch space and occupancy were checked regarding peaks of occupancy during lunchtime (13:30-15:30) (see Table 8).

Table 8. Occupancy table highlighting kitchen occupancy during regular lunchtime (between 13:30 and 15:30). Numbers indicate the number of employees occupying the kitchen divided by the capacity of the space, expressed as a percentage. The number of employees present at each space per hour. Dark colors highlight the areas with more users present at a time.

| Floor | DAR Code | DAR | 09:00 | 09:30 | 10:00 | 10:30 | 11:00 | 11:30 | 12:00 | 12:30 | 13:00 | 13:30 | 14:00 | 14:30 | 15:00 | 15:30 | 16:00 | 16:30 | 17:00 | 17:30 | 18:00 |
|-------|----------|-----|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 0     | A Altar  | 50  | 25    | 25    | 25    | 25    | 25    | 25    | 25    | 25    | 25    | 25    | 25    | 25    | 25    | 25    | 25    | 25    | 25    | 25    |
|       | C Clients| 14  | 29    | 29    | 29    | 29    | 29    | 29    | 29    | 29    | 29    | 29    | 29    | 29    | 29    | 43    | 29    | 29    | 43    | 43    |
|       | F Flower | 13  | 38    | 50    | 50    | 38    | 38    | 50    | 50    | 50    | 50    | 50    | 50    | 50    | 50    | 50    | 50    | 50    | 50    | 38    |
|       | K Kitchen| 6   | 6     | 6     | 13    | 6     | 13    | 13    | 6     | 6     | 31    | 25    | 13    | 9     | 13    | 13    | 13    | 13    | 13    | 13    |
|       | R Reception| 50 | 50    | 100   | 100   | 100   | 100   | 100   | 100   | 50    | 50    | 50    | 50    | 50    | 50    | 50    | 100   | 100   | 100   |
|       | W Workshop| 5   | 5     | 15    | 20    | 20    | 25    | 25    | 25    | 25    | 30    | 30    | 25    | 25    | 25    | 25    | 30    | 30    | 25    | 25    |

3.3. Duration of Stay Results

As the assessment of duration of stay data requires identifying who is occupying each space at each moment of time, it was only enabled by QMs and QD. Figure 10 shows the average timespan of the users per DAR. Timespans demonstrate the purpose and use of space. Workspaces are designed for longer timespans whereas informal areas are designed for shorter timespans or occasional interactions. Data are filtered by eliminating any stays shorter than 10 min. Although QD could accurately register stays shorter than 10 min, both QM studies could not. QMv could only register stays every 30 min during each walkthrough, and for QMs the employees would forget to register their short stays for coffees or chats as they were focused on their daily tasks. To ensure accuracy and eliminate randomization, the minimum stay registered was 10 min; this was communicated to employees for the QMs, and data for short stays were erased from the study for QD.

Figure 10. Graph showing average stay per DAR in minutes.
3.4. Reiteration Results

Only the QMs and QD enabled reiteration assessment because they are the only data collection methods that enable the identification of the occupants of the spaces. Due to QMs being significantly difficult to implement and unreliable, QD is essentially the only way to understand users’ choices, which is fundamental in a flexible workspace. Understanding users’ preferences enables a better understanding of the sample to improve employee-centric spatial design.

Reiteration of space usage is essential to understanding work dynamics of the employees. Insights gained from free movement choice-habits tailored to the user profiles enable future HCD of spaces [53,62]. Reiterative presence in certain areas or what is called “iteration” shows satisfaction with space. It enables the understanding of occupancy trends and the measurement of the popularity of each space. When designing office spaces for flexible users, the intention is to design attractive workspaces for the different teams and user profiles; employees occupy different spots and interact between teams to foster collaboration and creativity [63].

Figure 11 shows the popularity index of spaces, highlighting the spaces that have been occupied by users of different teams. The spaces with the highest popularity indexes have been occupied by users that belong to different teams or departments, improving the number of indirect interactions by sitting close to each other.

| Floor | DAR Code | DAR |
|-------|----------|-----|
| A     | Altar    |     |
| C     | Clients  |     |
| F     | Flower   |     |
| K     | Kitchen  |     |
| R     | Reception|     |
| W     | Workshop |     |
|       | FP       |     |
|       | Fix Position |     |
|       | G        |     |
|       | Green    |     |
|       | J        |     |
|       | Garden   |     |
|       | O        |     |
|       | Orange   |     |
|       | P        |     |
|       | Pradera  |     |
|       | RR       |     |
|       | Red      |     |
|       | S        |     |
|       | Salon    |     |
|       | V        |     |
|       | Video    |     |
| D     | Dungeons |     |
| GG    | Grey     |     |
| I     | Imperial |     |

Figure 11. Space popularity graph (each color represents an anonymized employee).

3.5. Proximity between Users

An evolution from the previous learning, user choice, is the correlation between users and the proximity to others, directly studying the relations between teams and users and what spaces are regarded as concentration spaces or formal or informal interaction between users [64,65]. A future line of research could be to further analyze interaction patterns between users and how space enhances or limits those interactions.

4. Discussion

It is important to consider that this study was conducted during a specific moment in time, during one week in May 2019, pre-COVID-19. The importance of this study for a pandemic and post-pandemic period is related to the possibility to use QD and Wi-Fi tracking methods to understand behavioral patterns of the use of the office and occupancy specifically now after a pandemic when workplace dynamics are evolving and quickly changing due to restrictions, regulations, and growth of hybrid and flexible
new ways of working. QD enables a scalable, fast sensor-free method to understand workplace dynamics.

The relevance of the paper becomes essential to a post-COVID-19 situation, when offices are going back to presential or semipresential work and there is a critical need to measure occupancy of spaces due to health situations and compliance with COVID-19 regulations in constant evolution.

QD proved to be the only feasible assessment method that enables an almost real-time measure of occupancy of spaces inside an office with any degree of mobility, and Wi-Fi is the only assessment tool that is already installed in most of the current offices and enables a fast analysis, 24 h, without added manpower (without viewers like QMv), self-registration QMs (unsustainable for the long run), or additional equipment such as sensors. Using Wi-Fi as an indoor location technique and QD as the assessment methodology would enable tracking and ensuring health and wellbeing in the offices, as well as ensuring occupancy compliance and optimization of spaces.

Regarding POE, an additional value of QD methods relies on the scalability of the assessment, as QD could be performed at any moment once the mechanism for data collection is established, whereas both QM methods require a higher investment in time and budget to be performed over the period and ensure accurate human-centered assessment over the period.

QD and QMs also enabled the correlation of the information collected with the different users, later aggregated and anonymized. Therefore, QD and QMs enable a deeper analysis of behavioral routine and employees’ relationships if segregated by parameters such as department, team, hierarchy, and sex. This enrichment of the data enables the undertaking of deeper studies towards human-centered, sustainable, and inclusive workplaces.

Regarding users’ feedback on the three parts of the study, between the three different collection methods, the users highlighted that they preferred QD data collection because it was less intrusive than QMv and did not require any task to be done by themselves, unlike QMs.

4.1. Global Occupancy of the Workplace

The first conclusion is that users, as they have freedom of choice, tend to sit in the spaces that suit their preferences of spatial comfort or team networks and habits. The three methods, QD, QMs, and QMv, enable the measurement of the global occupancy of the workplace. The office space has a capacity of 48 employees (Figure 12) (plus occasional external visitors); when employees were asked about their level of satisfaction with the space, their answer was that the office was overcrowded and required additional capacity. The average occupancy measured in the workspace was 86%, the median being 90% and the highest peak being 106%. The workspace never surpassed the capacity of the space by more than 6% of the total. The problem was, therefore, not the global occupancy but the uneven distribution.

4.2. Occupancy per Space (Measured in DAR)

The occupancy of the different spaces is uneven (Table 6). There are two spaces that often face overcapacity, namely Pradera and the Jardín. Both spaces are in the central area of the office, close to the meeting rooms and between each other. For Pradera, employees highlighted the ergonomic chairs; the fact that several workstations have double screens, despite these only being 30% of the total workstations; the size of the DAR that enables medium-sized teams to sit nearby; and the proximity to the meeting rooms. In the case of Jardín, the reasons given were different, including the comfort of the chairs, the silence, the natural light, and the views, as it is the only area in the office with a view of the park.
Accordingly, the spaces that have the lowest occupancy ratios have informal and no working chairs, a lack of natural light, and low artificial light. The relevance of the study relies on the efficiency of understanding the spaces to identify why they are less occupied and to understand what the preference between the users is. The study of occupancy and distances is of vital relevance in a post-pandemic future workplace, where occupancy will be constantly monitored, as will the quality of space, comfort, light, and ventilation, to prevent health risks and ensure user comfort.

4.3. Future Lines of Research

A future line of research could repeat the study during a pandemic period to compare results and outcomes. An additional future line of research would be to perform the same experiment after COVID-19 when offices return to 100% capacity to analyze differences in routines and use of space before and after COVID-19.

A future line of research could study “occasional encounters”, short stays of less than 10 min in the office; these data were dismissed from the current study to focus on other patterns and behaviors.

Other data sources could add new dimensions to the data analysis such as human resources datasets to cross occupancy and usage insights with user experience, satisfaction [50,66], productivity, or performance [47,67–69].

A future line of research could be to use the methods of space analysis (QMs, QMv, and QD) to focus on different types of employees according to their use of spaces. Employees have similarities and differences in the use of space; when understanding the use of space dynamics, these different patterns create what are called user profiles or “personas”. This detailed study can enable the development of what are called “personas” in a digital categorization of different typical employees according to their use of space that remains anonymous and aggregated.

5. Limitations

There are relevant limitations to the current study. First, the authors acknowledge that the geographical, cultural, and temporal contexts of the collection of the data inputs impact the output of the study. This study was developed in an office building in Madrid during 2019, pre-COVID-19. The social, cultural, economic, and environmental contexts are relevant to the study and impact the final conclusions. The aim of the current work was not to generalize patterns of use and behavior in the office. Instead, the authors intended to demonstrate how POE digitally driven data analysis can provide valuable insights and
new opportunities for spatial analysis of the office spaces, especially after COVID-19 when office spaces are redefining a new way of working.

6. Conclusions

The study demonstrates that data analysis of the workplace through employees’ digital trails and indoor location techniques enables a more complete, efficient, and quantifiable analysis of the workplace occupancy and usage towards future HCD of spaces.

The following conclusions were reached:

1. “Flexible workspaces” require data analysis to understand the levels of occupancy and use of the workplace and to assess user experience, operations, and health and wellbeing feedback. The POE spatial analysis tool can analyze the overall office performance and provide a detailed understanding of the use of the different spaces and the preferences and work dynamics of users.

2. QD was demonstrated to be an innovative method with added-value insights on office space use and user dynamics. It could be implemented in other workspaces in order to understand post-COVID-19 use of spaces and evolving work dynamics. It is seamless, scalable, and 24 h, without additional infrastructure, and it can be managed remotely, ensuring the health and wellbeing of employees and enabling mobility in space and compliance with both COVID-19 and employee privacy regulations.

3. Using existing digital infrastructure, such as Wi-Fi digital trails, enables continuous and cost-efficient data collection that provides insights not obtainable by analog methods. They are also perceived as less intrusive by employees and can manage greater amounts of data over time with little to no infrastructure, thus being more scalable.

4. Workplace data analytics show valuable insights addressing not only COVID-19 regulations but also space performance, team dynamics, employee routines, and levels of satisfaction with space. This will become essential to shaping future space learning from environments in continuous change.

The study demonstrates that employees who are given the opportunity to move and choose where to work value spaces that foster team building and wellbeing. Spaces that enable networking activities and are close to meeting rooms and spaces with ergonomic furniture and high-quality screens and chairs were preferred to spaces with less comfort, little access to natural light, low artificial light, and isolated or uncomfortable furniture, which were unoccupied for the majority of the assessed period.

Data analytics will become a basis for understanding workspace operations, user dynamics and behavior, and spatial wellbeing to improve spatial design for the future of spaces.

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**Abbreviations**

The following abbreviations are used in this manuscript:

- ABW: Activity-based working
- AP: Access point
- BICG: Business Innovation Consulting Group
- COVID-19: Coronavirus disease 2019
- DAR: Minimum measurable area space distinguished by the measurement tool
- GDPR: General Data Protection Regulation
- HCD: Human-centered design
- MDPI: Multidisciplinary Digital Publishing Institute
- POE: Post-occupancy evaluation
- QMs: Quantitative manual “self-registering”
- QMv: Quantitative manual “viewers”
- QD: Quantitative digital
- VAS: Value-added services
- Wi-Fi: Wireless local area network

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