UNIVERSIDAD
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DOCTORAL THESIS

ARCHITECTURE FOR SUSTAINABLE HOTELS: ANALYSIS OF CURRENT MEASURES AND PROPOSAL OF ENVIRONMENTAL STRATEGIES

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TITULO: *ARCHITECTURE FOR SUSTAINABLE HOTELS: ANALYSIS OF CURRENT MEASURES AND PROPOSAL OF ENVIRONMENTAL STRATEGIES*

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PD. INGENIERÍA AGRARIA, ALIMENTARIA, FORESTAL
Y DE DESARROLLO RURAL SOSTENIBLE
UNIVERSIDAD DE CÓRDOBA

ARCHITECTURE FOR SUSTAINABLE HOTELS: ANALYSIS OF CURRENT MEASURES AND PROPOSAL OF ENVIRONMENTAL STRATEGIES

ARQUITECTURA PARA HOTELES SOSTENIBLES: *ANÁLISIS DE LAS MEDIDAS ACTUALES Y PROPUESTA DE ESTRATEGIAS Y HERRAMIENTAS MEDIOAMBIENTALES.*

AUTHOR: María Magdalena Serrano Baena
DIRECTORS: Dr. Rafael Enrique Hidalgo Fernández and Dr. Paula Mª Triviño Tarradas
DEPARTMENT: Graphic Engineering, University of Cordoba
DATE: July 2023

A mis abuelos

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INFORME RAZONADO DE LAS/LOS DIRECTORAS/ES DE LA TESIS

Este documento se presentará junto con el depósito de la tesis en https://moodle.uco.es/ctp3/

DOCTORANDA/O

Maria Magdalena Serrano Baena

TÍTULO DE LA TESIS:

Architecture for sustainable hotels: analysis of current measures and proposal of environmental strategies

INFORME RAZONADO DE LAS/LOS DIRECTORAS/ES DE LA TESIS
(se hará mención a la evolución y desarrollo de la tesis, así como a trabajos y publicaciones derivados de la misma)

La presente Tesis Doctoral se centra en el diseño y evaluación de una arquitectura sostenible de hoteles en el marco de la Unión Europea. Temas que se encuentran actualmente en auge en estos momentos de transición ecológica y digital. Ya que los planes ambientales para las próximas décadas resaltan la gran importancia de un turismo sostenible, para lo que es necesario contar con una arquitectura hotelera, también sostenible, desde su diseño.

Este trabajo ha seguido la modalidad de compendio de artículos científicos, cumpliendo con los requisitos que exige la Universidad de Córdoba, asegurando que los resultados obtenidos y sus conclusiones han alcanzado con creces los estándares rigurosos y el respaldo científico necesario para su publicación en revistas de alto impacto. La investigación, por tanto, comprende cuatro artículos científicos publicados en prestigiosas revistas internacionales, la publicación de un capítulo de libro y la participación en una conferencia internacional. Por lo tanto, la fase inicial de esta investigación se ha centrado en la identificación, clasificación y cuantificación de las implicaciones de las certificaciones energéticas, en particular el Building Research Establishment Environmental Assessment Method (BREEAM), con uso generalizado en Europa. Se ha explorado cómo dicha certificación contribuyen a lograr los Objetivos de Desarrollo Sostenible de la Agenda 2030, dentro del marco del diseño hotelero. Con este fin, se han desarrollado dos artículos científicos que abordan estas hipótesis. El primero, titulado "Implications of BREEAM Sustainability Assessment on the Design of Hotels" y el segundo, titulado "How the Implementation of BREEAM in Hotels Could Help to Achieve the SDGs. La segunda parte de la investigación se ha centrado en lograr una recuperación sostenible para el sector en la era Postpandemia. Se han identificado elementos en los servicios, el diseño y la arquitectura de hoteles que podrían mejorar la resiliencia. Estas hipótesis se han desarrollado y explorado en el artículo científico titulado "Promoting the Sustainable Recovery of Hospitality in the Post-Pandemic Era: A Comparative Study to Optimize the Servicescapes". Por último, la última parte de la investigación, ha incluido el desarrollo y aplicación de una herramienta sostenible en forma de metodología basada en BIM, para optimizar el cálculo del Análisis de Ciclo de Vida (ACV) en edificios complejos, como los hoteles. Así lo muestra el artículo científico titulado "Optimising LCA in complex buildings with MLCAQ: a BIM-based methodology for automated multi-criteria materials selection".

- **Serrano-Baena, M.M.; Triviño-Tarradas, P.; Ruiz-Díaz, C.; Hidalgo Fernández, R.E. "Implications of BREEAM Sustainability Assessment on the Design of Hotels". Sustainability 2020, 12, 6550. https://doi.org/10.3390/su12166550.**
  Journal Rank: JCR - Q2 (Environmental Sciences)
  Impact Factor: 3.889 (2021);

- **Serrano-Baena, M.M.; Hidalgo Fernández, R.E.; Carranza-Cañadas, P.; Triviño-Tarradas, P. "How the Implementation of BREEAM in Hotels Could Help to Achieve the SDGs". Appl. Sci. 2021, 11, 11131. https://doi.org/10.3390/app112311131.**
  Journal Rank: JCR - Q2 (Engineering, Multidisciplinary)
  Impact Factor: 2.838 (2021);

- **Serrano-Baena, M.M.; Hidalgo Fernández, R.E; Ruiz-Díaz C.; Triviño-Tarradas, P. "Promoting the Sustainable Recovery of Hospitality in the Post-Pandemic Era: A Comparative Study to Optimize the Servicescapes". Int. J. Environ. Res. Public Health 2023, 20(2), 1100; https://doi.org/10.3390/ijerph20021100**
  Journal Rank: JCR – Q1 (Public, Environmental & Occupational Health)

Impact Factor: 4.614 (2022);

- **Serrano-Baena, M.M.; Ruiz-Díaz, C.; Gilabert Boronat, P.; Mercader-Moyano, P; "Optimising LCA in complex buildings with MLCAQ: A BIM-based methodology for automated multi-criteria materials selection". Energy and Buildings 2023, 294, 113219. https://doi.org/10.1016/j.enbuild.2023.113219**
Journal Rank: JCR – Q1 (Construction & Building Technology)
Impact Factor: 6.700 (2022);

Asimismo, se informa que la doctoranda ha seguido con un destacado aprovechamiento las actividades propuestas por la Comisión Académica del Programa de Doctorado en Ingeniería Agarria, Alimentaria, Forestal y del Desarrollo Rural Sostenible.

Por todo ello, se autoriza la presentación de la tesis doctoral.

Córdoba, a 13 de julio de 2023

Las/los directoras/es

Firmado por HIDALGO FERNANDEZ RAFAEL ENRIQUE - ***1451** el día 13/07/2023 con un certificado emitido por AC FNMT Usuarios

TRIVIÑO TARRADAS PAULA MARIA - 30794106G

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Fecha: 2023.07.13 16:43:27 +02'00'

Fdo.:R.E. Hidalgo Fdez. y P. Triviño Tarradas

AGRADECIMIENTOS

Esta página es la última que escribo de todo el trabajo, no por menos relevancia para mí sino por todo lo contrario. En este apartado quiero corresponder en forma de agradecimiento a todas las personas que, tanto en lo profesional como en lo personal, han contribuido con el desarrollo de esta tesis.

En primer lugar, me gustaría agradecer a mis directores, Rafael Hidalgo y Paula Triviño, por su contribución. Su experiencia, consejos e ideas aportados en estos años me han servido para abordar esta investigación de manera satisfactoria. Su optimismo a lo largo de este proceso ha sido fundamental para su finalización. También me gustaría agradecer a la investigadora Pilar Mercader, el haber compartido conmigo sus conocimientos sobre la construcción sostenible y por guiarme a lo largo de nuestra publicación.

En un ámbito más personal, me gustaría agradecer a mis padres por los valores que me han dado de esfuerzo y perseverancia, valores que han sido fundamentales para poder alcanzar siempre mis propósitos. También quiero darles las gracias por haberme animado a empezar este doctorado, de no ser así, no estaría hoy escribiendo estas líneas. A mi hermana, Raquel, por enseñarme la importancia de ayudar a los demás y por estar a mi lado, defendiéndome siempre.

A mis tíos, Isabeli y Rafa, por quererme como a una nieta y por su generosidad infinita.

A Carlos, que ha sido mi principal apoyo en el día a día y quien mejor ha conocido los altibajos de este trabajo. Gracias por su calma y por cuidar de Luna cuando yo no podía. Gracias también por haber cogido la maleta para acompañarme, tantas veces ha sido necesario y sin pensárselo.

Para finalizar, quiero dedicar estas últimas palabras a mis abuelos. Por un lado, a mi abuela Luisa, por crear ese vínculo familiar tan especial que tenemos gracias a ella, seguro que sigue disfrutando viéndonos a todos reunidos allá donde esté. Y, por otro lado, a mis abuelos Manolo y Pepa, por cuidar de mí siempre con todo su corazón. Gracias por demostrarme que la generosidad, la bondad y la sencillez van por encima de todo. A vosotros os dedico este trabajo.

STRUCTURE OF THE DISSERTATION

This research work has been developed during a period of transition and uncertainty, encompassing personal interest in sustainable hotel architecture derived from my professional experience in the sector and the European Union's emphasis on ecological and digital transition. The future environmental plans for the upcoming decades highlight the significance of sustainable tourism and hotel architecture, underscoring the necessity for further research in these domains to fulfil these plans. Moreover, the unforeseen arrival of the global COVID-19 pandemic has further reinforced the relevance of this research, considering its detrimental impact on the tourism and hospitality industry. Consequently, it became imperative to incorporate this new context into the research, focusing on facilitating a responsible and sustainable recovery of the sector from a design and architectural perspective. This document follows the modality of a compendium of scientific papers, ensuring that the results and conclusions derived from the research adhere to the rigorous standards and scientific support required for publication in high-impact journals, specifically those within the first two quartiles of the "Journal Citation Report" (JCR) and “Scimago Journal Rank” (SJR) indicators.

The present research comprises four research papers published in esteemed international journals, a book chapter publication, and a participation in an international conference. Thus, the initial phase of this research primarily involves the identification, classification, and quantification of the implications of energy certifications, particularly the Building Research Establishment Environmental Assessment Method (BREEAM), which holds widespread usage in Europe. It has been explored how such certifications contribute to achieving the Sustainable Development Goals within hotel design (*FAO,2023*, s. f.). In order to do this, two scientific papers have been developed covering these hypotheses. The first one, under the title *“Implications of BREEAM Sustainability Assessment on the Design of Hotels”* and the second entitled *“How the Implementation of BREEAM in Hotels Could Help to Achieve the SDGs”* of which a book chapter was extracted and published under the same title. The second part of the research focuses on achieving a sustainable recovery for the sector in the post-pandemic era. Its primary objective is to propose sustainable measures for the hotel’s servicescapes* and promote a sustainable recovery of the sector. While the research primarily focuses on hotels, its findings can be extrapolated to buildings with similar characteristics. Notably, this research stands out as one of the pioneering studies about servicescapes that assists the One Planet Vision proposed by the World Tourism Organization (UNWTO), contributing to a responsible and sustainable recovery. To accomplish this, the study examines the impact of hotel services on people's well-being and investigates their experiences of staying in hotels during the pandemic, in 2020, against their opinions about the same topics in 2022. It identifies elements in the services, design, and architecture of hotels that could enhance resilience. These hypotheses have been developed and explored in the scientific paper titled "*Promoting the Sustainable Recovery of Hospitality in the Post-Pandemic Era: A Comparative Study for Optimizing Servicescapes*". Lastly, the last part of the research, includes the development and application of a sustainable tool in the shape of a BIM-based methodology, to optimise the calculation of the Life Cycle Assessment (LCA) in complex buildings, such as hotels. This is shown in the scientific paper entitled *“Optimising LCA in complex buildings with MLCAQ: a BIM-based methodology for automated multi-criteria materials selection”,* where a hotel of 39 storey hotel has been used as a case study to validate the system.

The research carried out is presented as a single document composed of the main sections of the scientific method as objectives, introduction and context of the research, literary review that emerges from the different research related to the study, the methodology used and the tools that compose it, the results extracted from the research and, finally, the discussion. The introduction,

context and objectives of the thesis are common. The methodology and results have been divided into sections that articulate each of the publications, following a chronological sequence of publication and logic in the research process that it comprises. The next five chapters of the document, are related with the published research articles that have shaped this research are included with their related references and other research contributions. The last chapter, presents the main conclusions extracted from the research, limitations and future lines of research that unify the set of studies and culminate the present investigation. The conclusions and discussion drawn have been grouped to provide general knowledge about the study conducted. Regarding the language of this research, the scientific articles have been developed exclusively in English, following the internationalization guidelines. The rest of the thesis has been developed also in English with relevant parts in Spanish as well, given the topic addressed and the economic, social and environmental significance it may have internationally. Thus, a complete document is presented in English, with translations into Spanish in the summary, introduction, objectives and conclusions. This will allow its national and international diffusion. The work has been extended to an international context with a total of 6 months of research stays in tourism and hospitality architecture research centers in the United Kingdom and Portugal. These stays have been especially useful to examine hotels with different geography, to develop comparative studies and share knowledge among expert researchers in the field addressed here. The results obtained provide useful data at a technical and social level from an international perspective, guaranteeing the ecological transition in the hospitality sector. The usefulness of integrating sustainable practices such as energy certifications in hotel architecture has been demonstrated in order to successfully address future sustainable plans. The conclusions of the research incorporate implications in the design of hotels, promoting an ecological regeneration in the tourism sector from the first phases of its development. The international scope includes case studies conducted in England and Spain, contributing to the development and publication of the research papers presented here.

* servicescape: It is defined by Booms and Bitner as *"The environment in which the service is assembled and in which the seller and customer interact, combined with tangible commodities that facilitate performance or communication of the service"* (Booms & Bitner, 1981).

ESTRUCTURA DE LA TESIS

La presente tesis ha sido desarrollada en un período de transición e incertidumbre, promovida por un interés personal en la arquitectura sostenible de hoteles derivado de mi experiencia profesional en el sector y el énfasis de la Unión Europea en la transición ecológica y digital. Los planes ambientales futuros para las próximas décadas resaltan la importancia del turismo sostenible y la arquitectura hotelera, subrayando la necesidad de más investigaciones en estos campos para cumplir con dichos planes. Además, la llegada inesperada de la pandemia global de COVID-19 ha reforzado aún más la relevancia de esta investigación, considerando su impacto negativo en la industria del turismo y la hostelería. En consecuencia, se volvió imperativo incorporar este nuevo contexto en la investigación, centrándose en facilitar una recuperación responsable y sostenible del sector, desde una perspectiva arquitectónica y de diseño. Este trabajo sigue la modalidad de compendio de artículos científicos, asegurando que los resultados y conclusiones derivados de la investigación cumplan con los estándares rigurosos y el respaldo científico necesario para su publicación en revistas de alto impacto, específicamente aquellas dentro de los dos primeros cuartiles del indicador "Journal Citation Report" (JCR).

La investigación, por tanto, comprende cuatro artículos científicos publicados en prestigiosas revistas internacionales, la publicación de un capítulo de libro y la participación en una conferencia internacional. Por lo tanto, la fase inicial de esta investigación se centra en la identificación, clasificación y cuantificación de las implicaciones de las certificaciones energéticas, en particular el Building Research Establishment Environmental Assessment Method (BREEAM), que tiene un uso generalizado en Europa. Se ha explorado cómo dicha certificación contribuyen a lograr los Objetivos de Desarrollo Sostenible de la Agenda 2030, dentro del marco del diseño hotelero. Con este fin, se han desarrollado dos artículos científicos que abordan estas hipótesis. El primero, titulado *"Implications of BREEAM Sustainability Assessment on the Design of Hotels"* y el segundo, titulado *"How the Implementation of BREEAM in Hotels Could Help to Achieve the SDGs"*, del cual se extrajo un capítulo de libro y se publicó bajo el mismo título. La segunda parte de la investigación se centra en lograr una recuperación sostenible para el sector en la era Postpandemia. El objetivo principal aquí es proponer medidas en los servicescapes* del hotel para promover una recuperación sostenible en el sector. Si bien el estudio se centra en hoteles, sus hallazgos se pueden extrapolar a edificios con características similares. Es importante destacar que esta investigación es uno de los estudios pioneros que arroja datos actualizados sobre los servicescapes para apoyar el One Planet Vision propuesto por la Organización Mundial del Turismo (OMT), contribuyendo a una recuperación responsable y sostenible. Para lograr esto, el estudio examina el impacto de los servicios de hotel en el bienestar de las personas e investiga sus experiencias de hospedaje en hoteles durante la pandemia, en 2020, contrastándolas con sus opiniones sobre los mismos temas en 2022. Identifica elementos en los servicios, el diseño y la arquitectura de hoteles que podrían mejorar la resiliencia. Estas hipótesis se han desarrollado y explorado en el artículo científico titulado *"Promoting the Sustainable Recovery of Hospitality in the Post-Pandemic Era: A Comparative Study to Optimize the Servicescapes"*. Por último, la última parte de la investigación, incluye el desarrollo y aplicación de una herramienta sostenible en forma de metodología basada en BIM, para optimizar el cálculo del Análisis de Ciclo de Vida (ACV) en edificios complejos, como los hoteles. Así lo muestra el artículo científico titulado *"Optimising LCA in complex buildings with MLCAQ: a BIM-based methodology for automated multi-criteria materials selection"*, donde se ha utilizado como caso de estudio un hotel de 39 plantas para validar el sistema propuesto.

El trabajo de investigación se presenta como un único documento compuesto por los principales apartados del método científico, objetivos, introducción y contexto de la investigación,

revisión literaria que emerge de las diferentes líneas temáticas afines al estudio, la metodología llevada a cabo y las herramientas que la componen, los resultados extraídos de la investigación y la discusión. La introducción, contexto y objetivos de la tesis son comunes. La metodología y resultados han sido divididos en secciones que articulan cada una de las publicaciones, siguiendo una secuencia cronológica de publicación y lógica en el proceso de investigación que comprende. Los siguientes capítulos incluyen los artículos científicos publicados que han dado forma a esta investigación y otras contribuciones científicas, todo ello ha sido incluido con su correspondiente bibliografía. El último capítulo, presenta las principales conclusiones extraídas de la investigación, limitaciones y futuras líneas de investigación que unifican el conjunto de estudios y culminan la presente investigación. Las conclusiones y discusión extraídas han sido agrupadas para proveer conocimientos generales sobre el estudio realizado. Con respecto al idioma de la presente investigación, los artículos científicos han sido desarrollados exclusivamente en inglés, siguiendo las directrices de internacionalización. El resto de la tesis se ha desarrollado en inglés con las partes relevantes también en español, dado el tema abordado y la transcendencia económica, social y medioambiental que pueda tener a nivel internacional. Así pues, se presenta un documento completo en idioma inglés, con traducciones al castellano en el resumen, introducción, objetivos y conclusiones. Esto va a permitir su difusión nacional e internacional. El campo de estudio de esta investigación se ha extendido a un contexto internacional con un total de 6 meses de estancias de investigación en centros de investigación de turismo y arquitectura hotelera en el Reino Unido y Portugal. Estas estadías han sido muy útiles para examinar hoteles con diferentes características geográficas, desarrollar estudios comparativos y compartir conocimientos entre expertos investigadores en el campo abordado aquí. Los resultados obtenidos aportan datos de gran utilidad a nivel técnico y a nivel social desde una perspectiva internacional, garantizando la transición ecológica en el sector hotelero. Se ha demostrado la utilidad de integrar prácticas sostenibles como las certificaciones energéticas en la arquitectura hotelera para poder abordar los futuros planes sostenibles con éxito. Las conclusiones de la investigación incorporan implicaciones en el diseño de hoteles, promoviendo una regeneración ecológica en el sector turístico desde las primeras fases de su desarrollo. El alcance internacional incluye casos de estudio realizados en Inglaterra y España, que han contribuido con el desarrollo y publicación de los artículos de investigación incluidos en el presente documento.

* servicescape: Es definido por Booms y Bitner como *"El entorno en el que se ensambla el servicio y en el que interactúan el vendedor y el cliente, combinado con productos tangibles que facilitan el desempeño o la comunicación del servicio"* (Booms & Bitner, 1981).

PUBLICATIONS AND COMMUNICATIONS

The research papers and communications developed for this thesis are presented below. The doctoral student has been the first author in all of the documents cited below:

RESEARCH ARTICLES

- **Serrano-Baena, M.M.;** Triviño-Tarradas, P.; Ruiz-Díaz, C.; Hidalgo Fernández, R.E. "Implications of BREEAM Sustainability Assessment on the Design of Hotels". *Sustainability* 2020, *12*, 6550. https://doi.org/10.3390/su12166550.
  Journal Rank: JCR - Q2 (*Environmental Sciences*)
  Impact Factor: 3.25 (2020);

- **Serrano-Baena, M.M.;** Hidalgo Fernández, R.E.; Carranza-Cañadas, P.; Triviño-Tarradas, P. "How the Implementation of BREEAM in Hotels Could Help to Achieve the SDGs". *Appl. Sci.* 2021, *11*, 11131. https://doi.org/10.3390/app112311131.
  Journal Rank: JCR - Q2 (*Engineering, Multidisciplinary*)
  Impact Factor: 2.83 (2021);

- **Serrano-Baena, M.M.;** Hidalgo Fernández, R.E; Ruiz-Díaz C.; Triviño-Tarradas, P. "Promoting the Sustainable Recovery of Hospitality in the Post-Pandemic Era: A Comparative Study to Optimize the Servicescapes". *Int. J. Environ. Res. Public Health 2023, 20(2), 1100;* https://doi.org/10.3390/ijerph20021100
  Journal Rank: SJR – Q2 (*Public, Environmental & Occupational Health*)
  Impact Factor: 0.83 (2022);

- **Serrano-Baena, M.M.;** Ruiz-Díaz, C.; Gilabert Boronat, P.; Mercader-Moyano, P; "Optimising LCA in complex buildings with MLCAQ: A BIM-based methodology for automated multi-criteria materials selection". *Energy and Buildings* 2023, *294*, 113219. https://doi.org/10.1016/j.enbuild.2023.113219
  Journal Rank: JCR – Q1 (*Construction & Building Technology*)
  Impact Factor: 6.7 (2023);

BOOK CHAPTER

- **Maria M Serrano-Baena,** Rafael E Hidalgo Fernández, Pilar Carranza-Cañadas, Paula Triviño-Tarradas. "How the Implementation of BREEAM in Hotels Could Help to Achieve the SDGs". In: *Prime Archives in Applied Sciences*. Hyderabad, India: Vide Leaf. 2022.

COMMUNICATIONS

- **Serrano-Baena, M.M.;** Hidalgo Fernández, R.E.; Carranza-Cañadas, P.; Triviño-Tarradas, P (2021). "How the Implementation of BREEAM in Hotels Could Help to Achieve the SDGs". *30th International Conference on GRAPHICS ENGINEERING, XXX INGEGRAF CONGRESS*. Valencia (Spain).

INTERNATIONAL STAYS

- **Leach Rhodes Walker;** 50 Dearmans Pl, Manchester M3 5LH.
  Stay: 04/05/20 – 07/08/20
- **Escola superior de gestão, hotelaria e turismo;** Campus da Pena, Faro
  Stay: 03/10/22 – 03/01/23

CHAPTER I.

COMPREHENSIVE SUMMARY OF THE RESEARCH

1. OBJECTIVES

Despite its global implications, there is not much research on how improving the sustainability of hotels could help to successfully achieve the neutrality for 2050 in the tourism and hospitality sectors. It is essential to understand what the necessary measures are in order to design a hotel that generates the least possible environmental impact and promote a circular economy. This will allow to achieve the future environmental plans and successfully complete the ecological and digital transition in the hospitality and tourism sectors. After defining the current situation of sustainability in the hospitality and tourism industries, the current research on energy certifications applied in hotels, the proposal of sustainable strategies and tools, analysis of the impact that the COVID-19 pandemic has had on the sector and the new challenges that they face in order to meet the SDGs has been presented. Subsequently, the main objectives established to contribute with future sustainable plans that are aiming to achieve neutrality in the year 2050, provide new solutions, tools and advances, from a sustainable architecture point of view in a hospitality and touristic context are presented. The specific objectives of this research are:

- **To Identify the implications that the international certificate of BREEAM has on the design of hotels.** To examine how its implementation impacts on the design of hotels and their management processes. This objective will be addressed in the scientific paper 1, “Implications of BREEAM Sustainability Assessment on the Design of Hotels”.

- **To expose the key design elements and sustainable upgrades required to obtain a positive evaluation of the assessment**. To structure the upgrades linked to each of the case studies based on their nature in a specific context. This objective will be addressed in the scientific paper 1, “Implications of BREEAM Sustainability Assessment on the Design of Hotels”.

- **To provide insights into the benefits that energy certifications might have to the 2030 Agenda.** Relating the sustainable upgrades with each of the SDGs and exposing which of those SDGs are the most benefited from BREEAM. This objective will be addressed in the scientific paper 2, “How the Implementation of BREEAM in Hotels Could Help to Achieve the SDGs”.

- **To present the main servicescape dimensions and attributes of a hotel to consider during a health crisis.** To evaluate the negative impact that COVID-19 has had on the hospitality industry, study previous servicescape scales and propose a new scale with adequate dimensions and attributes for a pandemic context. This objective will be addressed in the scientific paper 3, “Promoting the Sustainable Recovery of Hospitality in the Post-Pandemic Era: A Comparative Study to Optimize the Servicescapes”.

- **To analyse what are the expectations of people about hotels’ servicescapes during and after COVID-19.** A comparative study is developed between 2020 and 2022 to study how their sentiments have changed along the years. This objective will be addressed in the scientific paper 3, “Promoting the Sustainable Recovery of Hospitality in the Post-Pandemic Era: A Comparative Study to Optimize the Servicescapes”.

- **To expose the proposed attributes of hotels’ servicescapes that must be considered for a sustainable recovery of the hospitality and tourism industries.** In order to achieve the 2030 Agenda and following the One Planet Vision, the attributes that must be implemented in a hotel to recover from the pandemic are presented based on the obtained results. This objective will be addressed in the scientific paper 3, “Promoting the Sustainable Recovery of Hospitality in the Post-Pandemic Era: A Comparative Study to Optimize the Servicescapes”.

- **To propose sustainable tools that collaborate with the future sustainable plans.** These tools or strategies must facilitate the ecological and digital transitions by promoting a circular economy from the design phase. This objective will be addressed in the scientific paper 4, “Optimising LCA in complex buildings with MLCAQ: A BIM-based methodology for automated multi-criteria materials selection”.
- **To simplify the analysis of the life cycle and cost of execution**. Unifying the process is essential to support the ecological and digital transition in the construction sector, so the linkage between the bill of quantities, bill of materials and environmental impact is essential. This objective will be addressed in the scientific paper 4, “Optimising LCA in complex buildings with MLCAQ: A BIM-based methodology for automated multi-criteria materials selection”.

The objectives of the present research and the published articles each of them are related to, are shown in Figure I.1.

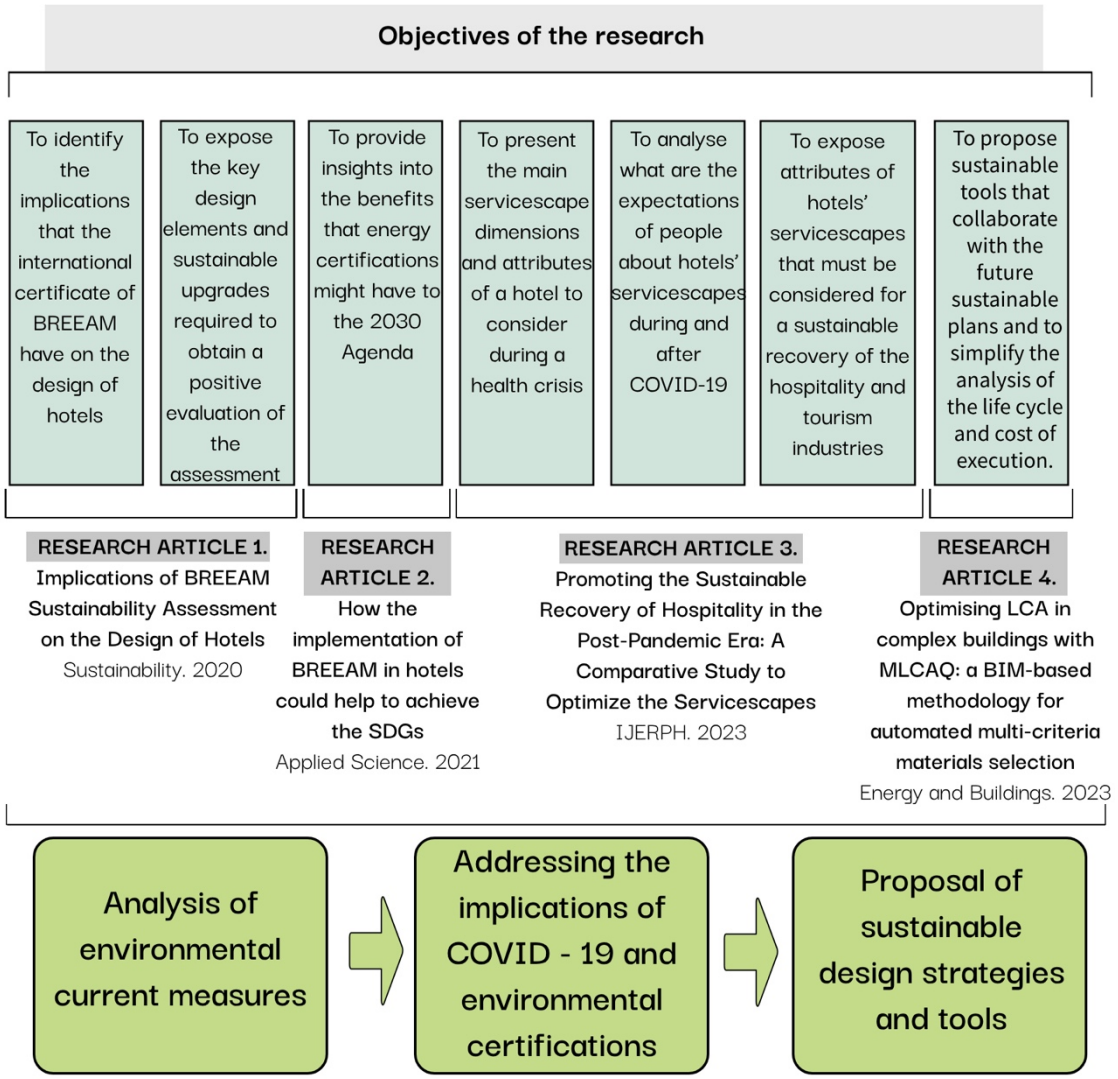

Figure I.1. Objectives of the research and related published research articles.

1. OBJETIVOS

A pesar de sus implicaciones globales, no hay mucha investigación sobre cómo mejorar la sostenibilidad de los hoteles podría ayudar a lograr con éxito la neutralidad para 2050 en el turismo y la hostelería. Es fundamental comprender cuáles son las medidas necesarias a tener en cuenta para diseñar un hotel que genere el menor impacto ambiental posible y promueve una economía circular. Esto permitirá alcanzar los futuros planes sostenibles a largo plazo y completar con éxito la transición ecológica y digital en los sectores de la hostelería y el turismo. Tras definir la situación actual de la sostenibilidad en la industria hotelera y turística, se ha expuesto la presente investigación sobre certificaciones energéticas aplicadas en los hoteles, propuesta de estrategias y herramientas sostenibles, análisis del impacto que ha tenido la pandemia del COVID-19 en el sector y los nuevos retos a los que se enfrentan para cumplir con los ODS. Posteriormente, se presentan los principales objetivos aquí establecidos para contribuir con futuros planes sostenibles que apunten a lograr la neutralidad en el año 2050, aportar nuevas soluciones, herramientas y avances, desde el punto de vista de la arquitectura sostenible en un contexto hotelero y turístico. Los objetivos específicos de la investigación buscan:

- **Identificar las implicaciones que tiene la certificación energética internacional de BREEAM en el diseño de hoteles.** Examinar cómo impacta su implementación en el diseño de los hoteles y sus procesos de gestión. Este objetivo se abordará en el artículo científico 1, “Implications of BREEAM Sustainability Assessment on the Design of Hotels”.

- **Exponer los elementos clave de diseño y mejoras sostenibles necesarias para obtener una evaluación positiva de la certificación.** Estructurar las actualizaciones vinculadas a cada uno de los casos de estudio en función de su naturaleza en un contexto específico. Este objetivo se abordará en el artículo científico 1, “Implications of BREEAM Sustainability Assessment on the Design of Hotels”.

- **Proporcionar información sobre los beneficios que las certificaciones energéticas pueden tener para la Agenda 2030.** Relacionar las mejoras sostenibles con cada uno de los ODS y exponer cuáles de esos ODS son los más beneficiados por BREEAM. Este objetivo se abordará en el artículo científico 2, “How the Implementation of BREEAM in Hotels Could Help to Achieve the SDGs”.

- **Presentar los principales atributos del servicescape de un hotel a considerar durante una crisis sanitaria. Ev**aluar el impacto negativo que ha tenido el COVID-19 en la industria de la hostelería, estudiar escalas de servicescape propuestas anteriormente y propone una nueva escala con dimensiones y atributos adecuados para un contexto de pandemia. Este objetivo se abordará en el artículo científico 3, “Promoting the Sustainable Recovery of Hospitality in the Post-Pandemic Era: A Comparative Study to Optimize the Servicescapes”.

- **Analizar cuáles son las expectativas de las personas sobre los servicescapes de los hoteles durante y después del COVID-19.** Se desarrolla un estudio comparativo entre 2020 y 2022 para estudiar cómo han cambiado sus sentimientos a lo largo de los años. Este objetivo se abordará en el artículo científico 3, “Promoting the Sustainable Recovery of Hospitality in the Post-Pandemic Era: A Comparative Study to Optimize the Servicescapes”.

- **Exponer los atributos de los servicescapes hoteleros a considerar para una recuperación sostenible de la industria hotelera y turística.** Para lograr la Agenda 2030 y siguiendo el One Planet Vision, se presentan los atributos a implementar en un hotel para recuperarse de la pandemia en base a los resultados obtenidos. Este objetivo se abordará en el artículo científico 3, “Promoting the Sustainable Recovery of Hospitality in the Post-Pandemic Era: A Comparative Study to Optimize the Servicescapes”.

- **Proponer herramientas sostenibles que colaboren con los futuros planes sostenibles.** Estas herramientas o estrategias deben de facilitar las transiciones ecológica y digital promoviendo una economía circular desde la fase de diseño. Este objetivo se abordará en el artículo científico 4, "Optimising LCA in complex buildings with MLCAQ: A BIM-based methodology for automated multi-criteria materials selection".

Los objetivos de esta investigación y los artículos publicados relacionados con cada uno de los objetivos, pueden verse en la Figura I.1.

2. INTRODUCTION AND CONTEXT

Climate change has emerged as one of the most significant challenges that must be addressed in the 21st century. The continuous emission of greenhouse gases by human activities has led to alarming consequences. Among these gases, carbon dioxide (CO_2) is particularly concerning due to its abundance and its ability to persist in the atmosphere for thousands of years. In fact, the construction sector alone is responsible for approximately 39% of the CO_2 emissions generated annually worldwide (*Data Overview*, s. f.). These emissions arise mainly from the energy used in building construction, waste disposal, transportation, and material manufacturing. Furthermore, buildings contribute to 35% of global industrial waste and consume 40% of total raw materials. Consequently, construction activities are major contributors to energy consumption and the depletion of raw materials on our planet. In this context, the tourism sector has undergone significant evolution in recent decades, yet it has received limited attention from various disciplines, with architecture being one of the least explored. The tourism industry, characterized by advances in technology, widespread internet access, and affordable air travel, experienced rapid growth prior to the COVID-19 pandemic. Just before the crisis, tourism represented approximately 12% of the world's Gross Domestic Product, making it a powerful ally in addressing the climate emergency and promoting responsible growth through the construction or renovation of sustainable hotels.

However, in order to achieve the ambitious goal of CO_2 neutrality by 2050, as outlined in the European Green Deal (*A European Green Deal*, s. f.), the tourism industry must make significant efforts to reduce its current emissions by 50% before 2030 and this reduction requires the active involvement of hotels. The hospitality industry has increasingly recognized the importance of environmental responsibility and incorporated it as a key corporate concern. The industry's long-term success hinges on adopting environmentally sound practices and demonstrating a commitment to responsible behaviors. Scholarly research, both theoretical and empirical, indicates that while the hospitality sector contributes positively to socio-economic development, it also bears responsibility for its negative environmental impacts (Su et al., 2020). One of the primary factors contributing to these impacts is the industry's exploitation of natural resources, which can lead to significant environmental damage such as air pollution, habitat loss, and soil erosion. In this context, the strategic adoption of environmental regulations and practices, including the pursuit of sustainability certifications, plays a pivotal role in bolstering corporate performance. By adhering to environmental regulations, companies demonstrate their commitment to responsible and sustainable business practices. Furthermore, actively seeking sustainability certifications signifies a proactive approach towards environmental stewardship, which can enhance a company's reputation, attract environmentally conscious consumers, and open doors to new business opportunities (Serrano-Baena et al., 2020). These initiatives not only contribute to improved environmental outcomes but also have the potential to generate long-term economic benefits and competitive advantages for organizations operating in today's sustainability-driven market.

Over the past decade, numerous researchers have dedicated their studies to exploring the incorporation of a circular economy into the construction and tourism industry (Ding et al., 2023; Shooshtarian et al., 2022). The prevailing models of production and consumption in the construction sector operate within a linear economy framework, following the "extraction-production-disposal" sequence. Unfortunately, this model lacks provisions for reusing discarded products and materials. In contrast, the circular economy represents a transformative shift, placing emphasis on a regenerative approach to production and consumption. This approach involves the design of manufactured products with enhanced value and longer lifecycles, the creation of versatile products that maximize utility, and the promotion of market competitiveness for recycled materials (Primc et al., 2020). The availability of tools and methodologies that facilitate the interpretation of existing information and

enable the generation of updated data is essential for navigating the ongoing digital and ecological transitions.

Efforts to restore high carbon density ecosystems and adopt collaborative technologies are essential in mitigating emissions (*COVID-19 Research for Hospitality Industry*, s. f.). The COVID-19 pandemic had a significant impact on the environment, resulting in notable reductions in greenhouse gas emissions and pollution levels. It also brought about sightings of various wildlife species in public areas. However, these positive environmental changes were short-lived as the world gradually returned to a sense of normalcy. Concerns have been raised regarding the relaxation of environmental regulations and policies during the COVID-19 crisis. While there were some immediate environmental benefits, the overall effect on global economies and societies has been devastating. The hospitality industry, particularly in developed countries, experienced temporary or permanent job losses, while the impact on the industry in less developed nations has been catastrophic. In the business sector, corporate sustainability and social responsibility have gained increasing importance for large companies. Leading companies in the hospitality industry have implemented corporate sustainability programs. The COVID-19 crisis presented both opportunities and challenges for these programs, however, it is crucial to acknowledge that the pandemic has limited financial resources, potentially forcing hospitality industry leaders to prioritize their core business operations. Despite the industry's previous commitment to the Sustainable Development Goals (SDGs) for a more sustainable and resilient future, there are concerns that the COVID-19 crisis has led to a decline in the industry's dedication to the SDGs (Jones & Comfort, 2020).

In response to the negative impacts caused by the pandemic, the European Commission approved a series of plans, such as the One Planet Vision (*UNWTO. One Planet*, s. f.), to aid in its recovery. Their strategy emphasized the potential for job creation and leveraging both ecological and digital transitions to foster growth. However, to truly achieve sustainability in the tourism sector, there is a need for the implementation of comprehensive and eco-friendly practices. This includes measures such as water conservation, energy efficiency, and proper waste management. It is crucial to incorporate these sustainable practices from the early planning stages of a hotel project and continue throughout its entire lifecycle, encompassing design, construction, and operation. A holistic approach is necessary to ensure that green buildings are designed and operated in a manner that minimizes environmental impact. From utilizing renewable energy sources and implementing energy-efficient systems to promoting recycling programs and employing eco-friendly materials, they have the potential to make a significant positive impact on the environment while meeting the expectations of environmentally conscious travellers (Serrano-Baena et al., 2021). In summary, to achieve CO_2 neutrality in the tourism industry by 2050 is crucial to move beyond superficial changes and embrace comprehensive sustainability practices throughout all stages of a hotel's lifecycle.

This research capitalizes on the current post-pandemic stage to strengthen sustainable consumption and production strategies in the tourism sector. Inspired by my experience as an architect in the hospitality industry, where I identified a lack of environmental knowledge needed for efficient hotel design, and the imminent shift needed to achieve the future sustainable plans, my focus has evolved towards analysing existing environmental measures and proposing new strategies and tools to design sustainable hotels. This research also addresses the impact of COVID-19 on the digital and ecological transitions and provides initial insights for a sustainable recovery of the hospitality sector. Figure I.2 shows the conceptual development of the research and the proposed framework. Hence, the aim is to provide practical strategies and recommendations for more environmentally conscious and resilient hotel design, leveraging circular economy principles. By embracing these findings, stakeholders in the tourism and hospitality sectors can minimize their environmental impact and contribute to a sustainable future and researchers of the field can provide further measures for the sustainable recovery of the sector based on the strategies proposed in this research.

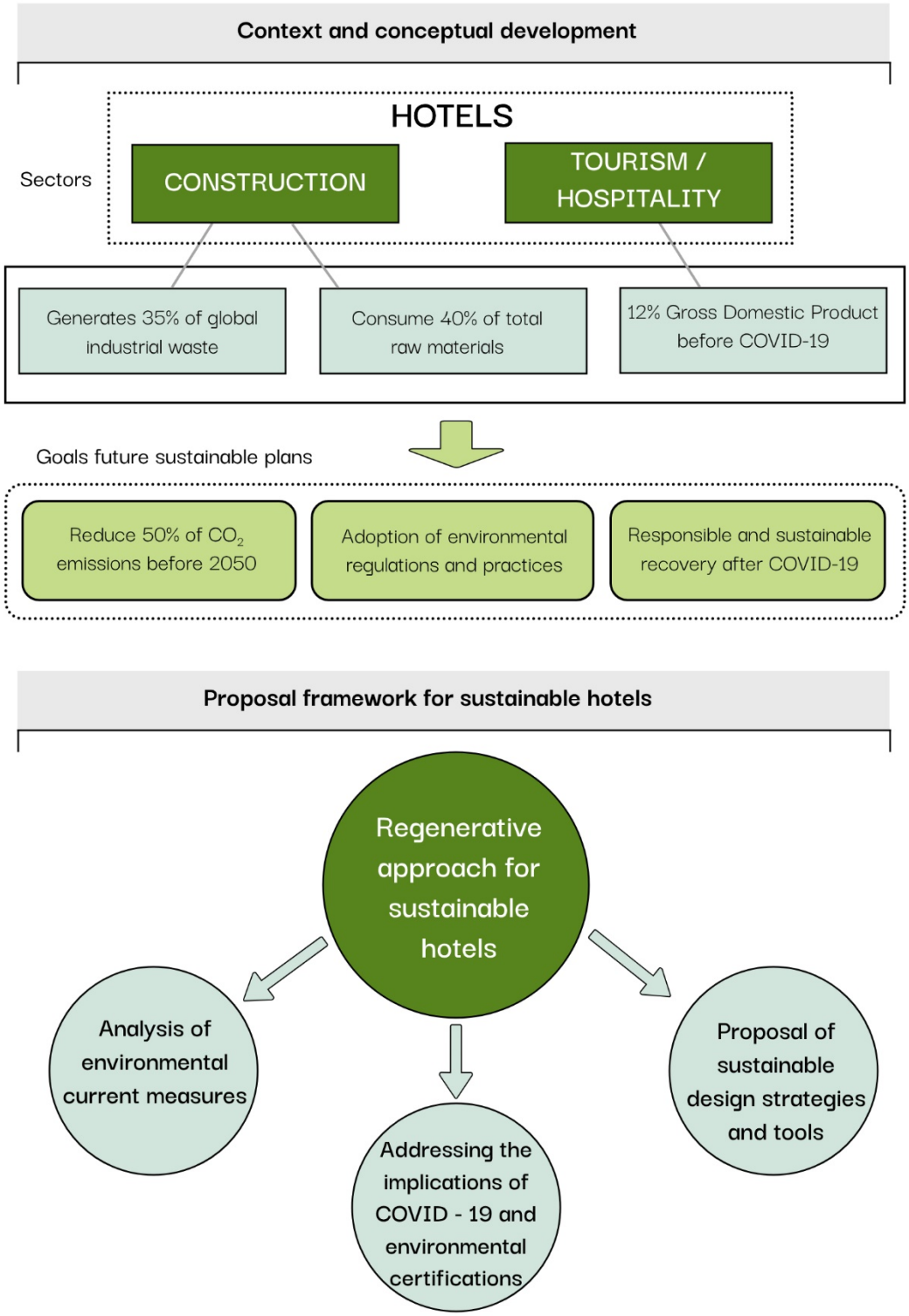

Figure I.2. Context, conceptual development and proposed framework.

2. INTRODUCCIÓN Y CONTEXTO

El cambio climático ha surgido como uno de los desafíos más significativos que se deben abordar en el siglo XXI. La continua emisión de gases de efecto invernadero debido a las actividades humanas ha llevado a consecuencias alarmantes. Entre estos gases, el dióxido de carbono (CO_2) es especialmente preocupante debido a su abundancia y su capacidad para persistir en la atmósfera durante miles de años. De hecho, el sector de la construcción por sí solo es responsable de aproximadamente el 39% de las emisiones de CO_2 generadas anualmente en todo el mundo (*Data Overview*, s. f.). Estas emisiones provienen principalmente de la energía utilizada en la construcción de edificios, la eliminación de residuos, el transporte y la fabricación de materiales. Además, los edificios contribuyen al 35% de los residuos industriales globales y consumen el 40% de los materiales primos totales. En consecuencia, la construcción es el gran contribuyente del consumo de energía y el agotamiento de los recursos naturales en nuestro planeta. En este contexto, el sector turístico ha experimentado una evolución significativa en las últimas décadas, sin embargo, ha recibido una atención limitada en diversas disciplinas, siendo la arquitectura una de las menos exploradas. La industria del turismo, caracterizada por avances tecnológicos, acceso generalizado a Internet y viajes aéreos asequibles, experimentó un crecimiento rápido antes de la pandemia de COVID-19. Justo antes de la crisis, esta industria representaba aproximadamente el 12% del Producto Interno Bruto mundial, lo que la convierte en una poderosa aliada para abordar la emergencia climática y promover un crecimiento responsable mediante la construcción o renovación de hoteles sostenibles.

Sin embargo, para lograr el ambicioso objetivo de neutralidad de CO_2 para el año 2050, como se describe en el Pacto Verde Europeo, la industria turística debe hacer esfuerzos significativos para reducir sus emisiones actuales en un 50% antes de 2030, y esta reducción requiere la participación activa de los hoteles. La industria hotelera ha reconocido cada vez más la importancia de la responsabilidad ambiental y la ha incorporado como una corporativa clave para tener en cuenta. El éxito a largo plazo de la industria depende de adoptar prácticas ambientalmente sostenibles y demostrar un compromiso con prácticas y acciones responsables con el medioambiente. Investigaciones científicas, tanto teóricas como empíricas, indican que, si bien el sector hotelero contribuye positivamente al desarrollo socioeconómico, también es responsable de sus impactos ambientales negativos (Su et al., 2020). Uno de los factores principales que contribuye a estos impactos es la explotación de los recursos naturales por parte de la industria, lo que puede generar daños ambientales significativos como la contaminación del aire, la pérdida de hábitats y la erosión del suelo. En este contexto, la adopción estratégica de regulaciones y prácticas ambientales, incluida la búsqueda de certificaciones energéticas, desempeña un papel fundamental en el fortalecimiento del desempeño corporativo. Al adherirse a las regulaciones ambientales, las empresas demuestran su compromiso con prácticas comerciales responsables y sostenibles. Además, buscar activamente la obtención de certificaciones energéticas supone un enfoque proactivo hacia la gestión ambiental, lo que puede mejorar la reputación de una empresa, atraer a consumidores conscientes y responsables con el planeta y abrir puertas a nuevas oportunidades comerciales (Serrano-Baena et al., 2020). Estas iniciativas no solo contribuyen a mejorar los resultados ambientales, sino que también tienen el potencial de generar beneficios económicos a largo plazo y ventajas competitivas para las organizaciones que operan en el mercado actual impulsado por la sostenibilidad.

Durante la última década, numerosos investigadores han dedicado sus estudios a explorar la incorporación de una economía circular en la industria de la construcción y el turismo (Ding et al., 2023; Shooshtarian et al., 2022). Los modelos de producción y consumo predominantes en el sector de la construcción operan dentro de un marco de economía lineal, siguiendo la secuencia "extracción-producción-disposición". Desafortunadamente, este modelo carece de disposiciones para la reutilización de productos y materiales desechados. En contraste, la economía circular representa un cambio transformador, poniendo énfasis en un enfoque regenerativo de la producción y el consumo.

Este enfoque implica el diseño de productos manufacturados con mayor valor y ciclos de vida más prolongados, la creación de productos versátiles que maximicen la utilidad y la promoción de la competitividad en el mercado de materiales reciclados (Primc et al., 2020). La disponibilidad de herramientas y metodologías que faciliten la interpretación de la información existente y permitan la generación de datos actualizados es esencial para navegar por las transiciones digitales y ecológicas en curso.

Por tanto, los esfuerzos para restaurar ecosistemas con alta densidad de carbono y adoptar tecnologías colaborativas son esenciales para mitigar las emisiones (*COVID-19 Research for Hospitality Industry*, s. f.). La pandemia de COVID-19 tuvo un impacto significativo en el medio ambiente, lo que resultó en reducciones notables de las emisiones de gases de efecto invernadero y los niveles de contaminación. También se observó la presencia de diversas especies de vida silvestre en áreas públicas. Sin embargo, estos cambios ambientales positivos fueron de corta duración, ya que el mundo gradualmente volvió a la normalidad. Se han planteado ciertas preocupaciones respecto a la relajación de las regulaciones y políticas ambientales durante la crisis de COVID-19. Si bien hubo algunos beneficios ambientales inmediatos, el efecto global en las economías y sociedades ha sido devastador. La industria hotelera, especialmente en los países desarrollados, experimentó pérdidas de empleo temporales o permanentes, mientras que el impacto en la industria en los países menos desarrollados ha sido catastrófico. En el sector empresarial, la sostenibilidad corporativa y la responsabilidad social han ganado cada vez más importancia para las grandes empresas. Las principales empresas de la industria hotelera han implementado programas de sostenibilidad corporativa. La crisis de COVID-19 presentó tanto oportunidades como desafíos para estos programas, pero es crucial reconocer que la pandemia ha limitado los recursos financieros, lo que potencialmente obliga a los líderes de la industria hotelera a priorizar sus operaciones comerciales centrales. A pesar del compromiso previo de la industria con los Objetivos de Desarrollo Sostenible (ODS) para un futuro más sostenible y resiliente, existen preocupaciones de que la crisis de COVID-19 haya llevado a una disminución en el enfoque de la industria en los ODS (Jones & Comfort, 2020).

En respuesta a los impactos negativos causados por la pandemia, la Comisión Europea aprobó una serie de planes, como el plan One Planet Vision (*UNWTO. One Planet*, s. f.), para ayudar en su recuperación. Su estrategia hizo hincapié en la creación de empleo y en aprovechar las transiciones ecológicas y digitales para fomentar el crecimiento. Sin embargo, para lograr una verdadera sostenibilidad en el sector turístico, es necesario implementar prácticas integrales y respetuosas con el medio ambiente. Esto incluye medidas como la conservación del agua, la eficiencia energética y una correcta gestión de residuos. Es crucial incorporar estas prácticas sostenibles desde las primeras etapas de planificación de un proyecto hotelero y mantenerlas durante todo su ciclo de vida, abarcando el diseño, la construcción y la operación. Se requiere un enfoque integral para asegurar que los edificios verdes sean diseñados y operados de manera que realmente minimicen el impacto ambiental. Desde utilizar fuentes de energía renovable e implementar sistemas de eficiencia energética, hasta promover programas de reciclaje y utilizar materiales respetuosos con el medio ambiente, tienen el potencial de tener un impacto positivo significativo en el planeta al tiempo que cumplen con las expectativas de los clientes conscientes (Serrano-Baena et al., 2021). En resumen, para lograr la neutralidad de CO_2 en la industria turística para 2050, es crucial ir más allá de cambios superficiales y adoptar prácticas de sostenibilidad integrales en todas las etapas del ciclo de vida de un hotel.

Esta investigación aprovecha la oportunidad actual, en la etapa de postpandemia, para fortalecer las estrategias de consumo y producción sostenible en el sector turístico. Inspirado por mi experiencia como arquitecto en la industria hotelera, donde identifiqué una falta de conocimiento ambiental necesario para un diseño eficiente de hoteles, y la inminente transformación necesaria para lograr los futuros planes sostenibles, mi enfoque ha evolucionado hacia el análisis de las medidas ambientales existentes y la propuesta de nuevas estrategias y herramientas para el diseño de hoteles sostenibles. Esta investigación también aborda el impacto de COVID-19 en las transiciones digitales y

ecológicas y ofrece ideas iniciales para una recuperación sostenible del sector hotelero. La Figura I.2 muestra el desarrollo conceptual de la investigación y el marco propuesto. Por lo tanto, el objetivo es proporcionar estrategias prácticas y recomendaciones para un diseño de hotel más resiliente y consciente con el medio ambiente, aprovechando los principios de la economía circular. Al adoptar los resultados presentados en este trabajo, los actores de los sectores turístico y hotelero pueden minimizar su impacto ambiental y contribuir a un futuro sostenible, y los investigadores del campo pueden proporcionar medidas adicionales para la recuperación sostenible del sector basadas en las estrategias propuestas en esta investigación.

3. LITERATURE REVIEW

3.1. European regulations for the ecological and digital transition in the tourism sector. New strategies for sustainable tourism

Europe is on track to become the first climate-neutral continent by 2050, producing no more greenhouse gases than ecosystems can naturally absorb; it will be a more resilient, digital and green continent. The current time is considered the digital decade of Europe in which it is intended to turn our cities into more efficient and intelligent places and combat climate change through artificial intelligence. The EU's long-term budget, together with the NextGenerationEU (*The 2021-2027 EU Budget*, s. f.), is the largest stimulus package ever financed in Europe. The package with the multiannual financial framework 2021-2027 consists of €1.211 trillion, together with the temporary recovery instrument of NextGenerationEU, of €806.9 billion. In total, 2.018 trillion euros will be allocated to rebuild Europe after COVID-19 (*NextGenerationEU*, s. f.). The adoption of environmental regulations aimed at managing corporate environmental performance serves as a driving force for organizations to actively embrace environmentally responsible practices and sustainability initiatives. From an institutional theory perspective, strict environmental regulations encourage enterprises to actively participate in environmental protocols and adopt comprehensive environmental management practices. Additionally, the enforcement of environmental regulations stimulates sustainable technology innovation and facilitates the development of environmentally friendly products or strategies to minimize environmental impact, leading to positive outcomes for sustainable operations (Zhao & Sun, 2016). Furthermore, it has been proved that the correlation between mandatory government regulations and corporate social responsibility (CSR) reporting quality results in an overall improvement. Consequently, environmental regulations have a significant influence on environmental reporting. It is imperative for firms to surpass mere compliance with environmental regulations and adhere to stricter requirements for greener practices, as this effectively enhances corporate performance (Moosa & He, 2021).

According to a study done by the UNWTO and the International Transport Forum, carbon emissions from the tourism sector will increase by at least 25% before 2030. Considering that hotels are included in the top five list of energy consumers in the tertiary sector (Salem et al., 2020), this makes them an exceptional goal to be ecologically improved. In October 2020, the European Commission published the Renovation Wave strategy in Brussels. Even it is not focussed on the tourism sector, it does affect hotels. The main objective of this document is to improve the quality of European buildings through digital energy saving solutions. Although new buildings require minimum energy standards for their approval, the majority of the building stock is constituted by old constructions that require efficient and sustainable renovations through current digital mechanisms and tools. In this context, the plan is focussed on three main areas, namely (*Renovation Wave*, 2020):

- Energy poverty and buildings with the worst performance. In 2018 nearly 34 million of Europeans were unable to keep their homes warm. The crisis of COVID-19 has also accelerated the urgency of addressing energy poverty to create a European society that provides for its habitants. Tackling this issue is a major challenge for the EU and has the potential to bring multiple benefits to society, such as improving wellbeing, reducing the spent-on healthcare and improving comfort among others. These benefits will also directly affect the EU by boosting economic growth and prosperity.
- Social infrastructure and public buildings. This means proposing stronger standards and regulations for buildings including minimum energy performance standards for existing buildings, energy certificates and building requirements for the public sector.
- Decarbonising heating and cooling. In order to achieve a reduction of 55% emission in 2030, the EU must reduce energy consumption of heating and cooling by 18% and energy consumption by 14%. As a consequence, in June 2021, the Renewable Energy Directive considered reinforcing renewable cooling and heating by introducing a minimum renewable energy level for buildings.

In 2015, the 2030 Agenda for Sustainable Development was approved. This plan establishes 17 Sustainable Development Goals (SDGs) and 169 targets to be achieved by 2030 that are currently considered a global emergency to mitigate and balance the three dimensions of sustainable development, the economic, social and environmental (*Transforming our World: The 2030 Agenda for Sustainable Development.*, s. f.). Since the Paris Agreement in 2021, the EU is playing an active role and will implement the 2030 Agenda domestically and globally in cooperation with partner countries. Furthermore, the New Urban Agenda adopted in October 2016 at the United Nations Conference aims to accelerate the achievement of the SDGs. Particularly it prioritizes the making of cities safer, more inclusive and sustainable by adopting a smart-city approach (*The New Urban Agenda*, s. f.). Smart city models require specific strategies to optimize their resources, reduce its waste and recycle, in this context, the generation of a circular economy plays an important role (Andrade & Yoo, 2019). The UNWTO has stated that tourism contributes directly or indirectly to the achievement of all the SDGs, particularly, it is included in objectives 8, 12 and 14.

- Goal 8: "Decent work and economic growth". According to a report from WTTC (World Travel and Tourism Council) in 2019, travel and tourism was the sector with the fastest growth in 2018 (3.1%), ahead of the construction (2.8%) and banking (2.6%) sectors. In addition, travel and tourism sustained a total of 319 million jobs across the world and induced 10% of all jobs, exceeding the impacts of the financial, health and banking sectors, among others (*Economic Impact Benchmarking Research | World Travel & Tourism Council (WTTC)*, s. f.). The contribution of the tourism sector is specified in Target 8.9 "By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products" (*Transforming our World: The 2030 Agenda for Sustainable Development.*, s. f.).
- Goal 12: "Responsible consumption and production". Tourism can accelerate the ecological transition in the sector by adopting sustainable consumption and production practices (SCPs) in hotels. If the tourism sector adopts SCPs, it can significantly accelerate the shift to a more sustainable planet (*UNWTO. Tourism in the 2030 Agenda*, s. f.). The One Planet Sustainable Tourism Programme (*UNWTO. One Planet*, s. f.) proposed by the UNWTO has the objective to improve the sustainable development impacts of tourism by promoting SCPs that use natural resources and produce less waste. The inclusion of green hotels is key for this goal. Clients are experiencing an awareness of environmental damage and the addition of sustainable measures in hotels is becoming a very important factor for their design.
- Goal 14: "Life below water". Tourism management of coastal areas must preserve the most fragile marine ecosystems, restore systems that help reduce CO_2 emissions and promote a blue economy. In this context, the blue economy has many similarities with the circular economy and its main idea lies in the imitation of the behaviour of natural ecosystems and seeks to ensure that all waste or residues are re-introduced into the economic process in the form of raw materials. It is specified in target 14.7 that "by 2030, increase the economic benefits to small island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism" (*Transforming our World: The 2030 Agenda for Sustainable Development.*, s. f.). Small Island Developing States (SIDS) rely on healthy marine ecosystems. Integrated Coastal Zone Management must include tourism development to preserve fragile marine ecosystems and promote a blue economy (*UNWTO. Tourism in the 2030 Agenda*, s. f.).

Lastly, to these plans we must add the objectives established in the recent Climate Change Conference of the Parties (COP26) that took place in Glasgow on 31st of October 2021. The Glasgow Declaration on Climate Action in Tourism arises from the need to accelerate climate action in tourism and ensure strategies that help achieve the 2050 neutrality goals (*The Glasgow Declaration on Climate Action in Tourism*, s. f.). Over 450 organizations took part in the declaration and agreed to implement the main five commitments. These are measurement of emissions, decarbonisation of tourism, regeneration of ecosystems, collaboration between all agents and financing in technology and research.

3.2. The Importance of Sustainability Certifications on hotels to achieve the 2030 Agenda: an approach to the application of BREEAM

In 1993, the UNWTO put forward the concept of "Sustainable Tourism Development". In 1995, United Nations Educational, Scientific and Cultural Organization (UNESCO), United Nations Environment Programme (UNEP) and UNWTO held in Spain the first World Conference on Sustainable Tourism and the Charter for Sustainable Tourism was adopted in this meeting (Hampton, 1995). Since then, sustainable tourism has occupied a dominant position in the tourism industry and become increasingly important with visitors looking for indicators that help them choose places that are suitable for their environmental requirements. Factors such as the CO_2 emissions produced by the hotel, the embodied energy needed to build it, or the generated waste are crucial in a European context.

Hotels' users consume a great amount of water and energy at the same time that generates an important amount of solid waste and effluents on a daily basis (Ad, 2017), but hotels may have a significant and positive impact on the environment by changing some of their management and design aspects. Customers have radically changed their attitude towards adopting environment-friendly practices in hotels and they often check their sustainable performance before booking them. In this context, terms such as "green hotels" and "smart tourism" are now very familiar to us. For instance, a green hotel must operate according to the principles of green hospitality. This does not mean planting some trees in front of it, but being environmentally friendly (Kostić et al., 2019). Moreover, smart tourism is closely related to the application of new technologies (Mehraliyev et al., 2020), these can enhance tourism in different ways. It has been demonstrated that hotels display their certificates and environmental practices online to show the customers their awareness of the environment (Fernández-Robin et al., 2019; Karaman & Sayin, 2017). Studies indicate that the application of environmental procedures and their consequent certifications can improve the image of the company and its operating performance (Bagur-Femenias et al., 2016). As a consequence, environmental assessments of buildings have become one of the most important steps in the sustainable built environment (Pham et al., 2020).

Nowadays, developing countries are leaders in green engineering procedures and, progressively, hotels are including sustainable standards in their designs, architecture and management (Khan et al., 2020). A sustainable hotel must operate according to the principles of green engineering by implementing waste management systems, recycling and saving water and energy, among other procedures (Kostić et al., 2019). The EU Energy Efficiency Building Directive (EPBD) and the UK Climate Change Act 2008 included sustainable buildings on their policy agenda. Since then, a wide variety of tools have been developed to assess and assist construction projects, the most used ones are LEED and BREEAM, with a latest addition from the European Union that aims to unify all the environmental standards in Europe, the Level(s) system. BREEAM (Building Research Establishment Environmental Assessment Method) leads the list and, although it was initially designed to focus primarily on environmental aspects (Cooper, 1999; Haroglu, 2013), in the last decade it has also highlighted social and economic aspects. BREEAM is regularly updated to make sure it meets the requirements for building sustainability, and it is used for public and private projects, applicable to residential and commercial buildings. In some cases, it is a mandatory requirement to satisfy certain planning conditions or regulations, particularly for the public sector projects. In other cases, it is used voluntarily to earn recognition due to its international prestige, and it is highly valued when it comes to indicate the carbon emissions of commercial buildings. Also hotels and tourism benefit from the application of sustainable assessments such as BREEAM (Bagur-Femenias et al., 2016).

In a European context, the BREEAM certificate supports the SDGs and the 2030 Agenda. It notes how significantly contributes to the achievement of the following goals (*Sustainable Development Goals - BRE Group*, 2022):

- SDG 3. Health and Well-being. The building must guarantee minimum requirements for comfort and health.
- SDG 6. Clean Water and Sanitation. Buildings must install systems that save water as well as monitor their consumption.
- SDG 7. Affordable and clean energy. It promotes the installation of renewable energy sources and the use of low consumption appliances and lighting.
- SDG 9. Industry, Innovation and Infrastructure. Rate and promote those projects that create or offer new sustainable solutions.
- SDG 11. Sustainable Cities and Communities. An urban environment requires different measures to those applied in a single building; therefore, the certificate proposes a tool that evaluates and certifies urbanized spaces.
- SDG 12. Sustainable Consumption and Production. It requires eco-labels that guarantee the responsible sourcing of materials used on site.
- SDG 13. Climate Action. Its main objective is to guide the construction sector towards sustainability.
- SDG 15. Life of Terrestrial ecosystems. It seeks to minimize the damage caused to the environment and its biodiversity when building.

Despite its importance, little research has been conducted about the effects that the application of this sustainability assessment method might have on the hotel's design and management process. Holmes and Hudson (2003) examined how BREEAM affects the design of an office building but the method has been through many changes since this study was taken and they focused more on the perceived value of the method than its design effects. Lowe and Watts (2011) analysed the benefits of implementing BREEAM on a two storey medical centre development but this research was focussed on the financial implications of the method. Fenner and Ryce (2008) compared BREEAM with the LEED method, analysing their limitations in current practice, but this research did not focus on the design aspect. Several studies taken from Haroglu (2013) and Schweber (2013) analysed in different studies the implication that BREEAM might have on the design process although these studies used different types of buildings as case studies such as educational, commercial, residential and healthcare (Schweber & Haroglu, 2014). Lu and Lai (2020) compared four rating tools: BREEAM, Leadership in Energy and Environmental Assessment (LEED), Green Star and Building Environmental Assessment method (BEAM Plus), and concluded that all of them were similar and focussed on the same environmental aspects, in terms of energy audit. The carbon audit, however, was not a common investigation focus on any of them.

3.3. Implications of COVID-19 on hotels and their sustainable recovery towards SDGs

The COVID-19 pandemic has caused major negative consequences on a global scale in the tourism sector. In December 2019, according to the statistics provided by the National Institute of Statistics, almost 83% of the total overnight stays were in hotels (*INE. Instituto Nacional de Estadística*, s. f.). This data was radically changed few months later with the unexpected arrival of the global pandemic of COVID-19, which changed the course of most sectors, including tourism and hospitality. For instance, a 2020 study taken by the Washington State University, investigated customer sentiments toward returning to patronizing hotels and restaurants during the pandemic in the United States (Gursoy & Chi, 2020). It indicated that 62.77% of the respondents were not willing to travel to a destination and stay in a hotel while only 23.46% of them travelled and stayed in a hotel during the previous two months.

In this context, a limited number of researchers have examined the perceptions and emotions of individuals during the pandemic to gain insights into people's behavioural responses. These have been done on tourists (Gursoy, 2021; Lin et al., 2021; Srivastava & Kumar, 2021) and also on hospitality and healthcare employees (Park et al., 2020; Xiang et al., 2022). These studies concluded that understanding people's emotions is crucial to successfully operate in the era of COVID-19 and build

their resilience. Keenan (2020) and Nunn (2020) also studied the factors that have affected tourism and it was concluded that the effects of COVID-19 differ in space and time. While some places have continued their businesses as usual ignoring the possibility of a new era of green growth and the reduction of carbon emissions, but other destinations have reconsidered the reorientation of their tourism industry and focus on more sustainable approaches.

The pandemic caused an economic and health crisis of large proportions, increased the levels of poverty, affected migration and mobility and attacked business operations and employment (Shulla et al., 2021). As a response to these crisis, the UNWTO published the One Planet Vision for a responsible recovery of the tourism sector (*UNWTO. One Planet*, s. f.). Released on May 2020, the plan was created to support the tourism and hospitality sectors to sustainably emerge stronger from the effects that COVID-19 has caused and contribute with the SDGs. Six lines of action guide the vision towards a responsible recovery for the planet and people. These are:

- Public health. The pandemic highlighted the relationship between public health and tourism. Countries that suffered subsequent waves of infection, also manifested negative tourism effects (Grech et al., 2020), and these effects have affected the SDGs; for instance, SDG 3 aims to ensure healthy lives and promotes well-being for all ages (*THE 17 GOALS | Sustainable Development*, s. f.). Long lasting synergies between tourism and public health are crucial to recover from the health crisis and compete with other touristic destinations. The interventions of public health in tourism or leisure contexts have been studied by several researchers in the past (Fang et al., 2021; Grech et al., 2020). It was concluded that governments play an important role in the recovery of the sector and stringent policies have led to a drop on participation in recreational activities and tourism. However, these interventions help the industry with its recovery in comparison with the cases of no intervention. The outcomes of the cooperation between stakeholders, researchers and health authorities must generate tailored guidance and protocols for all the operations in the tourism and hospitality sectors. It is necessary that these measures include sustainability principles to avoid any harmful effects on the environment as a consequence of hygiene standards (Daverey & Dutta, 2021). It is also relevant to integrate epidemiological indicators in the proposed measures and policies to provide evidence and related data; this will help with the economic recovery of the sector. It is also key to restore trust through proactive crisis communication on measures and standards in the business (Obembe et al., 2021; Pachucki et al., 2022). Understanding visitors' perceptions and needs and send clear messages to regain their confidence will help with their resilience.
- Social inclusion. The SDG 16 promotes more peaceful and inclusive societies for a successful sustainable development; however, the consequence of COVID-19 on tourism jobs have been devastating, especially on small and medium size enterprises which comprise around the 80% of the tourism business. It is important that these practices keep an attractive offer; embracing digital technologies might help with their continuity. Additionally, their resilience will be strengthened with the diversification of their revenue streams. On the other hand, many stakeholders are supporting their workers and communities. Targeted support that covers the needs of vulnerable groups such as indigenous, youth or women will promote a more inclusive recovery of tourism. Researchers studied the socio-economic impact of COVID-19 and demonstrated that rapid and efficient financial support to vulnerable groups will help for an equitable future disaster recovery (Sun et al., 2021). Financing approaches that creative industries provide to touristic destinations during a crisis will help with the sustainable recovery of the tourism and hospitality sectors, reduce social inequality and increase economic added value. These practices also reduce the dependence of destinations on foreign suppliers and support a circular economy in the sector (Schänzel, 2021).
- Biodiversity conservation. Health crisis of zoonotic diseases such as COVID-19 show the relevance of being surrounded by a healthy environment and biodiversity as natural barriers for the future. In the

tourism sector, the conservation efforts to provide a more sustainable recovery depend on the incomes of the business; some destinations largely depend on that in order to preserve marine and terrestrial ecosystems. SDGs 14 and 15 are focussed on these aspects and promote the conservation of oceans, seas, marine resources and terrestrial ecosystems and a sustainable management of forests (*THE 17 GOALS | Sustainable Development*, s. f.). In this context, researchers studied the importance of capturing the value of ecosystems services with the support of monitoring mechanisms that will enable the tourism business to sustainably invest on preservation and conservation practices (Whitelaw et al., 2014). These efforts must include the fight of illegal wildlife trade and preservation of cultural sites. Additionally, nature-based solutions must be considered in the path towards sustainable tourism. These are innovative solutions, inspired in nature and applied to contemporary problems; investing in them should help with the mitigation of environmental impacts caused by the tourism and hospitality industries and result in a better management of natural resources (Padma et al., 2022).

- Climate action. The 2030 Agenda has specifically included climate action in its SDG 13, which suggests taking urgent action to combat climate change and its impacts. In addition, SDG 11 aims to make cities and communities more sustainable and resilient (*THE 17 GOALS | Sustainable Development*, s. f.). However, in 2019 the UNWTO released a report providing some insights into the sustainable evolution of tourism up to 2030 (World Tourism Organization (UNWTO) & International Transport Forum, 2019). It revealed that CO_2 emissions from tourism will grow 25% by 2030 and, therefore, the urgent necessity to rethink tourism and hospitality operations to meet the goals. The first step would be measuring these emissions from tourism with the right monitoring mechanisms. The next action should reconsider the decarbonisation of the tourism and hospitality operations, which includes the development of low-carbon transportation and more ecological infrastructures (Boers & Cottrell, 2007; Dallen, 2007). Sufficient investment in these would improve the resilience in both sectors. Customers and visitors are increasing their demands towards adopting environment-friendly practices and as a result, tourism and hospitality businesses cannot ignore their environmental and social responsibilities. Moreover, smaller businesses would need enough advice and financial support to achieve these sustainable responsibilities. Lastly, tourism and hospitality sectors should engage in carbon removal through new technologies and the restoration of high carbon density ecosystems, in order to considerably reduce their CO_2 emissions before 2030 and achieve carbon neutrality by that year (*The Glasgow Declaration on Climate Action in Tourism*, s. f.).
- Circular economy. The SDG 12 proposes a sustainable consumption and production patterns in all sectors (*THE 17 GOALS | Sustainable Development*, s. f.). However, the pandemic highlighted the need and importance to rethink how products are manufactured or created and consumed. A circular economy can be implemented in all businesses, including hospitality, tourism and construction; it proposes a paradigm shift with a higher resource productivity, reuse or recycle of materials and adequate waste management. The transition from a linear economy, which is the most common approach in all sectors, to a circular economy requires a commitment from the stakeholders and financial support to achieve the needed measures. Supporting these actions in tourism can promote innovation, new sustainable models and add value for customers. Addressing plastic waste is also a crucial measure, around 300 million tons of plastics are produced yearly in the world and an important amount of them become marine litter (Rodríguez et al., 2020). In this context, it is necessary to increase the use of compostable plastics, integrate reuse models and recycling rates. Tourism causes a significant environmental impact and requires great amount of local resources such as water, food or energy. As a consequence of a linear economy, it generates large amounts of waste that need to be reduced and responsibly managed to reduce cost in the business, improve their efficiency and confront the CO_2 neutrality.

- Governance and finance. The exchange of information between the governments and the private sectors is crucial to overcome crisis and future sustainable plans. The health crisis of COVID-19 has shown the importance of this exchange for decision making and successfully manage the pandemic at an international level. Along these lines, sustainable development requires the same synergy between all parties; for instance, the SDG 17 proposes partnerships for the other goals and revitalise the global partnership (*THE 17 GOALS | Sustainable Development*, s. f.). The tourism and hospitality sectors must take this into account and consolidate partnerships between stakeholders, public and private groups internationally and locally to ensure a satisfactory recovery.

Resilience holds significant importance in the narratives of corporate sustainability within the hospitality industry, typically focusing on responding positively to challenges. However, Gössling et al. (2020) caution that the COVID-19 crisis has revealed the lack of resilience in the tourism industry, contradicting common assertions made by industry experts. The pandemic exposed vulnerabilities at the interface between human activity and the natural environment, highlighting the limitations imposed by ecological boundaries and sparking debates on sustainable consumption. Cohen (2020) acknowledges the global struggle with the pandemic but argues that it has brought about an outcome that scholars and policymakers have long sought—an opportunity to shift towards sustainable consumption. Their study suggests that the crisis offers a chance to move away from conspicuous consumption prevalent in developed nations and the consequent depletion of finite resources. It stresses the importance of leveraging the crisis to inform and shape policies promoting the adoption of more sustainable consumption patterns. Such a transition would require major changes in the traditional business models of leading players in the hospitality industry, which have historically relied on unrestricted natural resource utilization, high guest volumes, and low-cost labour. Despite the severity of the COVID-19 crisis, it is uncertain that either the industry leaders or the majority of their customers possess genuine enthusiasm for pursuing this transition or supporting legislation and policies aimed at facilitating such a shift.

3.4. Promoting a circular economy in the construction and hospitality sectors with sustainable design tools

The European Union has introduced initiatives like the European Green Deal and the Renovation Wave to accelerate energy rehabilitation by 2030 (*A European Green Deal*, s. f.; *Renovation Wave*, 2020). The Renovation Wave aims to enhance the quality of European buildings through digital energy-saving solutions, particularly for older structures that require sustainable renovations. While new buildings have minimum energy standards, the majority of existing buildings fall short, making it crucial to utilize current digital mechanisms and tools. The European Green Deal sets a target of achieving climate neutrality within the EU by 2050. It seeks to transition the EU into an efficient economy that optimizes resource utilization, eliminates greenhouse gas emissions, and decouples economic growth from resource consumption.

Studies indicate that approximately 75% of existing buildings do not meet mandatory standards, and even if they aim to align with EU sustainability objectives, 97% of them would still fall short of the required standards (Jiménez-Pulido et al., 2022). Considering that hotels are among the top energy consumers in the service sector, this makes them a prime target for ecological improvements (Salem et al., 2020). Thus, as mentioned before, in order to achieve the European Green Deal's objective of CO_2 neutrality by 2050, the tourism industry must reduce its current emissions drastically. In this endeavour, hotels play a crucial role, necessitating the incorporation of technologies and restoration of high-carbon density ecosystems to aid in emissions reduction. Furthermore, considering the importance of sustainable tourism in future environmental plans, the circularity of materials in hotel buildings can significantly contribute to long-term sustainability goals. Constructing

and rehabilitating more sustainable hotels would not only reduce CO_2 emissions but also protect ecosystems. The concept of a circular economy revolves around reducing waste, enhancing resource efficiency, and encouraging a regenerative approach to production and consumption. When applied to the hospitality sector, this entails designing hotels that prioritize renewable energy sources, optimize water usage, and implement efficient waste management systems (Batra & Shreshta, 2014; Ogbeide, 2012). To address these challenges, sophisticated tools are necessary for analysing the life cycle of these buildings, materials, and resources. Additionally, new systems and methodologies are needed to facilitate energy certification and sustainable designs.

In this context, Life Cycle Assessment (LCA) has been used for the past two decades to quantify and improve the environmental performance of buildings, although it is a complex methodology requiring extensive data exchange, particularly regarding materials. In addition to LCA, methodologies such as Life Cycle Costing (LCC) and Social Life Cycle Assessment (S-LCA) are included in the circular economy of building construction. Integrating these procedures is essential for comprehensive assessment of buildings. The introduction of Life Cycle Sustainability Assessment (LCSA) supports the implementation of a circular economy in sustainable construction, considering the three main pillars. The use of Building Information Modelling (BIM) has gained attention due to its digital model information format. Shibata et al. (2023) and Santos et al. (2019) have shown that incorporating BIM into LCA and LCSA can improve cost and environmental impact assessment. However, the integration of these concepts needs to be streamlined and facilitated. Currently, two primary approaches to LCA and LCSA utilizing BIM tools have been examined, with slight variations between them. The first approach involves carrying out LCA/LCSA directly in a BIM software through plug-ins such as Dynamo, without using additional tools. While this approach is useful for early design phases, it lacks flexibility and standardisation, making it challenging to implement in real-world scenarios. The second approach entails the extraction of the Bill of Material Quantities (BoMQ) from the digital model, followed by its importation into another software capable of generating LCA or LCSA. The lack of linkage between these two, results in a delay in the calculation. Moreover, when a complex building such a high-rise building or a hotel needs to obtained its LCA, the calculation process becomes almost impossible. Therefore, the construction and hospitality industries necessitate readily available tools and methodologies that place emphasis on the utilization and reutilization stages of building design including complex buildings, such as hotels.

4. METHODOLOGICAL FRAMEWORK AND RESULTS

This section corresponds to the methodological framework used in the thesis along with the results obtained. Due to its nature as a compendium of publications, there is not a unique methodology employed for the entire work, as it would be in a traditional thesis; instead, three main methodologies have been followed to obtain the needed results and insights. For this reason, and to facilitate its reading, it will be divided into three sections composed of a summary of the methodological framework used and results obtained, to effectively expose its particularities and explain the needs of its context.

4.1. Methodological framework 1 and results of the research articles: "Implications of BREEAM Sustainability Assessment on the Design of Hotels" and ""How the implementation of BREEAM in hotels could help to achieve the SDGs"

Starting with the two first published papers, the case studies were the same, however, one of the case studies was not included in the second paper due to its status. The research was designed at a pre-pandemic stage. Figure I.3 presents an overview of the methodological framework 1 devised for this research and showcases the outcomes obtained through its implementation. The main objectives of these articles were to analyse the effects of BREEAM on hotels' design decisions and explore the positive implications the assessment might have to achieve the SDGs. In this conceptual framework, the methodology is divided into three phases:

(I) Selection of the relevant case studies. In order to compare and examine different buildings of the same typology, these case studies needed to be based in the UK, due the relevance of the assessment there, present different construction stages and different BREEAM scores. In total, 7 case studies hotels were selected for the first paper and 6 of them for the second paper, each of them with different characteristics, locations, stages and BREEAM targets.

(II) A qualitative research is carried out to provide an in-depth understanding of how these BREEAM scores were achieved and what design changes were needed in the process. A qualitative method of analysis was used in the shape of personal interviews to a number of specialized hospitality professionals from the UK, both architects and architect technicians. They were selected based on their level of expertise in the field and quality of hotels produced during their careers. These professionals offered a variety of hotel projects assessed under BREEAM which were then selected based on their characteristics for the research. The interviews were undertaken during April and May of 2020 and, due to the mandatory lockdown, it was not possible to do the interviews face to face. Hence, they were done in English via Yealink Meeting Server and recorded, each of them lasting an average of 30 min per project. The semi-structured interviews were designed with a selection of open-ended questions based on previous literature reviews (Bagur-Femenias et al., 2016; Haroglu, 2013; Joner et al., 2017; Schweber & Haroglu, 2014; Verma & Chandra, 2018). In total, fifteen main questions were asked and divided into three categories: design and planning, BREEAM and sustainable design changes.

(III) The selection and analysis of the non-numerical data of each of the case studies. The collection of data was also supplemented with documentation provided by the designers including plans and elevations, BREEAM assessments, planning decision notices and any relevant information that influenced the design process.

The results section is divided into three main parts. The first part is a description and a brief of the information obtained from the architects and technicians about the required changes during the design process of each of the case studies. The second part exposes the key design changes extracted

from the interviews that were crucial in all the projects. The third part corresponds to the relation between BREEAM and the SDGs of the 2030 Agenda.

4.1.1. General description of the case studies

Case study A achieved a BREEAM Excellent score, the highest ever BREEAM score for a hotel in the UK. The building utilises a range of low energy technologies delivering an 87% reduction in CO_2. The assessor proposed many changes, mainly in the Mechanical and Electrical designing phase, where they asked for bigger plant rooms and more plant areas. It was required to incorporate a number of sustainable construction techniques including enhanced isolative building elements and a sustainable surface water drainage system. In addition, the hotel harvests rainwater, used to serve the toilets and to water the external landscape. Increasing the size of cycle store was also needed. Finally, the designers had to increase the size of the refuse store as a result of accommodating more numbers of bins and also provide an external bin store. The materials used for this building were assessed in order to meet the Building Regulations and BREEAM criteria, resulting in a combination of brick, metal and stone cladding.

Case study B was a regeneration and further extension of an existing historical building. The hotel had a planning requirement to achieve a BREEAM Very Good score. A pre-assessment was submitted as part of the planning application; planners reviewed it and conditioned it to make sure that the score was achieved. The designers had to increase the number of cycle storage spaces in the building in order to get the credits related. Under the ecology requirements, the architects had to include certain numbers of bat boxes housed on the roof levels designated for nesting bats as a results of the demolition of an adjacent building where bats could have nested in. The number and size of bins were increased and the refuse store was also slightly expanded. In regard to the building envelope, some of the windows had to be upgraded due to the acoustic requirements of BREEAM. The specification of the glass was changed but the size and position of the windows remained the same, so the design of the facade was not altered. Finally, the material of the new hotel was proposed by planners as render to match the existing building which, from a BREEAM perspective, is not ideal.

Case study C is an existing building refurbishment and extension. There is no space for landscaping and the existing building has a pitched roof, so there were no opportunities for proposing green roofs, bat or bird boxes and planters at ground floor; as a consequence, the ecology credits were difficult to achieve. In order to compensate this, The Mechanical and Electrical engineer presence was crucial. The installation of flow restrictors which help to save water by limiting the flow of particularly wasteful taps and showers. The water consumption is always a common factor to take into account for hospitality projects and its right management can drastically change the running cost of the hotel. Finally, to meet BREEAM acoustic requirements, the technicians had to enhance the existing glazing by adding a secondary glazing.

Case study D is a skyscraper building with a small footprint. It achieved an Outstanding, the highest BREEAM rating available at the time of completion. Ecology had a major impact on the project. Solar panels and a green roof were included in addition to beehives on the 39th floor to produce honey for guests. On the lower levels, bat and bird boxes for nesting were also incorporated. Due to the small footprint of the building, the ecologist recommended a separated external cycle store was designed with a green roof and green walls. Finally, the mechanical system had a vital importance; such as combined heat power system that contributes to a 30% reduction in CO_2 emissions and light regulation system that adjusts the level of light according to the time of day and season. In addition, waste management is crucial in this case; the hotel recycles cooking oil, general waste, soap and bottled bathroom products. Moreover, it uses eco-friendly products from local suppliers.

In case study E the client founders requested the BREEAM assessment method to help to reduce the running cost. In this case study, they also had to increase the cycle and bin stores' sizes in order to achieve the credits needed. For the ecology requirements, the designers had to include a total of 65

square metres of planting distributed on three separate roof levels. Internally, the architects had to increase the thickness and specifications of the partitions to meet BREEAM acoustic requirements. The technicians had to enhance the glazing specifications for some of the external windows to achieve the acoustic requirements. The architect explained that one of the hotel operators had very strict thermal requirements, which were well above Building Regulations and BREEAM requirements, so the insulation of the building did not need any adjustment to meet the credits. Finally, an adaptability study was needed, which is a document that studies the spatial, structural, and service strategies of the building and analyses the malleability of it in response to changing operational parameters over time. It proved that the hotel will be able to change its use if needed, thanks to the lightweight partitions and blade columns.

Case study F comprehends two buildings, a refurbished existing office building and a new hotel with some affordable accommodations included. Due to the different uses, planning required three separated permanent cycle stores and temporary short-term cycle storage. The temporary cycle store had to be increased as the BREEAM assessor recommended. In this case, it was a planning requirement to increase the number of bird and bat boxes that the ecologists advised, so BREEAM did not influence this decision. The designers decided to go for blade columns and lightweight partitions to facilitate the adaptability of the building and BREEAM rated this positively.

Case study G it has planning and operator's requirements for BREEAM Very Good and a pre-assessment was done. The main changes here were the bin and cycle stores and the inclusion of planters at ground floor level around the building, very similar to the rest of the case studies presented. After a few discussions with the ecologists, some of the planters were omitted as they contained trees that are no longer proposed. The design and illuminance of external lighting, including the hotel signage, was highlighted by the assessor to take into consideration to reduce future risks of non-conformance.

4.1.2. Key design changes

Several changes to the case studies described were needed during the design process to obtain the BREEAM credits. In addition, the presence of the Mechanical and Electrical engineer is crucial. As it has been demonstrated, hotels are linked to produce high levels of water consumption so implementing the right strategies and technologies help them to reduce their water consumption drastically. The key design changes can be classified under three main groups: upgrade through layout amendments, upgrade through performance and upgrade through additions.

Upgrade Through Layout Amendments

The increase in the cyclist facilities in order to house a greater number of cycles is a common factor. This amendment falls under the Transport section and credits are given with the adequate provision of cyclist facilities to promote exercise and help to reduce congestion and CO_2 emissions. Another key change required in the case studies A, B, E and G was the enlargement of the bins storage areas, this amendment falls under the Waste section and is related with an improvement of the waste management. BREEAM aims to promote sustainable waste management and divert recyclable waste from landfill or incineration. It has been demonstrated that around the 30% of a hotel´s solid waste can be recycled and reused.

Upgrade Through Performance

A different category of measures that can be applied to improve the efficiency of the hotels, especially for refurbished and existing buildings, are those related to the performance of their components. In case studies B, C and E, the architects had to change the type of windows by upgrading the glazing specifications and also, in case study E, they had to increase the thickness of the partitions to meet BREEAM acoustic requirements. These are associated with the Acoustic performance

subcategory of the Health and Wellbeing section of BREEAM. In this same section, in case study G they are working on the enhancement of lighting impact.

Upgrade Through Additions

Finally, two main categories can be classified in this group, Energy and Land Use and Ecology. Under the first category, solar panels are an immediate response when working on a sustainable hotel as happened in case study D. Certain actions are adopted to enhance the ecology of the site. These fall under the Land Use and Ecology BREEAM category, specifically under the subcategory Enhancing site ecology. The installation of bird and bat boxes at strategic locations on the site was a measure used in case studies B, D and E. Planters with native species or that are beneficial to local wildlife were distributed on different levels of the hotels in case studies D, E and G. Lastly, case study D has a green roof that improves air and water quality and creates a wildlife habitat.

4.1.3. Positive implications to the SDGs

These findings demonstrate that the measures to be taken are common in almost all hotels. For rehabilitated buildings, the most important categories to consider are Health and Well-being and Land Use and Ecology. In the case of new hotels, the categories Waste and Transportation have been a common factor. In addition to the elements mentioned above, the incorporation of green roofs and the inclusion of new technological measures, such as solar panels or solar cooling systems, are also key in new hotels (Martínez et al., 2020).

These hotels cases prove that the main categories in which BREEAM has the greatest impact are Health and Well-being, Land Use, Ecology and Waste and Transportation. Therefore, if we compare these categories with the SDGs that BREEAM and the UNWTO indicate (*Sustainable Development Goals - BRE Group*, 2022), we can affirm that the certificate applied in hotels contributes directly to the achievement of SDG 3, 6, 7, 12 and 15 and indirectly in SDG 8, 11 and 13. Moreover, it has been verified that BREEAM supports the inclusion of new technological measures, such as solar panels, which is why it also favours SDG 9. On the contrary, it has not been possible to verify that BREEAM supports SDG 14 in the case of hotels. It should be noted that none of the buildings studied here are near the coast, therefore the sustainable use of marine resources through the sustainable management of fisheries and aquaculture, indicated in SDG 14, is not feasible, but it may be in a coast hotel.

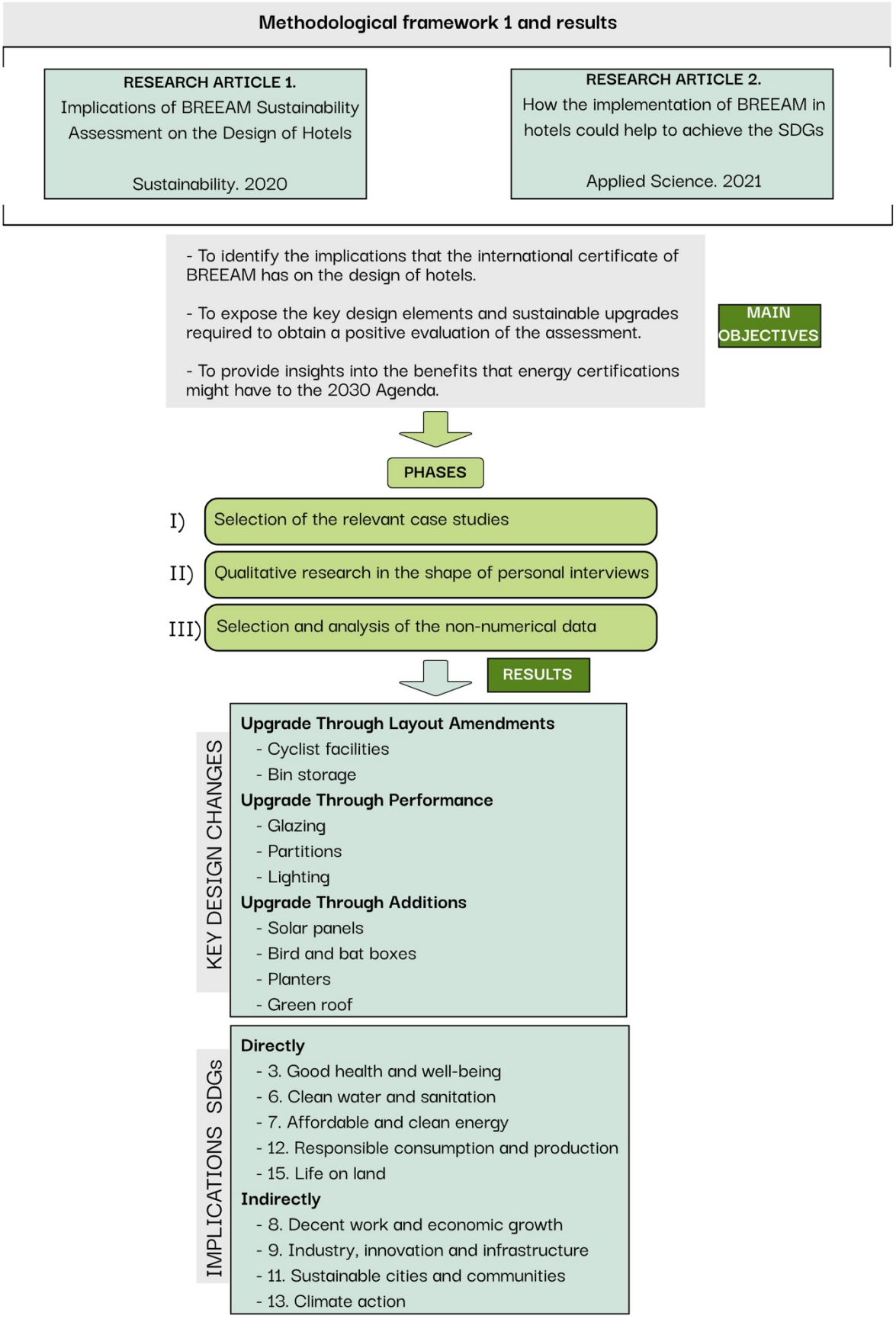

Figure I.3. Methodological framework 1 and results.

4.2. Methodological framework 2 and results of the research article: "Promoting the sustainable recovery of Hospitality in the Post-Pandemic Era: a comparative study to optimize the servicescapes"

This section of the research studies the negative impact the pandemic has had on the hospitality industry by analysing how the sentiments of people's have changed towards hotel's servicescapes and what do they expect to find in it since now on. Moreover, it has also been studied how the servicescapes could be improved for a sustainable recovery in the post-pandemic era from a design and service perspective. Figure I.4 presents an overview of the methodological framework 2 devised for this research and showcases the outcomes obtained through its implementation. For instance, an empirical research has been developed together with a comparative study between people's opinions about servicescapes in November 2020 against September 2022 in Andalusia. The methodology was developed into three phases:

(I) The generation of a proposed servicescape scale in a health crisis environment. This or similar events have not been studied before from a servicescape perspective. Hence, the author has created the scale shown in Table IV.1. (see the research paper "Promoting the sustainable recovery of Hospitality in the Post-Pandemic Era: a comparative study to optimize the servicescapes" and shown in chapter IV of this document). This scale is the result of the most relevant dimensions exposed by previous authors (Baker, 1986; Bitner, 1992; Lockwood & Pyun, 2018; Wakefield & Blodgett, 1994) together with latest research on previous airborne transmission diseases and servicescape. For this particular study, the author has completed the scale with further attributes and have added a proposed sixth factor under the category of 'Services', including the main services affected in the hotel during the current pandemic and are considered to be relevant.

(II) An online administered questionnaire was designed from the proposed servicescape scale. The reliability of the questionnaire and the margin of error were studied to validate the survey statistically. The questionnaire was based on a five points Likert-type scale. A total amount of 31 questions or statements grouped in 6 sections were provided, each of them are related with one or more attributes proposed by the author in Table IV.1 (see the research paper "Promoting the sustainable recovery of Hospitality in the Post-Pandemic Era: a comparative study to optimize the servicescapes" and shown in chapter IV of this document). The first group of respondents was formed by 223 with 222 of valid responses. The second group was formed by 249 with a total of 241 valid responses, all aged between 18 and 90 years old of all genders and based in Andalusia.

(III) Subsequently, a quantitative method was used and data was collected from the questionnaire. The analysis and comparison of the results provided the important insights shown below.

4.2.1. Key design changes

A number of interesting findings for practitioners, design experts and academics of the hospitality and tourism sectors can be extracted from this survey. Two main groups with the key design changes implemented in the hotels can be extracted. First group includes the attributes or improvements that are relevant for people and have remained constant during the phases of the pandemic, these will be called the "unaltered attributes". Second group includes the attributes that have changed from 2020 when the first survey was taken to 2022 when the second survey has been

taken and are also relevant, these will be called the “altered attributes”. Attributes from both groups must be taken into account and implemented in hotels for a sustainable recovery of the sector.

Unaltered Attributes

From the ‘Aesthetic Quality’ section, it was confirmed that customers’ satisfaction increased when the building includes some indoor plants. Similarly, a minimalist decoration style and clean lines furniture inspired customers’ positive responses as furniture with clean lines and a minimal design are usually easier to keep cleaned. From the ‘Atmosphere’ section, more than 85% of the participants expressed the importance of natural light and their preference towards the use of warm artificial lighting in the room against a cold artificial lighting. Moreover, the scent of cleanliness was highlighted, and it seems to be essential for questioned people. ‘Spaciousness’ has been a very important factor during COVID-19 and results from this dimension have remained constant from 2020 to 2022. Findings have clearly shown the significance of an outdoor space within the hotel. Participants were also asked about their preferences of having a big guestroom or a big bathroom being the first one significantly more valuable to them. The importance of indoor air quality has remained constant in both surveys. Finally, from the ‘Services’ section, a majority of participants strongly agreed with the use of masks by the staff of the hotel.

Altered Attributes

The results revealed that most of the participants were aware of the main COVID-19 procedures and measures, although they generally felt more flexible about them in 2022 than in 2020. Physical distancing and the use of masks inside the hotel seemed to be very important for the respondents but the mean for both show that these are not as relevant for them as during the pandemic. People seemed to be more comfortable with warning signs in 2022 so this attribute, contrarily to the other COVID-19 related attributes, gets a more positive feedback. In regards of the background noise, results confirmed the significance of a quiet and relaxing environment in the hotel. Some of the results from the ‘Physiological conditions’ section, provide evidences that most of the respondents agreed with the implementation of all COVID-19 protocols. Although our results clearly show that participants were aware and understood the restrictions, some of these attributes have been altered from 2020 to 2022. The spa services were examined and respondents supported a limited use. Lastly, the agreement for most of the respondents with the utilization of technology for bookings was revealed.

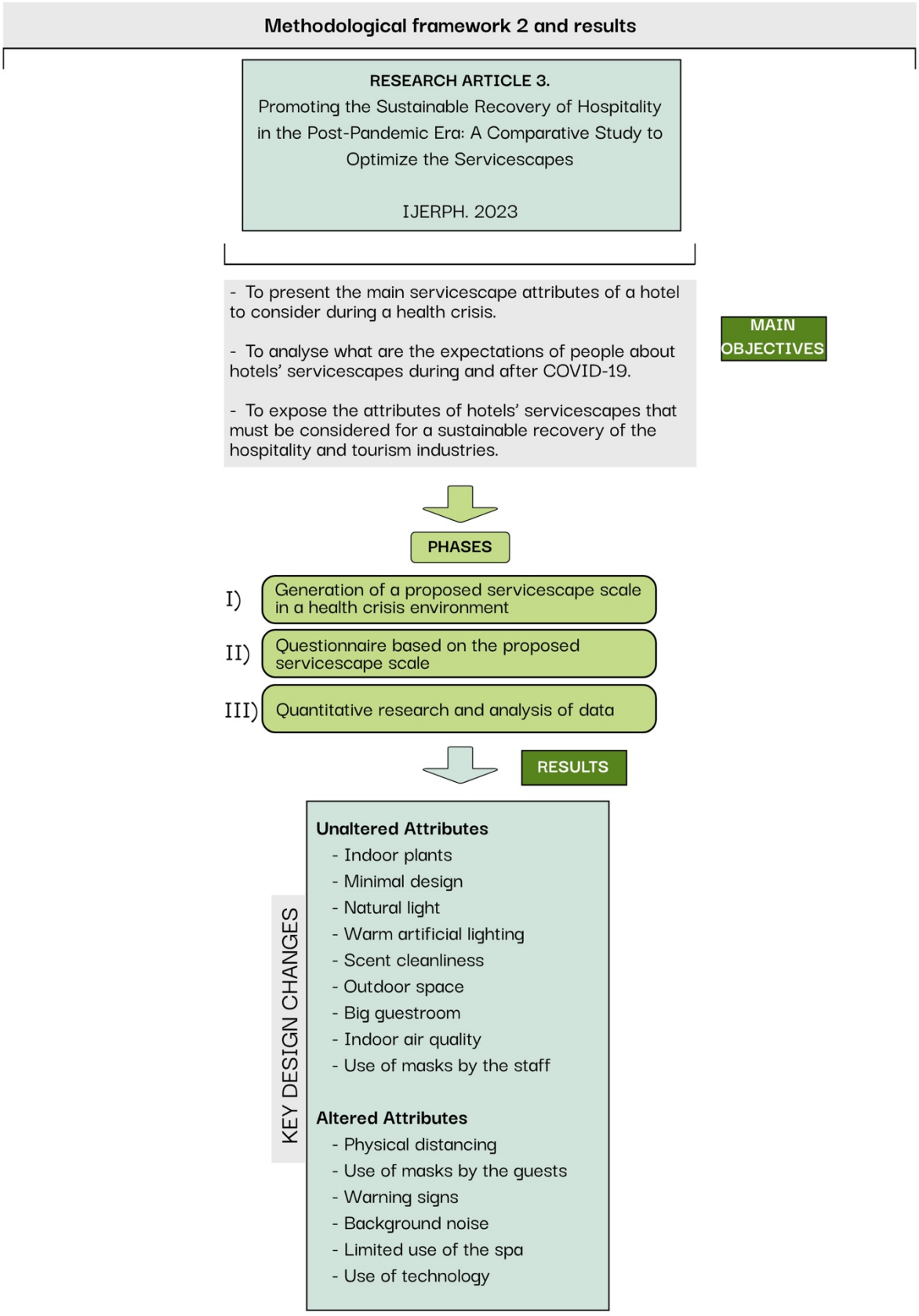

Figure I.4. Methodological framework 2 and results.

4.3. Methodological framework 3 and results of the research article: "Optimising LCA in complex buildings with MLCAQ: a BIM-based methodology for automated multi-criteria materials selection"

This section of the research focuses on the circularity of materials and proposes an optimised methodology to accelerate the LCA calculation process. This will facilitate the construction management of the building by decreasing the time and effort required for project preparation and enhancing coordination and collaboration among the various involved parties. It is centred on three main indicators, namely CO_2 emissions, embodied energy, and generated waste mass. Figure I.5 presents an overview of the methodological framework 3 devised for this research and showcases the outcomes obtained through its implementation. This methodological framework is comprised in five key phases:

(I). Program. It involves developing a novel tool that establishes a connection between the BIM format and the FIEBDC-BC3 format of price bases. The tool is designed to be robust and flexible, enabling accurate estimation, measurement, environmental impact and tracking of construction quantities. Its versatility makes it well-suited for effectively managing construction and engineering projects in various industries, including hospitality. Moreover, the utilization of open file formats enables the permanent storage and accessibility of information, addressing a previous limitation in existing research.

(II). Generate. During this phase, a 3D digital model will be created in the BIM format. This model will consist of the combination of construction elements, such as slabs, which are further composed of sub-elements like finishes. The digital model will encompass the key elements that define the hotel case study.

(III). Link. The developed tool will establish the connection between BIM and FIEBDC-BC3. This step is crucial in the proposed methodology and sets it apart from other approaches by enabling the extraction of quantities and properties from each IFC entity that comprises the hotel. To streamline the process, materials, along with their corresponding environmental and economic attributes (such as units, unit price, embodied energy, CO_2 emissions, unit mass of waste, and unit volume of waste), will be directly extracted from an online price database.

(IV). Quantify. All the information present in the model will be extracted automatically, encompassing environmental data, waste, measurements, and budget details. The importance of this step lies not only in the automated retrieval of budget and environmental information but also in the ability to obtain this data quickly and effortlessly, regardless of the complexity of the building. This case study illustrates that obtaining budget and environmental impact data for a high-rise hotel can be achieved without any additional challenges.

(V). Qualify. The final phase involves comparing two sets of construction solutions and selecting the most suitable option based on three indicators: CO2 emissions, embodied energy, and waste mass. In this phase, the results will be extracted and presented for evaluation.

4.3.1. Key environmental elements from each section

Material cost

The majority of the total material cost is attributed to the façade, which encompasses a curtain wall spanning the entire building from the ground to the top floor. While both sets of materials exhibit similar structural characteristics, there is a distinction in section size and cost between the two sets. In the case of this high-rise hotel with a curtain wall system, the most significant elements for LCC

analysis, contributing to over 85% of the total cost, are the façade, floor slabs, and interior partitions. When comparing the combined costs of these three elements from both sets, there is a difference of 24.77% or 6,857,169€ in total.

Embodied energy of materials

Within this category, the façade once again holds the greatest influence, showcasing a notable difference of 22,930,275.89MJ between the two solutions. The second most impactful element aligns with the total cost category, which is the floor slab. The third element that significantly contributes to embodied energy is the carpentry, specifically the interior doors of the case study. As a hotel, the presence of numerous interior doors makes their consideration crucial. Lastly, the fourth notable element in this category is the concrete stairs connecting the floors. Collectively, these four elements exhibit a difference of 39,636,274.01MJ in terms of embodied energy between the two sets.

CO_2 emissions of material

Here the most significant elements once again are the facade and the slabs. Additionally, the concrete walls are considered as well. The cumulative CO_2 emissions generated by these three elements account for over 85% of the total emissions from all materials, making them the focal point of this analysis. Specifically, the facade element of set 1 produces 7,916,099.71 kg of CO_2 emissions, whereas set 2 produces 6,407,396.39 kg. Furthermore, the slabs of set 1 result in a total of 3,472,383.33 kg of CO_2 emissions compared to set 2, which emits 2,361,350.88 kg. Lastly, the concrete walls of set 1 contribute 756,126.47 kg of CO_2 emissions, while set 2, which utilizes recycled concrete, emits 527,869.37 kg.

Waste mass of materials

The building elements that contribute the most to waste mass include the slabs, interior partitions, and concrete stairs. Consequently, the lost coffer slab from set 1 results in 257,580.30 kg of waste, while the recoverable PVC pod from set 2 generates 103,244.92 kg of residual mass. Interestingly, the stairs in set 1, constructed with traditional concrete, generate less waste compared to the stairs in set 2, made of recycled concrete. The use of recycled concrete may lead to increased waste mass due to the necessity of removing contaminants such as wood, paper, and plastics before the recycling process, which generates additional waste. Moreover, the production process of recycled concrete, involving crushing and screening, can contribute fines and dust that contribute to waste mass. However, although recycled concrete generates higher amounts of waste, the difference compared to traditional concrete is not significantly substantial.

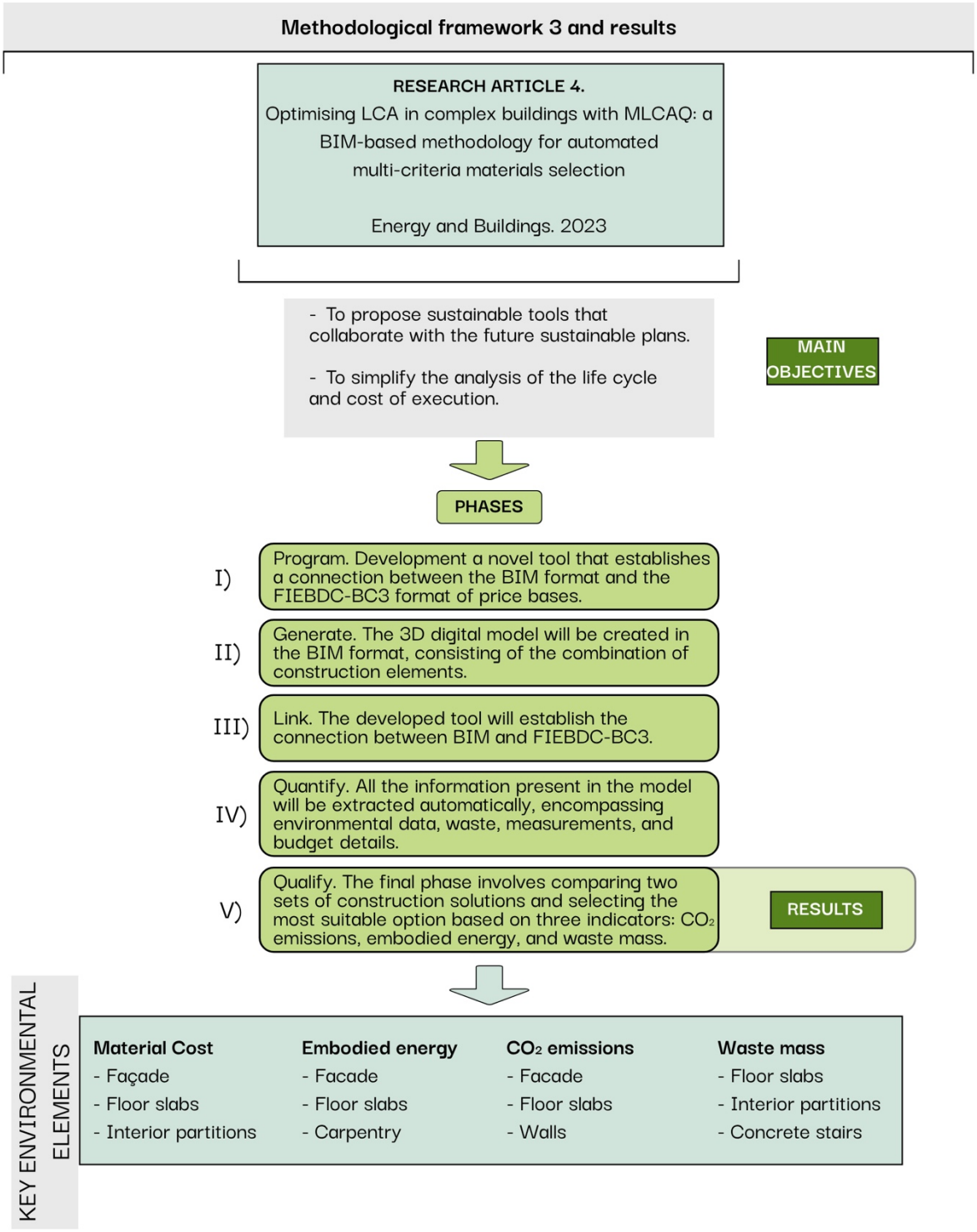

Figure I.5. Methodological framework 3 and results.

5. DISCUSSION

The results of the different studies developed in this research comprehend the sustainable measures that have been implemented in hotels in the recent years in addition of new measures, strategies and tools that should be applied for a sustainable recovery of the sector after COVID-19. The findings require further discussion in this section to compare what other researchers have studied before, what is the general knowledge about these results and to emphasize their application.

In regards of the results obtained from the analysis of BREEAM certificate, findings suggest important implications on the design of a sustainable hotel and the benefits towards future sustainable plans. The influence that energy certificates have on climate change has been widely studied. Zeppel and Beaumont (2013) investigated the CO_2 actions by environmentally certified tourism businesses. Their research revealed that hoteliers and operators implemented actions in water, energy and waste reduction and were aware of the consequences of climate change for tourism. This study confirms the evident relationship between climate change and energy certificates. It also confirms our finding implying the significance of BREEAM on hotels with regard to SDG 13. The data collected from the interviews shows that the impact that BREEAM might have on the design depends on whether the hotel is existing or newly built. In the case of existing buildings, the most important categories to consider are Health and Wellbeing and Land Use and Ecology. An update of the existing windows will improve the thermal and acoustic insulation conditions and the introduction of bat and bird boxes together with planters will immediately add an enhancement of the ecology of the hotel. In the case of newly built hotels, the Waste and Transport categories have been a common factor in all of them. An adequate design of the project that includes enough area designated to cycle and bins stores, will help in acquiring a sustainable hotel. Also, Health and Wellbeing and Land Use and Ecology categories are very important for newly built hotels. The incorporation of green roofs and solar panels will also contribute positively. The study conducted by Potrč Obrecht et al. (2019) evaluates three different building certification schemes, LEED, BREEAM and DGNB, and analyses their coverage of the main health and well-being aspects in buildings. Their results show that issues such as comfort, light or air quality that affect the inhabitant are addressed in all of the certification assessments. These results provide evidence that BREEAM contributes to the SDG 3, good health and wellbeing (*Sustainable Development Goals - BRE Group*, 2022).

The application of a sustainability assessment should be planned and done since the design stage of the project in order to facilitate the inclusion of actions and elements recommended by the assessor. Moreover, the provision of an assessor and the adequate technicians will facilitate and accelerate the development of a green hotel. This aligns with the comments by Haroglu (2013) about how the early involvement of BREEAM assessors can play an important role in the design and Fenner and Ryce (2008) that highlighted the significance that the assessor provides on the clarity of the BREEAM assessment. It was also revealed the importance of operational energy, water consumption and materials to ensure a high BREEAM rating (Haroglu, 2013). These findings corroborate the direct relation of the assessment with SDG 6 to “ensure availability and sustainable management of water and sanitation for all”, SDG 7 to “ensure access to affordable, reliable, sustainable and modern energy for all” and SDG 12 to “ensure sustainable consumption and production patterns” (*Sustainable Development Goals - BRE Group*, 2022). Two other professionals are key for the execution of the project under the BREEAM premises, the mechanical and electrical engineer (M&E) and the ecologist. Lowe and Watts (2011) stated in their study that the introduction of BREEAM on a construction development will cause an increment of the M&E workload, with most of the work being in the design of the systems. In regards of the ecology, SDG 15 states: “protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse

land degradation and halt biodiversity loss" (*Sustainable Development Goals - BRE Group*, 2022). Pedro et al. (2019) highlight the importance of urban planning tools to enhance sustainable use of land and propose a combination of geographical information systems with BREEAM-Communities as a valuable tool for urban planning. Their model confirmed the significance of land use and ecology to BREEAM and suggested an advanced tool that can help with the achievement of SDG 15. Similarly, SDG 11 hopes to "make cities and human settlements inclusive, safe, resilient and sustainable" (*Sustainable Development Goals - BRE Group*, 2022). Lastly, Norouzi and Soori (2020) have studied the ecological, social and economic aspects that assessment methods take into account when evaluating the sustainability of a building. Their research proved that BREEAM has the highest rank for the economic criterion of all the analysed certificates supporting SDG 8, which promotes inclusive and sustainable economic growth (*Sustainable Development Goals - BRE Group*, 2022). These findings are extremely useful for the 2030 Agenda, as they demonstrate that sustainable assessments, such as BREEAM or LEED, can be applied in any region of the world, and can be used by various groups if the right criteria and objectives are identified.

In regards of the key design attributes to be considered for a responsible and sustainable recovery after COVID-19, minimalism has proved to be a sustainable lifestyle that declutters not only spaces but minds. It has also been proved that it alleviates depression and improves wellbeing (Kang et al., 2021). Regarding the importance of natural light within the space, previous research has demonstrated the positive effects of natural environments on agitation and stress. Moreover, it has been proved that indoor environmental conditions, such as temperature comfort, lighting, noise or indoor air quality, influence emotional stress and sleeping hours (Zarrabi et al., 2021). It has also been proven the subconscious positive influence of ambient scents, white bedding, and even the presence of cleaning staff on an individual's perception of cleanliness during COVID-19 (Magnini & Zehrer, 2021). The use of outdoor recreational activity increased by 291% during the lockdown and the value of urban nature during a time of crisis was rediscovered. It has been proved that sometimes, the outdoors helps with mental health and wellbeing during a crisis (Jackson et al., 2021; Venter et al., 2020). Airborne viruses and poor indoor air quality are directly related. This is a field that needs to be researched further; so far little research has studied the improvement of air quality within buildings with proper design strategies and the integration of new engineering systems to control it (Megahed & Ghoneim, 2021). Concerning COVID-19 protocols, previous research has examined the safety and health measures for COVID-19 in the hospitality industry (Robina-Ramírez et al., 2021) and found that social distancing in hotels is one of the most effective measures in preventing infections. Results show a positive attitude toward the use of the spa, which complements the demonstrated benefits of spas and balneotherapy during COVID-19 (Kardeş, 2021; Martínez-Moure & Saz-Peiró, 2021). Finally, it has been investigated that new uses for technologies, such as the use of live-stream practices, AI, or facial recognition, are utilized on a daily basis to enhance the service quality in the hospitality sector to successfully recover from the virus (Lau, 2020).

There is a significant interest in promptly integrating a circular perspective into the early stages of building design to facilitate the transition from a linear to a circular economy within the buildings' life cycle. This approach not only expedites the design process but also profoundly impacts the building's value chain. In the field of construction, various tools have been developed to quantify the environmental impact, particularly in areas such as waste management, CO_2 emissions, and energy consumption in residential buildings (Camporeale & Mercader-Moyano, 2021). However, none of these tools currently enable the comprehensive collection of all these data within the Building Information Modeling (BIM) framework. Furthermore, existing methodologies lack standardization and fail to provide user-friendly access (Llatas et al., 2022; Marzouk et al., 2018). In this research, a

strategy is proposed to reduce the effort required for calculating the LCA of a 39-storey hotel while promoting a system that avoids delays in the decision-making and design stages. This proposal represents a relevant improvement in the qualities of existing LCA and LCC tools, including automation, data visualization, real-time calculation, and usability (Backes & Traverso, 2021). For instance, the workload for environmental and economic data preparation and BIM workflow adaptation is reduced through the establishment of a link between BIM and FIEBDC-BC3 formats. By automating these processes, relevant design changes can be implemented in real time without delaying the project's development. Moreover, the use of circular materials does not appear to have a detrimental impact on the total cost of the building. It is worth mentioning that prior research has also highlighted a positive correlation between a circular economy and economic growth (Hysa et al., 2020). Although the adoption of circular materials in the construction industry has often been associated with increased building costs, recent studies have demonstrated that the use of such materials not only reduces CO_2 emissions but also optimizes building costs for achieving an optimal design (Kertsmik et al., 2023; Wuni, 2022). Findings indicate the potential benefits of incorporating circular practices in the construction industry, both in terms of environmental impact and economic considerations.

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CHAPTER II.

"IMPLICATIONS OF BREEAM SUSTAINABILITY ASSESSMENT ON THE DESIGN OF HOTELS"

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Implications of BREEAM Sustainability Assessment on the Design of Hotels

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Abstract: This original research paper analyses the actual and important topic of the implications of BREEAM sustainability assessment on the design of hotels and it is a personal response to "The Agenda 2030 for Sustainable Development" and its influence on the Tourism and Hospitality Industry. The paper aims to examine the influence of the sustainable assessment method BREEAM on the design of hotels by using seven case studies and studying the changes that were implemented in order to achieve their targets. Qualitative data were obtained by conducting in-depth interviews and analyzing the supplied documentation. The authors notice that the results revealed that a BREEAM approach might limit the design of the hotels but, including the right measures at the early design stage of the project, the target can be easily achieved.

Keywords: hospitality; hotels; sustainable assessment; BREEAM methodology; green hotel

1. Introduction

Over the past decades, sustainable development has become very important in every economic sector but especially in the Construction and Tourism sectors [1]. Tourism is one of the most powerful drivers of development for the world economy and in particular, international tourism has been considered as a tool for development in emerging economies. Developing countries are leaders in including sustainability procedures for building and hotels are becoming more eco-friendly by including environmental standards in their design, architecture and management [2,3].

Hotels are key in this process of sustainability; in places where tourism is the main contributor to GDP (Gross Domestic Product), the addition of a sustainable design and sustainable certifications for new buildings and renovations is crucial [3]. For a decade, the Hospitality sector has been pressured to include environmental strategies and reduce the carbon footprint by government legislation, in order to minimize its impact on the environment [4,5].

Despite its involvement in sustainability, there is not much research on what is the best way to approach a "green hotel" and how the design can be affected by including sustainable measures [6]. This article is organized into three main sections. The first offers a brief overview of the impact of the Agenda 2030 on Tourism. The second exposes the existing literature about the importance of sustainable certificates on the Hospitality Industry and the background of one of the first sustainable European building assessment methods applicable to residential and commercial buildings, the Building Research Establishment Environmental Method (BREEAM) [7]. The last part aims to analyse by a qualitative method the impact of BREEAM on the design of hotels.

1.1. Impact of 2030 Agenda on the Tourism

In 2015, the Heads of State and Government of 193 countries met at the 70th General Assembly of United Nations and approved the resolution of "The 2030 Agenda for Sustainable Development". This plan is call to action to protect our planet, end poverty and improve the lives and prospects of everyone. The 2030 Agenda sets out 17 Sustainable Development Goals (SDGs) and 169 targets to be achieved by 2030 that are considered at the moment a global emergency to mitigate and balance the three dimensions of sustainable development, the economic, social and environmental [8,9]. This plan must be implemented entirely and as a whole, as all the different goals and targets are related to each other. The United Nations Resolution states that in order to achieve the completion of the SGDs, all the nations must take responsibility. The European Union has played an active role and will implement the 2030 Agenda internally and globally in cooperation with partner countries [10].

The UNWTO (World Tourism Organization) establishes that tourism contributes directly or indirectly to the achievement of all SDGs and in particular, it is included as a target in the Goals 8, 12 and 14 [8,11].

SDG 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all. According to a study from WTTC (World Travel and Tourism Council), Travel and Tourism was the sector with the fastest growth in 2018 (3.1%), ahead of the Construction (2,8%) and Banking (2.6%) sectors. In addition, Travel and Tourism sustained a total of 319 million jobs across the world and induced 10% of all jobs, exceeding the impacts of the Financial, Health and Banking sectors, among others [2,3]. The contribution of the Tourism sector is specified in Target 8.9 "By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products" [8].

SDG 12. Ensure sustainable consumption and production patterns. Tourism can play an important role in the evolution of a green economy and inclusive growth [2]. If the tourism sector adopts sustainable consumption and production practices (SCP), it can significantly accelerate the shift to a more sustainable planet [11]. The One Planet Sustainable Tourism Programme has the objective to improve

the sustainable development impacts of tourism by promoting SCP that use natural resources and produce less waste [12]. The inclusion of "green hotels" is key for this goal. Clients are experiencing an awareness of environmental damage and the addition of sustainable measures in hotels is becoming a very important factor for their design [13].

SDG 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development.

Coastal and maritime tourism are tourism's biggest segments. It is specified in target 14.7 that "by 2030, increase the economic benefits to small island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism" [8]. Small Island Developing States (SIDS) rely on healthy marine ecosystems. Integrated Coastal Zone Management must include tourism development to preserve fragile marine ecosystems and promote a blue economy [11].

2. Literature Review

2.1. The Importance of Sustainability Certifications for the Hospitality Industry

In 1993, the World Tourism Organisation (UNWTO) put forward the concept of Sustainable Tourism Development. In 1995, United Nations Educational, Scientific and Cultural Organization (UNESCO), United Nations Environment Programme (UNEP) and UNWTO held in Spain the first World Conference on Sustainable Tourism and the Charter for Sustainable Tourism was adopted in this meeting. Since then, Sustainable Tourism has occupied a dominant position in the Tourism industry [14,15]. Although the UNWTO has established that tourism contributes to the completion of the SDGs [10], the Hospitality industry faces the challenge of determining which of the 17 SDGs and associated targets are its priority [16].

Widely, the building sector accounts for one third of energy-related carbon emissions [17,18]. In the UK, buildings are responsible for half of the carbon emissions, half of the water consumption, one third of the landfill waste and one quarter of all raw materials used in the economy [19]. Hotels' users consume a great amount of water and energy at the same time that generates an important amount of solid waste and effluents on a daily basis [20], but hotels may have a significant and positive impact on the environment by changing some of their management and design aspects. Customers have radically changed their attitude towards adopting environment-friendly practices and as a result, hotels cannot ignore their environmental and social responsibilities [13,21]. For this, many hotels are now in the process of becoming "green hotels", but it has been demonstrated that most of them only focus on small changes such as reusing linen and towels [22,23]. A green hotel must operate according to the principles of green hospitality; this does not mean planting some trees in front of it, but being environmentally friendly, implementing waste management systems, recycling, and saving in water and energy, among other procedures [24].

The guests expect the implementation of more sustainable and eco-friendly practices such as water conservation, energy efficiency and proper waste division [25,26] and this approach should be incorporated from the planning stage to the demolition phase of the building. A green building must be designed as a whole and covers all the phases such as design, construction and operation [27].

As it has been studied before, the term smart tourism is closely related to the application of new technologies [28,29]. They propose to rethink the traditional approach to tourism and include the latest technology such as smartphones and tablets in its planning and programming. New technologies can enhance tourism in different ways; several studies demonstrate that hotels display, on the internet, their certificates and environmental practices to show their customers their awareness of the environment [30,31]. Studies indicate that the application of environmental procedures and their consequent certifications can improve the image of the company and its operating performance [32].

As a consequence, environmental assessments of buildings have become one of the most important steps in the sustainable built environment [5,7,33]. The European Union Energy Performance of Buildings Directive (EPBD) [34] and the UK Climate Change Act of 2008 set sustainable buildings on the UK policy agenda; since then, a wide variety of tools have been developed to assess and help construction projects, and BREEAM is one of the most successful of these tools [35].

2.2. Background of BREEAM Assessment

At first in the UK and now worldwide, BREEAM is leading the list of sustainability assessments; between 2013 and 2017, over 10,800 certified assessments were issued at both the Design and Post-construction stage [36]. The method was launched in the UK in 1990 by the Building Research Establishment (BRE); it was initially designed to focus predominantly on environmental aspects [33,37], but in the past decade it has also highlighted economic and social aspects. It has been applied in 77 countries [7,38].

BREEAM considers ten categories, shown in Table II.1. to measure sustainable value, including management, health and wellbeing, energy, transport, water, materials, waste, land use and ecology, pollution and innovation [38]. Each of these categories is divided into a range of assessment issues with its own target, aim and benchmarks.

Table II. 1. BREEAM Environmental section weightings

Environmental section	Weighting (%)			
	Fully fitted out	Simple building	Shell and core only	Shell only
Management	11	7.5	11	12
Health and Wellbeing	14	16.5	8	7
Energy	16	11.5	14	9.5
Transport	10	11.5	11.5	14.5
Water	7	7.5	7	2
Materials	15	17.5	17.5	22
Waste	6	7	7	8
Land Use and Ecology	13	15	15	19
Pollution	8	6	9	6
Total	100	100	100	100
Innovation (additional)	10	10	10	10

This weighting system is defined in more detail within the BRE Global Core Process Standard (BES5301).

A BREEAM assessor will determine when a target or benchmark is reached and will award with score points or credits as per Table II. 1, then these are weighted and aggregated on a scale of outstanding, excellent, very good, good, pass and unclassified [38], as shown in Table II. 2.

Table II. 2. BREEAM rating benchmarks

BREEAM Rating	% score
Outstanding	≥ 85
Excellent	≥ 70
Very Good	≥ 55
Good	≥ 45
Pass	≥ 30
Unclassified	< 30

BREEAM is regularly updated to ensure it meets the requirements for building sustainability and it is used for public and private projects, applicable to residential and commercial buildings [7]. In some

cases, it is a mandatory requirement to satisfy certain planning conditions or regulations, particularly for the public sector projects. In other cases, it is used voluntarily to earn recognition due to its international prestige [33], and it is highly valued when it comes to indicate the carbon emissions of commercial buildings.

It has been demonstrated that hotels and tourism benefit from the application of sustainable assessments such as BREEAM [32]. In addition, the method has shown its support to the SDGs and the Agenda 2030 and has demonstrated how and where the BREEAM family of standards and tools support the SDGs [39]. It has highlighted its significant contribution to meeting the following goals [8]:

SDG 3. Ensure healthy lives and promote well-being for all at all ages.

SDG 6. Ensure availability and sustainable management of water and sanitation for all.

SDG 7. Ensure access to affordable, reliable, sustainable and modern energy for all.

SDG 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.

SDG 11. Make cities and human settlements inclusive, safe, resilient and sustainable.

SDG 12. Ensure sustainable consumption and production patterns.

SDG 13. Take urgent action to combat climate change and its impacts.

SDG 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reserve land degradation and halt biodiversity loss.

Despite its importance, little research has been conducted about the effects the application of this sustainability assessment method might have on the hotel's design and management process. Holmes and Hudson [40] examined how BREEAM affects the design of an office building but the method has been through many changes since this study was taken and they focused more on the perceived value of the method than its design effects. Lowe and Watts [41] analysed the benefits of implementing BREEAM on a two storey medical centre development but this research was focussed on the financial implications of the method. Fenner and Ryce [42] compared BREEAM with the LEED method, analysing their limitations in current practice, but this research did not focus on the design aspect. Several studies taken from Haroglu and Schweber [33,35,43] analysed the implication that BREEAM might have on the design process although these studies used different types of buildings as case studies such as educational, commercial, residential and healthcare. Mengxue Lu [7] compared four rating tools: BREEAM, Leadership in Energy and Environmental Assessment (LEED), Green Star and Building Environmental Assessment method (BEAM Plus), and concluded that all of them were similar, covering the same environmental aspects, in terms of energy audit. The carbon audit, however, was not a common investigation focus in any of them.

This paper examines how the implementation of BREAAM impacts on the design of hotels and their management processes and demonstrates the changes that have occurred to the projects in a specific context as a result of the assessment. The intention of the study is not to generalize across specific design features of the hotels but rather to provide a general understanding of the influences and impact that the BREEAM method might have on the hotels' design stage. Due to the lack of research on this field and its importance in Tourism and Hospitality, this study examines the impact of the BREEAM assessment method on the design process of seven hotels in the UK.

3. Methodology

This study uses a qualitative method of analysis. The qualitative approach to research seeks to analyze the effect of BREEAM on hotels' design decisions; this is not confined to a specific phase of the projects but it comprehends the entire process from conception to completion and beyond. Although some researchers have investigated before about sustainable assessments and specifically BREEAM, little research has been focused on the implications that the method might have on the design of buildings [30,32,40] and no prior research has been found were the case study was a hotel. Hence, the study presents this limitation and the need for further development in this area of research. In addition, the qualitative method used in the research is based on human experience and is dependent on the individual skills of the researcher and the people interviewed.

In the present study, a number of specialized Hospitality professionals, both architects and architect technicians, were selected based on their level of expertise in the field and quality of hotels produced during their careers. All of them are Hospitality focused and the main people responsible for the selected projects of this study. They offered a variety of hotel projects assessed under BREEAM. In total, 7 case study hotels were selected, each of them with different characteristics, stages and BREEAM targets. As a context, all of the hotels are based in the UK due to the importance of this method there.

Architects and architectural technicians responsible for the design of the buildings were interviewed. The interviews were undertaken during April and May of 2020 and, due to the worldwide pandemic of COVID 19 and the mandatory lockdown in the UK during these months, it was not possible to do the interviews face to face. Hence, they were done via Yealink Meeting Server with each technician and architect. Each interview lasted an average of 30 min per project and they were recorded with Windows 10 Screen Recorder. The collection of data was also supplemented with documentation provided by the designers including plans and elevations, BREEAM assessments, planning decision notices and relevant information from several professionals that influenced in the design process of the hotels, with all of the information in pdf format. In Table II. 3, the details of the selected cases are shown such as the stage of the project, number of rooms, number of storeys and BREEAM target and final score. For confidentiality, the projects are named under the headings A, B, C, D, E, F and G.

Table II. 3. Case study hotel projects

Case studies	Stage	Nº rooms	Nº storeys	BREEAM target	BREEAM final score
A	Completed	216	5	Excellent	Excellent
B	Completed	302	7	Very Good	Very Good
C	Under construction	82	9	Very Good	On going
D	Completed	339	42	Excellent	Outstanding
E	Under construction	456	13	Excellent	On going
F	Under construction	153	9	Very Good	On going
G	Under construction	329	19	Very Good	On going

4. Results

An extensive amount of data was collected from the interviews about the influence that the BREEAM assessment method has on various aspects of the hotel design. This section includes two parts, the first is a description and a brief of the information obtained from the architects and technicians about the required changes during the design process of each case study. The second part exposes the key design changes extracted from the interviews that were crucial in all the cases.

4.1. General Description of Case Studies

In case study A, the client was very interested in getting a BREEAM Excellent score and it finally achieved the highest ever BREEAM score for a hotel in the UK. The building is now utilising a range of low energy technologies to reduce its energy demand and generates its own energy supply, delivering an 87% reduction in CO_2. The negotiation process with the assessor involved many changes in the project, mainly in the Mechanical and Electrical designing phase, where the assessor asked for bigger plant rooms and more plant areas in addition to several systems that were needed to achieve the credits. It was required to incorporate a number of sustainable construction techniques including enhanced isolative building elements and a sustainable surface water drainage system. In addition, the hotel harvests rainwater, which is used to serve the toilets in the building and to water the external landscaping areas. Increasing the size of cycle store was also needed; the technician explained that this is very common practice when working on a BREEAM project since it is an easy way to get the number of credits required and usually it does not impact excessively the design of it. Finally, the designers had to increase the size of the refuse store as a result of accommodating more numbers of bins and also provide an external bin store. The materials used for this building were assessed in order to meet the Building Regulations and BREEAM criteria, resulting in a combination of brick, metal and stone cladding.

Case study B was a regeneration and further extension of an existing historical building; as a result, the design process required special attention in this case. The hotel is located in the city centre and had a planning requirement to achieve a BREEAM Very Good score. A pre-assessment was submitted as part of the planning application, which is the standard process for most of the buildings in the UK. The planners reviewed it and conditioned it to make sure that the score was achieved; as a consequence, certain changes were needed in order to get BREEAM Very Good as the final score. The designers had to increase the number of cycle storage spaces in the building in order to get the credits related. Under the ecology requirements, even though it was a regeneration of an existing site, the architects and technicians had to provide an enhancement. They had to include certain numbers of bat boxes housed on the roof levels designated for nesting bats. This requirement was needed under the premises that the demolition of an adjacent building was needed in order to extend the hotel and it was deemed that bats could have nested there if they wanted to, so in order to replace this, bat boxes were included. The number and size of bins were increased and, as a consequence, the refuse store was also slightly expanded to accommodate them. In regard to the building envelope, some of the windows had to be upgraded due to the fact that the acoustic requirements of BREEAM were higher than the hotel operator's requirements. The specification of the glass was changed but the size and position of the windows remained the same, so the design of the facade was not altered. Finally, the material of the new hotel was proposed as rendered to match the existing building which, from a BREEAM perspective, is not ideal due to its characteristics but planning required it to keep the same material in order to minimise the impact of the extension.

Case study C is an existing building refurbishment and extension, it has planning approval and is currently under construction. The hotel is on the boundary on three sides and they are extending it out on the fourth side. There is no space for landscaping and the existing building has a pitched roof, so there were no opportunities for proposing green roofs, bat or bird boxes and planters at ground floor; as a consequence, the ecology credits were difficult to achieve. In order to compensate this, the BREEAM assessor advised that during the design stage, the architects should carry out an assessment to demonstrate that they were not able to provide ecological enhancements. The Mechanical and Electrical engineer presence was crucial in this hotel; although they always have an important role on the completion of BREEAM projects, in this specific case and due to the lack of ecological enhancements, the engineers had to bring new solutions to compensate this lack. The installation of flow restrictors helps to save water by limiting the flow of particularly wasteful taps and showers. The architect explained that the water consumption is always a common factor to take into account for Hospitality projects and its right management can drastically change the running cost of the hotel.

Finally, to meet BREEAM acoustic requirements, the technicians had to enhance the existing glazing by adding a secondary glazing. At the moment, they are on target for achieving BREEAM Very Good.

Case study D is a highly sustainable skyscraper building with a small footprint and 42 floors. It had a planning requirement for a BREEAM Excellent but it finally achieved an Outstanding, the highest BREEAM rating available at the time of completion. Ecology had a major impact on the project. Solar panels and a green roof were included in addition to beehives on the 39th floor to produce honey for guests. On the lower levels, bat and bird boxes for nesting were also incorporated. In addition, due to the small footprint of the building, it was impossible to include a cycle store within it, so a separated external cycle store was designed with a green roof and green walls under the recommendations of the ecologists. Finally, it is important to mention that the mechanical system of the hotel has a vital importance in this project. Several measures were included such as a combined heat power system that contributes to a 30 per cent reduction in CO_2 emissions and light regulation system that adjusts the level of light according to the time of day and season. In addition, waste management is crucial in this case; the hotel recycles cooking oil, general waste, soap and bottled bathroom products. Moreover, it uses eco-friendly products from local suppliers.

Case study E has planning approval and is currently under construction. In this project, there were no planning requirements for BREEAM but the client founders had a BREEAM target of Excellent; they requested the BREEAM assessment method to help to reduce the running cost of the hotel. The architect explained that the energy and water consumption in hotels is massive so by including some procedures that will reduce the impact of that, the benefits will be higher for the owners. As well as that, one of the hotel operators also had, as an employee requirement, the achievement of BREEAM Very Good for their projects, so although in this case it is a lower target than the founder´s, it is still important to take into consideration. The pre-assessment of the project is done and the building has a potential target of 79% score for BREEAM Excellent, higher than the 70% minimum score needed so it is highly possible that the project will achieve the targeted score. In this case study, they also had to increase the cycle and bin stores' sizes in order to achieve the credits needed. For the ecology requirements, the designers had to include a total of 65 square metres of planting distributed on three separate roof levels as a consequence of filling the site completely by the building at ground level. The ecologists made a report with their requirements and due to the lack of space for planting, the landscape architect had to include all these planters on different levels of the building to achieve the needed credits. Internally, the architects had to increase the thickness and specifications of the partitions to meet BREEAM acoustic requirements. The technicians had to enhance the glazing specifications for some of the external windows due to the fact that the operators had some requirements for the windows and, in some instances, BREEAM was above them so they had to upgrade the windows in order to achieve the acoustic requirements. The architect explained that one of the hotel operators had very strict thermal requirements, which were well above Building Regulations and BREEAM requirements so the insulation of the building did not need any adjustment to meet the credits. Finally, an adaptability study was needed, which is a document that studies the spatial, structural, and service strategies of the building and analyzes the malleability of it in response to changing operational parameters over time [44]. The study proved that the hotel will be able to change its use if needed, mainly because it is built in lightweight partitions and blade columns.

Case study F is under construction at the moment. This project comprehends two buildings in the same site, a refurbished existing office building and a newly built hotel with some affordable accommodations included. Due to there being three different uses sharing the site, planning required three separated permanent cycle stores and temporary short-term cycle storage. The temporary cycle store had to be increased as the BREEAM assessor recommended. In this case, it was a planning requirement to increase the number of bird and bat boxes that the ecologists advised, so BREEAM did not influence this decision. Since the hotel is a new building, the designers decided to go for blade

columns and lightweight partitions to facilitate the adaptability of the building if it changes its use, so BREEAM rated this positively.

Case study G has planning approval and it is under construction; it has planning and operator's requirements for BREEAM Very Good. There is a planning condition that it must get this targeted score, so a pre-assessment was done in the first place to study the best way to meet this requirement. As in the previous case studies, the main changes were the bin and cycle stores and the inclusion of planters at ground floor level around the building. After a few discussions with the ecologists, some of the planters were omitted as they contained trees that are no longer proposed; the architect explained that this aspect is being revised at the moment. Currently, the design and illuminance of external lighting, including the hotel signage, has been highlighted by the assessor to take into consideration in order to reduce future risks of non-conformance. A lighting assessor will revise these and recommend the best solution; as a consequence, it will have a minor impact on the external design.

4.2. Key Design Changes

Several changes were needed during the design process of the described projects. The key changes applied to the buildings explicitly to obtain the required BREEAM credits and under the instructions of the BREEAM assessor have been identified below. In addition to these changes, the presence of the Mechanical and Electrical engineer is crucial for the design of the hotels. As it has been demonstrated, hotels are linked to produce high levels of water consumption; people tend to consume more water when they stay in hotels than in their homes [45,46]. Implementing the right strategies, technologies and innovation measures help the hotels to reduce their water consumption drastically [47]; case studies C and E included water management systems. The key design changes can be classified under three main groups: upgrade through layout amendments, upgrade through performance and upgrade through additions. On the other hand, Haroglu [33] classified the key design changes under three main areas: building features, materials and water services.

4.2.1. Upgrade Through Layout Amendments

These changes were related to both internal and external amendments of the layout. The increase in the cyclist facilities in order to house a greater number of cycles is a common factor in all the case studies. This amendment falls under the Transport section and credits are given with the adequate provision of cyclist facilities to promote exercise and help to reduce congestion and CO_2 emissions [48]. It is a relatively easy way to get BREEAM credits and does not have a major impact on the layout.

Another key change that was required in the case studies A, B, E and G was the enlargement of the bins storage areas due to increase in the number of bins; this amendment falls under the Waste section. With the provision of dedicated storage facilities, BREEAM aims to promote sustainable waste management and divert recyclable waste from landfill or incineration [49]. With an inefficient management programme, hotel owners pay twice for their waste, one is in the form of packaging and the other is for their disposal. It has been demonstrated that around the 30% of a hotel´s solid waste can be recycled and reused [50].

4.2.2. Upgrade Through Performance

A different category of measures that can be applied to improve the efficiency of the hotels, especially for refurbished and existing buildings, are those related to the performance of their components. In case studies B, C and E, the architects had to change the type of windows by upgrading the glazing specifications and also, in case study E, they had to increase the thickness of the partitions to meet BREEAM acoustic requirements. These are associated with the Acoustic performance subcategory of the Health and Wellbeing section of BREEAM [51]. In this same section, the team involved in case study G are working on the enhancement of lighting impact to ensure artificial lighting is considered at the design stage to minimize its impact [52].

4.2.3. Upgrade Through Additions

Finally, there are specific elements that help to obtain the BREEAM target score and will help with the completion of a sustainable or green hotel. Mostly two main categories can be classified in this group, Energy and Land Use and Ecology. Under the first category, solar panels are an immediate response when working on a sustainable hotel as happened in our case study D. BREEAM promotes the reduce in atmospheric pollution and carbon emissions and encourages local energy generation taken from renewable sources [53].

Certain actions are adopted to enhance the ecology of the site. These fall under the Land Use and Ecology BREEAM category, specifically under the subcategory Enhancing site ecology [54]. The installation of bird and bat boxes at strategic locations on the site was a measure used in case studies B, D and E. Planters with native species or that are beneficial to local wildlife were distributed on different levels of the hotels in case studies D, E and G. Lastly, case study D has a green roof that improves air and water quality and creates a wildlife habitat.

5. Discussion

The results obtained in this work have important implications on what is the best way to approach the design of a sustainable hotel. The details obtained from the interviews suggest that the application of the sustainability assessment method of BREEAM on the project, should be planned and done since the first stage of its design in order to facilitate the inclusion of the actions or elements recommended by the BREEAM assessor. In addition, it has been found that the inclusion of a BREEAM assessor at the very early stages of the project and the right technicians will accelerate and facilitate the execution of a green hotel. This aligns with the comments by Haroglu [33] about the significance of how the assessment process is handled and how the early involvement of BREEAM assessors can play an important role in the design. Fenner and Ryce [42] also state that the assessor´s approach might have a significant effect on the clarity of the BREEAM assessment. It has been noticed that, in addition of the architects, two other professionals are key for the execution of the project under the BREEAM premises; they are the mechanical and electrical engineer (M&E), and the ecologist. These two technicians will help to adequately address the requirements that the assessor imposes on the hotel. This relates to the results of Lowe and Watts [41], which stated that the introduction of BREEAM on a construction development will cause an increment of the M&E workload, with most of the work being in the design of the systems.

The data collected from the interviews shows that the impact that BREEAM might have on the design depends on whether the hotel is existing or newly built. It has been explained by the architects that if the building is existing, both Planning and BREEAM are more flexible in qualifying the project under the BREEAM requirements due to the difficulty of adapting an existing hotel into a green hotel. In addition, it has been extracted that specifically for hotels, the measures to be taken are common in almost all the cases. In the case of existing buildings that require a refurbishment for their new use, the most important categories to consider are Health and Wellbeing and Land Use and Ecology. In this instance, an update of the existing windows will improve the thermal and acoustic insulation conditions. In addition, the introduction of bat and bird boxes and planters will immediately add an enhancement of the ecology of the hotel. In the case of newly built hotels, the Waste and Transport categories have been a common factor in all of them. An adequate design of the project that includes enough area designated to cycle and bins stores, will help in acquiring the necessary credits to classify the project as a sustainable hotel. Again, Health and Wellbeing and Land Use and Ecology categories are very important for newly built hotels; additionally to the elements mentioned above for refurbished hotels, the incorporation of green roofs will contribute positively to acquiring the BREEAM target score. As it has been already highlighted, the inclusion of new technological and sustainable measures, such as solar panels, is also key in new buildings.

6. Conclusions

The present study has shown the results of the investigation of seven case study hotels in order to examine the impact that BREEAM has on their design. It was found that the sustainability assessment has a major impact on the design of these buildings and the approach for designing a BREEAM hotel might seem challenging. The main implications of the sustainability assessment were found to be in the Health and Wellbeing and Land Use and Ecology categories for both refurbished and newly built hotels but some categories, such as Waste and Transport, have a major importance for newly built hotels.

The study utilises BREEAM as the tool for measuring the sustainability of different hotels because it is the most common sustainable method used in the UK, but the results can be extrapolated and used for reference for any other hotel that aims to become more sustainable or for those newly built hotels that need to include sustainable elements in their design to be green hotels. For instance, the key changes shown in this research can be applied for newly built or refurbished hotels.

BREEAM is expected to become even more popular and international in the following years ahead. This will implicate new restrictions and measures taken to incorporate BREEAM requirements and the need for further research on this field. While this paper makes a contribution to understanding the impact that BREEAM has on the design elements of hotels, the importance of water and waste management in hotels has been noticed. Hence, future research could seek to identify how BREEAM impacts on the water and waste management in hotels and how the right actions can enhance their performance.

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CHAPTER III.

"HOW THE IMPLEMENTATION OF BREEAM IN HOTELS COULD HELP TO ACHIEVE THE SDGS"

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How the Implementation of BREEAM in Hotels Could Help to Achieve the SDGs

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Abstract: The 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs) was approved in 2015 by the United Nations. It is a call of action to protect our planet, end poverty and improve the lives and prospects of all. Sustainable development has been fundamental in the tourism and construction sectors in the past few decades. Nowadays, developing countries are leaders in green engineering procedures, and progressively, hotels are including sustainable standards in their designs, architecture and management. In places where tourism is the main contributor to the Gross Domestic Product, the incorporation of energy certifications is crucial. In this context, this article explores the positive implications of the application of the Building Research Establishment Environmental Assessment Method (BREEAM) on hotels in relation to the achievement of SDGs. The study analyses the influence of BREEAM on hotel design using six case studies and examines the sustainable modifications incorporated. Qualitative data were obtained through in-depth interviews and by the analysis of the documentation provided. The results revealed that a BREEAM approach in the initial stage of a project will optimize the sustainability of the hotel and can help with the achievement of several of the SDGs.

Keywords: sustainable hotel; hospitality; innovative design; sustainability assessment; green engineering; 2030 Agenda

1. Introduction

In 2015, the Heads of State and Government of 193 countries met at the 70th General Assembly of the United Nations and approved the resolution of "The 2030 Agenda for Sustainable Development". This plan establishes 17 Sustainable Development Goals (SDGs) and 169 targets to be achieved by 2030 that are currently considered a global emergency to mitigate and balance the three dimensions of sustainable development: the economic, social and environmental [1]. The EU is playing an active role and will implement the 2030 Agenda domestically and globally in cooperation with partner countries [2]. Furthermore, the New Urban Agenda adopted in October 2016 at the United Nations Conference aims to accelerate the achievement of the SDGs. Particularly, it prioritizes the making of cities safer, more inclusive and sustainable by adopting a smart-city approach [3]. Smart-city models require specific strategies to optimize their resources, reduce its waste and recycle; in this context, the generation of a circular economy plays an important role [4].

As demonstrated in the past few decades, sustainable development has been fundamental in the tourism and construction sectors [5]. Nowadays, developing countries are leaders in green engineering procedures, and progressively, hotels are including sustainable standards in their designs, architecture and management [6]. The World Tourism Organization (UNWTO) has stated that tourism contributes directly or indirectly to the achievement of all the SDGs and is particularly included in objectives 8, 12 and 14.

SDG 8. "Promote inclusive and sustainable economic growth, employment and decent work for all" [7]. Travel and tourism maintain a total of 319 million jobs worldwide and induce 10% of all jobs [6,8]. The contribution of the tourism sector is specified in target 8.9 "By 2030 devise and implement policies to promote sustainable tourism which creates jobs, promotes local culture and products" [1,9].

SDG 12. "Ensure sustainable consumption and production patterns" [7]. By adopting responsible consumption and production practices, the tourism sector can significantly accelerate the shift towards a more sustainable planet [7]. The One Planet Sustainable Tourism Program aims to improve the impact of tourism on sustainable development through the promotion of responsible consumption and production practices, which use natural resources and generate less waste [10].

SDG 14. "Conserve and sustainably use the oceans, seas and marine resources" [7]. It is specified in target 14.7 "By 2030 increase the economic benefits to Small Islands Developing States (SIDS) and Least Developed Countries (LDCs) from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism" [1]. Integrated coastal zone management must include tourism development to preserve fragile marine ecosystems and promote a blue economy [7].

BREEAM and the Sustainable Development Goals

BREEAM supports the SDGs and notes how it significantly contributes to the achievement of the following goals by applying these methods [11]:

SDG 3. Health and Well-being. The building must guarantee minimum requirements for comfort and health.

SDG 6. Clean Water and Sanitation. Buildings must install systems that save water as well as monitor their consumption.

SDG 7. Affordable and clean energy. It promotes the installation of renewable energy sources and the use of low consumption appliances and lighting.

SDG 9. Industry, Innovation and Infrastructure. Rate and promote those projects that create or offer new sustainable solutions.

SDG 11. Sustainable Cities and Communities. An urban environment requires different measures to those applied in a single building; therefore, the certificate proposes a tool that evaluates and certifies urbanized spaces.

SDG 12. Sustainable Consumption and Production. It requires eco-labels that guarantee the responsible sourcing of materials used on site.

SDG 13. Climate Action. Its main objective is to guide the construction sector towards sustainability.

SDG 15. Life of Terrestrial ecosystems. It seeks to minimize the damage caused to the environment and its biodiversity when building.

Although the UNWTO has established that tourism contributes to the achievement of the SDGs [2], the hotel industry faces the challenge of determining which of the 17 SDGs and their associated targets are its priority [12]. Hotel guests have radically changed their attitude towards adopting environmentally friendly practices, and, as a result, hotels cannot ignore their environmental and social responsibilities [13–15]. Research on efficient energy-use procedures and interventions based on clients energy-related behavior is crucial for hoteliers to understand what the guests' needs are and how these can be incorporated in the hotel [16].

A sustainable hotel must operate according to the principles of green engineering by implementing waste management systems, recycling and saving water and energy, among other procedures [17]. These approaches must be incorporated from the design stage of the building. A recent study has shown that the application of environmental procedures and their consequent certifications can optimize the image of the firm and its operational performance [18]. The EU Energy Efficiency Building Directive (EPBD) and the UK Climate Change Act 2008 included sustainable buildings on their policy agenda. Since then, a wide variety of tools have been developed to assess and assist construction projects, with the Building Research Establishment Environmental Assessment Method (BREEAM) being among the most successful of them[19]. BREEAM leads the list and, although it was initially designed to focus primarily on environmental aspects [20, 21], in the last decade it has also highlighted social and economic aspects. Despite its global implications, there is not much research on how improving hotel sustainability can help successfully achieve the SDGs of the 2030 Agenda.

This paper studies the application of the BREEAM energy certificate in hotel design. It shows how the implementation of a sustainable certificate can help to redefine infrastructure and create sustainable hospitality buildings according to climate change needs and the SDGs of the 2030 Agenda.

2. Materials and Methods

In this conceptual framework, the study was designed in three levels:

The first level was to select the relevant case studies. In order to compare and examine different buildings of the same typology, these case studies needed to be based in the UK, present different construction stages and present different BREEAM scores. The second level consisted of a qualitative research to provide an in-depth understanding of how these BREEAM scores were achieved and what design changes were needed in the process. In order to achieve this, two different groups of four people each were interviewed about the selected case studies in which they were involved in. All of the interviewees were professionals specialized in hospitality, such as architects, designers and technicians. The third level was the selection and analysis of the non-numerical data of each of the case studies.

Nowadays, BREEAM is globally recognized and applied throughout the world, but it originated in England, where it is the most used sustainability assessment and certification process in the country. As such, all of the hotels in this paper were based in the United Kingdom. The selected case studies

were either finalized or under construction. They also have different final BREEAM scores or, in the case of the ones under construction, different BREEAM goals to be achieved).

This qualitative research was utilized to understand "how" and "why" the changes were applied in these hotels. The approach based on personal interviews with technicians was considered to be the best alternative due to its flexible condition. Data analysis focused on retaining rich meaning of the case studies instead of numerical data. Due to the COVID-19 restrictions, interviews were conducted through Yealink Meeting and recorded with Windows 10 Screen Recorder. The survey was done in May 2020, and a total of six hotels were selected as case studies. For privacy reasons, the names of the projects have been replaced by A, B, C, D, E and F. The semi-structured interviews were designed with a selection of open-ended questions based on previous literature reviews [12,14,18–20]. All case studies comprised the questions shown in Table III. 1, but as the conversation progressed, some further related questions were added with the aim to collect as much deep information as possible for each hotel. In total, fifteen main questions were asked and divided in three categories: design and planning, BREEAM and sustainable design changes.

Table III. 1. Main Questions

Category	Question
Design and planning	How many floors and total number of rooms does this hotel have?
	Is this hotel a new building or a restored building?
	Is the building finished or under construction?
	Does it have planning permission?
	Is there any specific planning requirement for this hotel?
BREEAM	What was the BREEAM goal score for this building?
	Did the BREEAM goal score match the BREEAM final score?
	Was BREEAM certification part of the planning requirements?
	Was the BREEAM advisor considered during the design stage of the hotel?
	Which ones were the main BREEAM categories for this building?
	What were main design changes involved in the building to obtain the BREEAM score?
Sustainable design changes	Is there any low-consumption technology used in this site?
	Was the ecology of the building relevant in this case?
	Did the envelope of the hotel change?
	Was the landscape of the building redesigned?

Data Collected

Table III. 2 shows a summary of each case study including the stage, number of rooms, number of floors, BREEAM goal and BREEAM final score of each hotel. BREEAM considers ten categories to measure the sustainability of the building: Energy, Health and Well-being, Land Use and Ecology, Management, Materials, Transport, Water, Waste, Pollution and Innovation. Each one of them frames different requirements that can be fulfilled according to the chosen strategy. A BREEAM advisor will determine when these requirements are obtained and will score them; these points undergo an environmental weighting factor that classifies them as Outstanding, Excellent, Very Good, Good and Pass [22].

Table III. 2. Hotels Case Studies

Case Studies	Stage	No. of Rooms	No. of Floors	BREEAM Goal Score	BREEAM Final Score
A	Finalized	216	5	Excellent	Excellent
B	Finalized	302	7	Very Good	Very Good
C	Under Construction	82	9	Very Good	In progress

D	Finalized	339	42	Excellent	Outstanding
E	Under Construction	456	13	Excellent	In progress
F	Under Construction	329	19	Very Good	In progress

Hereafter, all case studies are discussed to identify the most relevant aspects that have changed in their designs during all construction stages to make a positive impact in their BREEAM score.

Case study A. For this hotel, the objective was to obtain BREEAM Excellent. The score was successfully achieved and reached the maximum score obtained by a hotel at the time of its construction. The building used low-consumption technology to reduce its energy demand and to generate its own energy supply, reducing its CO_2 emissions by 87%. It collected rainwater that was used for bathrooms and to irrigate the outdoor garden areas. Finally, it was necessary during the design stage to increase the size of the bicycle parking to promote this practice.

Case study B was a rehabilitation and extension of a historic building with the planning requirement of achieving a Very Good BREEAM score. The architects increased the cycling area. Under the advice of the ecologist and due to the demolition of the adjacent building, they included a series of shelter boxes for bats on the roofs so that they could nest in them. Regarding the building envelope, some windows had to be upgraded as a result of BREEAM acoustic requirements.

Case Study C was a remodel and extension of an existing building and was being built on site at the time of the interview. It aimed to obtain a Very Good BREEAM score. In this case, there was not enough space for landscaping or green surfaces. To compensate for this absence, the presence of mechanical and electrical engineers was crucial. The installation of flow limiters helped save water by reducing the output in taps and showers. Additionally, technicians had to optimize the existing glazing by adding double-pane windows.

Case study D was a sustainable skyscraper with 42 floors and a small footprint. It achieved a score of Outstanding; the ecology category was the main contributing factor for that score. Solar panels and a green roof were included, as well as beehives on the 39th floor that produced honey, which was then consumed by guests. Shelter boxes for bats and birds were also incorporated into the lower levels. Due to its small size on the ground floor, a separated parking area from the building was needed to store the bicycles. This one was designed with a green roof and walls. The mechanical system in this hotel was also of vital importance. It included a thermal energy system that reduces CO_2 emissions by 30% and a light regulation system that adjusts depending on the day and season. Furthermore, the hotel recycled cooking oil to produce its soaps and bath products.

Case Study E was approved and under construction at the time of the interview. They submitted a preliminary report that established a potential score of 79% for an Excellent BREEAM score. In this case, it was also necessary to increase the size of the bicycle parking and the recycling point. For the ecological requirements, the architects included 65 square meters of greenery distributed in three roof levels. Inside, they increased the thickness of the partitions. They also had to improve the glazing specifications on some of the external windows. Finally, a study of adaptability was necessary to demonstrate how the hotel can change its use if necessary. This was possible due to the structure being based on blade columns and light-weight partitions.

Case study F is currently under construction and has a planning requirement to obtain a Very Good BREEAM score. To achieve this, the main changes made by the technicians thus far include an increase in the recycling and bicycle area and the inclusion of planters on the ground floor. Currently, the exterior lighting, including the hotel logo, have been pointed out by the BREEAM advisor to be taken into account. Therefore, an expert lighting technician will undertake a study to present the best solution and reduce light pollution.

3. Results and Descriptive Data Analysis

During the design process of the case studies, several changes have been key in achieving BREEAM accreditation under the instruction of the BREEAM assessor. These improvements have been classified into three main groups: layout, performance and additions.

3.1. Upgrades through Layout

These changes include internal and external modifications to the design. The increase in the area of the bicycle facilities is a common factor in all of the hotels. This change belongs to the Transportation section of the certificate that promotes exercise and helps reduce CO_2 emissions. These credits were given due to the adequate provision of bicycle parking spaces. In some of the hotels, it was also necessary to increase the recycling areas, such as case studies A, B and E. This change belongs to the Waste section; BREEAM aims to promote sustainable waste management and divert items that are recyclable from the landfill or incinerator. It has been shown that around 30% of a hotel's solid waste can be recycled and reused [23].

3.2. Upgrades through Performance

Another category of sustainable measures applied especially in rehabilitated and existing buildings are those related to performance. The window typology was changed by updating the glazing specifications and increasing the thickness of the partitions to meet the acoustic requirements of BREEAM. These changes are associated with the acoustic performance subcategory of the Health and Wellness section of BREEAM and were necessary in case studies B, C and E. In this same section, a proposal to reduce light emissions and ensure that artificial lighting is examined at the design stage to minimize contamination, as it causes degradation in ecosystems.

3.3. Upgrades through Additions

Finally, there are specific elements that will help in achieving a green hotel, which can be classified into two main categories, namely, Ecology and Energy. Certain actions are taken to optimize the ecology of the site, such as shelter boxes for birds and bats and flower boxes located in strategic places in the hotels, which occurred in case studies B, D and E. Moreover, including green roofs improves air and water quality and creates habitat for wildlife. In the category of Energy, solar panels and cooling systems can contribute to the reduction of energy consumption in hotels and are an immediate response that can be included to an existing building to optimize its sustainability [24]. BREEAM promotes the reduction of air pollution and carbon emissions and encourages the production of local energy from renewable sources. Renewable energy plays an important role in reducing the effects of climate change and global warming. Accurate research of renewable energy power is crucial in the completion of the 2030 Agenda [25].

These findings demonstrate that the measures to be taken are common in almost all hotels. For rehabilitated buildings, the most important categories to consider are Health and Well-being and Land Use and Ecology. In the case of new hotels, the categories Waste and Transportation have been a common factor. In addition to the elements mentioned above, the incorporation of green roofs and the inclusion of new technological measures, such as solar panels or solar cooling systems, are also key in new hotels [24].

In the case of hotels, it has been proven that the main categories in which BREEAM has the greatest impact are Health and Well-being, Land Use, Ecology and Waste and Transportation. Therefore, if we compare these categories with the SDGs that BREEAM and the UNWTO indicate, we can affirm that the certificate applied in hotels contributes directly to the achievement of SDG 3, 6, 7, 12 and 15 and indirectly in SDG 8, 11 and 13. Moreover, it has been verified that BREEAM supports the inclusion of new technological measures, such as solar panels, which is why it also favors SDG 9. On the contrary, it has not been possible to verify that BREEAM supports SDG 14 in the case of hotels. It

should be noted that none of the buildings studied here are near the coast, therefore the sustainable use of marine resources through the sustainable management of fisheries and aquaculture, indicated in SDG 14, is not feasible, but it may be in a coast hotel.

4. Discussion

The current study provides a number of interesting findings for hoteliers, design experts and academics. The influence that sustainable certificates have on climate change has been widely studied. Specifically for tourism, Zeppel and Beaumont investigated the CO_2 actions by environmentally certified tourism businesses [26]. Their research revealed that hoteliers and operators implemented actions in water, energy and waste reduction and were aware of the consequences of climate change for tourism. This study confirms the evident relationship between climate change and sustainable certificates. It also confirms our finding implying the significance of BREEAM on hotels with regard to SDG 13 [27].

The study conducted by Potrč Obrecht et al. evaluates three different building certification schemes, LEED, BREEAM and DGNB, and analyses their coverage of the main health and well-being aspects in buildings [28]. Their results show that issues such as comfort, light or air quality that affect the inhabitant are addressed in all of the certification assessments. These results provide evidence that BREEAM contributes to the SDG 3 [27]. Furthermore, Haroglu revealed the importance of operational energy, water consumption and materials to ensure a high BREEAM rating [20]. These findings corroborate the direct relation of the assessment with SDG 6 to “ensure availability and sustainable management of water and sanitation for all”, SDG 7 to “ensure access to affordable, reliable, sustainable and modern energy for all” and SDG 12 to “ensure sustainable consumption and production patterns” [27]. Lamy et al. also studied the potential contribution and benefits that green certificates might have on urban sustainability [29]. Their work demonstrates that when environmental certifications are applied to a high number of buildings in the city, it results in energy savings of 9.9 million MWh and enough water savings for a month and a half of water supply.

SDG 15 states: “protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss” [27]. Pedro et al. [30] highlight the importance of urban planning tools to enhance sustainable use of land and propose a combination of geographical information systems with BREEAM-Communities as a valuable tool for urban planning. Their model confirmed the significance of land use and ecology to BREEAM. It also suggests an advanced tool that can help with the achievement of SDG 15. Their findings also provide evidence of the positive impact BREEAM might have on the city. Similarly, SDG 11 hopes to “make cities and human settlements inclusive, safe, resilient and sustainable” [27]. Additionally, the study carried out by Hamedani and Huber [31] concluded that sustainable certificates can measure and guarantee sustainable development achievements in any region by adopting adequate strategies. Their findings are extremely useful for the 2030 Agenda, as they demonstrate that sustainable assessments, such as BREEAM or LEED, can be applied in any region of the world, and they can also be used by various groups if the right criteria and objectives are identified.

Finally, Norouzi and Soori have studied the ecological, social and economic aspects that assessment methods take into account when evaluating the sustainability of a building [32]. Their research proved that BREEAM has the highest rank for the economic criterion of all the analyzed certificates, with 24.1% of the total score. This finding supports SDG 8, which promotes inclusive and sustainable economic growth [27].

5. Conclusions

This study represents a major advancement in the success of the 2030 Agenda and reflects the impact that tourism and the hotel sector have in its achievement. We provide initial insights into the

benefits that the BREEAM energy certificate, applied in hotels, may offer to successfully accomplish the SDGs. We found that the certificate contributes to the achievement of 9 of the 17SDGs proposed by the 2030 Agenda. Nevertheless, the contribution to SDG 14, proposed by the UNWTO, has not been demonstrated through the case studies presented here since this objective focuses on unviable marine resources at our hotels. Despite the absence of studies regarding the impact of sustainable hotels on achieving the goals of the 2030 Agenda, this article demonstrates that an adequate touristic and hospitality approach can generate promising and substantial results in accomplishing SDGs. The current research allows the hospitality industry to better position itself and its role in the sustainable tourism field in the 2030 Agenda; however, it presents some limitations. The case studies employed in this article were not able to confirm any contribution to eight of the SDGs, including: 1, No poverty; 2, Zero hunger; 4, Quality education; 5, Gender equality; 10, Reduced inequalities; 14, Life below water; 16, Peace, justice and strong institutions; and 17, Partnerships for the goals. Some of these goals may not be related to the hospitality industry and contribution to their achievement may not be possible. On the other hand, others, such as goals 5 and 10, can be addressed by the hospitality industry and could make a positive impact on the 2030 Agenda. Hence, further research focused on all types of sustainable hotels, including coastal hotels, and their contributions will be necessary to delve into this field and provide more data pertaining to which SDGs are most influenced by the sustainable hotel industry. Additionally, further research examining the reduction of energy consumption for rehabilitated buildings will help hoteliers improve their existing hotels in a more sustainable approach. Finally, data of social perception towards green hotels will be beneficial in confronting global climate change and contribute to sustainable tourism.

Hotels play a major role in sustainable tourism. The current paper reveals the adaptations that hotels can make to obtain a high BREEAM score, which contributes to a number of SDGs. This innovative approach demonstrates the use of a BREEAM certificate as a tool for hoteliers and hospitality stakeholders to directly and indirectly fulfill 9 of the 17 SDGs and place them in a favorable position to confront the 2030 Agenda. Further research is needed to explore how hotels may contribute to the unexplored SDGs of this study.

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CHAPTER IV.

"PROMOTING THE SUSTAINABLE RECOVERY OF HOSPITALITY IN THE POST-PANDEMIC ERA: A COMPARATIVE STUDY TO OPTIMIZE THE SERVICESCAPES"

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Promoting the Sustainable Recovery of Hospitality in the Post-Pandemic Era: A Comparative Study to Optimize the Servicescapes

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Abstract: As COVID-19 spread throughout the world, the hospitality and tourism sectors were hard hit as no other industry. For this reason, the UNWTO developed the One Planet Vision as a response to a sustainable recovery of the tourism sector. At present, when people are starting to travel and stay at hotels again, it is important to analyze what their expectations are of hotels to move forward in the post-pandemic era. For instance, empirical research has been developed to examine people's sentiments toward servicescapes, and a comparative study is presented between 2020 and 2022. Findings contribute to the research by identifying new servicescape attributes during a health crisis. These also lead to practical implications by proposing a scale to evaluate customers' perceptions and to increase their wellbeing and resilience. The current research is one of the first studies to collaborate with the One Planet Vision by empirically proposing improvements in the servicescapes of hotels for a responsible recovery.

Keywords: hotel; servicescape; post-pandemic; resilience; sustainability; recovery

1. Introduction

Since the beginning of the pandemic, the tourism and hospitality sectors have been dramatically disrupted and forced to make adaptations. With the introduction of social distancing and traveling restrictions as the most common responses to contain the virus, the tourism and hospitality industries were, as no other, hard hit. Due to its negative effects, researchers have studied its implications throughout the different stages [1,2]. Nowadays, most of the relevant studies are focused on its socio-economic impacts but there is limited work reviewing the resilience aspect [3,4]. Moreover, a small number of researchers have examined the perceptions and emotions of individuals, both customers [5] and employees [6,7], during the pandemic to gain insights into people's behavioral responses. It has been concluded that understanding people's emotions is crucial to successfully operating in the post-pandemic era and building their resilience. However, the existing literature about the social dimension of sustainability which includes wellbeing, working conditions, and human rights, among others, is limited [8].

In a sustainable context, some existing studies have investigated the sustainability in the hospitality sector [9,10]; however, the current health crisis might entail new ways of approaching the 2050 neutrality proposed by the European Union and other relevant future sustainable plans. With the aim of successfully achieving these, some further and deeper research should be conducted about how the sentiments of people have progressed from the beginning of the pandemic to the current post-pandemic period in a hotel context; additionally, it should also be studied how the different servicescapes could be sustainably improved to recover from the adverse effects of an airborne health crisis, such as COVID-19. To address this gap and sense of urgency, this paper studies the negative impact the pandemic has had on the hospitality industry by analyzing how the sentiments of people have changed toward hotel servicescapes and what they expect to find in them from now on. The following questions have guided the research:

RQ1. Which are the servicescape attributes and dimensions to consider during an airborne health crisis, such as COVID-19?
RQ2. How have the sentiments of people toward the servicescapes of hotels changed from 2020 to the post-pandemic era?
RQ3. What are the main attributes that must be taken into account for a sustainable recovery of hotels in the post-pandemic era?

Empirical research has been developed in this paper to collaborate with the One Planet Vision proposed by the UNWTO as a response to a sustainable recovery in the tourism and hospitality sectors [11]. A comparative study between people's opinions about servicescapes in November 2020 and September 2022 has been developed in the tourist region of Andalusia, Spain. The novelty of this paper lies in the recent status of the post-pandemic stage and the lack of empirical research proposing improvements in hotels for a responsible recovery toward 2050 neutrality.

2. Literature Review

2.1. Implications of COVID-19 in the Sustainable Development of Hospitality

The COVID-19 pandemic has caused major negative consequences on a global scale. The UNWTO Secretary-General Zurab Pololikashvili has expressed that "COVID-19 has impacted travel and tourism like no other event before in history. Governments have put public health first and introduced full or partial restrictions on travel. With tourism suspended, the benefits the sector brings are under threat, millions of jobs could be lost, and progress made in the fields of equality and sustainable economic growth could be rolled back" [12]. Several studies have provided a review of the health crisis and its effects on the tourism sector. The factors that affect the recovery of tourist destinations were analyzed and it was concluded that the effects will differ in space and time [13]. Some places might continue their businesses as usual ignoring the possibility of a new era of green growth, but others may reconsider the reorientation of their businesses following a sustainable approach [14]. As it has been

found, the pandemic could motivate stakeholders to think more sustainably, by fighting for an advantage in the post-pandemic stage [15].

The UNWTO has expressed the importance of tourism in the Sustainable Development Goals of the 2030 Agenda. The Agenda contemplates tourism specifically in Goals 8,12 and 14. It expresses the need to implement new policies that promote sustainable tourism, adopt more responsible production and consumption strategies, preserve ecosystems, and promote a blue economy [16]. It has also highlighted the need to reduce the current emissions of tourism by 50% before 2030 in order to achieve the goal of CO_2 neutrality by 2050. It is in this context, in May 2020, when the UNWTO proposed the One Planet Vision. This plan was created as a recovery response to help the tourism and hospitality sectors to emerge stronger, rebuild sustainably, and improve their resilience after the pandemic. It establishes six axes of action: climate action, the circular economy, the conservation of biological diversity, social inclusion, public health, and governance and finance. In addition, the Glasgow Declaration on Climate Action in Tourism arises from the need to accelerate climate action in tourism and ensure strategies that help achieve the 2050 neutrality goals established by the European Green Deal [17]. Considering that hotels are included in the top five list of energy consumers in the tertiary sector [18], this makes them an exceptional goal to be ecologically improved. Therefore, in order to achieve the goal of CO_2 neutrality, it is necessary to involve hotels in the process and include updated measures for their recovery [9]. Regardless of the newness of this topic, some researchers are now evaluating the effects of the pandemic on sustainable development [1,2,19–21]. For instance, Elkhwesky et al. (2022) developed a comprehensive literature review of sustainable practices in hospitality and demonstrated important progress from 2020 to 2021. Renzi et al. (2022) evaluated consumers' awareness of the achievement of Agenda 2030 in terms of sustainable behavior after COVID-19. Moreover, Gössling and Schweiggart (2022) reviewed the existing literature published about tourism and COVID-19; they suggested the importance of studying the pandemic to gain some insights into the management of climate change. Waste management in the hospitality sector has also been evaluated in the post-pandemic era. Filimonau (2021) proposed potential strategies to address food and plastic waste; furthermore, the author highlights the need of investing in green strategies and innovation for a sustainable recovery. The current period, when people are starting to feel more comfortable traveling, is an opportunity to strengthen the hospitality and tourism sectors by sustainably improving their buildings.

2.2. Hospitality Servicescapes Effects

Widespread research has been published about the servicescape effects on hotel customers' and employees' conduct [22–24]. Bitner (1992) proposed the concept of "servicescape", one of the most widely cited conceptual frameworks, by exploring the impact that physical surroundings have on customers' and employees' behaviors. The servicescapes are constituted by a mix of environmental features that influence internal responses and behaviors. These include all the objective physical factors that the firm can control in order to enhance or constrain the customer and employee actions. These factors comprehend an extensive list of elements, such as layout, materials, lighting, temperature, signage, and color. Bitner identified three primary dimensions of the servicescape: 'Ambient conditions', 'Spatial layout and Functionality', and 'Signs, Symbols and Artefacts' that influence people's perceptions. The second and third were commonly referred to as the 'Built Environment'. Later on, Wakefield and Blodgett (1994) studied the importance of servicescapes in leisure and focalized on the 'Built Environment'. Their findings suggest that the servicescape has a powerful effect on the time that customers wish to stay in the leisure service and is a determinant for customers' intentions.

In a more recent context, a comprehensive literature review has revealed a number of studies on the dimensions of the servicescapes in the hospitality industry [25–31]. Spielmann et al. (2012) proposed a scale incorporating physical complexity and social interaction. The scale indicated how certain perceptions influenced consumers' behaviors. Lockwood and Pyun (2018) reviewed the attributes and dimensions of the hotel servicescape and revealed five main factors with high reliability,

these are ‘Aesthetic Quality’, ‘Functionality’, ‘Atmosphere’, ‘Spaciousness’, and ‘Physiological Conditions’. In 2019, they also tested this scale and proved it to be valid and reliable. Their study showed that four of the five dimensions contribute to the feelings of pleasure and arousal; the effect of ‘Functionality’ was not confirmed, and this might be due to the characteristics of the hotels selected for the survey. Contrarily, Wakefield and Blodgett (1994) proved that ‘Functionality’ plays a very important role in the leisure service, so its effects have been proved to be also a determinant. Ozkul et al. (2019) explained the importance of lighting and color in the service atmosphere in tourism and hospitality for the customer’s perception and satisfaction. The methodology proposed some design recommendations for color and lighting for different services. Trinch (2021) evaluated the existing literature review about the impact of COVID-19 on the hotel service industry. As a result, it was concluded that addressing the weaknesses and transforming these into opportunities will solidify the resilience of the hospitality sector. Moreover, Willems et al. (2021) demonstrated how the COVID-19 crisis could prompt the digital and technological boost of services and retailing. Finally, Lugosi et al. (2022) examined the effects of several servicescape dimensions on visitors’ satisfaction in a cancer treatment context. The study considered design, spatial layout, functionality, ambient conditions, and physical surroundings, among others. Findings showed that ambient conditions had the greatest impact on satisfaction. It was also found that the right management of these dimensions might help to compensate for some deficiencies in other areas of the servicescape, especially during the the COVID-19 pandemic.

3. Materials and Methods

In order to carry out this empirical research, the methodology was developed into three phases:

(I) The generation of a proposed servicescape scale in a health crisis environment. This or similar events have not been studied before from a servicescape perspective and the previous scales did not reflect any attributes related to an airborne health crisis, such as COVID-19. Hence, due to the novelty of this topic, the authors created the proposed scale shown in Table IV. 1 based on the existing literature related to servicescapes and the recent research about the pandemic.
(II) An online administered questionnaire was designed from the proposed servicescape scale. Participants were asked to answer the questionnaire from a pandemic perspective and consider the context they were in at the time of responding. The reliability of the questionnaire and the margin of error were studied to validate the survey statistically. In this case, convenience sampling was considered to be the best technique for the survey. This type of non-probability sampling involves the sample being drawn from a part of the population that is close to hand.
(III) Subsequently, a quantitative method was used and information was collected from the questionnaire. The survey was conducted at two different stages: the first one during the high peak of the disease in November 2020 and the second one in September 2022, once the restrictions were eased. An analysis and comparison of results were performed in order to provide insights about how people’s sentiments have changed over the time of this pandemic and what is expected from now on in a hotel.

3.1. Proposed Servicescape Scale for an airborne Health Crisis

Table IV. 1 shows the authors’ proposed scale. This scale is the result of the most relevant dimensions exposed by previous authors about servicescapes [22,28,32,33], together with the latest research on airborne transmission diseases, the current COVID-19 pandemic, and its implications in the servicescape. For this particular study and future research involving the servicescape during and following the pandemic, the authors have created an upgraded scale with further attributes to be considered and have added a proposed sixth dimension under the category of ‘Services’, including the main services affected in the hotel during the current pandemic that are crucial for this context [34–58]. Hence, the first column of Table IV. 1 shows the proposed 6 main dimensions of the proposed servicescape scale. The second column shows the proposed attributes related to each dimension; the attributes shown with a * have been proposed by the authors based on the existing research in a pandemic context, and the rest of the attributes have been selected from previous authors. The third

column corresponds to the servicescape references that support the proposed attributes and the fourth column corresponds to the COVID-19 references. All of the attributes are supported by existing research for a pandemic context, as shown in the fourth column. Due to the lack of previous research that validates the relationship between the disease and some of the existing attributes that other authors proposed in the past, they have been omitted from the proposed scale. These are 'The height of tables and chairs', 'The design of the hotel's exterior', 'The fabrics used', and 'Texture/pattern'.

Table IV. 1. The servicescape scale during an airborne health crisis

Dimensions	Attributes	Servicescape References	COVID-19 References
Aesthetic Quality	The pictures and photos on display	Bitner (1992); Lockwood and Pyun (2018)	Keenan (2020)
	The style of the ornaments	Bitner (1992); Wakefield and Blodgett (1994); Lockwood and Pyun (2018); Baker (1986)	Keenan (2020); Jiang and Wen (2020); Shamaileh (2021)
	The use of flowers and plants	Lockwood and Pyun (2018)	Jackson et al. (2021); Jeon and Yang (2021)
	The style of the furniture used	Bitner (1992); Wakefield and Blodgett (1994); Lockwood and Pyun (2018); Baker (1986)	Keenan (2020); Jiang and Wen (2020); Shamaileh (2021)
	The flooring design	Wakefield and Blodgett (1994); Lockwood and Pyun (2018); Baker (1986); Lugosi et al. (2022)	Keenan (2020); Ekwall et al. (2021)
Functionality	The space between furniture	Bitner (1992); Wakefield and Blodgett (1994); Lockwood and Pyun (2018); Baker (1986); Lugosi et al. (2022)	Shin and Kang, 2020; Zhao et al., 2020
	The practicality of the flooring	Lockwood and Pyun (2018); Lugosi et al. (2022)	Keenan (2020); Ekwall et al. (2021)
	The use of physical distancing*	Proposed by the authors	Shin and Kang (2020); Zhao et al. (2020)
	The use of warning signs and banners	Bitner (1992); Baker (1986)	Ekwall et al. (2021)
	The mandatory use of masks*	Proposed by the authors	Zhai (2020); Blocken et al. (2021)
Atmosphere	The artificial lighting	Lockwood and Pyun (2018); Ozkul et al. (2019); Lugosi et al. (2022)	Miao and Ding (2020)
	Background music	Bitner (1992); Lockwood and Pyun (2018)	Hennessy et al. (2021); Ziv and Hollander-Shabtai (2021); Zarrabi et al. (2021)
	The amount of natural light	Lockwood and Pyun (2018); Lugosi et al. (2022)	Miao and Ding (2020); Zarrabi et al. (2021)
	Noise level	Bitner (1992); Lockwood and Pyun (2018); Baker (1986)	Miao and Ding (2020); Zarrabi et al. (2021)
	Cleanliness	Bitner (1992); Wakefield and Blodgett (1994); Lockwood and Pyun (2018);	Vilnai-Yavetz and Gilboa (2010); Shin and Kang

			(2020); Magnini and Zehrer (2021)
Spaciousness	The amount of free space and the feeling of spaciousness	Lockwood and Pyun (2018); Lugosi et al. (2022)	Keenan (2020); Jeon and Yang (2021); Jackson et al. (2021); Zarrabi et al. (2021)
	The use of outdoor areas*	Proposed by the authors	Jeon and Yang (2021); Jackson et al. (2021)
	The use of indoor patios*	Proposed by the authors	Jackson et al. (2021)
Physiological Conditions	Sanitation facilities*	Proposed by the authors	Vilnai-Yavetz and Gilboa (2010); Shin and Kang (2020); Girard et al. (2019)
	The use of regular hygiene standards*	Proposed by the authors	Vilnai-Yavetz and Gilboa (2010); Shin and Kang (2020); Girard et al. (2019)
	Air quality	Bitner (1992); Baker (1986)	Blocken et al. (2021); Megahed and Ghoneim (2021)
Services	Cleaning service	Wakefield and Blodgett (1994); Baker (1986)	Vilnai-Yavetz and Gilboa (2010)
	Measures on the staff members*	Proposed by the authors	Zhai (2020); Savavibool (2016)
	Restrictions on the facilities*	Proposed by the authors	Kardeş (2021); Martínez-Moure and Saz-Peiró (2021)
	The use of technology and smartphones	Wakefield and Blodgett (1994); Willems et al. (2021)	García et al. (2021); Sztorc (2022); Xiang et al. (2022); Lau (2020)

* These attributes have been proposed by the authors and are based on the existing research available.

3.2. Questionnaire Design and Reliability of the Survey

The questionnaire is based on a five-point Likert-type scale to express importance (1. unimportant to 5. very important), quality (1. very poor to 5. excellent), agreement (1. strongly disagree to 5. strongly agree), or satisfaction (1. very dissatisfied to 5. very satisfied). A total amount of 31 questions or statements grouped into 6 sections were provided, each of them related to one or more attributes proposed by the authors in Table IV. 1. An online approach was determined to be the best procedure, distributed via Google Forms; the first approach in November 2020 and the second approach in September 2022. The first group was formed with a total of 223, including 222 valid responses. The second group was formed with a total of 249, including 241 valid responses, comprising all participants aged between 18 and 90 years old of all genders based in Andalusia. According to the Statistic National Institute of Spain, the population comprised between 18 and 90 years old in Andalusia in 2020 was 5,916,787 people [59]. The margin of error (MOE) was calculated following the following formula:

$$MOE = z * \sqrt{p} * (1 - p)/\sqrt{(N - 1)} * n/(N - n)$$

where z = 1.96 for a confidence level (α) of 95%, p = proportion (expressed as a decimal), N = population size, and n = sample size.

$$MOE_{Andalusia\ 2020} = 0.98 / 14.9 * 100 = 6.57\%$$

$$MOE_{Andalusia\ 2022} = 0.98 / 15.5 * 100 = 6.31\%$$

Hence, with a 95% of confidence level, the MOE for Andalusia in the 2020 survey is ±6.57% and ±6.31% in the 2022 survey. In order to check the reliability of the questionnaire, Cronbach's alpha coefficient was calculated to measure the internal consistency of the 31 questions. In this case, the internal consistency was acceptable, with Cronbach's alpha being $\alpha = 0.70$ in both cases. The significance level for this research is 0.05.

4. Results and Data Analysis

The raw data from the survey were extracted in the shape of an Excel file containing all the questions and the Likert scores from each individual. In order to statistically study the significance of each dimension, a t-test has been conducted to analyze the quantitative data extracted [60]. A *p*-value ≤ 0.05 proves that the null hypothesis is rejected, showing a difference in the sentiments of people from 2020 to 2022. Contrarily, a *p*-value > 0.05 proves that there is no significant effect and the null hypothesis must be retained in those cases, showing that people's sentiments have not significantly changed. The analysis of the survey is divided into two steps with the purpose of fulfilling a complete data analysis. The first step consists of statistically interpreting the interval data; this includes the mode, mean, standard deviation, *p*-value, and t-value for each dimension and period of time. The second step is to analyze the data by interpreting the charts extracted from each category of the survey. The descriptive statistics for each of the dimensions and attributes are presented below. As a means to obtain a full understanding of respondents' behaviors and thoughts, they were asked a series of questions regarding their perception of the servicescape dimensions of the hotel during COVID-19 and at the post-pandemic stage, and their responses are shown below.

4.1. Analysis of the Aesthetic Quality dimension

An analysis of people's responses toward the aesthetic quality dimension of the hotel, see Table IV. 2 and Figure IV.1., show that the pictures and photos on display do not affect their wellbeing or make a positive or negative impact on their resilience. This finding is supported by the mode and mean from Q1, which highlight the neutrality of this attribute. The key finding of Q2 suggests that the use of flowers and plants in the hotel has a positive impact on people. This has not changed throughout the health crisis and it seems to be as important in 2022 as it was in 2020. However, the addition of plants within the room does not seem to affect people's perception of the quality. This can be extracted from the mode of Q3, where the majority of respondents found the room acceptable without any plants. These results have not changed in the post-pandemic stage, so it can be assumed that people feel the same way about this attribute independently of the stage of the pandemic they were in. On the other hand, the style/design of the ornaments, furniture, and flooring positively affects their resilience toward COVID-19. People gravitated toward a more minimalistic style and a clean-lined design seemed to improve the quality of the space from people's perspective, making them feel more comfortable in it. This can be extracted from the mode and mean of Q4 and Q5 which have remained constant.

Table IV. 2. Interval data analysis of the Aesthetic Quality dimension

Aesthetic Quality	**t: 2.50**	***p*-Value: 0.03**					
Item	**Attributes Related to the Question**	**November 2020**			**September 2022**		
		Mode	**Mean**	**SD**	**Mode**	**Mean**	**SD**
Q1. How important is it for your comfort that there is the use of artwork in the communal areas of the hotel?	The pictures and photos on display	3	2.82	1.06	3	2.78	1.08
Q2. Is it important for you to find indoor plants in the building?	The use of flowers and plants	4	3.71	0.99	4	3.68	1.04
Q3. How do you feel in the room if there are no indoor plants?	The use of flowers and plants	4	3.47	0.83	4	3.46	0.87

Q4. A minimal space is easier to keep clean and disinfected. Do you feel comfortable with a minimalist decoration style?	The style of the ornaments The style of the furniture used The flooring design	4	4.15	0.76	4	4	0.80
Q5. How do you feel about a room with clean lines of furniture?	The style of the ornaments The style of the furniture used	4	4.30	0.61	4	4.22	0.58

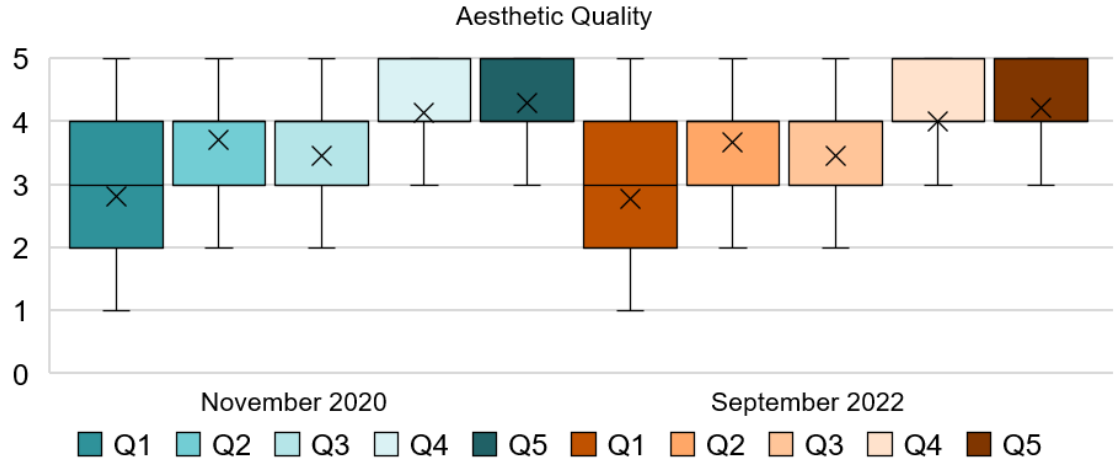


Figure IV.1. Interval data graph of the Aesthetic Quality dimension

Figure IV.2 shows the percentage of the responses for each of the five-point Likert scale scores of the aesthetic quality dimension. Results of Q1 show that about 40% of the respondents claimed that the use of artwork was unimportant or slightly important for their comfort in the hotel during both stages. In this case, respondents did not have a resounding answer. Similarly, in Q2 for approximately 60% of them, it was important and very important to find plants in the hotel, and 30% expressed that it was moderately important in both stages of the pandemic. Indoor plants in the room did not affect their perception of the quality for 55% of people, as shown in Q3, where the room was found good or excellent without them. In regards to Q4 and Q5, answers are very similar but the responses changed slightly from 2020 to 2022. In the first stage, more than 85% of the respondents expressed that they felt very comfortable with a minimalistic decoration style and find a room with clean lines of furniture of excellent or good quality. Responses from Q4 have lessened by 5% in 2022, while responses from Q5 show an increase of 3% from the first stage. From this section of the questionnaire, it can be extracted that people's sentiments toward the aesthetic quality of the hotel have not dramatically changed in the past two years and their responses have remained constant.

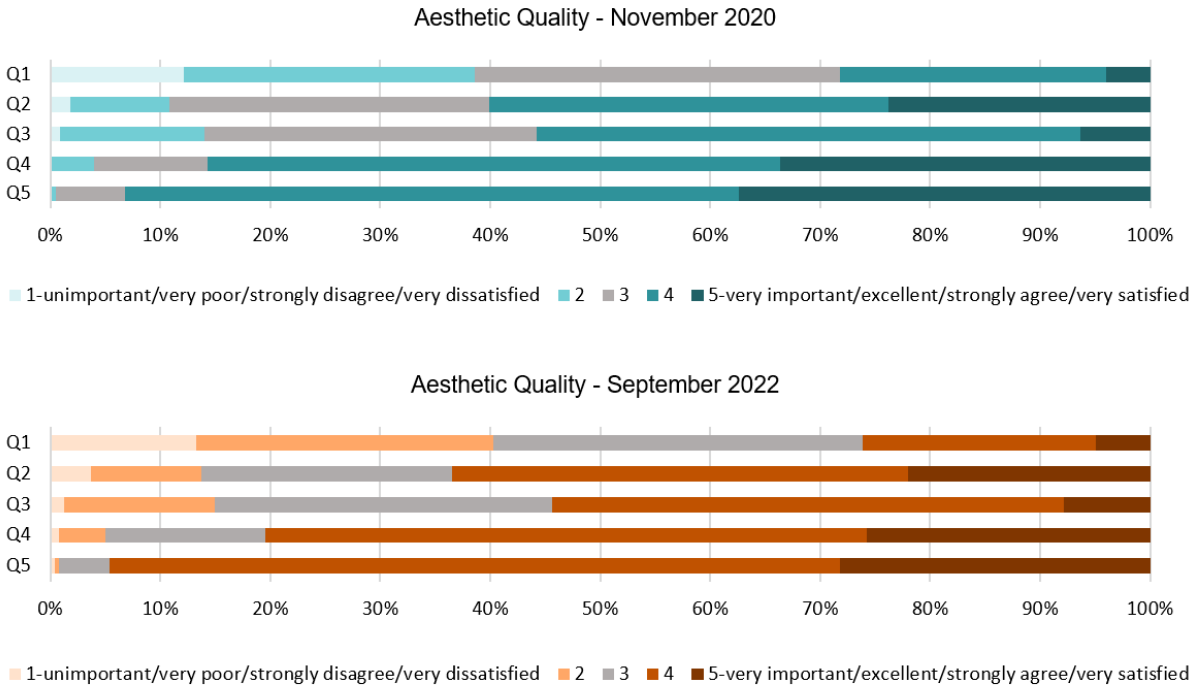


Figure IV.2. Aesthetic Quality dimension chart

4.2. Analysis of the Functionality dimension

Some interesting findings can be extracted from Table IV. 3 and Figure IV.3. Q6 shows a unanimous response regarding the implementation of physical distancing. This can be extracted from the standard deviation below in both stages of the survey. Similarly, Q8 also shows a unanimous response although, in this case, the mode has been reduced from 5 to 4 in the second stage. On the other hand, Q7 and Q9 present a varied range of responses, especially in the first stage. Q7 shows that people have slightly changed their minds and, in 2022, they only disagree with the asked statement. It can be interpreted that people did not strongly agree with distancing furniture; this is probably reinforced due to the post-pandemic stage and resistance against the virus developed within the last two years. Q9 remains similar and people still disagree with the use of banners affecting their comfort. In short, the mode from Q6 and Q8 shows the high importance and support that people give to the use of masks and physical distancing with resounding responses, as shown in the SD. Conversely, Q7 and Q9 are more dispersed. Their SD values show us the spread of these responses.

Table IV. 3. Interval data analysis of the Functionality dimension

Functionality	**t: 2.22**	***p*-Value: 0.05**					
Item	**Attributes Related to the Question**	**November 2020**			**September 2022**		
		Mode	**Mean**	**SD**	**Mode**	**Mean**	**SD**
Q6. How important is it for the implementation of physical distancing in the hotel during the pandemic?	The space between furniture The use of physical distancing	5	4.77	0.49	5	4.31	0.78
Q7. A lobby with furniture keeping the recommended distance to prevent the spread of the virus makes you feel uncomfortable.	The space between furniture The use of physical distancing	1	2.91	1.64	2	2.82	1.32

Q8. Would you agree with the use of a mask for the hotel staff?	The mandatory use of masks	5	4.72	0.63	4	4.10	0.87
Q9. The use of floor stickers, signs, and banners supports a safe environment in the hotel. Do you think these measures affect your comfort?	The use of warning signs and banners	2	2.72	1.45	2	2.66	1.19

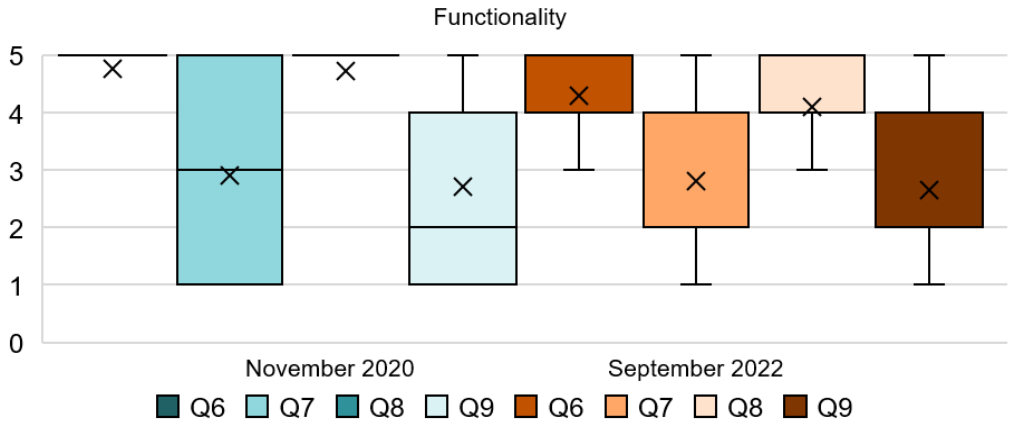


Figure IV.3. Interval data graph of the Functionality dimension

Results of Q6 in Figure IV.4 shows that in 2020, 97% of the respondents found it important and very important the implementation of physical distancing in the hotel. This percentage has been slightly reduced to 87% in the 2022 respondents. On the other hand, the results of Q7 were quite diverse for both stages of the survey. In 2020, 50% of the participants did not agree with the stated action making them uncomfortable, while the other 50% of people thought the opposite. In 2022, the percentage of people that did not agree with the statement increased to 54%. From the first stage to the second stage, it can be noticed that people's sentiments tend to concentrate toward more neutral responses while avoiding extreme answers. The categorical answers of Q8 in 2020 reflect that only 2% of the respondents disagreed with the use of masks in the hotel. Additionally, 77% of them strongly agreed with their use. However, these responses have been reduced to only 34% in 2022. Lastly, for Q9, 35% of the people could confirm that the use of floor stickers, signs, and banners during COVID-19 might affect their comfort while in 2020, 53% established that these measures did not affect it. Results from 2022 are similar and 28% of respondents confirmed that these measures might affect their comfort.

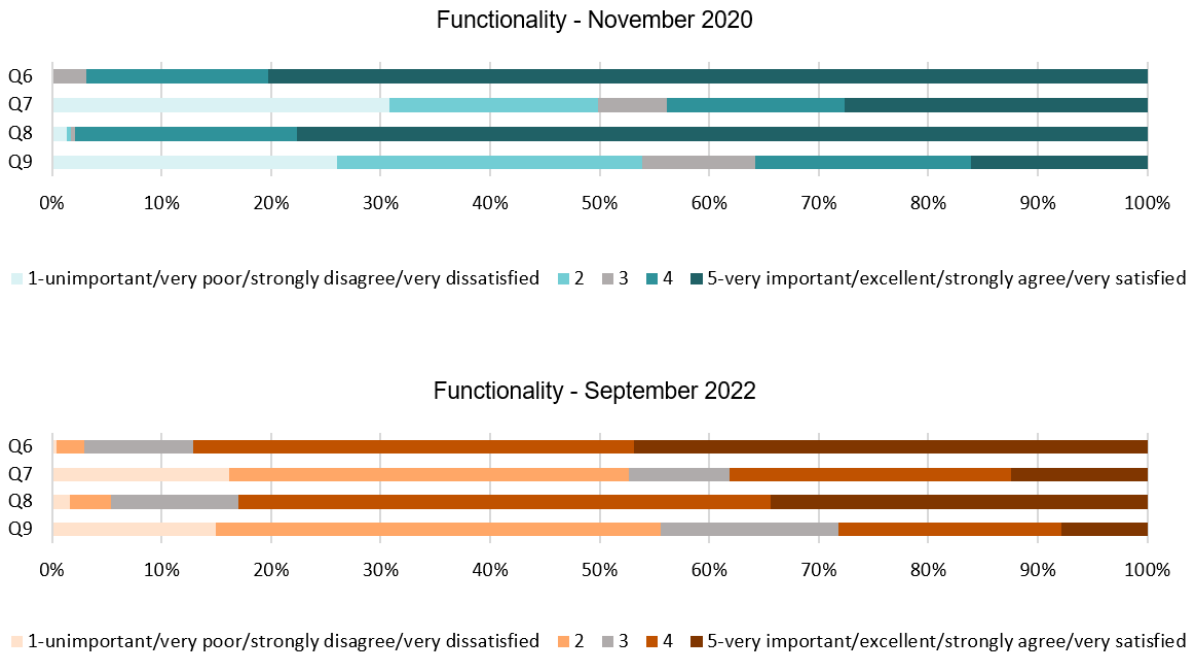


Figure IV.4. Functionality dimension chart

4.3. Analysis of the Atmosphere dimension

The results found in the atmosphere dimension are consistent throughout both stages; see Table IV. 4 and Figure IV.5. From Q10 and Q11, the mode reflects the importance to perceive a quiet and relaxing background. While in 2020 this attribute was very important in 2022, the majority of people find it only slightly important. In addition, chill-out music and a quiet environment could also help with their wellbeing, as can be seen in the mean in Q11 of both stages. The use of warm lighting seems to make people feel calmer. The mean and mode for Q12 show that people agreed with the use of warm artificial lighting, and this aspect remained almost the same in both stages. Similarly, with respect to the amount of natural light mentioned in Q14 and Q15, a vast majority of the respondents felt the amount of natural light very important, in this case in the lobby and restaurant both in 2020 and 2022. The SD being ≤1 reflects the undispersed responses. As for the Q13, people were also very strong in their responses and most of them found the attribute of "Cleanliness" very important. This is clearly shown in the mode and the mean in both stages.

Table IV. 4. Interval data analysis of the Atmosphere dimension

Atmosphere	**t: 1.37**	***p*-Value: 0.11**					
Item	**Attributes Related to the Question**	**November 2020**			**September 2022**		
		Mode	**Mean**	**SD**	**Mode**	**Mean**	**SD**
Q10. How important is for a quiet environment?	Noise level Background music	5	4.13	0.87	4	4.07	0.85
Q11. Chill-out music would make you feel more comfortable.	Background music	4	3.68	0.92	4	3.70	0.92
Q12. Does the use of warm lighting in your room make you feel calm?	The artificial lighting	4	4.18	0.79	4	4.11	0.74
Q13. Cleanliness is key for reducing the risk of spreading the virus, but how important is it for you a to have a clean scent in the hotel?	Cleanliness	5	4.59	0.67	5	4.61	0.66

Q14. Due to the amount of time that you might spend in the hotel, how important is it for you to have natural light in the lobby?	The amount of natural light	5	4.39	0.80	5	4.36	0.76
Q15. How important is it for you to have natural light in the restaurant?	The amount of natural light	5	4.39	0.79	5	4.38	0.67

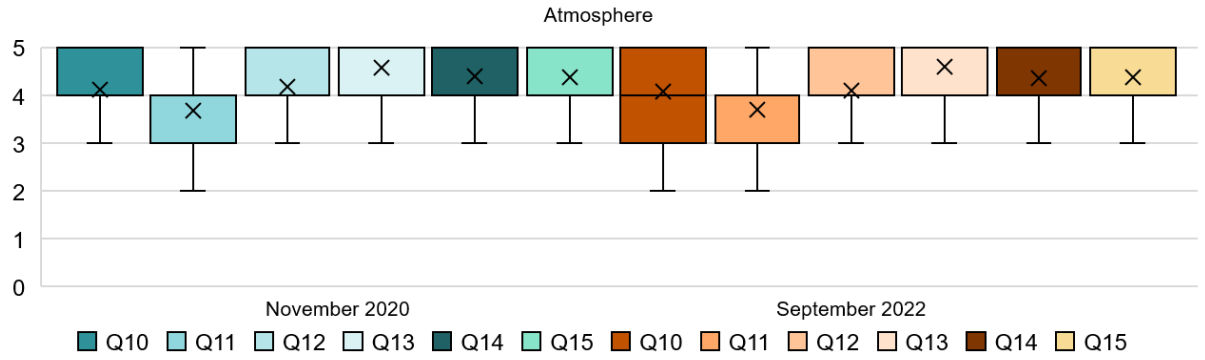
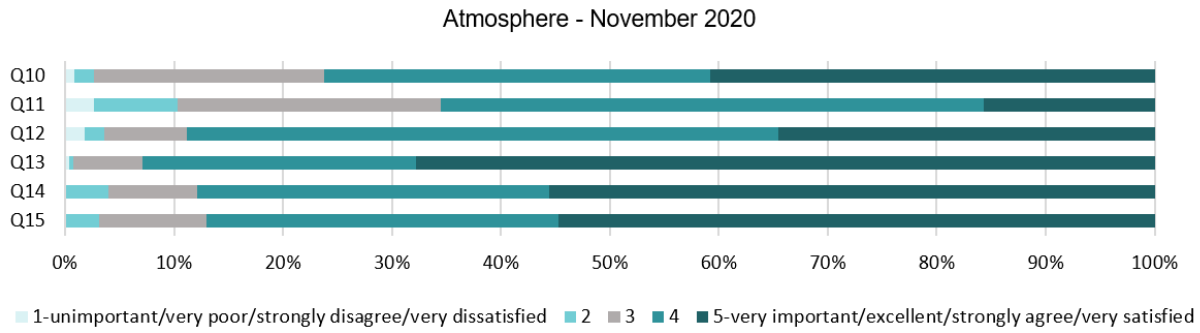


Figure IV.5. Interval data graph of the Atmosphere dimension

As shown in Figure IV.6, Q10 reveals that for 76% of the respondents, it was important or very important to have a quiet environment in 2020, and for 74% of them in 2022; so, responses remained very similar in the two years studied. Q11 states that chill-out music would make them feel more comfortable, and 65% of the participants agreed with this statement in the first stage and 73% in 2022. In both stages for Q12, about 88% of the respondents expressed that the use of warm light in their guestrooms makes them feel calmer. The results for Q13 provide clear evidence that the respondents found it important, 25%, and very important, 67%, to perceive a clean scent within the hotel during the pandemic. Only 1% did not find this important and 6% moderately important. Very similar responses have been reported in the post-pandemic phase. Q14 and Q15 asked about the importance of natural light in the lobby and restaurant, respectively. Both questions obtained similar results in 2020 and 2022; more than 85% of the people found the use of natural light important and very important. Surprisingly, these last attributes have not changed in two years, so it can be assumed that natural light is a very important aspect of the servicescape that have not been altered since COVID-19.



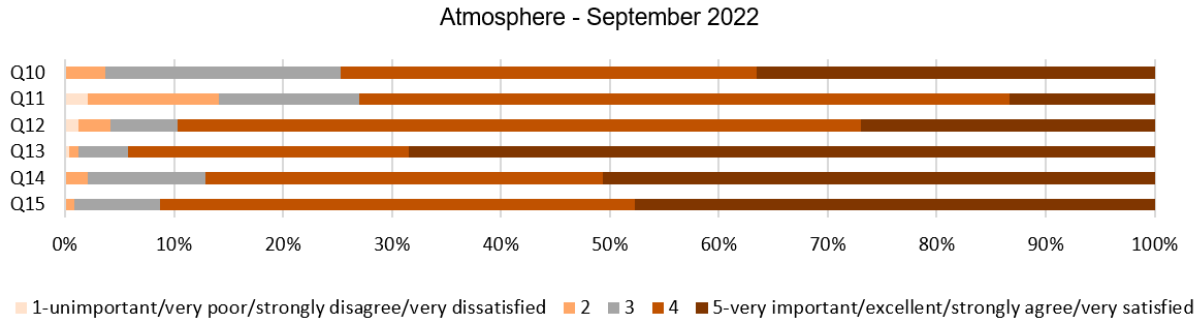


Figure IV.6. Atmosphere dimension chart

4.4. Analysis of the Spaciousness dimension

Based on the results of the questionnaire, see Table IV. 5 and Figure IV.7, the feeling of spaciousness, free space, and outdoor/indoor areas have been clearly highlighted as positive attributes for people's resilience during and following the pandemic. Q16 and Q17 are congruent with each other and reveal that people prefer a big guestroom over a big bathroom for both stages of the survey; this can be noticed by comparing the mode of Q16 to the mode of Q17. Moreover, Q19 and Q20 responses reflect the necessity of outdoor areas and an indoor patio to improve people's wellbeing. Again, responses regarding these attributes have remained constant. Specifically, the use of outdoor areas is very important for a vast majority of the respondent; the mode of Q19 supports this finding. On the other hand, Q18 reflects that a double-height space in the lobby does not seem to be relevant for a considerable amount of people.

Table IV. 5. Interval data analysis of the Spaciousness dimension

Spaciousness	**t: 0.90**	***p*-Value: 0.20**					
Item	**Attributes Related to the Question**	**November 2020**			**September 2022**		
		Mode	**Mean**	**SD**	**Mode**	**Mean**	**SD**
Q16. A big hotel guestroom is more important for you than a big bathroom.	The amount of free space and the feeling of spaciousness	4	3.78	0.87	4	3.71	0.91
Q17. A big bathroom is more important for you than a big hotel guestroom.	The amount of free space and the feeling of spaciousness	2	2.50	0.98	2	2.58	0.91
Q18. Due to the amount of time that you might spend in the hotel, how important is it for you to have a double-height space in the lobby?	The amount of free space and the feeling of spaciousness	2	2.55	1.03	2	2.43	0.96

Q19. How important is it for you to find an outdoor common area in the hotel?	The use of outdoor areas	5	4.36	0.95	5	4.32	0.90
Q20. Considering the amount of time you might spend in the hotel, an indoor patio would make you feel more relaxed and less overwhelmed.	The use of indoor patios	4	3.99	0.94	4	4.10	0.80

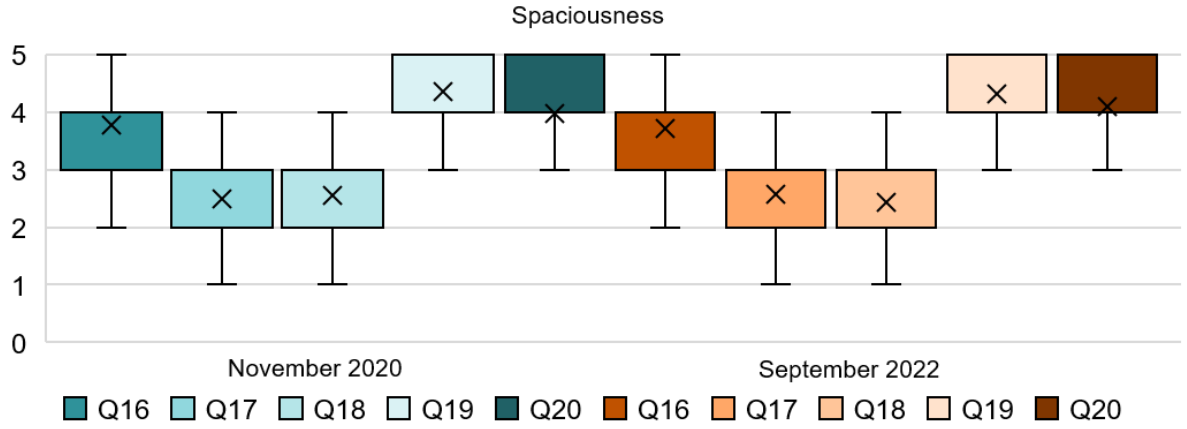


Figure IV.7. Interval data graph of the Spaciousness dimension

Figure IV.8 shows the percentage of the responses for each of the five-point Likert scale scores of the spaciousness dimension. The items in Q16 and Q17 examine the designated space for the bathroom and guestroom. In Q16, very similar results were extracted and 69% of people preferred a big guestroom and a small bathroom, while 22% in 2020 and 18% in 2022 were neutral about this statement. Conversely, results from Q17 revealed that only 15% of people agreed about preferring a big bathroom and a small guestroom in 2020, and 19% of them in 2022. Results of Q18 are almost identical in both stages and showed that for approximately 18% of people, it was important or very important to have a double-height space in the lobby, and 53% revealed that this was not important for them. In 2020, 87% of the respondents of Q19 expressed a great importance to find an outdoor common area in the hotel. This number was slightly reduced in 2022, with 85% of people expressing a great importance. Similarly, Q20 reveals that 76% of the participants from the first stage agreed with the statement that 'an indoor patio would make you feel more relax and less overwhelmed', and 81% agreed to this in 2022. Only less than 8% of the respondents disagreed with it in both stages of the survey.

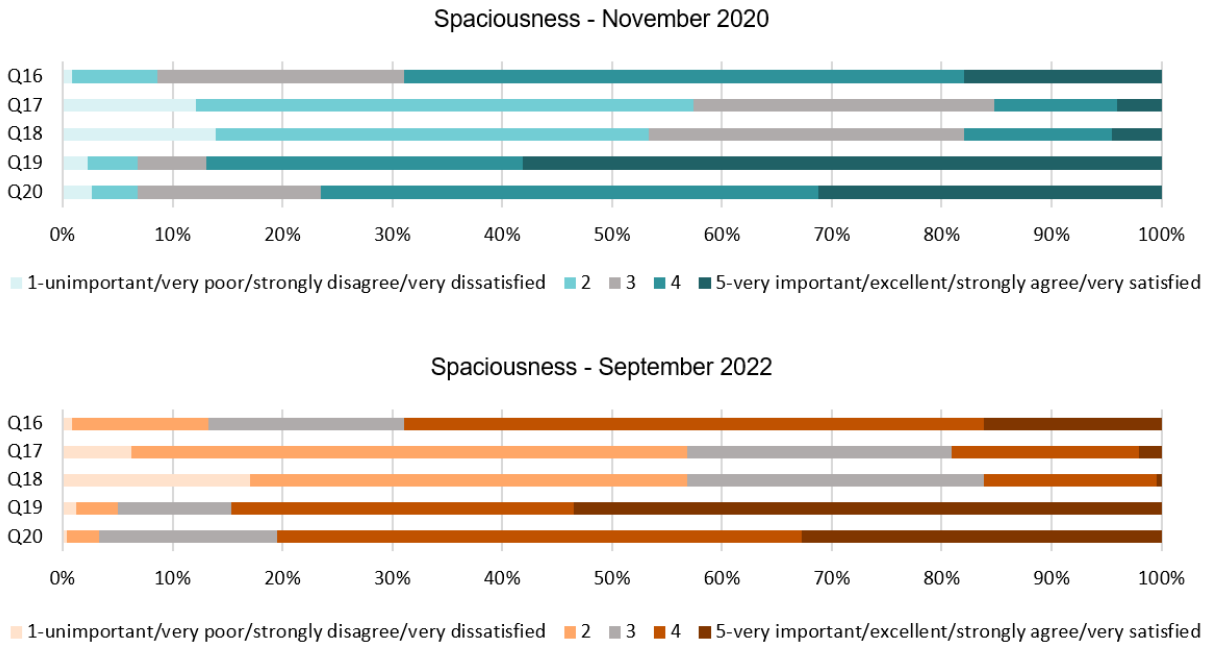


Figure IV.8. Spaciousness dimension chart

4.5. Analysis of the Physiological Conditions dimension

The findings in this section are consistent with the results in the previous ones; see Table IV. 6 and Figure IV.9. All the questions regarding the physiological conditions seem to show a positive general response. In this case, the use of regular hygiene standards and sanitation facilities is supported by people, as can be seen in the mode and mean in all questions. Participants are willing to cooperate with these measures and consider them important to reduce the spread of the virus. While in Q7 and Q9, some dispersed results were found and people felt hesitant when the measures affected their comfort, in this case, regarding the hygiene standards, all the responses are almost unanimous, as can be extracted from the SD which is ≤1 in all questions. Moreover, another important factor can be extracted from Q24 with respect to the air quality. Although all responses seem to be positive, there has been a slight drop in regard to Q21, Q22, and Q25 in 2022. Responses to the three questions showed a mode of 5 in 2020 and this has been reduced to 4 in 2022. For instance, people seem to be less satisfied with constant reminders about the virus, such as a signage of hygiene standards.

Table IV. 6. Interval data analysis of the Physiological Conditions dimension

Physiological Conditions	**t: 2.16**	***p*-Value: 0.04**					
Item	**Attributes Related to the Question**	**November 2020**			**September 2022**		
		Mode	**Mean**	**SD**	**Mode**	**Mean**	**SD**
Q21. Hotels might need to provide regular reminders and signage to maintain hygiene standards. Would you be satisfied with this measure?	The use of regular hygiene standards	5	4.47	0.77	4	4.10	0.59
Q22. How important is it for you to stay in a hotel with enough sanitation facilities?	The use of regular hygiene standards Sanitation facilities	5	4.52	0.67	4	4.25	0.69
Q23. Keeping the toilets clean after your use is also important to reduce the spread of the virus. Would you agree with more regularity of the cleaning service during your stay in the hotel?	The use of regular hygiene standards	5	4.65	0.57	5	4.44	0.69

Q24. Keeping a space ventilated by opening windows and doors where and when possible reduces the risk of spreading the virus. Would you be satisfied with this measure?	Air quality	5	4.68	0.58	5	4.47	0.61
Q25. Using signs and posters to build awareness of good handwashing techniques might be helpful to reduce the spread of the virus. Would you agree with this measure?	The use of regular hygiene standards	5	4.48	0.71	4	4.22	0.69

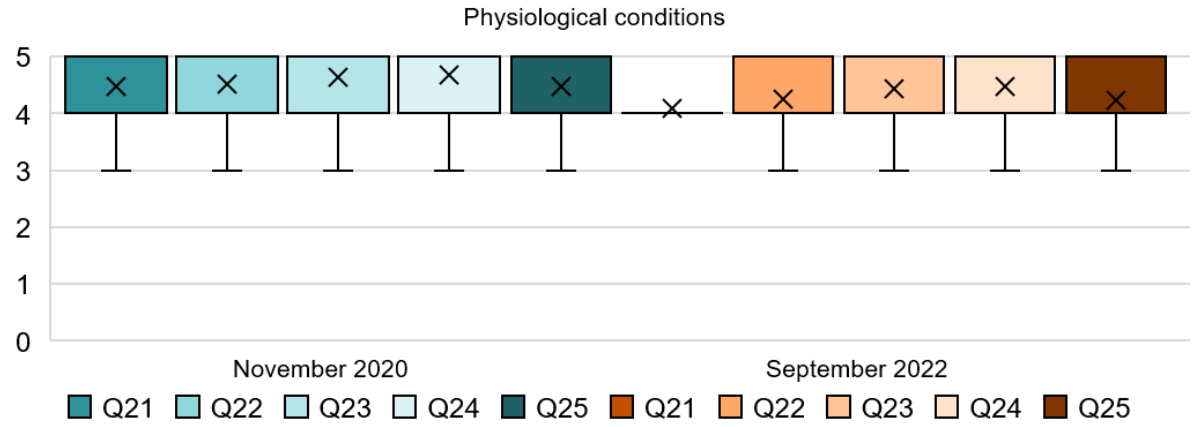


Figure IV.9. Interval data graph of the Physiological Conditions dimension

Figure IV.10 proves the consistency of this section. The results seem to be very positive for all five questions in both stages but all of them show a slight decrease in 2022. For instance, Q21 reveals that 96% of the respondents in 2020 were satisfied with hotels' need of providing regular hygiene reminders. This amount, although still high, has been reduced to 90% in 2022. Q22 shows that for 91% of the people from the first stage of the survey, it was important or very important to stay in a hotel with enough amount of sanitation facilities; while in the second stage, it was important for 88%. Q23 asked about the cleaning service in the toilets, and 98% of the participants agreed with more regularity of this service in 2020 compared to 92% in 2022. For Q24, the results indicate that in 2020, 98% of people were satisfied with a space ventilated with opened windows and doors where and when possible. Results from 2022 show that 95% of people were satisfied with the measure. Lastly, in Q25, 93% of the respondents agreed with the use of signs and posters to help to reduce the spread of the virus in the first stage, which was very similar to the results from 2022, when 91% of people agreed with the measure.

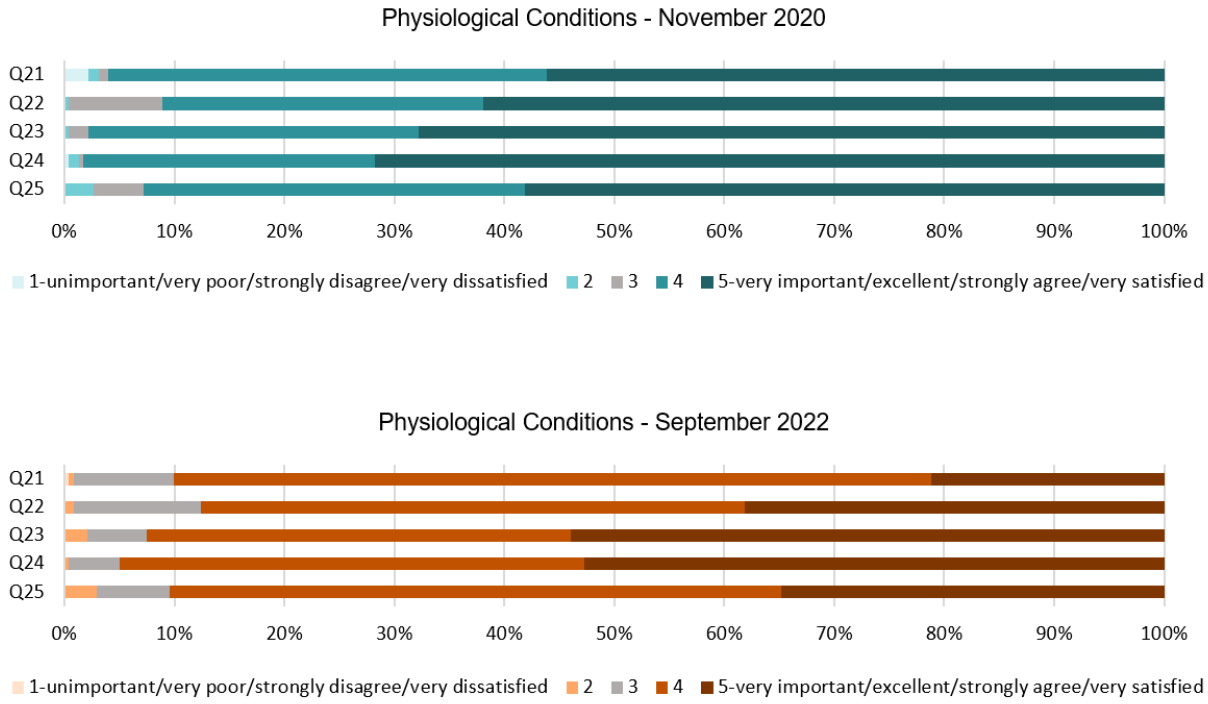


Figure IV.10. Physiological Conditions dimension chart

4.6. Analysis of the Services dimension

This section shows very interesting results; see Table IV. 7 and Figure IV.11. Firstly, Q26 expresses the disagreement between people toward changes in the cleaning service. The SD from both stages of the survey are dispersed, so this finding might not be strong enough to make a conclusion but it is relevant considering the very different feelings that people had about the statement. This is also supported by the previous responses from Q7 and Q9 regarding COVID-19 measures that might affect the comfort of respondents. The following questions, Q27 to Q30, seem to show a more positive response in 2020 from the respondents; this is supported by the mode. People seemed to be satisfied and agreed with the hypothetical service conditions exposed, although some of the results have changed in 2022. For instance, results from Q28 have lessened from a mean of 3.35 to a mean of 2.56, and results from Q29 have changed from 4.31 to 3.86. Additionally, Q30 shows a lower mean in 2022 than in 2020 with regard to the level of satisfaction with treatments with minimal contact. Lastly, an important finding has been found from Q31. In this case, people in the first stage presented strong support for the use of technology and smartphones to minimize the interaction when booking a room; respondents strongly agreed with this measure. However, we find a slight decrease in the mean, from 4.38 in 2020 to 3.93 in 2022.

Table IV. 7. Interval data analysis of the Services dimension

Services	**t: 6.25**	***p*-Value: 0.0007**					
Item	**Attributes Related to the Question**	**November 2020**			**September 2022**		
		Mode	**Mean**	**SD**	**Mode**	**Mean**	**SD**
Q26. Some hotels have temporarily canceled the room cleaning service while guestrooms are occupied. Would you be satisfied with this decision?	Cleaning service	2	2.52	1.21	2	2.28	1.12

Q27. Staff might be wearing a face mask to reduce the risk of spreading the virus. Would you approve of this measure?	Measures on the staff members	5	4.82	0.46	5	4.42	0.73
Q28. Some hotels have temporarily closed all the restaurant areas and just offered room service. Would you be satisfied with this decision?	Restrictions on the facilities	4	3.35	1.10	2	2.56	1.10
Q29. The spa management might consider limiting its use to one guest per booked appointment with a break between sessions for cleaning. Would you be satisfied with this decision?	Restrictions on the facilities	5	4.31	0.84	4	3.86	0.97
Q30. Treatments with minimal contact are recommended for guests that may feel nervous about visiting the spa. Would you be satisfied with this choice?	Measures on the staff members Restrictions on the facilities	4	4.08	0.84	4	3.65	0.93
Q31. The use of technology such as smartphones, tablets, or laptops for bookings minimizes the interaction between staff and guests and helps to reduce the risk of spreading the virus. Do you agree with this alternative?	The use of technology and smartphones	5	4.38	0.80	4	3.93	0.91

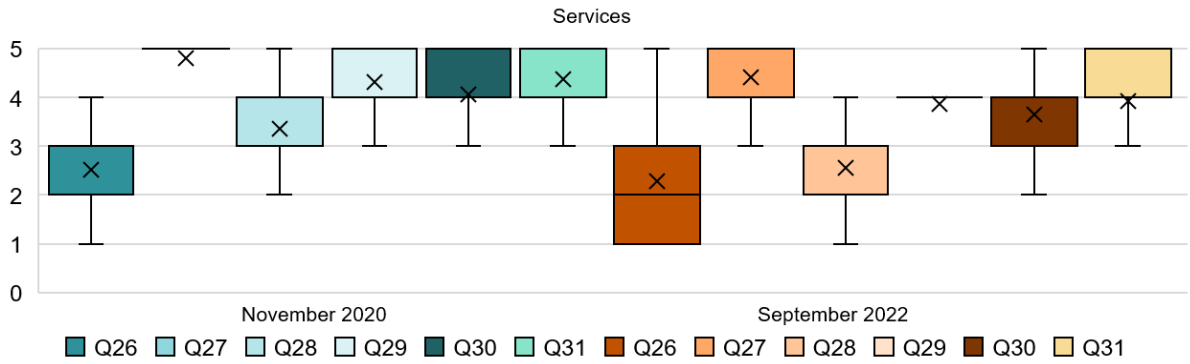


Figure IV.11. Interval data graph of the Services dimension

As shown in Figure IV.12, for Q26, very diverse answers were found. In 2020, 54% of people were not satisfied with the temporary cancellation of the room cleaning service while the guestrooms are occupied, while 23% were neutral about it. However, the number of people not satisfied with this decision increased in 2022 to 68%, and 12% felt neutral about it. Q27 reveals an almost unanimous response with regards to the staff wearing a face mask in 2020; 83% strongly agreed and 16% agreed with this, while in 2022, 53% strongly agreed and 40% agreed. Results from Q28 show that, in 2020, about half of the participants were satisfied or very satisfied with the temporary closing of the restaurants, 25% of them were not sure about it, and 23% disagreed with it. However, in 2022, 56% of people disagreed or strongly disagreed with this decision. Q29 investigates the limit to one guest per booked appointment in the spa. In this hypothesis, 89% of the participants were mostly satisfied with

the measure in the first stage but, in the second stage, this was only approved by 76% of respondents. Q30 also shows a decrease from 2020 to 2022 with regard to satisfaction. It was revealed that, in 2020, 77% of people were satisfied or very satisfied; however, in 2022 only 62% responded positively. Finally, Q31 proposes the use of technology for bookings. It can be seen that 89% of the participants from 2020 agreed and strongly agreed with it. A dropping in percentage can be seen in 2022, with 79% of respondents agreeing with the statement.

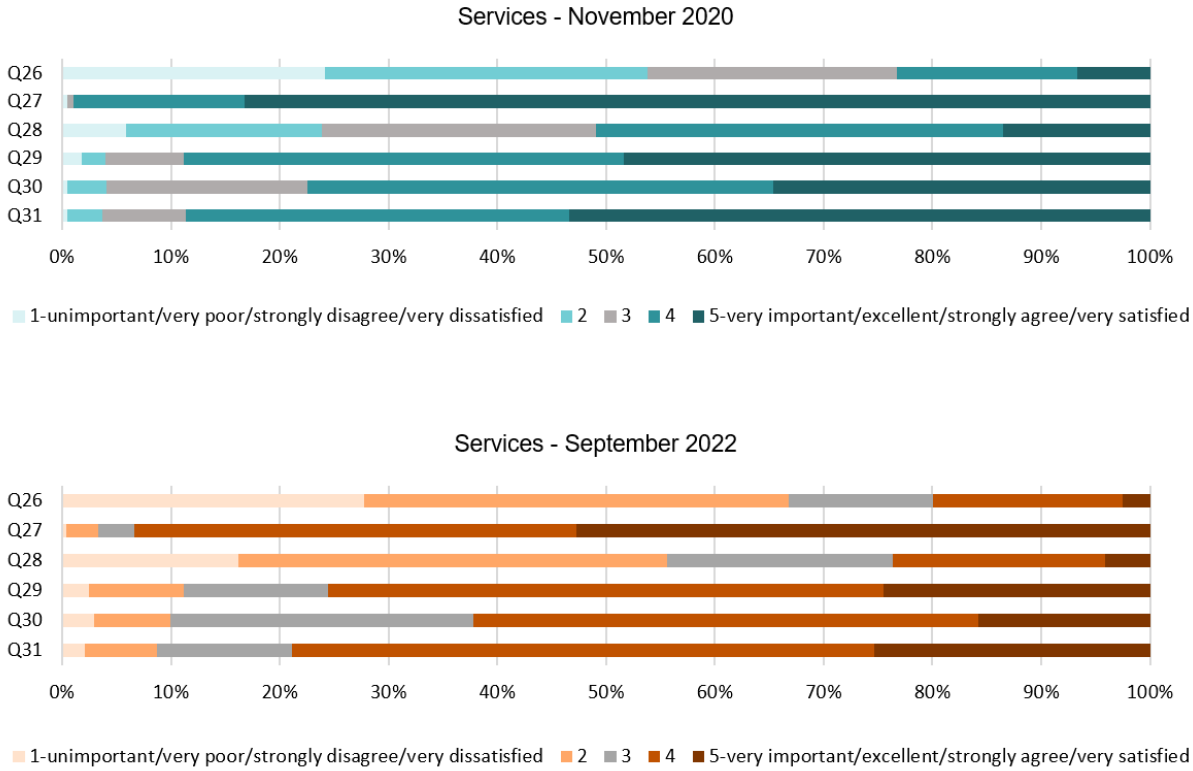


Figure IV.12. Services dimension chart

In summary, based on the 2020 and 2022 surveys, the attributes that received the most positive responses for a sustainable recovery of hotels are, for the aesthetic quality dimension, the style of the ornaments/furniture (Q5, mean 4.30–4.22). For the functionality dimension, the space between the furniture and the use of physical distancing (Q6, mean 4.77–4.31). For the atmosphere dimension, the cleanliness (Q13, mean 4.59–4.61). For the spaciousness dimension, the use of outdoor areas (Q19, mean 4.36–4.32). For the physiological conditions dimension, the air quality (Q24, mean 4.68–4.47). Lastly, for the services dimension, the measures on the staff members (Q27, mean 4.82–4.42).

5. Discussion and Sustainable Recovery Attributes

The current study provides a number of interesting findings for practitioners, design experts, and academics of the hospitality and tourism sectors. Table IV. 1 was created in response to the research question RQ1 and, based on the existing literature, in order to present the main servicescape attributes to consider during an airborne health crisis, such as COVID-19. The quantitative analysis presented above shows how the sentiments of people toward servicescapes have changed over the course of the pandemic, with the aim of responding to RQ2. Finally, in order to respond to RQ3, two main groups can be extracted from the results. The first group includes the attributes or improvements that are relevant for people and have remained constant during the phases of the pandemic; these will be called the ‘unaltered attributes’. The second group includes the attributes that have changed from 2020, when the first survey was taken, to 2022, when the second survey was taken and is also relevant; these will be called the ‘altered attributes’. Attributes from both groups must be taken into account and implemented in hotels for a sustainable recovery of the sector.

5.1. Unaltered Attributes

The first section, 'aesthetic quality', confirmed that customers' satisfaction increased when the building includes indoor plants. Several recent studies have confirmed the benefits that indoor plants can provide and their contribution to a better indoor environment during COVID-19 [61,62]. Similarly, a minimalist decoration style and clean lines of furniture inspired customers' positive responses. The perception of the respondents with respect to inhabiting a minimalist hotel is related to the published research of Jiang and Wen (2020), which states that hotel surfaces that receive constant human contact are more likely to be contaminated and become a source of spread of COVID-19 and other infectious diseases. For instance, furniture with clean lines and a minimal design is easier to keep clean. Minimalism has proved to be a sustainable lifestyle that declutters not only spaces but minds. It has also been proved that it alleviates depression and improves wellbeing [63]. People seem to be more comfortable with warning signs in 2022 so this attribute, contrarily to the other COVID-19-related attributes, obtains more positive feedback. Banners and signs about the spread of the virus have proved to be a very efficient method to warn people about it [64]. From the 'Atmosphere' section, more than 85% of the participants expressed the importance of natural light and their preference for the use of warm artificial lighting in the room, which is consistent with previous research about the positive effects of natural environments on agitation and stress [55]. The scent of cleanliness was highlighted and, therefore, is essential for questioned people. It has been proven the subconscious positive influence of ambient scents, white bedding, and even the presence of cleaning staff on an individual's perception of cleanliness during COVID-19 [46]. In regards to the background noise, results confirmed the significance of a quiet and relaxing environment in the hotel. This importance is coherent with several researchers who stated that indoor environmental conditions, such as temperature comfort, lighting, noise or indoor air quality, influence emotional stress and sleeping hours [55]. 'Spaciousness' has been a very important factor during COVID-19 and results from this dimension have remained constant from 2020 to 2022. Results clearly show the significance of outdoor space within the hotel. The use of outdoor recreational activity increased by 291% during the lockdown [65] and the value of urban nature during a time of crisis was rediscovered. It has been proved that sometimes, the outdoors helps with mental health and wellbeing during a crisis [39,65]. Participants were also asked about their preferences for having a big guestroom or a big bathroom, and the former was significantly more valuable to them. The importance of indoor air quality has remained constant in both surveys. Airborne viruses and poor indoor air quality are directly related. This is a field that needs to be researched further; so far little research has studied the improvement of air quality within buildings with proper design strategies and the integration of new engineering systems to control it [48].

5.2. Altered Attributes

The results reveal that most of the participants are aware of the main COVID-19 procedures and measures, although they generally felt more flexible about them in 2022 than in 2020. Physical distancing and the use of masks inside the hotel are very important for the respondents but the mean for both shows that these are not as relevant for them as during the pandemic. Previous research has examined the safety and health measures for COVID-19 in the hospitality industry [66] and found that social distancing in hotels is one of the most effective measures in preventing infections. Some of the results from the 'physiological conditions' section, provide evidence that most of the respondents agreed with the implementation of all COVID-19 protocols. Although our results clearly show that participants were aware of and understood the restrictions, some of these attributes have been altered from 2020 to 2022. For instance, the use of regular hygiene standards and sanitation facilities is crucial to prevent the spreading of other infectious diseases. People increased their frequency of hand hygiene practices during the pandemic and this should be constant in the future stages as well [67]. From the 'services' section, a majority of participants strongly agreed with the use of masks by the staff of the hotel. Although this finding has been altered from 2020 to 2022, it is still relevant. This is consistent with published research which demonstrated that most respondents had an acceptable knowledge of the use of face masks and were confident to correctly put it on [68]. The spa services

were also examined and respondents supported limited use. This positive attitude toward the use of the spa complements the demonstrated benefits of spas and balneotherapy during COVID-19 [42,47]. The agreement for most of the respondents with the utilization of technology for bookings was revealed. It has been investigated that new uses for technologies, such as the use of live-stream practices, AI, or facial recognition, are utilized on a daily basis to enhance the service quality in the hospitality sector to successfully recover from the virus [45].

In order to facilitate the understanding of the results extracted from the research, a comparison between the means of each survey from the unaltered and altered attributes exposed has been shown in Figure IV.13.

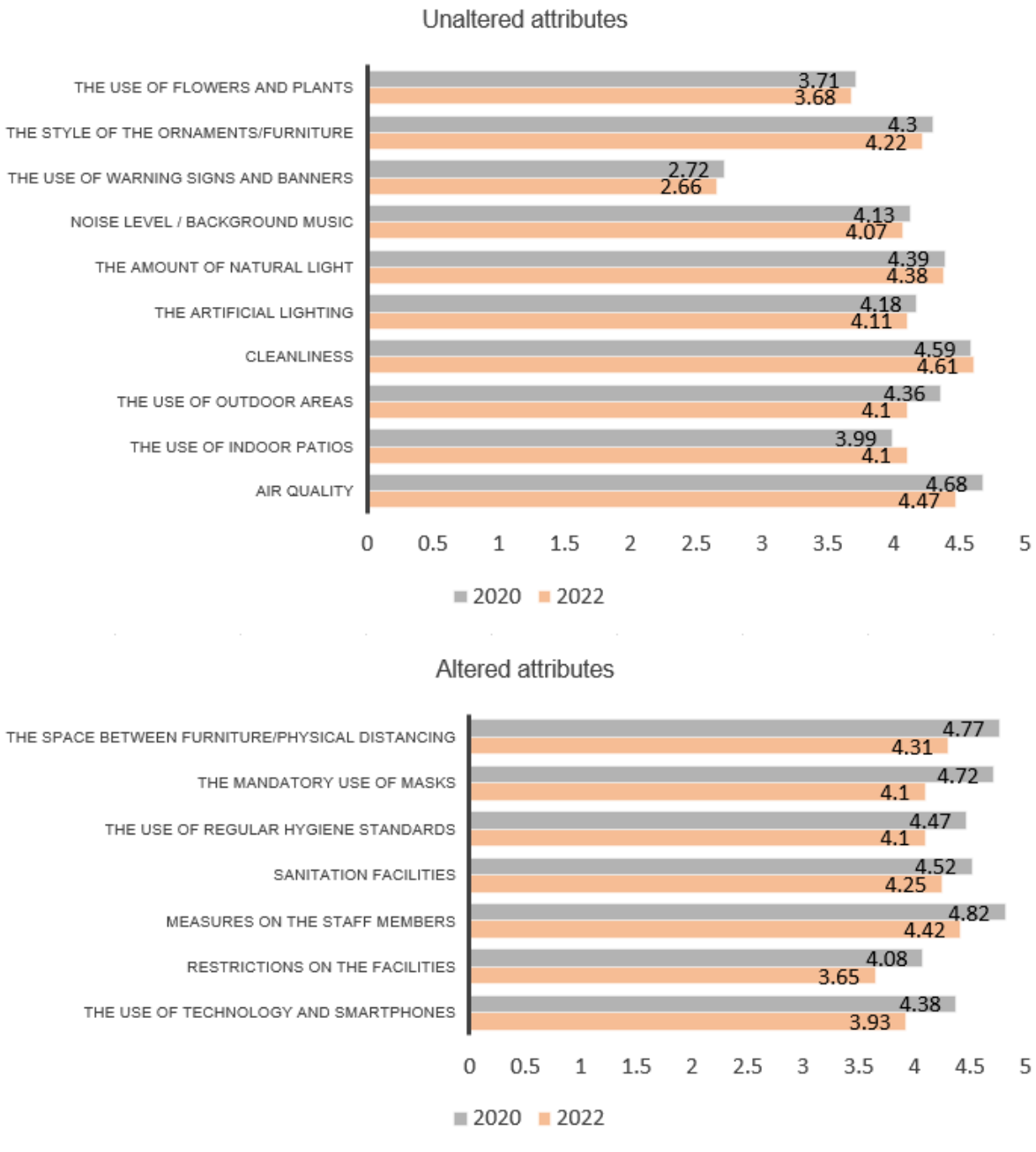


Figure IV.13. Unaltered and altered attributes for a sustainable recovery

6. Conclusions and Future Research

This paper provides initial insights into the sentiments that people have had toward the hotel servicescapes during and after COVID-19 in a tourism context to support the UNWTO One Planet Vision for a sustainable recovery from the pandemic. Relevant findings can be extracted from this research and the attributes presented should be taken into consideration due to their importance over the years in people's perspectives. The most relevant finding confirms the importance of greenery; an indoor patio and indoor plants in the hotel are crucial for people's wellbeing. The second finding suggests that a minimalistic decoration and the incorporation of clean-lined furniture generate a positive response. Practicing minimalism offers significant contributions not only to the body but also to the environment by promoting responsible consumption, a circular economy of products, and a self-sufficient mindset. The third finding confirms the relevance of indoor environmental quality including natural light, warm artificial lighting, a relaxing/quiet background, controlled air quality, and the scent of cleanliness proves to be beneficial. The fourth finding suggests that the feeling of indoor and outdoor spaciousness have a very positive impact on people. Lastly, participants seem to feel more flexible in the second stage of the post-pandemic era regarding COVID-19 measures. These results were expected, considering that a high number of the population are now vaccinated and governments have eased the restrictions. However, people emphasized the importance of physical distancing, facial masks, limited use of the spa, and online bookings in the hotel to cope with the virus, even in 2022. It was noticeable that the majority of the respondents have a clear knowledge of the recommended procedures and feel cooperative; however, results also suggest that respondents were slightly reluctant when these actions affect their comfort. Additionally, technological innovation can play a key role to reduce customers' perceived health risks. From a broader perspective, the physiological conditions and atmosphere dimensions have the highest mean value, and positive responses from the participants about the servicescapes of hotels during and following the pandemic. This is an important finding and shows the dimensions that positively impact a sustainable recovery of the sector in the post-pandemic era.

The limitations of our survey are common to most surveys involving personal responses. For instance, the validity of the Likert scale attitude measurement can be compromised due to social desirability; this means that the individuals involved in the survey may lie to present themselves in a positive light. In this case, the questionnaire asked relevant questions with regard to COVID-19 measures, and although most of the respondents agreed with these restrictions, there is a chance that they might not be truthful with their statements and follow instead what is socially accepted.

The magnitude of the COVID-19 crisis represents a challenge for all researchers of different disciplines. The pandemic has paralyzed the course of hospitality toward zero neutrality, but adequate management is crucial for a sustainable recovery and to meet future sustainable plans. Understanding what needs to be improved, what are people's needs, and what are the right tools to use are priorities from now to 2050. Theoretical implications have been extracted from this research, and the main aspects that should be deeply analyzed and incorporated in hotels have been presented to cast some light on the impact that COVID-19 has had upon people's wellbeing in a hotel. Additionally, practical implications can be drawn for hospitality managers and stakeholders of hotels to understand their customer's needs and feelings. It is time for both the hospitality industry and scholars to work together and bring new models, approaches, and ideas that will help to overcome the devastating effects of the pandemic. Future research will be required to provide further data for a sustainable recovery of the sector in the post-pandemic era. For instance, the spaciousness and atmosphere dimensions have not rejected the null hypothesis presented as their *p*-value, which is higher than the significance considered; as a consequence, it has not been possible to prove a significant effect on these dimensions. Although some of their attributes have shown a positive response, other attributes have remained unaltered and do not demonstrate a significant difference between 2020 and 2022. Further research about these dimensions might be needed to reinforce the unaltered nature of these attributes.

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Conflicts of Interest: The authors declare no conflicts of interest.

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CHAPTER V.

"OPTIMISING LCA IN COMPLEX BUILDINGS WITH MLCAQ: A BIM-BASED METHODOLOGY FOR AUTOMATED MULTI-CRITERIA MATERIALS SELECTION"

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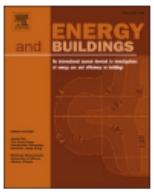

Article

Optimising LCA in complex buildings with MLCAQ: a BIM-based methodology for automated multi-criteria materials selection

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Abstract: Recent scientific studies have highlighted the importance of integrating Life Cycle Assessment (LCA) in the construction industry to achieve the future sustainable plans. At the moment, most of existing LCA methodologies have failed to automate the calculation process, causing delays in the decision-making and design phases. Moreover, the complexity of buildings poses significant challenges to the calculation. To address this, the authors developed the MLCAQ, a streamlined methodology designed to compare different material alternatives based on the environmental and economic cost impact and guide the early design stages. To implement the methodology, the study presents the development of a BIM-based software and validates its application in a high-rise building. The research compares multi-dimensions of two sets of construction materials, analysing the total economic cost, CO_2 emissions, embodied energy and waste mass. The results demonstrate the effectiveness, replicability, consistency and viability of the tool. The data generated from the system indicates that using circular materials results in a significant reduction in embodied energy (26.40%), CO_2 emissions (24.55%) and waste mass (49.19%), as well as a net reduction of €7.6 million in total economic cost. The research contributes to the integration of multi-dimensional real-time assessment into the building design process.

Keywords: Set-based design; circular materials; life cycle assessment; environmental impact; BIM-enhanced;

1. Introduction

Climate change has become one of the biggest problems to mitigate in this century. Human beings continually emit greenhouse gases into the atmosphere. In particular, carbon dioxide (CO_2) is the most worrying of all, not only because of its abundance but also because of its ability to remain in the atmosphere for thousands of years (Jiang et al., 2021). Specifically, the construction sector contributes to the 39% of CO_2 emissions generated annually on the planet. These emissions come from the energy used to build new buildings, dispose of their waste and transport and manufacture the materials among others. Furthermore, buildings generate 35% of global industrial waste and consume 40% of total raw materials. These make buildings and construction as a whole, the main responsible for energy consumption and the depletion of raw materials. Europe is on track to become the first climate-neutral continent by 2050, producing no more greenhouse gases than ecosystems can naturally absorb. The main international financial organisms, together with the European Commission, have proposed a series of mitigation measures to reduce the environmental impact generated in the recent decades. In 2015 the United Nations Member States adopted the 2030 Agenda for a Sustainable Development. This was an urgent call for action to mitigate the biggest problems facing humanity at the moment, namely ending poverty, protecting the planet and ensuring that by 2030, all people will enjoy of peace and prosperity. To achieve it, 17 Sustainable Development Goals or Global Goals were proposed (Climate Change - United Nations Sustainable Development, n.d.) with strategies to improve education and health, reduce inequality, stimulate economic growth, address climate change and preserve oceans and forests.

The European objectives initiated in 2020 such as the European Green Deal (A European Green Deal, n.d.) and Renovation Wave (Renovation Wave, 2020) promote accelerating the pace of energy rehabilitation by 2030. The main objective of the Renovation Wave is to improve the quality of European buildings through digital energy saving solutions. Although minimum energy standards are required for the approval of new buildings, the majority of the existing building stock is comprised of older structures that necessitate efficient and sustainable renovations, which can be achieved through the use of current digital mechanisms and tools. According to the European Green Deal, the objective is to achieve climate neutrality within the EU by 2050. The pact seeks to facilitate the transition of the EU into an efficient economy that optimises the utilisation of resources, ensuring zero net emissions of greenhouse gases, and decoupling economic growth from resource utilisation (A European Green Deal, n.d.). Moreover, the objectives established in the Climate Change Conference that took place in Sharm el-Sheikh in November 2022 must be added (Sharm El-Sheikh Climate Change Conference - November 2022 | UNFCCC, n.d.). It is estimated that around 75% of the existing buildings do not meet the mandatory standards, and even if these buildings intend to comply with the sustainable objectives set by the EU, 97% of them would not be able to meet the required standards (Jiménez-Pulido et al., 2022). By constructing and rehabilitating more sustainable buildings, the construction sector would reduce its CO_2 emissions while safeguarding ecosystems. To address these, sophisticated tools are required to analyse the life cycle of buildings, their materials and resources, as well as new systems and methodologies that facilitate the energy certification of buildings and their sustainable design (Serrano-Baena et al., 2021). Lastly, the EU's long-term budget, together with the NextGenerationEU, is the largest stimulus package ever financed in Europe. In total, 2.018 trillion euros will be allocated to rebuilding Europe after COVID-19. It will be a more resilient, digital and green Europe. The package with the multiannual financial framework 2021-2027 consists of €1.211 trillion, together with the temporary recovery instrument, NextGenerationEU, of €806.9 billion (The 2021-2027 EU Budget, n.d.). The European Commission has highlighted in its strategy the possibility of growing, creating jobs and taking advantage of both ecological and digital transitions.

In this context, the integration of a circular economy in the construction industry has been the subject of study by many researchers in the last decade (Ding et al., 2023; Shooshtarian et al., 2022). The dominant models of production and consumption in the construction sector are characterized by a linear economy, which follows the sequence of "extraction-production-disposal". This model lacks provisions for the reutilization of discarded products and materials. In contrast, the circular economy

presents a paradigm shift that emphasizes a regenerative approach to production and consumption, which involves designing manufactured products with added value and longer lifecycles, creating versatile products that maximize their use, and promoting the market competitiveness of recycled materials (Primc et al., 2020). Larsen et. al (2022) highlighted the importance of integrated tools and methodologies used to assess circularity for buildings. In recent years, the infinite possibilities offered by Building Information Modelling (BIM) for automation and optimisation in the construction sector have been deeply considered. Different studies examine the added difficulty that current standards and protocols entail in the implementation of BIM, due to the use of all available information and its generation during the building design phases (Jiménez-Pulido et al., 2020). Hence, the availability of tools and methodologies that facilitate the interpretation of existing information and enable the generation of updated data, are indispensable for the current digital transition.

Sustainable construction is founded on the holistic integration of three main aspects: economic, environmental, and social (Forth et al., 2023; Larsen et al., 2022). Over the last two decades, LCA has been utilised to quantify and enhance the environmental performance of buildings. However, this methodology is complex and requires extensive data exchange, particularly related to materials. Additionally, other methodologies, such as LCC and Social Life Cycle Assessment (S-LCA), are included in the circular economy of the building. There is a need to integrate these procedures to deeply assess a building at its full complexity (Larsen et al., 2022). The Life Cycle Sustainability Assessment (LCSA) is created as a response to support the implementation of a circular economy in sustainable construction through these three main pillars. In this context, the inclusion of BIM has garnered significant interest in the scientific community due to the digital model information format. Authors such as Shibata et al. (2023) have proved that inclusion BIM inclusion for LCA and LCSA could enhance the approach to cost and environmental impact assessment. As highlighted by Santos et al. (2019), the application of BIM can be a revolution to quantify the environmental, social and economic impact of buildings. However, in order to achieve this, it is imperative to streamline and facilitate the integration of these concepts. Presently, two primary approaches to LCA LCSA utilising BIM tools have been examined, with minor variations between them.

Method 1 involves carrying out LCA/LCSA directly in a BIM software without using additional tools. This approach has been implemented in studies by Röck et al. (2018), Llatas et al. (2022) and Hollberg et al. (2020). The method involves importing IFC elements with LCA/LCSA characteristics and environmental properties incorporated or using plug-ins such as Dynamo to perform the LCA/LCSA in BIM. While this approach is useful for early design phases, it lacks flexibility and standardisation, making it challenging to implement in real-world scenarios. Furthermore, the software used require a high-budget license, limiting the accessibility. In practice, a full project is rarely conducted entirely with a single BIM software, as calculations for the structure and installations require more specific software. Therefore, determining the environmental impact of this method is incomplete, as it depends on the elements developed in a single BIM software. The second method entails the extraction of the Bill of Material Quantities (BoMQ) from the digital model, followed by its importation into another software capable of generating LCA or LCSA. Santos et al. (2020) and Figueiredo et al. (2021) provide illustrative examples of this approach. Nonetheless, the compatibility between the two tools poses a challenge for this methodology. The lack of linkage between them results in a delay in the calculation. Moreover, the current systems do not permit significant modifications when the design is already finalised, so this method is neither flexible nor immediate. Table V.1 shows the contributions and limitations of the most relevant research conducted from 2018 to date on linking BIM-LCA/LCSA with the main methods 1 and 2 previously described.

Table V.1. Main contributions and limitations of existing BIM-LCA/LCSA research methodologies

Reference	BIM-LCA/LCSA tools	Contributions (C) / Limitations (L)
Röck et al. (2018)	Autodesk Revit Custom script – Dynamo eBKP-H (SN 506 511)	(C) Specific hotspots of the design can be visualized for communication of LCA results. (C) Support decision making in the early design stage.

		(L) The methodology is not a standardized process to be used by other researchers. (L) The process is linked to expensive tools.
Marzouk et al. (2018)	NSGA-II Monte-Carlo Simulation Autodesk Revit	(C) International application through the certificate LEED. (L) The methodology is not construction focussed so there is a limitation in the technical approach. (L) Data needs to be added manually and it is not an automated process. (L) Life cycle cost focussed.
Santos et al. (2019)	IDM/MVD Autodesk Revit	(C) Reduction of errors linked with the use of different tools. (C) Compatibility of IFC schema with IDM/MVD was proved. (L) Restricted to certain agents of the project. (L) Data needs to be added manually and it is not an automated process.
Hollberg et al. (2020)	Autodesk Revit Dynamo Ökobilanzdaten im Baubereich by KBOB Umweltbelastungspunkte	(C) The approach is viable during the design process. (L) The methodology needs to be adapted for technical elements. (L) The embodied impact has not been optimised and included as a parameter. (L) The process is linked to expensive tools.
Santos et al. (2020)	Autodesk Revit/Revit API WPF CYPE Ingenieros S.A. Ecoinvent	(C) Provide semantic data treatment and automatic simulations using BIM models. (L) MEP elements are not included in the methodology.
Rad et al. (2021)	Green Building Studio Autodesk Revit Revit API	(C) Accurate life cycle cost towards earthquake is provided. (L) Resilience of a building towards several natural disasters is not considered. (L) Life cycle cost focussed.
Figueiredo et al. (2021)	Autodesk Revit Green Building XML SINAPI TRACI 2.1 TALLY GaBi database	(C) The LCSA proposed methodology combines environmental, social and economic aspects. (L) Inflexible methodology. (L) List of pre-defined materials needs to be determined at early stage. (L) Several tools involved in the process.
Salehabadi and Ruparathna (2022)	BEES Dynamo WSM	(C) The LCSA proposed methodology combines environmental, social and economic aspects. (L) Single family detached homes focussed. (L) Data needs to be added and weighted manually and it is not an automated process.
Llatas et al. (2022)	Autodesk Revit Custom script - Dynamo CYPE Ingenieros S.A. BEDEC/ BCCA/ Ecoinvent	(C) The LCSA proposed methodology combines environmental, social and economic aspects. (L) The social aspect of the LCSA is not accurate and lacks from standard weighting units so this aspect needs to be researched further. (L) The methodology is not a standardized process to be used by other researchers, only for advanced users. (L) The process is linked to expensive tools.

The construction sector requires accessible tools and methodologies that prioritise the use and reuse phases of building design. This study presents the development of a set-based design system, as opposed to a point-based design system, to meet this need, see Figure V.1. A set-based design system considers a wide range of options, including materials and construction solutions, which are narrowed down based on specific requirements until a final proposal is reached (Lee et al., 2012). This process fosters effective communication among all stakeholders until the design phase's completion.

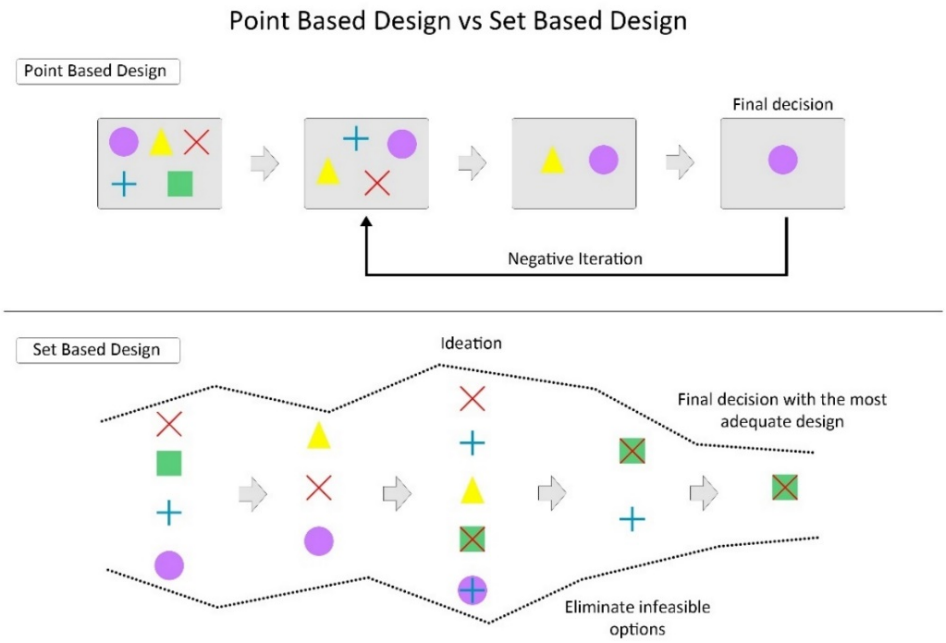

Figure V.1. Difference between point-based design system and set-based design system

To foster and ensure a circular economy within the construction industry, a comprehensive and unified approach to Life Cycle Assessment (LCA) must be implemented across all stages of the building process, from its initial design to its eventual reuse. The following questions have guided this research:

- RQ1. How do the existing methodologies approach LCA and LCSA and what are their limitations?
- RQ2. Is it possible to conduct and automatic calculation of the environmental and economic cost impact of a complex building using BIM tools without delaying the decision-making process?
- RQ3. What is the impact regarding energy and building cost of utilising circular materials?

Therefore, the Materials Life Cycle Assessment and Quantities tool (MLCAQ) has been developed to address these questions, supported by a new software that simplifies the calculation of LCA and Life Cycle Costing (LCC) for all types of buildings. The methodology section comprises four of the five steps that constitute the system and has been designed to be applicable to buildings of any complexity or size. To validate the effectiveness of the system, a high-rise building was chosen as a case study, demonstrating the novelty of this approach that does not exclude any building. The fifth step is presented in the results section, involving the analysis and comparison of the data collected during the previous stages. This comprehensive methodology provides a robust framework for evaluating the environmental and economic impact of buildings, facilitating the identification of areas for improvement and supporting the transition towards a more sustainable construction industry. The objective of this research is to develop a streamlined methodology that facilitates and accelerates the calculation of the environmental and economic cost impact of materials in complex buildings. Simplifying the analysis of the life cycle and cost of execution while unifying the process is essential to support the ecological and digital transition in the construction sector. This study focuses on the circularity of materials and proposes an optimised methodology entitled Materials Life Cycle Assessment and Bill of Quantities (MLCAQ) through the development of a new tool, entitled Open BIM Quantities. The software facilitates efficient and precise management of construction materials through the utilization of BIM models, thereby decreasing the time and effort required for project preparation and enhancing coordination and collaboration among the various involved parties. It is centred on three main indicators, namely CO_2 emissions, embodied energy, and generated waste mass. Embodied energy and CO_2 emissions are considered to be the most important environmental factors to analyse when selecting circular materials. Embodied energy refers to the total energy consumed in the entire life cycle of a product, from the extraction of raw materials to the end-of-life

disposal. CO_2 emissions are another key factor to consider, as they contribute to climate change and global warming. Additionally, waste management is essential for achieving circularity, as it ensures that materials are kept in the economy for as long as possible, rather than being disposed of in landfills or incinerated.

Numerous studies have highlighted the importance of embodied energy and CO_2 emissions in selecting sustainable and circular materials. For instance, Bontempi (2017) proposed an approach to evaluate the sustainability of raw materials substitution based on embodied energy and the CO_2 footprint. Another study by Abanda et al. (2017) discussed the integration of BIM and proposed a system that can automate the computation of embodied energy/ CO_2 of buildings. The objective functions for the cost, embodied energy, and CO_2 emissions were set and numerous optimization analyses for reinforced concrete were analysed by Yoon et al. (2018). Moreover, the embodied energy and CO_2 emissions of life cycle assessment (LCA) were discussed by Pakdel et al. (2021) to unravel the environmental benefits of using traditional techniques of Iranian construction systems. Lastly, waste management was highlighted as an important factor for LCA of waste management solutions by Bisinella (2017), the influence of waste composition data was quantified. These indicators together with the price per unit can be compared within different materials alternatives to select the most appropriate ones for the project. The work presented has the potential to bring significant implications for the construction industry by providing a practical and efficient approach to optimising construction solutions specifically tailored for complex buildings. The significance of this study extends beyond the analysis of a life cycle for buildings. It arises as a response to digitalisation in construction, optimisation and improvement of productivity, allowing collaborative work on the same digital model. Therefore, the proposed methodology emphasizes flexibility, open-source tools, and automation to provide optimal construction solutions for the project, with controlled building costs until the end of the design stage, qualities that until now have not been considered in a single methodology.

2. Methodology

The proposed MLCAQ methodology, as depicted in Figure V.2, represents a novel approach referred to as method 3. This methodology is the outcome of integrating the advantages offered by methods 1 and 2 listed in Table V.1. It involves linking the BIM format with the FIEBDC-BC3 format (Asociación FIEBDC, n.d.) through the creation of a new software. This connection enables the utilisation of a set-based design system in any kind of project, irrespective of its scale or complexity, without having to manually include IFC components with environmental characteristics or utilising an external software to compute LCA. This approach facilitates a multidisciplinary and collaborative workflow, allowing the project to be executed in a coordinated and simultaneous manner by all agents involved. By connecting any FIEBDC-BC3 database with BIM, this open-source system can be implemented through various software based on these two formats. The COVID-19 pandemic has had a profound impact on several sectors, including the construction (Serrano-Baena et al., 2023). Against this backdrop, a 39-storey hotel situated in Andalusia (Spain) has been subjected to analysis, to promote sustainable practices in the field. The methodology employed comprises five key phases. Academics and professionals within the construction and engineering sectors can pursue phases 2 to 5 to obtain comparable results for their research or projects. Furthermore, tools and platforms highlighted in this research are freely accessible:

1. Program. It consists of the creation of the new tool that links the BIM format with the FIEBDC-BC3 format of price bases.
2. Generate. The 3D digital model will be generated in BIM format formed of the sum of the construction elements, such as slabs, in turn formed of sub-elements, such as finishes.
3. Link. The BIM-FIEBDC-BC3 link will be made with the developed tool.
4. Quantify. All the information contained in the model will be automatically extracted, including environmental data, waste, measurements and budget.
5. Qualify. The last phase will consist of the comparison of two sets of construction solutions and selection of the most adequate ones based the three indicators, CO_2, embodied energy and waste mass.

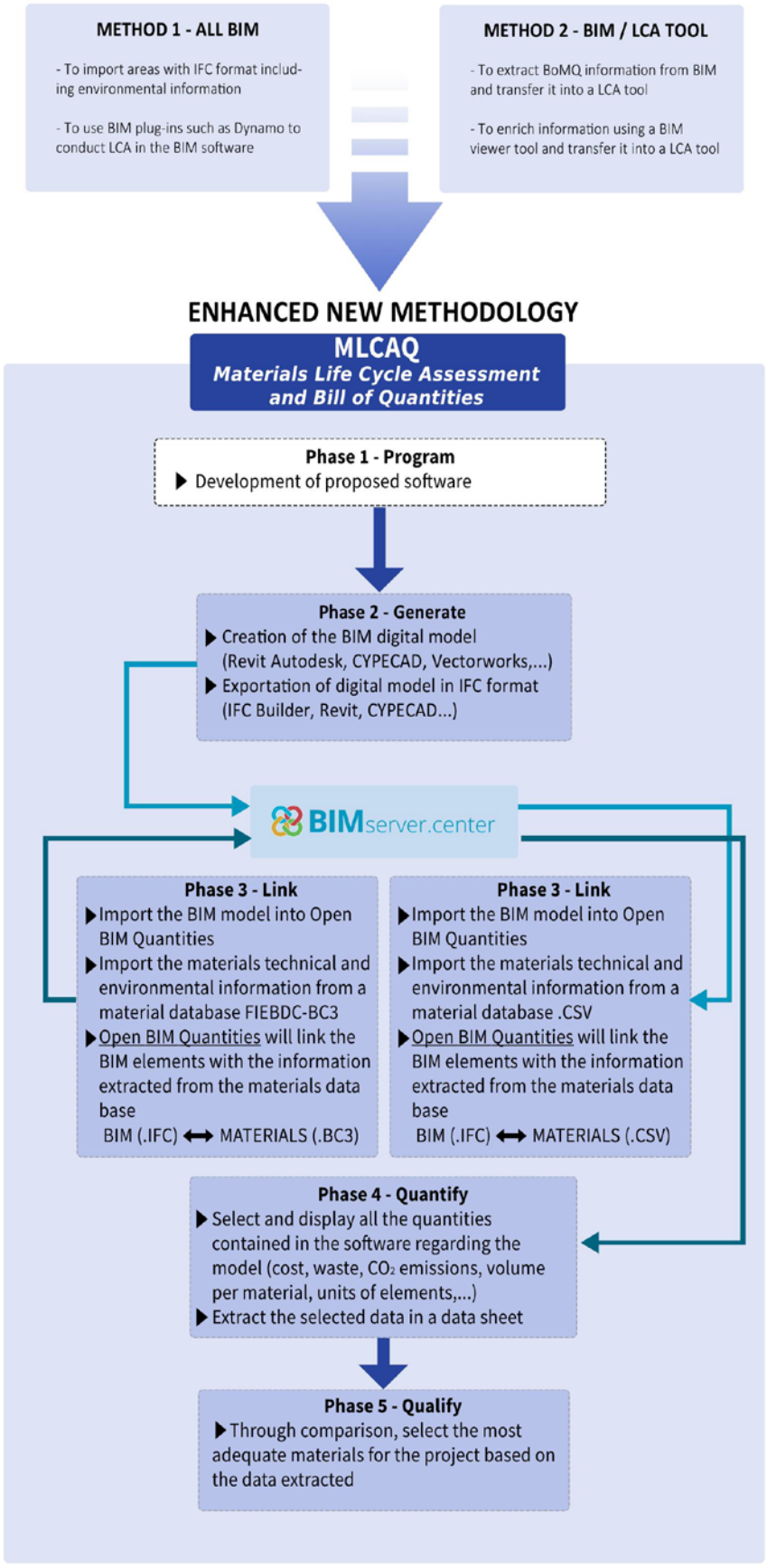

Figure V.2. MLCAQ methodology

Phase 1 – Program

The first stage of this methodology involves creating the software to calculate the environmental and economic cost impact. The authors, in collaboration with the European project Circular BIM (CircularBIM, n.d.), have developed Open BIM Quantities, which favours the use of the Industry Foundation Classes (IFC) format, an interoperability standard developed by BuildingSmart (Oxlade, n.d.) It consists of two main components: the IFC model data and the constructive solutions database, which relate to each other and automatically extract information such as environmental data, generated waste mass, measurements, and total building cost. Its accessibility is attributed to its reliance on open formats, which guarantee transparency and reproducibility. One of the key strengths of the tool is its ability to use the CSV (Comma Separated Values) file format, which is commonly used to store and exchange data related to construction quantities. The simple, tabular structure of CSV files makes it easy to import and export data between different software systems, regardless of the location or language. In addition, the tool also supports the BC3 file format. This format uses an XML-based structure, allowing for the exchange of detailed cost information between different software systems. It represents a powerful and adaptable tool for estimating, measuring, and tracking construction quantities, making it optimal for managing construction and engineering projects across different locations and industries. The use of open file formats also allows for permanent storage and access of information, a previously missing capability in other research.

The presented software stands out due to its unique feature of concurrently calculating the environmental impact and generating measurements and budget information, making it a comprehensive and efficient tool compared to others on the market. To ensure accessibility and replicability of the methodology, the Circular BIM platform provides a download link within the products section, catering to individuals within the scientific, academic, and professional fields of the engineering and construction sectors. The platform is available in several languages, including British English, Spanish, Portuguese, and Romanian, and the tool interface can be installed in multiple languages, such as British English, Spanish, French, Portuguese, and Italian.(CircularBIM, n.d.).

Phase 2 – Generate

After the tool development phase, the next step is the creation of a 3D digital model. This can be accomplished using any software that supports BIM modelling and subsequently exporting it in an IFC file format through IFC Builder or a similar tool. In this particular case, the digital model was created using Revit Autodesk. During the execution phase, it is essential that each group of construction elements is classified by categories to facilitate their subsequent measurement in Open BIM Quantities. The digital model comprises the main elements that shape the hotel case study, including curtain walls, structure, floors, interior partitions, exterior walls, stairs, windows, and doors. Since the focus of this research is on the design phase, only the objects or elements that contain dimension data are needed, such as the surface area, volume, and other relevant measurements. This information will be sufficient for linking the units and establishing measurement criteria based on these dimensions. Upon completion of the digital model, it shall be uploaded onto the BIMserver.Center platform (BIMserver.Center. BIM in the Cloud., n.d.). This cloud-based platform enables unrestricted access by authorized parties and contains all information pertaining to the digital model. Additionally, it grants the ability to select which agents will be participants to view or alter the information. Consequently, any modifications made by participating agents to the building will be promptly reflected in the platform, as well as all associated software. This methodology facilitates real-time alterations to the building by all stakeholders promoting the set-based design system.

Phase 3 – Link

During this phase, the digital model will be imported into the new software, and the BIM-FIEBDC-BC3 or the BIM-CSV link will be established. This step is critical to the proposed methodology and distinguishes it from other approaches. The new tool enables the reading of all quantities and

properties contained in each IFC entity that constitutes the hotel. The FIEBDC-BC3 or the CSV format must be utilised to import the materials database. While the software allows for manual addition or modification of material data, it can also be done automatically. To expedite the process, the materials are extracted, along with their associated environmental and economic characteristics (units, price per unit, embodied energy, CO_2 emission, unit mass of waste, and unit volume of waste) directly from an online price bank. In this case, the Construction Price Generator produced by CYPE has been used, a free platform containing the necessary information to define the cost and material database in the FIEBDC-BC3 format. Although the developed tool can be freely accessible from any country and linked to several databases, the price bank utilised in the research is currently accessible for twenty-seven countries: In Africa, Angola, Algeria, Cape Verde, Cameroon, Ivory Coast, Gabon, Mali, Morocco, Mozambique, Republic of Congo, and Senegal; in the Americas: Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guatemala, Honduras, Mexico, Panama, Paraguay, Peru, and Uruguay; and in Europe, Spain, France, and Portugal (Generador de Precios de La Construcción de CYPE Ingenieros, n.d.). In order to import the BC3, the option to "Import the entire file" must be selected, in this way, all concepts contained in the file are included, which accelerates the process and allows a more comprehensive import of data from the file.

The Import CSV option is also available. To import data successfully, the CSV file must contain specific columns, including information for Code, Type, Item, Summary, Quantity, and Rate fields. To ensure proper importation, users can specify the index of each column from the file import configuration panel. Additionally, users can specify the character set, the index of the first line of text to be imported, and the field separator. An example of how to import these types of files is shown in Appendix A, using a CSV database from France, available in the Construction Price Generator (Generador de Precios de La Construcción de CYPE Ingenieros, n.d.), to show the internationalisation of this tool and its versatility by using both BC3 or CSV files. The software also permits users to choose between deleting the previous data from the cost databases before importing or updating them, similar to the FIEBDC-3 format files.

For the presented case study, a BC3 has been used, which is widely used in Spain and Latin America for cost estimation and management. The hotel case study is located in Andalusia, hence the materials have been imported in the Spanish version. The material classification scheme of the Construction Price Generator consists of chapters, subchapters, sections, and items presented both graphically and parametrically. Moreover, the database provides the option of selecting materials not only by their constructive solution but also by manufacturer, making the selection process more efficient. Many online price banks offer this information in an automated manner, rendering the proposed methodology open source.

The developed software provides the capability to quantify materials, including their environmental characteristics and generated waste mass, measure and quantify construction elements, and generate a comprehensive budget. The quantification of waste, embodied energy, and CO_2 emissions from the Construction Price Generator (Generador de Precios de La Construcción de CYPE Ingenieros, n.d.) is conducted through the use of international databases containing LCAs of construction products and Environmental Product Declarations (EPDs) accessible on ECO-Platform (Home - Eco Platform En, n.d.). This European platform for EPD programs within the construction sector is established with the objective of implementing EN 15804 (ISO_15804:2012+A1:2013, 2012). Appendix A file presents a description and graphical representation of how to use the software to obtain similar results and it shows how to import BC3 and CSV files. The structure of chapters, construction units, and unit prices imported from the FIEBDC-BC3 file is displayed. The created price database can be adjusted and modified, as well as exported for future projects with similar materials. Subsequently, once the price bank has been established, the model will be linked to the created or imported database to convert the elements into construction units, and the building can be measured with the new tool. This link is accomplished through the use of measurement criteria or rules, a set of intelligent rules that filter elements based on their properties and indicate which of their quantities will be utilised in the measurement process. These rules are created based on a distinguishing

characteristic of the element, such as its name, to specify which elements of the digital model need to be measured. Once the selection criteria are defined, the next step is to assign codes with the corresponding formula to measure the elements using construction units. The software allows for easy configuration of these construction units with all the necessary data, including the chapter, assigned code, unit, reference, detail line, and labels. It is crucial to ensure that the correct unit is used for accurate linking and measurement. Therefore, as an example, when assigning construction units for interior panels, the net area of the partitions in square meters should be used since this is the same unit used to define the construction unit of the assigned material.

Phase 4 - Quantify

At this point, all the information contained in the software related to the building is extracted and quantified. The primary objective of this phase is to automatically obtain the measurements, budget, environmental impact indicators, and construction and demolition waste data from the model, without requiring any additional calculations. The tool generates the chapters, construction units, and details of the measurements and budget based on the pre-defined measurement criteria. Table V.2 displays the elements, main description of material, and assigned code for the two sets of constructive solutions considered in this study. Additionally, it presents the obtained data from the system, including units, quantity, total economic cost, total embodied energy, total CO_2 emissions, and total waste mass. The first figure of the assigned code corresponds to each of the considered options, while the second figure corresponds to the building element.

The significance of this phase lies not only in the automatic acquisition of budget and environmental information but also in the fact that the complexity of the building does not impact the speed and ease of obtaining said information. As demonstrated by this case study, the budget and environmental impact data for a high-rise hotel can be obtained without any added difficulty. This represents a significant improvement over traditional methods where information was entered manually and obtaining data for a complex building such as a 39-story hotel was a laborious task.

Table V.2. Bill of quantities and data obtained from the proposed MLCAQ tool for the constructive solutions.

Element	Set	Code	Main description	Unit	Quantity	Economic Cost (€)	Embodied Energy (MJ)	CO_2 Emissions (kg)	Waste Mass (kg)
Slab	1	SL1	Waffle slab with permanent pods	m^2	36577.2	4007763.80	38569699.08	3472383.33	257580.30
	2	SL1	Waffle slab with recoverable pods			3324867.48	26637444.66	2361350.88	103696.36
Walls	1	WA1	Concrete wall	m^3	2362.91	709629.13	7364609.19	756126.47	26351.17
	2	WA1	Recycled concrete wall			685031.24	5938002.28	527869.37	27100.21
Columns	1	CO1	Concrete circular columns ø150-600mm	m^3	86.24	88327.87	329251.82	35043.02	6380.55
	2	CO1	Recycled concrete circular columns ø150-600mm			51888.88	274622.31	24122.79	3353.27

Partitions	1	PA1	Drywall DBBLOK partitions	m^2	36417.96	1749154.62	7504346.75	453949.87	182891.00
	2	PA1	Drywall PANELSYSTEM partitions			941040.09	2560255.42	11078.34	51240.07
Facade	1	FA1	Aluminium Curtain wall	m^2	52189.82	21918158.71	112600058.55	7916099.71	30301.41
	2	FA1	Aluminium Curtain wall			16552001.41	89669782.66	6407396.39	20995.96
Carpentry	1	CA1	Rolling garage aluminium door	Ud	2	4317.62	72.96	3.48	0.98
	2	CA1	Galvanized steel sliding garage door			6885.8	72.64	3.46	0.98
Carpentry	1	CA2	Hinged interior door, galvanized steel	Ud	2	510	4625.42	354.742	0.268
	2-CA2	2-CA2	Hinged interior door, galvanized steel			510	4625.42	354.742	0.268
Carpentry	1	CA3	Wooden folding interior door	Ud	2690	1196135.4	10153109.10	114655.87	5530.64
	2	CA3	Wooden MDF folding interior door			669218.2	6789118.84	89004.03	4040.38
Carpentry	1	CA4	Aluminium exterior carpentry	Ud	8	4353.28	11944.78	825.89	4.09
	2	CA4	PVC exterior carpentry			3088.08	7490.74	736.42	2.40
Carpentry	1	CA5	Double lift doors in galvanized steel	Ud	512	338764.8	414564.35	32073.22	109.06
	2	CA5	Double lift doors in galvanized steel			338764.8	414564.35	32073.22	109.06
Roof	1	RO1	Walkable PROJAR flat roof, not ventilated	m^2	539.24	55557.90	2534300.74	15318.73	3853.41
	2	RO1	Walkable ZINCO flat roof, not ventilated			60012.02	857231.34	30200.55	3085.32
Stairs	1	ST1	Steel in structure of stairs	kg	398.98	3634.71	3921.97	203.48	5.98

	2	ST1	Steel in structure of stairs			3634.71	3921.97	203.48	5.98
Stairs	1	ST2	Steel in stair railings	kg	4232.28	50998.97	41603.31	2158.46	63.48
	2	ST2	Steel in stair railings			50998.97	41603.31	2158.46	63.48
Stairs	1	ST3	Stairs slab of concrete	m^2	3423.46	400031.30	5314671.74	183483.76	32159.98
	2	ST3	Stairs slab of recycled concrete			385344.66	4895445.10	221566.33	32564.52
Stairs	1	ST4	Exposed concrete staircase	m^2	3423.46	509068.50	7824742.34	356888.86	63652.39
	2	ST4	Exposed recycled concrete staircase			491369.21	6414988.90	356888.86	64188.16
Stairs	1	ST5	Cross laminated wood panel (CLT) step	Ud	5354	417237.22	4162156.77	0	3396.47
	2	ST5	Wood step			285957.14	874147.58	0	682.64

3. Results

Phase 5 – Qualify – Through comparison

During this final phase, the data generated in the previous stage is carefully examined for each construction element and compared in an environmentally conscious manner by extracting critical information from multiple aspects. Appendix B provides a comprehensive overview of all the materials used in this study, including their detailed specifications. To better understand the methodology behind the environmental comparison and how the materials can be integrated into circular practices, the data has been examined from three primary environmental perspectives: embodied energy, CO_2 emissions, and construction waste mass. It is important to note that the total economic cost of the materials has also been automatically extracted and must be taken into consideration. These three aspects were chosen due to their relevance to the ecological transition and the accomplishment of carbon neutrality by the year 2050. By considering these crucial factors it can be assured that the construction elements chosen are not only effective but also sustainable and environmentally conscious.

The analysis and qualifying process commences with the translation of the data extracted from step 3 and presented in Table V.2 into an Excel format, which includes the element, code, material, main description, detailed description, units, and quantities. In addition, the total material economic cost (€) per element and environmental data, including total embodied energy (MJ), CO_2 emissions (kg), and total waste mass (kg), have been included. The collected data is then converted into graphs to demonstrate the contrast between the first and second sets of constructive solutions, with the latter utilising materials with superior environmental characteristics. The platform Circular BIM provides graphical data analysis based on the excel generated with the proposed software. These graphs will show a summary of the main construction units, including the amount, CO_2 emissions, embodied energy, waste mass and waste volume. The application to generate this graphical analysis y freely accessible and available (CircularBIM, n.d.). To summarise the environmental enhancement achieved by the second set of solutions compared to the first set, Figure V.3 has been created from the Circular

BIM platform. This figure displays the principal environmental indicators and the total economic cost. The comparison between elements from both sets from the CO_2 emissions, embodied energy and waste mass perspective are shown in Figure V.4. There, it can be seen the elements and materials that make the most positive or negative impact in the circularity of the building.

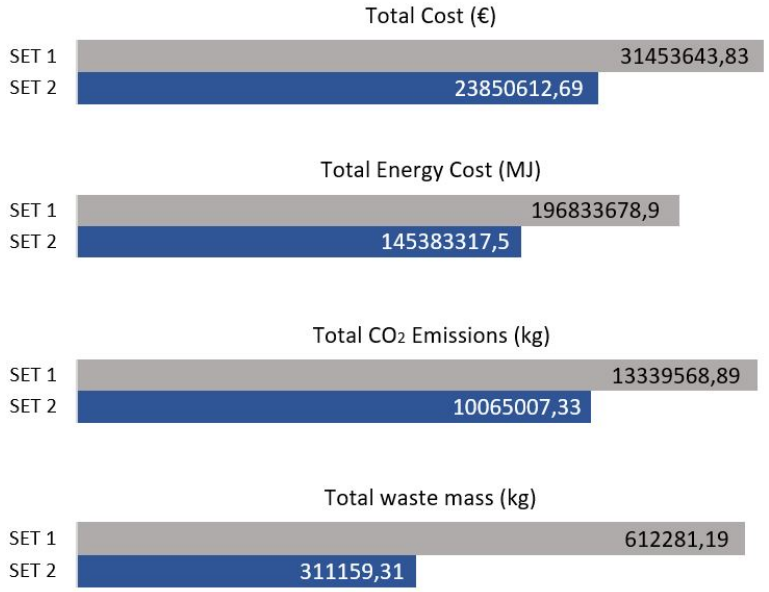

Figure V.3. Total of economic cost, embodied energy, CO_2 emissions and waste mass.

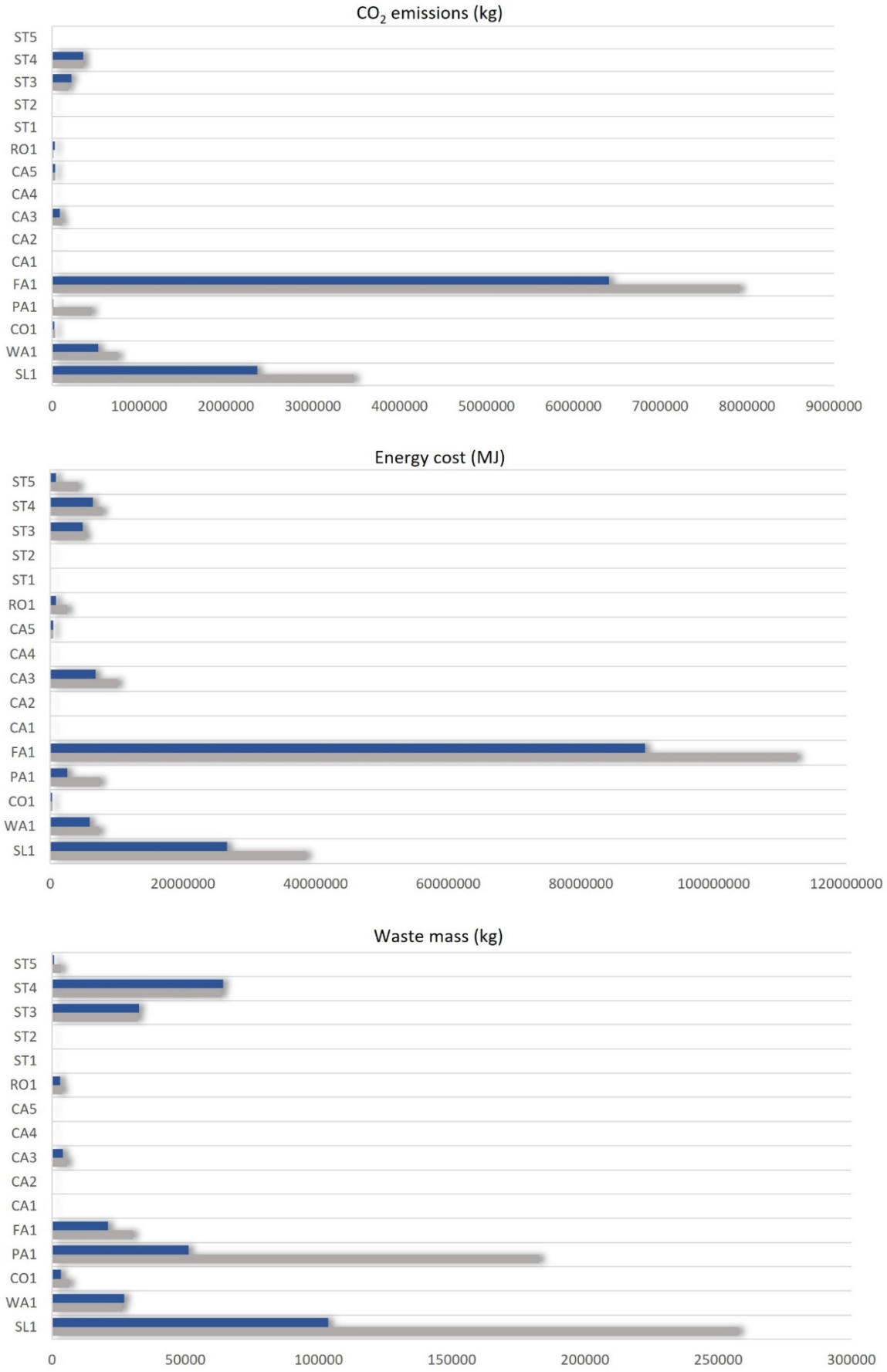

Figure V.4. Environmental cost comparative of two sets of constructive solutions.

In order to qualify each indicator, this section have been divided into four subsections comparing the elements and materials, specified in Appendix B, with each other and analysing the quantities and metrics extracted from the system and shown in Table V.2. For each section, the main elements that have the greatest impact in each category have been considered, and the sum of all of them represents a total contribution of over 80%. Therefore, while the remaining elements are still relevant, their involvement is not significant enough to cause a major impact.

3.1. Detailed analysis of the total material cost

Starting with the total cost of the building, this was expressed in euros (€) due to the case study's location in Spain. The façade accounts for the majority of the total material cost, as it includes a curtain wall that covers the entire building from the ground to the top floor. Although both sets of materials have similar structural characteristics, there is a difference in section size and cost between the two sets. Specifically, the first set, 1-FA1, includes a curtain wall with 175x52mm uprights section and 70.5x52mm anodized crosspieces, while the second set, 2-FA1, includes 170x52mm uprights section and 55x52mm anodized crosspieces. Both sets use the same glass specification. The cost of 1-FA1 is €21,918,158.71, while the cost of 2-FA1 is €16,552,001.41. The difference in cost between the two sets amounts to €5,366,157.3, which represents 17.06% of the total cost of the building for 1-FA1 and 22.5% for 2-FA1. This finding highlights the significant cost implications of the choice of materials for the building's façade, particularly for a high-rise building. This is noticeable in Figure V.4. The following element that has accounted for the majority of the material economic cost of the project is the floor slab. The total area of the floor slab is 36,577 square meters. The first material choice, 1-SL1, is a reinforced concrete slab with a reticular structure and a lost coffer, made with HA-25/F/20/XC2 concrete manufactured at the plant and poured with a cupola. The total cost of this material choice amounts to €4,007,763.80. On the other hand, the second set of materials, 2-SL1, amounts to a total of €3,324,867.48. The materials have similar characteristics but with a recoverable PVC pod measuring 64x70x25 cm. By comparing both alternatives, it can be verified that the 2-SL1 set represents a material cost saving of €682,896.32. Continuing with the set of interior partitions, the comparison between set 1, 1-PA1, consisting of a 6.5 cm thick masonry sheet of acoustic hollow concrete brick, and set 2, 2-PA1, made of lightweight fiberglass-reinforced gypsum panel, represents a cost difference of €808,114.53, nearly double. This demonstrates that the appropriate choice of this element is also crucial to the total cost of the project. The resulting elements account for less than 15% of the total economic cost of the project. Therefore, for this type of high-rise building with a curtain wall system, the most relevant elements to consider for LCC analysis accounting for more than the 85% of the total cost are the façade, the floor slabs, and the interior partitions. From the sum of the three elements 1-FA1, 1-SL1 and 1-PA1 (€27,675,077.13) against 2-FA1, 2-SL1 and 2-PA2 (€20,817,908.89), there is a difference of 24.77% from the set 1 total cost.

3.2. Detailed analysis of the total embodied energy of materials

In this category, as shown in Figure V.4, the element that has the greatest impact is again the façade. In this case, the embodied energy for 1-FA1 is 112,600,058.55MJ. In contrast, for set 2, a construction solution has been chosen with an embodied energy of 89,669,782.66MJ. There is a significant difference of 22,930,275.89MJ between the two solutions. The second most relevant element coincides with the one in the total cost category, which is the floor slab. In this case, 1-SL1 contributes a total of 38,569,699.08MJ, however, 2-SL1 has an embodied energy of 26,637,444.66MJ. On the other hand, the third element that generates the most impact in relation to embodied energy is the carpentry. Unlike the previous categories, the carpentry referring to the interior doors of the case study is an important element to consider regarding embodied energy. Since it is a hotel, the number of interior doors is high, and their consideration is important. For set 1, 1-CA3, doors with horizontal boarding of solid melis pine wood boards have been chosen. In contrast, for set 2, 2-CA3, MDF doors have been chosen. The difference between the two is 10,153,109.10MJ versus 6,789,118.84MJ. Finally, the fourth most relevant element to consider in this category is the concrete stairs between floors, 1-ST4 and 2-ST4. On the one hand, for set 1, traditional concrete HAF-25/P-1,5-1,5/P/12-48/XC2 with a reinforcing fibre content of 3 kg/m3 has been chosen, which contributes an

embodied energy of 7,824,742.34MJ. In contrast, 2-SL4 consists of HRA-25/P/20/XC2 concrete with a maximum percentage of recycled aggregates of 20%, manufactured at the plant, which contributes an energy of 6,414,988.90MJ. In total, with these four elements, there is a difference of embodied energy of 39,636,274.01MJ between the two sets. As we can see in Figure V.3, the total energy for set 1 is 196,833,678.9MJ, so this reduction is significant.

3.3. Detailed analysis of the total CO_2 emissions of materials

In this category, the most relevant elements are again the facade and the slabs. Thirdly, the concrete walls are considered. The emissions of CO_2 produced by these three elements exceed 85% of the total emissions of all materials. Therefore, they are the focus of this analysis. In this case, 7,916,099.71 kg of CO_2 emissions are produced by the facade element 1-FA1, while 6,407,396.39 kg are produced by 2-FA1. On the other hand, a total of 3,472,383.33 kg is produced by the slabs of set 1, 1-SL1, compared to 2,361,350.88 kg from set 2. Finally, 756,126.47 kg of CO_2 emissions are produced by the concrete walls of the first set, 1-WA1, composed of HAF-25/P-1.5-1.5/P/12-48/XC2 concrete with a reinforcing fibre content of 3 kg/m3, manufactured at the plant. In contrast, 527,869.37 kg of CO_2 emissions are produced by the second set 2-WA1, which is composed of HRA-25/P/20/XC concrete, with a maximum percentage of recycled aggregates of 20%, manufactured at the plant.

3.4. Detailed analysis of the total generated waste mass of materials

The building elements that generate the most waste mass are the slabs, interior partitions, and concrete stairs. Once again, the presence of concrete in the building is highly relevant to its circularity. Thus, the 1-SL1 lost coffer slab generates 257,580.30 kg of waste, while the 2-SL1 recoverable PVC pod generates 103,244.92 kg of residual mass. In the case of partitions, the first set of partitions, 1-PA1, generates 182,891 kg, while the second set, 2-PA1, generates 51,240.07 kg. Finally, the stairs in set 1 made of traditional concrete, 1-ST3 and 1-ST4, respectively produce 32,159.98 kg and 63,652.39 kg. As seen in Table V.2, the stairs in set 2 made of recycled concrete, 2-ST3 and 2-ST4, generate higher amounts of waste, 32,564.52 kg and 64,188.16 kg, respectively. Recycled concrete may lead to increased waste mass because of the need to remove contaminants like wood, paper, and plastics before recycling, which generates additional waste. Additionally, the production process of recycled concrete, which involves crushing and screening, can also generate fines and dust that contribute to waste mass. However, even though recycled concrete generates higher amounts of waste, the difference compared to traditional concrete is not too significant.

Upon applying the MLCAQ system, the case study yielded results that are depicted in Figures V.3 and V.4. These figures exhibit a significant contrast between the two sets of construction materials chosen for this research. The second set, comprising the most circular materials, manifests a reduction of 51,450,361.40 MJ (26.40%) in embodied energy, 3,274,561.56 kg (24.55%) in CO_2 emissions, and 301,121.88 kg (49.19%) in waste mass. The acquired data reveals the considerable economic and environmental impact caused by the envelope, specifically the curtain wall in this instance. Furthermore, the structure plays a pivotal role in all environmental indicators, emphasizing the necessity of employing suitable concrete for this high-rise hotel. Although elements such as carpentry or stairs remain relevant, their influence on the overall environmental cost of the building materials is not as pronounced. Lastly, as shown in Figure V.3, the use of eco-efficient and circular materials results in a total cost of €23.85 million, representing a reduction of €7.6 million from the first set. This outcome demonstrates that the utilisation of environmentally friendly materials does not entail an increase in total cost.

4. Discussion

Starting from the first research question RQ1, the existing methodologies used to calculate the LCA and LCSA fail to automate the process and are not adequately operational. This causes a delay in the design phase, especially with complex buildings. In addition, most of the existing methodologies are linked to expensive tools, making the process unusable for many of the practitioners in the

building. Due to these disadvantages, there is a great interest to include a circular view upon buildings' life cycle as promptly as possible in the early stages of building design to transition from a linear to a circular economy. This not only speeds up the process but also impacts in the building's value chain. There are various tools for quantifying the environmental impact in construction, related to waste management, CO_2 emissions or energy consumption in residential buildings (Camporeale & Mercader-Moyano, 2021; Mercader-Moyano et al., 2021), but none of them allows obtaining all these data together in BIM. Moreover, existing methodologies do not follow a standardized process, or facilitate the access for the user (Llatas et al., 2022; Marzouk et al., 2018). Following the proposal of Santos et al. (2019) to use the potential of BIM tools as a repository of life cycle and cost analysis information, this study proposes the MLCAQ tool that uses the information contained in the BIM digital model and relates it to databases BC3, all this is done automatically and in real time. With this, the importance of digitalisation in the ecological transition has been demonstrated and how both transitions, digital and ecological, go in parallel.

The research addresses RQ2 by proposing a strategy that reduces the effort to calculate the LCA of a 39-storey hotel and promoting a set-based design system that does not delay the decision-making and design stages. The strategy is supported by the development of a new software entitled Open BIM Quantities by the authors. The results demonstrate the feasibility of conducting real-time environmental and economic impact calculations in the BIM environment, regardless of the complexity of the building, using a system based on the LCA method. Within the BIM environment, the MLCAQ tool enables the automatic evaluation of materials circularity and cost impact, with the results presented visually. The capability of the system to enable project agents and technicians to implement changes and modifications in real-time, without the need for additional steps such as material quantities take off in the BIM model, enhances usability and data visualization compared to previous studies, as shown in Table V.1. Furthermore, the present research illustrates that the tool has the capability to conduct automatic multi-criteria assessments to assist in building material selection within the BIM environment, as proposed by researchers such as Aryan et al. (2023) to promote a robust decision-making tool in the LCA field. This is considered a relevant improvement in qualities of existing LCA and LCC tools such as automation, data visualisation, real-time calculation and usability (Backes & Traverso, 2021). For instance, the link between BIM and FIEBDC-BC3 formats reduces the workload for environmental and economic data preparation and BIM workflow adaptation. This automation process enables to implement relevant changes to the design in real time without delaying the development of the project. The data extracted from the methodology includes the CO_2 emissions (kg), embodied energy (MJ), generated waste mass (kg) and material economic cost.

Finally, in order to address RQ3, the present study examines the various materials and their respective circularity aspects. As illustrated in Figure V.4, a comparison is made between two sets of construction materials, with the circular materials set showing marked reductions in CO_2 emissions, embodied energy, waste generation, and overall building costs. Notably, the use of circular materials does not appear to have a detrimental impact on the total cost of the building. It is worth noting that prior research has also demonstrated a positive correlation between a circular economy and economic growth, as highlighted by Hysa et al. (2020). The adoption of circular materials in the construction industry has been commonly associated with increased building costs, but latest research demonstrate that the use of such materials not only reduces the CO_2 emissions but also the building cost for an optimal design (Kertsmik et al., 2023; Wuni, 2022). The case study presented in this research has revealed a significant reduction of 25% in the total material cost through the utilization of materials that possess superior environmental qualities.

5. Conclusion

The aim of this study is to develop a system that supports material selection while calculating the total material economic cost and quantities during the early stages of a project using a high-rise hotel as a case study. The presented MLCAQ methodology offers a reliable approach for comparing construction materials from an environmental perspective and assists the LCA and LCC calculation

process to be obtained for any building typology. The tool is free to use and links the IFC components with databases of constructive solutions, making it an international resource.

The data generated in this research indicates that using circular materials results in a net reduction of €7.6 million in total economic cost, along with significant reductions in embodied energy (51,450,361.40 MJ or 26.40%), CO_2 emissions (3,274,561.56 kg or 24.55%), and waste mass (301,121.88 kg or 49.19%). These findings support the idea that selecting materials with low embodied energy and high circularity is a viable approach for achieving environmental sustainability and cost-effectiveness in the construction sector. Concrete has been identified as a significant factor in reducing CO_2 emissions, and incorporating recycled concrete into construction solutions can lead to a considerable reduction in the total emissions generated by building materials while promoting the conservation of natural resources. The findings indicate that recycled concrete requires less energy and generates fewer greenhouse gas emissions compared to new concrete, primarily because it uses less cement. While the use of recycled concrete may result in slightly more waste mass compared to traditional concrete, this factor is not critical concerning circularity and other environmental considerations. As a circular material, recycled concrete can contribute to a more sustainable and efficient use of resources in the construction industry. Additionally, the use of recycled concrete can help to decrease the reliance on virgin materials, leading to a more sustainable use of natural resources. Moreover, using recoverable PVC pod slabs compensates for the small increase in residual mass generated by recycled concrete. This approach results in a reduction of 153,883.94 kg, representing a 25% reduction of the total, by solely utilising this type of slab. This finding highlights the potential of using recoverable slab formwork systems as a sustainable alternative in the construction industry.

In conclusion, this study highlights the crucial role of the construction industry in addressing pressing environmental issues, such as climate change and waste management, by adopting circular practices and resource efficiency. The development of tools that can accelerate the calculation process of LCAs is essential for promoting digital and ecological transitions. By leveraging environmental calculation tools, policymakers and construction professionals can make informed decisions, optimise their processes, and contribute to the development of a more sustainable built environment. The limitations of the study include the absence of additional environmental factors, such as water consumption, the nature of waste associated with each material, land use, toxicity and human health impact or eutrophication. Future research can expand on this methodology by including the social environmental aspect of each material and integrating it into the process.

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Appendix A. Supplementary software graphic data
Appendix B. Supplementary materials detailed data

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Appendix A. How to use the created tool "Open BIM Quantities"

This document aims to show how to use the created software, named Open BIM Quantities, using a hotel as a case study. After the BIM model is created and uploaded to the BIM server center and linked with the software, the BIM linking with a price database, either in BC3 or CSV format, is carried out, please see Figure V.A.1 for the BC3 import and Figure V.A.2 for the CSV import. Figure V.A.2 includes an example of an international CSV from France that has been extracted from the Construction Price Generator by CYPE, to show the internationalisation of the proposed tool. In this practical example, the BIM-FIEBDC-BC3 linking is used. Although it is possible to manually add or modify material data in Open BIM Quantities, automatic extraction of materials with their associated environmental and economic characteristics from an online price database is also possible. In this case, a Spanish BC3 price database available online is used. If a project's price table or cost database receives BC3 file through drag and drop, an option to "Import the entire file" becomes available. By selecting this option, all concepts contained in the file are included, as opposed to only selecting individual concepts with "Assign concept" or "Add concept". This allows for a more comprehensive import of data from the file.

Materials can be quantified in Open BIM Quantities, including their environmental characteristics and generated waste, and the software enables measurement and quantification of construction elements and total budget generation. An example of the list of materials selected for the case study's curtain wall system is shown in Figure V.A.3. The imported chapter structure, work units, and unit prices from the FIEBDC-BC3 file can be seen. The software provides tools to adjust and modify this price database and export it for use in future projects with similar materials. Therefore, this system is fully flexible and can be adapted to any material, project, or construction solution.

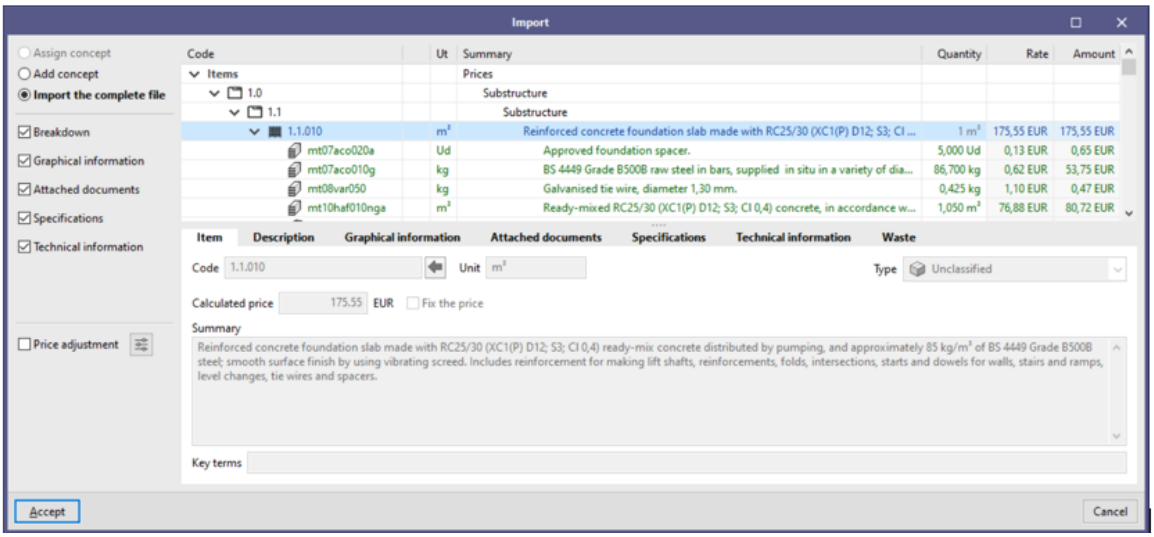

Figure V.A.1. BC3 Import

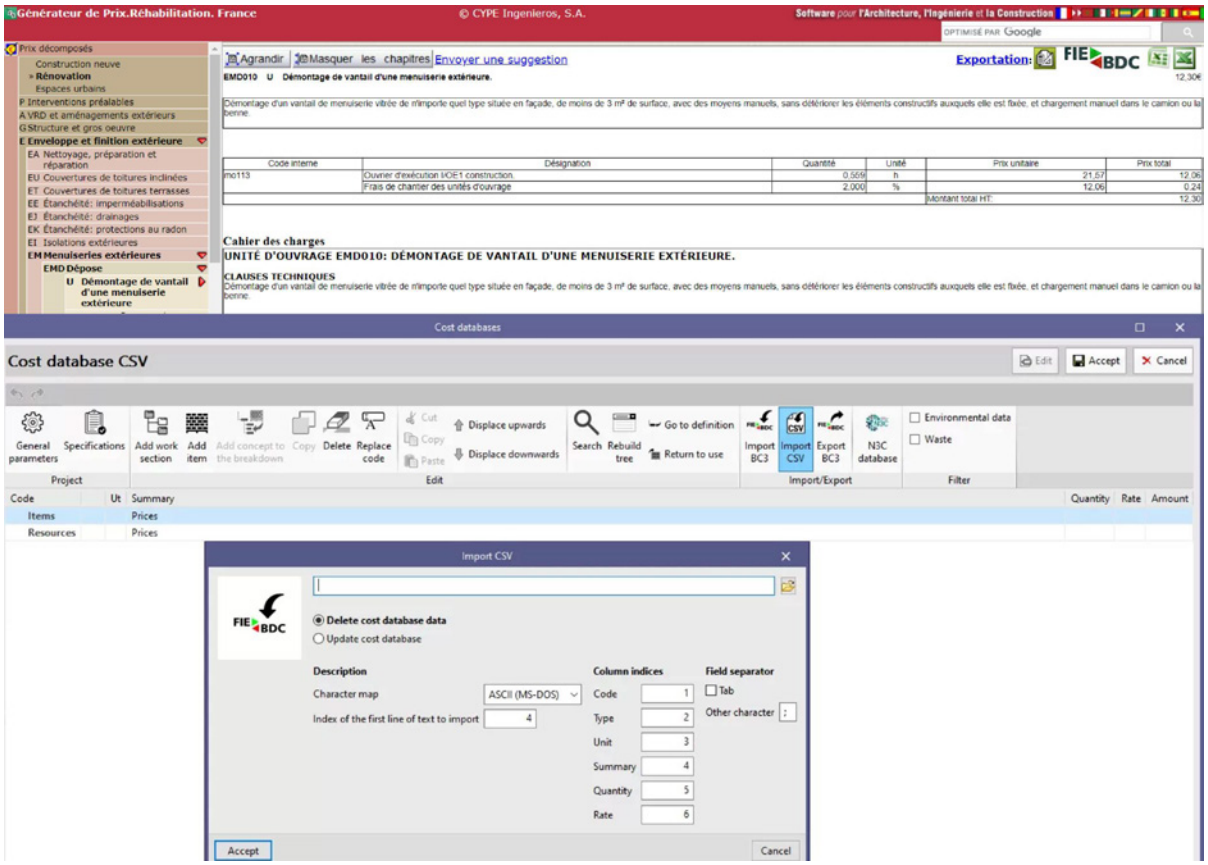

Figure V.A.2. France price database available in .BC3 and .CSV (top) from the Construction Price Generator by CYPE. Import CSV command (bottom)

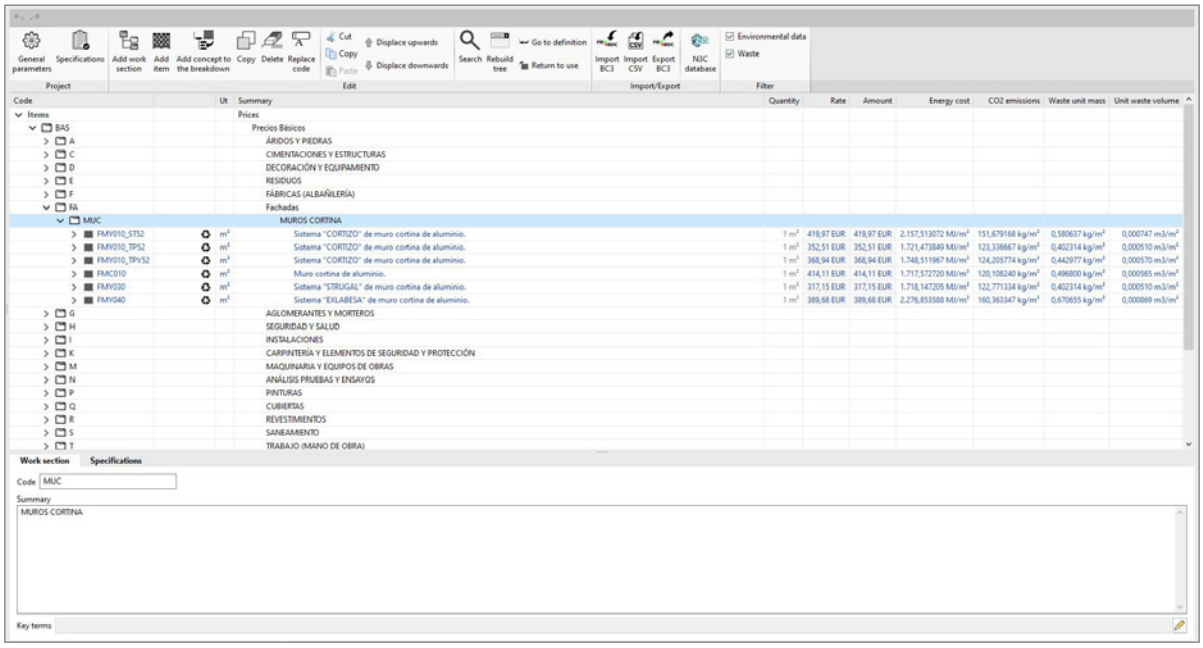

Figure V.A.3. Price bank and list of selected materials

Once we have the price database, the next step is to link the model to the created or imported database, so that the elements of the model can be converted into real work units, and the building can be measured in Open BIM Quantities. This linking is accomplished by means of measurement criteria, which are a set of intelligent rules that allow elements to be filtered based on their properties, and which indicate which quantities will be used in the measurement of the work units. It is very simple

to assign materials to each of the elements in the BIM digital model, which is classified into categories or elements such as pillars, slabs, walls, and carpentry, among others. As shown in Figure V.A.4, the measurement rules, which are found in the "Measurement Criteria" section and referred to in the work unit chapters of the price database, are defined by the user. The interface under the “Measurement Criteria” section is divided into three parts: “Work Section Structure”, “Rules of Measurement” and “ Section-Items”. Each of them has the same editing options, namely adding, editing, copying, and deleting.

In the “ Work Section Structure” section, the chapters of the previously created or imported price database are associated with the measurement rules that will be defined. The rules are created automatically using the “Selection” and “Work Units” tools, which are found on the right side of the interface, and which determine how and which digital model elements will be measured. For instance, with the “Selection” tool, the elements of the project that need to be measured are defined by a characteristic that differentiates them from the rest, such as their name.

Once the selection criteria have been defined, the measurement of these elements is determined by assigning codes with the desired parameter and corresponding formula in the “Work Units” section. The desired unit of the price database is selected by clicking the “Assign Codes” button, and the appropriate unit is chosen, followed by clicking “Add.” This action opens a new window that allows the configuration of the work unit with all the data automatically completed, including chapter, assigned code, unit, reference, detail line, and labels. It is important to verify the unit of the work unit, as the parameter to be selected for proper linking and measurement depends on it. As shown in Figure V.A.5, for the assignment of work units for interior panels, the net area of these partitions will be used, as it is the same unit by which the material work unit is defined.

After the measurement has been performed on the digital model, all information contained in Open BIM Quantities regarding the building is extracted. In this way, in the “Bill of Quantities” tab, “Update the quantities” is selected and the program will automatically generate the chapters, units of work, and measurement detail lines of the budget according to the previously introduced measurement criteria. As shown in Figure V.A.6, this section includes detailed information on waste, embodied energy, and CO_2 emissions from materials, as well as measurement and total economic cost. Additionally, if necessary, new chapters and units of work can be added in this section using the top bar. To obtain all this information, “BoQ Reports” is selected, and the desired categories are chosen in the pop-up window. In this case study, measurements and budget, environmental impact indicators, and construction and demolition waste have been selected, while price justification and specifications have been omitted, but this information can also be obtained from the digital model.

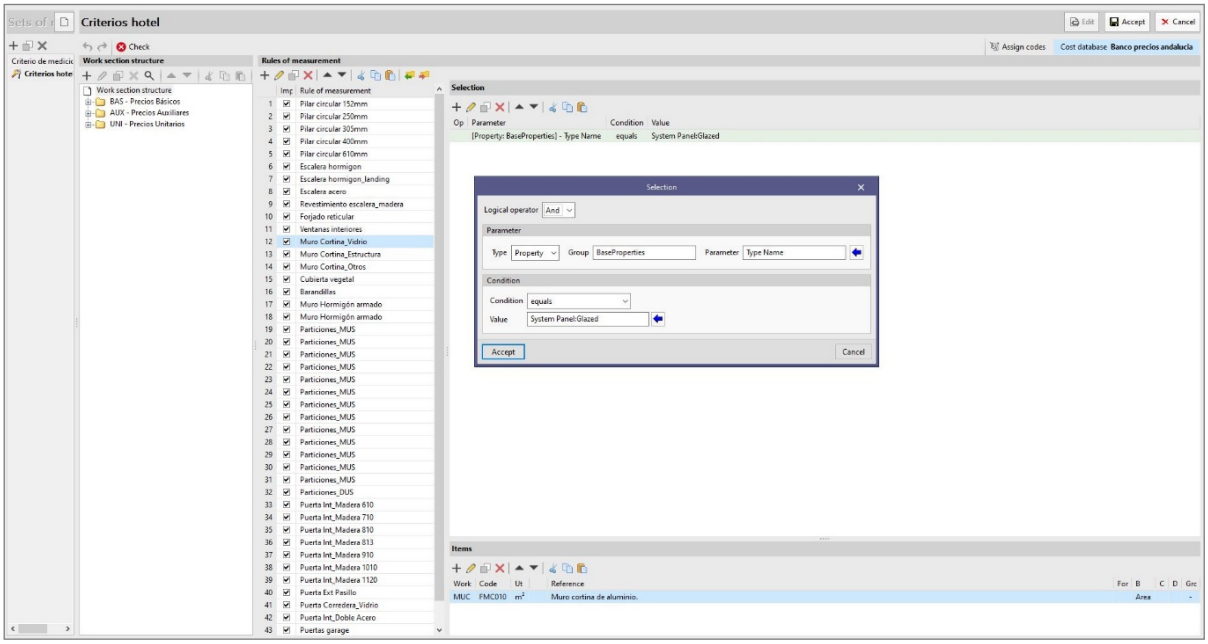

Figure V.A.4. Measurement criteria and chapter structure

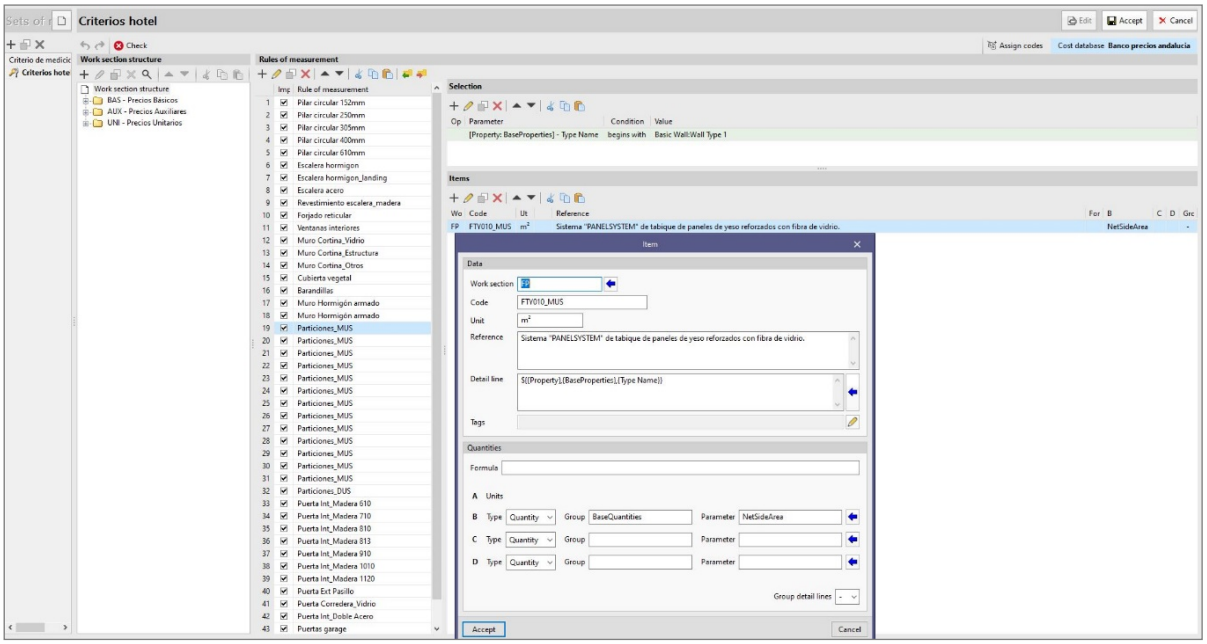

Figure V.A.5. Linking and measuring the construction units with the elements

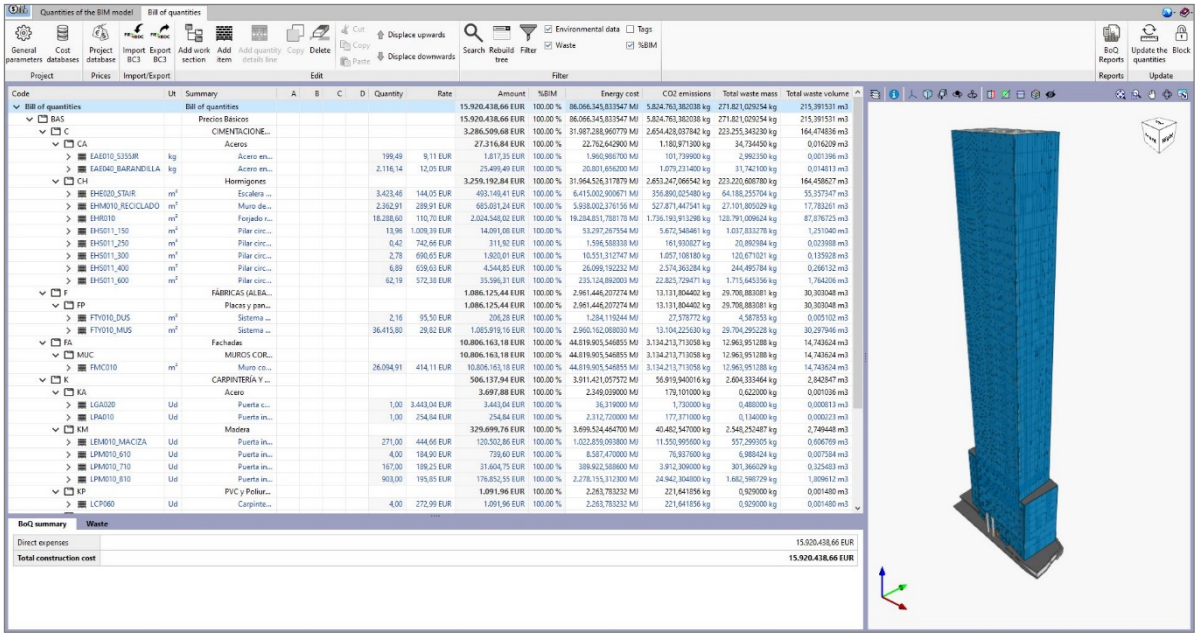

Figure V.A.6. Detailed budget information, measurements, waste and environmental data

Appendix B.

Table V.B.1. Detailed specifications of materials used in set 1 and 2 of the case study

CODE	DETAILED DESCRIPTION
1-SL1	Reticular reinforced concrete slab with lost coffer, horizontal, with 15% solid areas, made with concrete HA-25/F/20/XC2 manufactured at the plant, and poured with a cupola.
2-SL1	HA-25/F/20/XC2 concrete, manufactured at the plant. Recoverable PVC pod, 64x70x25 cm. Even special pieces.
1-WA1	HAF-25/P-1,5-1,5/P/12-48/XC2 concrete, manufactured at the plant, with a reinforcing fibre content of 3 kg/m3.
2-WA1	HRA-25/P/20/XC2 concrete, with a maximum percentage of recycled aggregates of 20%, manufactured at the plant.
1-CO1	HA-25/F/20/XC2 concrete, manufactured at the plant. Disposable cylindrical mould, made of spiral kraft paper, aluminium and polyethylene bands, for formwork of concrete pillars, up to 3 m high and 15 cm in average diameter, for unseen concrete finishing.
2-CO1	Circular section pillar of reinforced concrete, with an average diameter of 35 cm, made with HRA-25/B/20/XC2 concrete, with a maximum percentage of 20% recycled aggregates, manufactured at the plant, and poured with a cupola, and steel UNE-EN 10080 B 500 S, with an approximate amount of 120 kg/m
1-PA1	Interior partition for partition walls, made using the "DBBLOK" system, made up of a 6.5 cm thick masonry sheet of acoustic hollow concrete brick, Geroblok Partition "DBBLOK", to be covered, 49x6.5x19 cm, received with Cement mortar, industrial, M-7.5, coated on both sides with 15 mm of B1 construction plaster, sprayed, and final finish with a layer of C6 thin-layer plaster application.
2-PA1	Interior partition (separation within the same unit of use), TC-7 "PANELSYSTEM" partition system, 70 mm total thickness, made of lightweight fiberglass-reinforced gypsum panel, TC-7 "PANELSYSTEM".
1-FA1	Aluminium curtain wall made using the ST 52 Facade system, by "CORTIZO", with a load-bearing structure calculated for a maximum overload due to the action of the wind of 60 kg/m², made up of a grid with a separation between studs of 150 cm and a distance between the axes of the slab or anchor points of 300 cm, comprising 3 divisions between floors. Uprights section 175x52 mm, anodized; crosspieces 70.5x52 mm (Iy=23.46 cm4), anodized
2-FA1	Aluminium curtain wall made using the S52NT system, with traditional caps, by "STRUGAL", with a load-bearing structure calculated for a maximum load due to the action of the wind of 60 kg/m², made up of a grid with a separation between studs of 150 cm and a distance between the axes of the slab or anchor points of 300 cm, comprising 3 divisions between floors. 170x52 mm section uprights, silver anodized; 55x52 mm crosspieces, silver anodized.
1-CA1	Roll-up garage door, made up of smooth extruded aluminium slats, 300x250 cm, with a white pre-lacquered finish, with manual opening.
2-CA1	Single-leaf folding garage door, made of folded galvanized steel sheet with a ribbed texture, 300x250 cm, with a frame of cold-rolled steel profiles, welded together and claws for receiving the work, with manual opening.
1-CA2	Two-leaf interior hinged door, 38 mm thick, 1840x2045 mm clear and clearance height, galvanized finish made up of two 0.5 mm thick galvanized steel sheets with die-cut ventilation grilles on the top and bottom, in 200x250 mm each, folded, assembled and assembled, with an intermediate chamber filled with polyurethane, on a 1 mm thick galvanized steel frame with anchoring lugs to the work, with hinges welded to the frame and riveted to the leaf, embedded lock for closing at one point, brass cylinder with key, escutcheons and black nylon handles.
2-CA2	Two-leaf interior hinged door, 38 mm thick, 1840x2045 mm clear and clearance height, galvanized finish made up of two 0.5 mm thick galvanized steel sheets with die-cut ventilation grilles on the top and bottom, in 200x250 mm each, folded, assembled and assembled, with an intermediate chamber filled with polyurethane, on a 1 mm thick galvanized steel frame with anchoring lugs to the work, with hinges welded to the frame and riveted to the leaf, embedded lock for closing at one point, brass cylinder with key, escutcheons and black nylon handles.

1-CA3	Interior folding door, blind, with a 203x82.5x3.5 cm leaf, with horizontal boarding of solid melis pine wood boards, varnished in the workshop; 90x35 mm country pine frame; solid galces, melis pine 90x20 mm; Solid flashing, melis pine 70x15 mm on both sides. Including hinges, fittings for hanging, closing and crank on a long wrought iron shield, basic series.
2-CA3	MDF rebate, with wood veneer, sapele, varnished in the workshop. Blind interior door, made of chipboard, veneered with sapele, varnished in the workshop. According to UNE 56803.
1-CA4	Aluminium window, basic range, two practicable leaves, opening inwards, dimensions 1000x1000 mm, white lacquered finish, with the QUALICOAT seal, which guarantees the thickness and quality of the lacquering process, composed of a 48 mm sheet and 40 mm frame, beading, rebate, EPDM sealing gaskets, handle and fittings, according to UNE-EN 14351-1; frame thermal transmittance: Uh,m = from 5.7 W/(m²K); maximum thickness of glazing: 26 mm.
2-CA4	PVC window, two practicable leaves opening inwards, dimensions 1000x1000 mm, composed of frame, sash and beading, standard finish on both sides, white colour, 70 mm wide profiles, miter welded, incorporating five chambers interiors, both in the section of the sheet and in the frame, to improve thermal insulation; rebate with a 5% slope to facilitate drainage; with interior reinforcements, EPDM seals, handle and fittings; frame thermal transmittance: Uh,m = 1.3 W/(m²K); maximum thickness of glazing: 40 mm
1-CA5	Double lift doors, according to UNE-EN 1634-1, with two sheets of 63 mm thickness, clearance between 880 and 1100 mm and clearance height between 901 and 1950 mm, for a masonry hole with a width between 980 and 1,200 mm and a height between 1,051 and 2,050 mm, with a white lacquered finish made up of two 0.8-mm-thick galvanized steel sheets, folded, assembled and assembled, with an intermediate wool chamber high-density rock and plasterboard, on a 1.2 mm thick galvanized steel frame with an intumescent joint and anchoring claws to the work, including height-adjustable double-blade hinges, welded to the frame and bolted to the leaf , according to UNE-EN 1935, mortise lock with one-point closure, cylinder with knob, keys and shields in black.
2-CA5	Double lift doors, according to UNE-EN 1634-1, with two sheets of 63 mm thickness, clearance between 880 and 1100 mm and clearance height between 901 and 1950 mm, for a masonry hole with a width between 980 and 1,200 mm and a height between 1,051 and 2,050 mm, with a white lacquered finish made up of two 0.8-mm-thick galvanized steel sheets, folded, assembled and assembled, with an intermediate wool chamber high-density rock and plasterboard, on a 1.2 mm thick galvanized steel frame with an intumescent joint and anchoring claws to the work, including height-adjustable double-blade hinges, welded to the frame and bolted to the leaf , according to UNE-EN 1935, mortise lock with one-point closure, cylinder with knob, keys and shields in black.
1-RO1	Walkable flat roof, not ventilated, extensive landscaped (ecological), Projar Flora "PROJAR" system, slope from 1% to 5%. FORMATION OF SLOPES: by taping hips, valleys and joints with double hollow ceramic brick masters and a layer of expanded clay, poured dry and consolidated on its surface with cement grout, providing a compressive strength of 1 MPa and with a conductivity thermal of 0.087 W/(mK), with an average thickness of 10 cm; with a levelling layer of cement mortar, industrial, M-5, 4 cm thick, trowelled finish; WATERPROOFING: two-layer type, adhered, composed of a layer of bitumen modified with SBS elastomer, LBM(SBS)-30-FV, with a 60 g/m² fiberglass felt reinforcement, with an unprotected surface and a layer of bitumen modified with SBS elastomer, LBM(SBS)-50/G-FP, with reinforced and stabilized polyester felt reinforcement of 150 g/m², with green mineral self-protection, with resistance to root penetration, fully adhered with a torch , without coinciding their joints.
2-RO1	Walkable flat roof, non-ventilated, extensive landscaped (ecological), "ZINCO" Sedum Upholstery system, slope from 1% to 5%. FORMATION OF SLOPES: by taping hips, valleys and joints with double hollow ceramic brick masters and a layer of cement-based aerated concrete and plasticizer-aerating additive, with a compressive strength of 0.2 MPa and a density of 350 kg/m³, made on site with grey cement and plasticizing-air-entraining additive, with an average thickness of 10 cm; with a levelling layer of cement mortar, industrial, M-5, 2 cm thick, trowelled finish; WATERPROOFING: two-layer type, adhered, composed of a layer of bitumen modified with SBS elastomer, LBM(SBS)-30-FV, with a 60 g/m² fiberglass felt reinforcement, with an unprotected surface and a layer of bitumen modified with SBS elastomer, LBM(SBS)-50/G-FP, with reinforced and stabilized polyester felt reinforcement of 150 g/m², with green mineral self-protection, with resistance to root penetration, fully adhered with a torch , without coinciding their joints; flexible low-density polyethylene anti-root membrane, WSF 40 "ZINCO", black, to prevent roots from penetrating the waterproof membrane"ZINCO".

1-ST1	Rolled steel UNE-EN 10025 S355JR, in hot-rolled profiles, single pieces, for structural applications, finished with anti-rust primer. Worked and assembled in the workshop, to be placed with welded joints on site.
2-ST1	Rolled steel UNE-EN 10025 S355JR, in hot-rolled profiles, single pieces, for structural applications, finished with anti-rust primer. Worked and assembled in the workshop, to be placed with welded joints on site.
1-ST2	Rolled steel UNE-EN 10025 S275JR, in hot-rolled profiles, simple pieces, for structural applications, of the L, LD, T series, round, square, rectangular or flat, finished with anti-rust primer. Worked and assembled in the workshop, to be placed with welded joints on site.
2-ST2	Rolled steel UNE-EN 10025 S275JR, in hot-rolled profiles, simple pieces, for structural applications, of the L, LD, T series, round, square, rectangular or flat, finished with anti-rust primer. Worked and assembled in the workshop, to be placed with welded joints on site.
1-ST3	HAF-25/P-1,5-1,5/P/12-48/XC2 concrete, manufactured at the plant, with a reinforcing fibre content of 3 kg/m3.
2-ST3	HRA-25/P/20/XC2 concrete, with a maximum percentage of recycled aggregates of 20%, manufactured at the plant.
1-ST4	HAF-25/P-1,5-1,5/P/12-48/XC2 concrete, manufactured at the plant, with a reinforcing fibre content of 3 kg/m3.
2-ST4	HRA-25/P/20/XC2 concrete, with a maximum percentage of recycled aggregates of 20%, manufactured at the plant.
1-ST5	Counter-laminated wood panel footprint (CLT), 1000x360x60 mm, made up of three layers of wooden boards, glued with urea-formaldehyde-free adhesive, with successive layers perpendicular to each other and transversal arrangement of the boards in the outer layers, surface finish visible quality for housing on one side, made of Douglas fir (Pseudotsuga menziesii) and unseen quality on the other side, made of red spruce (Picea abies) and Scots pine (Pinus sylvestris), Euroclass D-s2, d0 reaction to fire.
2-ST5	Solid Scots pine (Pinus sylvestris) wood step, 800x300x32 mm, made up of a continuous-slat planked board, varnished in the workshop with synthetic varnish with a glossy finish, installed using a hidden fixing system on a wooden stair stringer. Even accessories and elements for fixing the step. The price does not include the stair stringer.

CHAPTER VI.

OTHER RESEARCH CONTRIBUTIONS

BOOK CHAPTER

"How the Implementation of BREEAM in Hotels Could Help to Achieve the SDGs"

Prime Archives in Applied Sciences. Hyderabad, India: Vide Leaf. 2022.
URL: https://videleaf.com/how-the-implementation-of-breeam-in-hotels-could-help-to-achieve-the-sdgs/

Book Chapter

How the Implementation of BREEAM in Hotels Could Help to Achieve the SDGs

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Departamento de Ingeniería Gráfica y Geomática de la Universidad de Córdoba, Spain

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INTERNATIONAL COMMUNICATION

"Cómo la implementación de BREEAM podría ayudar a alcanzar los ODS"

30th International Conference on GRAPHICS ENGINEERING, XXX INGEGRAF CONGRESS
Valencia (Spain)

INGEGRAF

INGEGRAF

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

Cómo la implementación de BREEAM podría ayudar a alcanzar los ODS

María M. Serrano-Baena
Rafael E. Hidalgo Fernández
Pilar Carranza Cañadas
Paula Triviño-Tarradas

INTERNATIONAL STAYS

LEACH RHODES WALKER 50 Dearmans Pl, Manchester M3 5LH.
Stay: 04/05/20 – 07/08/20

Escola superior de gestão, hotelaria e turismo Campus da Pena, Faro
Stay: 03/10/22 – 03/01/23

AGREEMENT BETWEEN THE COMPANY **LEACH RHODES WALKER** LOCATED IN **MANCHESTER, UK** AND THE STUDENT **MARIA M. SERRANO BAENA** TO DEVELOP A RESEARCH INSTERNSHIP IN THE COMPANY DURING A PERIOD OF THREE MONTHS FOR THE PHD AT THE UNIVERSITY OF CORDOBA

COMPANY

Leach Rhodes Walker is a design-focused architectural practice, around 90 people strong, with its head office in Manchester and expanding offices in London and Bucharest. It has specialised in Hospitality Architecture. The practice has been operating for over 60 years throughout the UK and Europe. Its portfolio of works ranges in value from £250,000 to over £500m.

RESEARCH PROJECTS

Project Name: The Mere Golf Resort and Spa, Cheshire
Project Description: The Mere is branded as the most prestigious and luxurious resort in the North West and is located in the Green Belt near Knutsford, in the borough of Cheshire East. The client's vision for the project is to strengthen its position as a luxury resort whilst providing world-class facilities and experience to its customers. Current project budget sits at £23 million and aims to be completed by 2021.
Project Tasks: Helped to prepare the Design and Access Statement to be reviewed with the planning consultant. Assisted to the site and reviewed with the director and the client the hotel design. Submitted our planning application on 21st June 2020.

Project Name: North Western Hall, Liverpool
Project Description: The existing building is Grade II listed and is constructed in stone with a notable slate roof. North Western has been in use as offices and student accommodation for the last twenty-two years. A full planning permission and listed building consent application have been approved. The project is currently in construction.
Project Tasks: Helped the project architect to develop technical and planning drawings.

Project Name: Napier Gateway Hotel, Luton
Project Description: The site is 2.76 hectares and is part of the previously consented scheme for Napier Park and Stirling Place- a mixed-use scheme with a focus to delivery residential accommodation. No statutorily listed buildings are present, nor does it fall within a designated conservation area. Our proposal is to base the design on a 3-4 stars' hotel area schedule and includes a retail unit on the ground (Class A3).
Project Tasks: The team was tasked to provide various proposed options to identify the best strategy to house a 300 bed hotel, a separated 500 SQM conference facility, 100 space car park and a 1000SQM office block. Helped with the design of several options and assisted the director when required.

AGREEMENT

The company Leach Rhodes Walker accepts the student Maria M. Serrano Baena and confirms her participation on projects related with the thesis "Guía Práctica para el diseño del hotel en la actualidad". The research internship has taken place in 50 Dearmans Pl, Manchester, Salford M3 5LH during a period of three months starting 04/05/20 and ending 07/08/20 from 9am to 5pm completing a total of 640 hours.
Mentor: Justin Marks
Mentor's Role: Director
Mentor's Email: justin.marks@lrw.co.uk

Signed 29/10/20

Justin Marks (Director)

LeachRhodesWalker
Architects

Maria Serrano (PhD Student)

UNIVERSIDAD DE CORDOBA

UAlg ESGHT
UNIVERSIDADE DO ALGARVE
ESCOLA SUPERIOR DE GESTÃO, HOTELARIA E TURISMO

12th July 2022

INVITATION

To whom it may concern,

We are pleased to invite **MARÍA MAGDALENA SERRANO BAENA**, from the University of Córdoba (Spain), to perform a research stay between the 3rd October 2022 and the 3rd January 2023.

During this period, María Magdalena Serrano Baena will conduct research on the effects of the hotel servicescape and its influence on the resilience of people during COVID-19. This research stay does not involve any costs for ESGHT or the University of Algarve.

Prof. Marisol Correia and Prof. Ana Isabel Renda from the **CITUR - Centre for Tourism Research, Development and Innovation - Algarve** will follow up María Magdalena Serrano Baena during her stay in our institution.

We are looking forward to welcome María Magdalena Serrano Baena at our **School of Management, Hospitality and Tourism, University of the Algarve**.

Kindest regards,

Maria Alexandra Patrocínio Rodrigues Gonçalves
Assinado de forma digital por Maria Alexandra Patrocínio Rodrigues Gonçalves
Dados: 2022.07.13 17:52:25 +01'00'

Assinado por: **MARISOL DE BRITO CORREIA**
Num. de Identificação: 09956253
Data: 2022.07.13 14:10:12+01'00'

CARTÃO DE CIDADÃO

Alexandra Rodrigues Gonçalves, Ph.D.

Director of the School of Management, Hospitality and Tourism / University of the Algarve

Marisol Correia, Ph.D.

CITUR - Centre for Tourism Research, Development and Innovation - Algarve

CHAPTER VII.

CONCLUSIONS, LIMITATIONS AND FUTURE LINES OF RESEARCH

The present research represents a great advance in the achievement of the 2030 Agenda and 2050 neutrality and it highlights the impact that the hospitality architecture has in their successful accomplishment. This topic has been approached from three main perspectives from a sustainability point of view. Firstly, this work studies the benefits that green certificates, in this case BREEAM, applied in hotels might have to successfully fulfil the SDGs and the impact of the assessments in their design. Secondly, and after the negative effects caused by COVID-19 in the hospitality sector, this research has investigated the sentiments that people have had towards the hotels servicescapes during and after the pandemic to support the proposed One Planet Vision plan and to propose updated strategies for a sustainable recovery from a design and services perspective. Lastly, a new sustainable system is developed that supports material selection while calculating the total economic cost and quantities during the design stage using a high-rise hotel as a case study due to its complexity, to validate the system in a hospitality context.

In this context, the dissertation has contributed to the following inputs:

- **To substantiate the profound influence that the BREEAM sustainability assessment exerts on the design of hotels.** The research has revealed the findings of analysing seven case study hotels which applied for a BREEAM score during their design process. For existing buildings requiring a refurbishment, the crucial categories to consider are Health and Wellbeing, along with Land Use and Ecology. Upgrading the existing windows can improve thermal and acoustic insulation, while introducing bat and bird boxes and planters can enhance the ecological aspects of the hotel. In the case of newly constructed hotels, Waste and Transport categories were consistently important. A well-designed project that allocates sufficient space for cycling and bin storage contributes to the acquisition of credits required to classify the project as a sustainable hotel. Similarly, to refurbished hotels, Health and Wellbeing and Land Use and Ecology categories are crucial for newly built hotels. Additionally, incorporating green roofs positively contributes to achieving the BREEAM target score.

- **To demonstrate the advantageous impact of implementing the BREEAM energy certificate in hotels towards effectively achieving the SDGs.** The certificate contributes to nine out of the seventeen SDGs proposed by the 2030 Agenda, with the greatest impact observed in the categories of Health and Wellbeing, Land Use, Ecology, Waste, and Transportation. By comparing these categories with the SDGs outlined by BREEAM and the UNWTO, it can be confirmed that the certificate directly contributes to SDGs 3, 6, 7, 12, and 15, and indirectly supports SDGs 8, 11, 13, and 9 through its endorsement of new technological measures like solar panels. This research highlights that an appropriate approach within the tourism and hospitality industry can yield promising and substantial results in accomplishing the SDGs.

- **To unveil the key servicescape dimensions crucial for a sustainable recovery, based on the analysis of extracted quantitative data.** The physiological conditions and atmosphere dimensions received the highest mean value and garnered positive responses from participants regarding hotel servicescapes during and after the pandemic. This finding is crucial as it sheds light on the dimensions that positively impact a sustainable recovery of the sector in the post-pandemic era.

- **Initial insights into people's sentiments towards hotel servicescapes during and after the COVID-19 pandemic to contribute to the One Planet Vision.** The findings extracted from this research hold significance and should be considered due to their enduring importance in people's perspectives. The most significant finding underscores the value of incorporating greenery, such as indoor patios and indoor plants, in hotels as it has a crucial impact on people's wellbeing. It has also been found that a minimalistic decoration approach and the use of clean-lined furniture elicit a positive response. The relevance of indoor environmental quality was proved. Moreover, a positive impact of providing a sense of spaciousness was found, both indoors and outdoors, on people's experiences. Technological innovations can play a pivotal role in reducing customers' perceived health risks. Lastly, participants exhibited increased flexibility in the second stage of the post-pandemic era. It was evident that the majority of respondents possessed a clear understanding of recommended procedures and demonstrated cooperation. However, the results also indicate a slight reluctance when these measures potentially encroach upon their comfort.

- **A multi-dimensional real-time system entitled MLCAQ is proposed.** This sustainable system is designed to compare different material alternatives based on the environmental and economic cost impact and guide the early design stages. It emphasizes the automation to provide optimal construction solutions for the project, with controlled building costs until the end of the design stage, qualities that until now have not been considered in a single methodology.

- **A new model of circular practice and resource efficiency results in a reduction of total economic cost, along with significant reductions in embodied energy, CO_2 emissions and waste mass.** Findings from this research support the idea that selecting materials with low embodied energy and high circularity is a viable approach for achieving environmental sustainability and cost-effectiveness in the construction sector.

In addition, the results achieved in the different studies have enabled the following statements:

- The BREEAM sustainability assessment significantly influences the design of hotels, exerting a profound impact on various aspects.

- Health and Wellbeing, along with Land Use and Ecology, are crucial categories to consider for existing buildings undergoing refurbishment, as revealed by the research findings.

- Waste and Transport categories consistently play an important role in newly constructed hotels, emphasizing the significance of sustainable practices in these areas.

- Upgrading existing windows enhances thermal and acoustic insulation, while incorporating bat and bird boxes and planters improves the ecological aspects of the hotel.

- The research highlights the substantial contribution of the BREEAM energy certificate in hotels towards achieving the SDGs, emphasizing the importance of an appropriate approach within the tourism and hospitality industry.

- Initial insights into hotel servicescapes during and after the pandemic contribute to the One Planet Vision, emphasizing the enduring importance of people's perspectives.

- Understanding the impact of physiological conditions and atmosphere dimensions on hotel servicescapes is crucial for a sustainable recovery, as revealed by the analysis of quantitative data.

- The value of incorporating greenery and indoor plants in hotels for improved wellbeing emerges as a significant finding from the research on people's sentiments towards hotel servicescapes.

- Minimalistic decoration and clean-lined furniture elicit a positive response, highlighting the impact of design choices on people's experiences in hotels.

- Technological innovations can effectively reduce customers' perceived health risks in hotels, showcasing their pivotal role in enhancing safety.

- In the post-pandemic era, there is an observable trend of increased flexibility and understanding of recommended procedures, accompanied by a slight reluctance when these measures potentially compromise personal comfort.

- Automation's introduction into construction, specifically through BIM implementation, reshapes the industry by enabling the achievement of optimal construction solutions and meticulous management of building costs, thereby filling a long-standing gap in existing methodologies.

- Opting for materials with low embodied energy and high circularity achieves environmental sustainability and cost-effectiveness.

While this research makes a valuable contribution to future sustainable plans from a hospitality perspective, it is important to acknowledge its limitations. Although the significance of water management in hotels has been recognized, this research did not provide any relevant insights in this regard. Future studies should aim to investigate and provide data on the specific implications and practices related to this. Additionally, the case studies presented are city hotels, so further research encompassing all types of hotels, including coastal and rural hotels, is necessary to comprehensively explore this field and gather more data regarding the SDGs. Regarding the data extracted from the questionnaire and the validity of the Likert scale attitude measurement, there is a possibility that social desirability bias could compromise the accuracy of responses. Participants in the survey may provide answers that they believe are socially accepted or present themselves in a more positive light. In this case, although the questionnaire included relevant questions about COVID-19 measures and most respondents expressed agreement with these restrictions, there remains a chance that their statements may not reflect their true behaviour. Future research should consider mitigating the impact of social desirability bias and explore alternative methodologies to gather more reliable data. Additional data for a sustainable recovery of the sector in the post-pandemic era should be gathered. While some attributes have shown a positive response, other attributes have remained unchanged and do not exhibit a significant difference between 2020 and 2022. Therefore, future research should delve deeper into these dimensions to further explore their consistent nature.

Theoretical implications have been derived from this research, shedding light on the aspects that should be thoroughly analysed and incorporated in hotels to address the impact of green certificates and the COVID-19 pandemic on their design towards achieving future sustainable goals. Furthermore, practical implications and sustainable strategies can be drawn for hospitality managers and hotel stakeholders to better understand their customers' needs and preferences. On the other hand, a system is provided to facilitate the calculation of sustainable materials for hotel design experts and technicians. In light of the impact of the pandemic in the hospitality and tourism sectors and the urge to achieve the 2050 neutrality, it is imperative for scholars, technicians, and stakeholders to join forces and collaboratively develop new models, approaches, and ideas to apply in hotels. By leveraging the diverse expertise and perspectives of industry practitioners, academic researchers, technicians, and stakeholders, innovative solutions can be fostered to navigate the complexities of the current landscape. This collective effort can forge a path forward, envisioning and implementing transformative strategies that will help to achieve the future sustainable plans and mitigate the devastating effects of the pandemic for a sustainable recovery on the hospitality sector. In the spirit of collaboration and resilience, this research has been undertaken to contribute to the collective efforts of the hospitality industry and scholars in achieving the sustainable goals while overcoming the far-reaching impacts of the pandemic.

La presente investigación representa un gran avance en el logro de la Agenda 2030 y la neutralidad 2050 y destaca el impacto que tiene la arquitectura hotelera en su exitoso cumplimiento. Este tema ha sido abordado desde tres perspectivas principales desde la sostenibilidad. En primer lugar, este trabajo estudia los beneficios que pueden tener los certificados verdes, en este caso BREEAM, aplicados en los hoteles para cumplir con éxito los ODS y el impacto de las evaluaciones en su diseño. En segundo lugar, y tras los efectos negativos causados por el COVID-19 en el sector hotelero, esta investigación ha investigado los sentimientos que las personas han tenido hacia los servicios hoteleros durante y después de la pandemia para apoyar el plan One Planet Vision y proponer estrategias actualizadas para una recuperación sostenible desde el diseño y servicios. Por último, se desarrolla un nuevo sistema sostenible que permite la selección de materiales mientras calcula el costo económico total y las cantidades durante la etapa de diseño utilizando un hotel de gran altura como caso de estudio debido a su complejidad, para validar el sistema en un contexto de hostelero.

En este contexto, la tesis ha contribuido con los siguientes insumos:

- **Justificar la profunda influencia que ejerce la evaluación de sostenibilidad BREEAM en el diseño de los hoteles.** La investigación ha revelado los resultados de analizar siete hoteles de casos de estudio que solicitaron una puntuación BREEAM durante su proceso de diseño. Para los edificios existentes que requieren una remodelación, las categorías cruciales a considerar son Salud y Bienestar, junto con Uso del Suelo y Ecología. Actualizar las ventanas existentes puede mejorar el aislamiento térmico y acústico, mientras que la introducción de cajas para murciélagos y pájaros y jardineras puede mejorar los aspectos ecológicos del hotel. En el caso de los hoteles de nueva construcción, las categorías de Residuos y Transporte fueron consistentemente importantes. Un proyecto bien diseñado que asigna suficiente espacio para guardar bicicletas y contenedores contribuye a la adquisición de los créditos necesarios para clasificar el proyecto como un hotel sostenible. Del mismo modo, para los hoteles reformados, las categorías de Salud y Bienestar y Uso del Suelo y Ecología son cruciales para los hoteles de nueva construcción. Además, la incorporación de cubiertas verdes contribuye positivamente a alcanzar la puntuación objetivo de BREEAM.

- **Demostrar el impacto positivo de la implantación del certificado energético BREEAM en los hoteles para la consecución efectiva de los ODS.** El certificado contribuye a nueve de los diecisiete ODS propuestos por la Agenda 2030, observándose el mayor impacto en las categorías de Salud y Bienestar, Uso del Suelo, Ecología, Residuos y Transporte. Al comparar estas categorías con los ODS descritos por BREEAM y la OMT, se puede confirmar que el certificado contribuye directamente a los ODS 3, 6, 7, 12 y 15, e indirectamente apoya a los ODS 8, 11, 13 y 9 a través de su aprobación de nuevas medidas tecnológicas como los paneles solares. Esta investigación destaca que un enfoque apropiado dentro de la industria del turismo y la hostelería puede generar resultados prometedores y sustanciales para lograr los ODS.

- **Revelar las dimensiones clave de los servicescape cruciales para una recuperación sostenible, con base en el análisis de los datos cuantitativos extraídos.** Las condiciones fisiológicas y las dimensiones de la atmósfera recibieron la media más alta y obtuvieron respuestas positivas de los participantes con respecto a los servicios del hotel durante y después de la pandemia. Este hallazgo es crucial ya que arroja luz sobre las dimensiones que impactan positivamente en una recuperación sostenible del sector en la era postpandemia.

- **Conocimientos iniciales sobre los sentimientos de las personas hacia los servicios hoteleros durante y después de la pandemia de COVID-19 para contribuir a One Planet Vision.** Los hallazgos extraídos de esta investigación tienen importancia y deben ser considerados debido a su relevancia perdurable en las perspectivas de las personas. El hallazgo más significativo subraya el valor de incorporar vegetación, como patios interiores y plantas de interior, en los hoteles, ya que tiene un impacto crucial en el bienestar de las personas. También se ha encontrado que un enfoque de decoración minimalista y el uso de muebles de líneas limpias provocan una respuesta positiva. Se comprobó la relevancia de la calidad ambiental interior. Además, se encontró un impacto positivo respecto a proporcionar una sensación de amplitud, tanto en interiores como en exteriores, para las personas. Las innovaciones tecnológicas pueden desempeñar un papel fundamental en la reducción de los riesgos para la salud percibidos por los clientes. Por último, los participantes exhibieron una mayor flexibilidad en la segunda etapa de la era postpandémica. Era evidente que la mayoría de los encuestados poseía una comprensión clara de los procedimientos recomendados y cooperación demostrada. Sin embargo, los resultados también indican una ligera renuencia cuando estas medidas potencialmente interfieren con su comodidad y confort.

- **Se propone un sistema multidimensional en tiempo real denominado MLCAQ.** Este sistema sostenible está diseñado para comparar diferentes alternativas de materiales en función del impacto medioambiental y económico y guiar las primeras etapas de diseño. Enfatiza la automatización para brindar soluciones constructivas óptimas al proyecto, con costos de construcción controlados hasta el final de la etapa de diseño, cualidades que hasta ahora no han sido consideradas en una sola metodología.

- **Un nuevo modelo de práctica circular y eficiencia de los recursos da como resultado una reducción del costo económico total, junto con reducciones significativas en la energía incorporada, emisiones de CO_2 y residuos.** Los hallazgos de esta investigación respaldan la idea de que la selección de materiales con baja energía incorporada y alta circularidad es un enfoque viable para lograr la sostenibilidad ambiental y la rentabilidad en el sector de la construcción.

Además, los resultados obtenidos en los diferentes estudios han permitido realizar las siguientes afirmaciones:

- La evaluación de sostenibilidad BREEAM influye significativamente en el diseño de los hoteles, ejerciendo un profundo impacto en varios aspectos.

- La Salud y el Bienestar, junto con el Uso del suelo y la Ecología, son categorías cruciales a tener en cuenta para los edificios existentes que se están renovando, según revelan los resultados de la investigación.

- Las categorías de Residuos y Transporte siempre juegan un papel importante en los hoteles de nueva construcción, lo que enfatiza la importancia de las prácticas sostenibles en estas áreas.

- La actualización de las ventanas existentes mejora el aislamiento térmico y acústico, mientras que la incorporación de cajas y nidos para murciélagos y pájaros mejora los aspectos ecológicos del hotel.

- La investigación destaca la contribución sustancial del certificado energético BREEAM en los hoteles para lograr los ODS, enfatizando la importancia de un enfoque adecuado dentro de la industria del turismo y la hostelería.

- Los conocimientos iniciales sobre los servicescape hoteleros durante y después de la pandemia contribuyen a One Planet Vision, enfatizando la importancia perdurable de las perspectivas de las personas.

- Comprender el impacto de las condiciones fisiológicas y las dimensiones de la atmósfera en los servicios hoteleros es crucial para una recuperación sostenible, como lo revela el análisis de datos cuantitativos.

- El valor de incorporar vegetación y plantas de interior en los hoteles para mejorar el bienestar surge como un hallazgo significativo de la investigación sobre los sentimientos de las personas hacia los servicios hoteleros.

- La decoración minimalista y los muebles de líneas limpias provocan una respuesta positiva, destacando el impacto de las opciones de diseño en las experiencias de las personas en los hoteles.

- Las innovaciones tecnológicas pueden reducir efectivamente los riesgos para la salud percibidos por los clientes en los hoteles, mostrando su papel fundamental en la mejora de la seguridad.

- En la era posterior a la pandemia, existe una tendencia observable de mayor flexibilidad y comprensión de los procedimientos recomendados, acompañada de una ligera renuencia cuando estas medidas pueden comprometer la comodidad personal.

- La introducción de la automatización en la construcción, específicamente a través de la implementación de BIM, remodela la industria al permitir el logro de soluciones de construcción óptimas y una gestión meticulosa de los costos de construcción, llenando así un vacío en las metodologías existentes.

- Optar por materiales con baja energía incorporada y alta circularidad ayuda a la sostenibilidad medioambiental y rentabilidad económica.

Si bien esta investigación hace una valiosa contribución a los futuros planes sostenibles desde la perspectiva de la hostelería, es importante reconocer sus limitaciones. Aunque se ha reconocido la importancia de la gestión del agua en los hoteles, esta investigación no proporcionó información relevante al respecto. Los estudios futuros deben tener como objetivo investigar y proporcionar datos sobre las implicaciones y prácticas específicas relacionadas con esto. Además, los estudios de caso presentados son hoteles urbanos, por lo que es necesario realizar más investigaciones que abarquen todo tipo de hoteles, incluidos los hoteles costeros y rurales, para explorar de manera integral este campo y recopilar más datos sobre los ODS. En cuanto a los datos extraídos del cuestionario y la validez de la escala Likert, existe la posibilidad de que el sesgo de deseabilidad social pueda comprometer la precisión de las respuestas. Es decir, los participantes en la encuesta pueden proporcionar respuestas que creen que son socialmente aceptadas o presentarse de una manera más positiva. En este caso, aunque el cuestionario incluía preguntas relevantes sobre las medidas de COVID-19 y la mayoría de los encuestados expresaron su acuerdo con estas restricciones, existe la posibilidad de que sus declaraciones no reflejen su verdadero comportamiento. La investigación futura debería considerar

mitigar el impacto del sesgo de deseabilidad social y explorar metodologías alternativas para recopilar datos más contrastados. Se deben recopilar datos adicionales para una recuperación sostenible del sector en la era posterior a la pandemia. Si bien algunos atributos han mostrado una respuesta positiva, otros atributos se han mantenido sin cambios y no muestran una diferencia significativa entre 2020 y 2022. Por lo tanto, la investigación futura debería profundizar en estas dimensiones para explorar más a fondo su naturaleza consistente.

De esta investigación se han derivado implicaciones teóricas que arrojan luz sobre los aspectos que deben analizarse e incorporarse en los hoteles para abordar el impacto de los certificados verdes y la pandemia de COVID-19 en su diseño y lograr así los futuros objetivos sostenibles. Además, se pueden extraer implicaciones prácticas y estrategias sostenibles para que los gerentes de los hoteles y las partes interesadas del mismo comprendan mejor las necesidades y preferencias de sus clientes. Por otro lado, se propone un sistema para facilitar a los técnicos y expertos del diseño hotelero el cálculo de materiales sostenibles. A la luz del impacto de la pandemia en los sectores de la hostelería y el turismo y la urgencia de lograr la neutralidad de 2050, es imperativo que académicos, técnicos y partes interesadas unan fuerzas y desarrollen en colaboración nuevos modelos, enfoques e ideas para aplicar en los hoteles. Al aprovechar la experiencia y las perspectivas diversas de los profesionales de la industria, los investigadores académicos, los técnicos y las partes interesadas, se pueden fomentar soluciones innovadoras para abordar las complejidades del panorama actual. Con este esfuerzo colectivo se puede forjar un camino a seguir, visualizando e implementando estrategias transformadoras que ayudarán a lograr los futuros planes sostenibles y mitigar los efectos devastadores de la pandemia para una recuperación sostenible en el sector hotelero. Con este espíritu de colaboración y resiliencia, esta investigación se ha llevado a cabo para contribuir a los esfuerzos colectivos de la industria hotelera y los académicos para lograr los objetivos sostenibles y superar los impactos de largo alcance de la pandemia.