

Athens Journal of Tourism

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The *Athens Journal of Tourism* (AJT) is an Open Access quarterly double-blind peer reviewed journal and considers papers from all areas of tourism and related disciplines such as culture, leisure, recreation, geography, urban planning, heritage, sports, historical cities, landscape, architecture etc. The AJT considers theoretical and empirical papers as well as case studies and policy papers. The journal's aim is to be useful to both academics of tourism research and the practitioners of the tourism industry. Many of the papers published in this journal have been presented at the various conferences sponsored by [the Tourism, Leisure & Recreation Unit](#) of the Athens Institute. All papers are subject to Athens Institute's Publication Ethical Policy and Statement. A journal publication might take from a minimum of six months up to one year to appear. All papers are subject to Athens Institute's [Publication Ethical Policy and Statement](#).

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The current issue is the fourth of the twelfth volume of the *Athens Journal of Tourism (AJT)*, published by the [Tourism, Leisure & Recreation Unit](#) of Athens Institute.

Gregory T. Papanikos
President
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- Submission of Paper: **2 March 2026**

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Resonant Connections: The Stroke Rods of Badia Tedalda and the Musical Legacy of Guido d'Arezzo

*By Mark Konewko**

This article explores the acoustic and musical properties of aluminum stroke rods installed in Badia Tedalda, Italy, and their physical and conceptual connection to the medieval musical advances of the theorist Guido d'Arezzo. The stroke rods—aluminum rods with changing lengths supported at their midpoint harmonic node—create distinctive tonal qualities when stimulated by methods. The modern acoustic system establishes a bridge between contemporary sound exploration and medieval music theory. From the 11th century, Guido d'Arezzo's advanced music pedagogy with a revolutionary hexachord system that furnished a methodical approach to pitch organization.¹ This study illustrates, by analyzing the physical properties of the stroke rods and the mathematical principles underlying their acoustic characteristics and the pedagogical advances of Guido d'Arezzo, how both innovations represent milestone approaches to understanding and organizing sound. In what ways does the geographic placement of the stroke rods installation in the province of Arezzo create meaningful connections between medieval music pedagogy and contemporary acoustic exploration? The installation of the stroke rods at Monte Botolino in Badia Tedalda provides both a scientific and artistic demonstration of the region's musical tradition, connecting the possible source of modern musical notation with contemporary acoustic experimentation. This investigation adds to our understanding of how mathematical relationships in sound production have supplied musical theory across centuries while giving prominence to the cultural significance of this distinctive installation in the province of Arezzo.

Introduction

The relationship between physical properties and musical sound production has fascinated theorists, musicians, and scientists for millennia. Using string lengths from Pythagoras's experimentations to recent acoustic engineering, the mathematical foundations of music persist in providing a rich foundation for both artistic and scientific exploration.² This article examines a curious connection between the medieval music theory, in particular the pedagogy of Guido d'Arezzo, and contemporary acoustic innovation namely the stroke rods installation in Badia Tedalda, a municipality in the province of Arezzo. In this article there is an attempt to answer two questions. The first is how do the acoustic properties of the Badia Tedalda stroke rods reflect mathematical principles like those underlying Guido d'Arezzo's hexachord system?

There is an educational dimension that runs through both acoustic concepts of aluminum rods, (frequency relationships, harmonic series, and tuning systems), and the organizational structure of medieval hexachords. Leading us to the next

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question, what pedagogical parallels exist between Guido d'Arezzo's systematic approach to teaching pitch relationships and the experiential learning opportunities provided by the stroke rods as a physical manifestation of acoustic principles?

The installation of the musical instrument stroke rods is made up of aluminum rods varying in lengths fixed at the midpoints. This configuration produces distinctive harmonic properties when activated. The geographic and conceptual proximity to the birthplace of modern musical notation is what makes this installation particularly significant. The Benedictine monk Guido d'Arezzo, who revolutionized music education in the 11th century, developed a framework of pitch organization and notation that continue to influence Western music today.³ The positioning of the stroke rods in the province of Arezzo constructs a symbolic continuum between medieval advancement and contemporary acoustic study.

As noted by Alberto Santucci, the mayor of Badia Tedalda, in a 1997 publication: "*Qui potremmo germarci, sancendo salvo prova contraria che le sette note musicali nacquero a Badia Tedalda*" (we may affirm, barring contrary evidence, that the seven musical notes were born in Badia Tedalda).⁴ This statement, while potentially provocative with musicologists, nonetheless focuses on the cultural significance assigned to the region's musical culture and supports context for the interpretation of the symbolic importance of the stroke rods installation.

This article investigates the acoustic theories fundamental to the stroke rods, their installation in Badia Tedalda, and their conceptual relationships to Guido d'Arezzo's hexachord system. Examining these parallel advances removed by nearly a millennium, one can obtain comprehension into how organized approaches to sound organization have developed while maintaining foundational connections to acoustic principles.

Methodology

This study involves an interdisciplinary interpretive outline that mixes historical musicology, acoustic physics, and cultural geography to examine the connections between the Badia Tedalda stroke rods installation and Guido d'Arezzo's medieval musical innovations and teaching strategies. The methodological approach combines conceptual analysis with empirical observation, drawing on three primary investigative strategies.

Conceptual Analysis and Theoretical Framework

This article uses a comparative conceptual analysis to point out parallels between medieval music theory and contemporary acoustic design. The approach examines the mathematical foundations underlying both Guido d'Arezzo's hexachord system and the physical properties of the stroke rods, focusing on pitch organization, harmonic relationships, and pedagogical applications. By analyzing these systems through the lens of acoustic physics, vibrating rods and historical tuning systems, the study establishes fundamental connections that go above chronological or geographic proximity.

The framework draws on interdisciplinary scholarship in organology (the study of musical instruments), sound studies, and music pedagogy. This context acknowledges that both historical and current practices in sound organization reflect what Born and Devine describe as the "materialization of musical thought"—the process by which abstract acoustic principles become embodied in physical or notational systems.⁵ The analysis engages with current scholarship on inharmonic spectra and the phenomenology of acoustic perception, recognizing that the stroke rods' unique timbral properties challenge conventional understandings of pitch and harmonic organization.⁶

Empirical Documentation and Site-Specific Investigation

The practical element of this research involves direct observation and documentation of the stroke rods installation at Monte Botolino, beginning with the author's initial site visit in 1986 and the subsequent installation process. Physical measurements of the aluminum rods, including precise length dimensions (365.76 cm to 91.44 cm), mounting specifications, and activation methods, offer quantifiable data for acoustic analysis. The study applies established principles from vibration theory and materials science to demonstrate the rods' acoustic behavior, using the standard equation for transverse vibrations in fixed-free rods to predict frequency relationships.⁷

This site-specific methodology supports contemporary methodologies in sound studies that highlight the importance of environmental context in acoustic phenomena. As Bandt, Duffy, and MacKinnon argue, sound installations cannot be fully understood apart from their spatial and cultural settings.⁸ The remote, mountainous location of the stroke rods significantly shapes both their acoustic properties, allowing sustained tones to dissipate naturally without architectural interference, and their cultural meaning as a contemplative, almost pilgrimage-like destination. Field documentation therefore extends beyond physical measurements to include consideration of how environmental factors influence the sonic experience and symbolic interpretation of the installation.

Source Choice and Historical Interpretation

The historical component utilizes a cultural-geographical approach to investigate the relationship between Guido d'Arezzo's theoretical work and the region of Badia Tedalda. Source choice prioritizes primary medieval texts, including Guido's *Epistola de ignoto cantu* and references in *Micrologus*, alongside secondary scholarly literature from musicology, medieval history, and music theory. The study examines chronological references to Guido's movements, particularly the Latin phrases "a finibus septentrionalibus" and the distinction between "a finibus" and "extra finibus", to evaluate the possibility of his residence in Badia Tedalda.

This approach acknowledges the interpretive nature of historical reconstruction while maintaining scholarly rigor. Rather than making authoritative historiographical claims, the methodology treats the geographic connection as a culturally significant context for understanding how communities construct musical heritage. This perspective uses recent work in cultural geography and heritage studies, particularly research on how places develop identity through associations with historical innovations.⁹ As Watkins demonstrates in her analysis of medieval music

transmission, the relationship between geographic location and theoretical development often involves complex networks of patronage, institutional support, and environmental influence that resist modest documentation.¹⁰

The incorporation of contemporary resources in acoustic physics, organology, and sound art confirms that the analysis of the stroke rods reflects current scientific understanding. Sources were selected to provide authoritative perspectives on vibration theory (Fletcher and Rossing), historical tuning systems (Duffin, Lindley), medieval music pedagogy (Pesce, Busse Berger), and contemporary sound installation practices (LaBelle, Born). This multi-disciplinary source base facilitates the study to bridge historical musicology and contemporary acoustic science, regarding both as equally valid approaches to understanding the organization and perception of sound.

Limitations and Interpretive Boundaries

This study recognizes several methodological limitations. The historical connection between Guido d'Arezzo and Badia Tedalda, while supported by textual evidence and geographic logic, remains interpretive rather than conclusively documented. The acoustic analysis of the stroke rods, though grounded in established physics, relies on theoretical modeling rather than comprehensive spectral analysis of recorded performances. Also, comparative context necessarily emphasizes certain aspects of both systems, mathematical relationships, pedagogical functions, systematic organization, while underemphasizing others, such as the aesthetic and devotional contexts of medieval music or the contemporary art-world positioning of sound installations.

These limitations are acknowledged not as weaknesses but as fundamental qualities of interdisciplinary interpretive research. The article's value lies not in definitive proof of direct historical causation but in informative meaningful resonances (conceptual, mathematical, and cultural) that connect diverse historical moments in the enduring human expansion of organizing and understanding sound.

Historical Structure and Setting

Musical Legacy of Guido d'Arezzo

During the early 11th century, Guido d'Arezzo (c.991-1033) changed musical pedagogy. He delivered practical methods that addressed the problems of learning music by rote. His methods dealt with the practical problems in music learning and practice during a time when melodies and performance practices were passed on primarily with an oral tradition.¹¹ Staff notation, solmization syllables, and the hexachord system using various positions of the human hand are some of his revolutionary contributions.

The visual representation of notation with clearly defined lines and spaces gave a strong system of reading music that has not been previously seen.¹² This development of Guido assisted an accurate way of learning melodies and sped up the learning process for singers. The well known "Hymn to St. John", *Ut queant laxis*, became a base for Guido's solfège system. The beginning syllables of each

entrance or phrase—ut, re, me, fa, sol, la—provided singers with a structure for sight-singing.¹³ In Claude Palesca’s *Music and Ideas in the Sixteenth and Seventeenth Centuries*, he argues that this system is, “the single most important innovation in Western music pedagogy before the modern era.”¹⁴

The hexachord arrangement demonstrated Guido’s efficient method to organize pitch intervals and relationships among them. Overlapping six-note scales became his development.

1. *Hexachordum naturale* (C-D-E-F-G-A)
2. *Hexachorum durum* (G-A-B-C-D-E)
3. *Hexachordum molle* (F-G-A-Bb-C-D)

By utilizing these three intersecting six-note scales, these hexachords contribute to the same core organization with the semitone, half step, continuously appearing connecting the third and fourth degrees, mi-fa. This organization gave vocalists an abstract structure for recognizing the pitch intervals contained within the modes of medieval music through a method called “mutation,” where singers would move among hexachords as a melody passage traversed through different ranges.¹⁵ The common implementation throughout Europe of this system is well documented and extensive in manuscripts from this period validating the practical implementation of Guido d’Arezzo’s system.¹⁶

The work of Guido d’Arezzo profoundly changed music learning by delivering systematic processes for understanding and reproducing musical pitch. These innovations remain and impact contemporary music theory and pedagogy. As Thomas Kelly states, “Guido’s practical systems allowed musicians to conceptualize sound in ways previously impossible, transforming abstract aural experiences into concrete, teachable concepts.”¹⁷

Stroke Rods of Badia Tedalda

In 1986, the author visited Monte Botolino in the municipality of Badia Tedalda in the province of Arezzo, an installation of stroke rods was proposed to then-mayor Giuliano Vittori Bochicchio. The mayor eagerly approved the project while immediately identifying the connection between this modern acoustic installation and the area’s association with Guido d’Arezzo. Bochicchio’s enthusiastic endorsement embodies a significant illustration of civic engagement with both historic legacy and modern aural art, a movement that Herber and Kertz-Welzel classify as all the time more momentous in cultural preservation efforts.¹⁸

The stroke rods installation consists of 24 aluminum rods of varying lengths, with the longest measuring 365.76 centimeters and the shortest 91.44 centimeters. These rods are fixed, heliarc welded to a solid spine of aluminum at their midpoints (182.88 and 45.72 respectively and progressively)—a significant harmonic node—which results in pure and unique acoustic properties when the rods are actuated. The stroke rods are played/activated by using cotton gloves impregnated with pulverized rosin dust. When a performer strokes the rods, the friction initiates vibrations in the aluminum creating very long sustained tones with distinctive timbral qualities.¹⁹ The

closest resemblance of the aural experience is to the glass harmonica developed in the 18th century, but the resulting sound is very different and the physical properties of vibrating glass and vibrating rods hold significantly different results.²⁰

By suppressing the fundamental frequency, a result of the fixation points at the middle of each rod, the distinction of this installation is acoustically unique. The experience of the listener is shaped by hearing the upper harmonics beginning with the fourth harmonic, octaves above the silenced fundamental. Depending where and how the rod is stroked, the higher partials are heard. This phenomenon has been explored in depth by researchers investing inharmonic spectra²¹ and creates a unique sonic experience where the perceived pitch relationships differ from conventional musical instruments.

Accessible only by foot rather than by vehicle, the installation's location atop a mountain near Monte Botolino carries both practical and symbolic significance. The site's remoteness demands a deliberate physical journey, fundamentally shaping the visitor's encounter with the work. This inaccessibility functions on multiple levels: practically, it ensures isolation from mechanical noise and urban interference; symbolically, it sets the installation as a destination requiring effort and intention, transforming the approach itself into part of the aesthetic experience. As described by Shafer, the open-air environment of this location permits the lasting tones to resonate liberally without the intrusion of enclosed spaces, a consequence that aligns with modern acoustic ecology.²² Symbolically, the placement of the installation in the province of Arezzo connects it to the origin of organized music notation, forming a conceptual bridge between medieval novelty and contemporary acoustic.

Material Properties and Construction

The primary material used in the stroke rods installation is aluminum. This selection of aluminum is fundamental to its acoustic character. Recent research on aluminum rods used for sound production has demonstrated that aluminum's specific physical properties directly influence timbral qualities and sustain of generated tones.²³ Unlike denser metals such as steel or bronze, aluminum produces a distinctive brightness while preserving extraordinary resonance duration. Metal selection ensures both structural integrity for outdoor installation and uniform acoustic performance in seasonal temperature differences.

The heliarc welding technique represents a critical construction detail. This precision welding method creates molecular continuous joints between each rod and the central aluminum spine, eliminating the damping effects that other fasteners would introduce. The welds must be made with special care at each rod's exact midpoint, where displacement during vibration theoretically reaches zero. Deviation from this precise location would compromise the fundamental frequency suppression that defines the installation's unique acoustic signature.

The dimensional progression from 365.76 cm to 91.44 cm creates a carefully calibrated frequency spectrum. Using the standard formula for a rod fixed at its center and free at both ends, the fundamental frequency varies with the inverse square of the length. This 4:1 length ratio translates to a 16:1 frequency ratio, spanning approximately four octaves of suppressed fundamentals. The corresponding midpoint

fixation distances, 182.88 to 45.72 cm, ensure that each rod's vibrational node aligns perfectly with its midpoint.

Acoustic Phenomena and Harmonic Structure

The suppression of the fundamental frequency represents the installation's most significant acoustic innovation. When a rod vibrates while constrained at its nodal point, the fundamental mode cannot be produced. This is because the fixed center physically prevents the formation of the displacement pattern required for first-node vibration, which would otherwise generate the fundamental frequency. Instead, the rod vibrates at a higher node, producing a frequency approximately four times higher than the suppressed fundamental. The actual pitch relationship follows the harmonic series of a center-fixed rod: the audible tones begin at the second harmonic, approximately 2.756 times the fundamental, creating an unusual starting point for the overtone series.

This modal complexity generates what researchers call an "inharmonic spectrum." Recent work on inharmonicity in musical instruments established that unlike strings or air columns that produce integer-multiple harmonics, many instruments exhibit inharmonic partials with non-integer ratios, creating beating patterns and interference happenings that shift depending on which components sound simultaneously. Research published in 2024 on the evolution of inharmonicity in music confirmed that inharmonic spectra create distinctive timbral qualities that differ fundamentally from harmonic sounds, with psychoacoustic systems processing them differently.²⁴ The listener encounters a shimmering, evolving sonic texture as partials drift in and out of phase relationships, producing a "spectral instability", a quality rarely experienced in conventional instruments.

The excitation method—cotton gloves impregnated with pulverized rosin—introduces controlled friction along the rod's length. By not striking or plucking, this stroking technique allows the performer to introduce energy controlled and continuous into the vibrating system, sustaining tones for extended durations limited only by the performer's determination. A seminal 2000 study by Smith and Woodhouse on rosin usage revealed that the friction coefficient of rosin depends not only on sliding velocity but also on the contact temperature creating a broad frequency spectrum²⁵. The particles of rosin construct microscopic grip and release cycles at approximately 200-2000 Hz, depending on stroke speed and pressure, exciting a broad spectrum of the rod's resonant nodes. The performer can emphasize different partials by varying stroke location: stroking near the free ends emphasizes higher modes, while stroking nearer the center (within the allowable distance from the node) emphasizes lower audible harmonics.

Environmental Acoustics and Spatial Experience

The mountaintop location changes the installation from a musical instrument into an acoustic phenomenon intimately attached to its environment. Sound behavior is altered at high altitudes. The slightly thinner atmosphere allows high-frequency sounds to travel farther, extending the installation's audible range. Additionally, remote

mountain environments exhibit exceptionally low ambient noise, often below 20 dBA, creating conditions where even the softest tones from the stroke rods remain clearly perceptible. The installation's location is thus integral to its acoustic character rather than merely incidental.

A 2025 study on acoustic ecology noted that R. Murray Schafer and the World Soundscape Project examined how open-air environments permit lasting tones to resonate without the intrusion of enclosed spaces, creating unique relationships between sound, space, and perception²⁶. The installation essentially uses the entire landscape as its resonant chamber. The physical effort required to reach the installation, ascending Monte Botolino on foot, creates a ritualistic characteristic to the experience. This pilgrimage-like approach establishes anticipation with audiences arriving in an intensified state of awareness, already attuned to their surroundings. The climb also guarantees smaller, more intimate audiences, transforming each activation of the stroke rods into a rare, special experience rather than casual entertainment. Inaccessibility functions as a filter, selecting individuals with genuine curiosity and commitment.

The physical act of stroking—requiring sustained arm movement, careful pressure, and rosin management—creates an intimate connection between human movement and acoustic outcome. Performers feel kinesthetic feedback through the gloves as vibrations transmit back through their arms, making their sensation literally connected to the rods' resonance. This tactile dimension transforms performance into a whole-body experience, suspending the boundary between player and instrument.

Geographic research on sound art from 2006 emphasized how site-specific works engage with environmental, sonic, cultural, and historical personalities of particular locations, creating what scholars describe as 'memoryscapes' through nuanced foldings of sound and spatial perception²⁷. The relationship with natural soundscapes situates the stroke rods within acoustic ecological framework. The installation's tones become part of the existing sonic elements of wind, distant animal calls, rustling vegetation. The pure, sustained tones create an interaction with nature's irregular, transient sounds.

Acoustic Physics and Musical Structures

Physical Properties of Aluminum Stroke Rods

The acoustic properties of the stroke rods are derived from the physics of aluminum and the principles of vibrating fixed and free rods. High elasticity, low internal damping, and moderately low density, the properties of aluminum, make it particularly suitable for this application. Because of these properties, aluminum rods can sustain vibrations with efficiency, producing pure tones with lengthy decay times. These attributes have been considerably recorded in research on percussion instruments.²⁸

When the fundamental frequency is blocked because of this mounting design, fixed at its midpoint the location of an upper harmonic node, it stifles the rod from vibrating in its fundamental. Using this model, the rod vibrates in its higher harmonic nodes. For a rod at the length of L , the frequency of vibration is determined by:

$$f_n = (n^2\pi/2) \times \sqrt{(EI/\rho A)/L^2}$$

where:

- n is the node number ($n = 1, 2, 3\dots$)
- E is Young's modulus for aluminum
- I is the moment of inertia of the cross-section
- ρ is the density of aluminum
- A is the cross-sectional area
- L is the rod length

If one follows an inverse square relationship between length and frequency, an explanation of why shorter rods produce higher pitches while longer rods produce lower pitches is evident. The relationship of rods involves the square of the length unlike stringed instruments, where the frequency is inversely proportional to length, thus creating a different scaling pattern. This feature is crucial for understanding the novel tonal characteristics of the stroke rods. This characteristic has been analyzed in depth regarding instrument scaling researched by Hutchins and Benade.²⁹

The technique used to excite the rod—stroking it with rosin impregnated cotton gloves—creates friction that activates the vibration along the length of the rod. By using this particular technique, a rich spectrum of overtones is activated that differs from the harmonic series that can be heard in vibrating strings, tubes, or air columns. The overtones of a vibrating rod result in an inharmonic series where the frequency ratios between partials are not simple integer multiples of the fundamental. In the recent research of Papich and Rainbow, they established that these inharmonic patterns could have noteworthy inferences for hearing pitch and its awareness and the tonal organization of pitch.³⁰

Tuning Approaches and Harmonic Associations

The installation of the stroke rods in Badia Tedalda uses an arithmetic sequence of rod lengths unlike most conventional musical tuning systems. By using an arithmetic order, this methodology results in unique pitch intervals that are closely similar to Pythagorean tuning where the perfect fifth with a frequency ratio of 3:2 and perfect fourths with a frequency ratio of 4:3. This connection with Pythagorean theories generates a fascinating relation to ancient Greek theoretical practices that directly inspired medieval music theory.³¹

Guido d'Arezzo presented his hexachord system during the medieval period during which time Pythagorean tuning was widespread. This tuning system creates pure perfect fifths and fourths but also produces an inconsistency when a circle of fifths is formed. The "Pythagorean comma" or the "wolf interval" is the discrepancy that results from these pure fifths and fourth if continued through the circle of fifths.³² The natural acoustic properties of the stroke rods overtone production align with Pythagorean tuning where pure fifths and fourths are present. The measured consequences of these tuning systems have been considerably examined by Duffin determining how various historical methods to tuning indicate distinct concessions between mathematical integrity and practical musicality.³³

The correlation between the stroke rods and the hexachord system of Guido d'Arezzo goes beyond geographic proximity to theoretical similarities in how both organize sound. Both the arithmetic tuning of the stroke rods and the arrangement of the hexachord engage with the harmonic series and mathematical connections between pitches, albeit in diverse disciplines. The hexachords of Guido d'Arezzo give a structure for the usage of the whole and half step associations in the diatonic scale, whereas the installation of the stroke rods physically exhibit mathematical associations through its structure and the resulting acoustic properties. Cohen discusses this correlation between mathematical thought and physical appearance that denotes a continuous and consistent line through the history of Western music theory.³⁴

Both Fletcher and Rossing state, "Systems that organize pitch relationships invariably reflect some compromise between pure mathematical ratios and practical consideration for musical performance."³⁵ This compromise is represented manifest in the approaches in both Guido d'Arezzo's system and the stroke rods. Guido d'Arezzo shaped a pedagogical structure founded on existing musical practice and the stroke rods established a physical manifestation of mathematical associations in sound.

Assimilation of Medieval Theory and Contemporary Practice

Instructional Uses

The driving motivation for Guido d'Arezzo for initiating his hexachord system and the usage of a staff for notation was for instructional usage. His focus was to develop ways that would give singers a new way to learn new music quicker, more efficiently, and accurately. From his own writings in the *Epistola de ignoto cantu*, "After I had tried to teach choirboys with our antiphoner, at length Divine Grace was with us, and some of them learned to sing unknown chants so easily, after practicing with the monochord for three days, that they certainly amazed others, who scarcely manage to do even this much for a whole week."³⁶ His sensible view and approach to music pedagogy demonstrates what Busse Berger states as a foundational shift in medieval methods to musical knowledge teaching.³⁷

Likewise, the pedagogical potential for exploring acoustic principles is significantly present with the stroke rods. The actual assembly of the instrument exemplifies the basic models of vibration theory while the activation of their sound demonstrates principles of harmonics and overtones in a real form. When used as a teaching tool, they permit a direct investigation with the variables that influence pitch, timbre, and resonance. An experiential approach to instruction of acoustics associates itself with modern teaching theories that accentuate embodied understanding and multisensory encounter.

Tangible experiential learning occasions are presented by both innovations that transform conceptual acoustic theories into concrete understanding. The conversion of the abstract concept of relative pitch into an organized context with clear rules offered by Guido d'Arezzo's hexachords and the stroke rods shifting mathematical associations in acoustics into a physical object that can be manipulated and experienced directly are evidence of instructional perceptible experiential learning

opportunities. Thompson notices that this realization of abstract principles acts as a commanding pedagogical approach that goes beyond historical periods.³⁸

Systematic Advances to Sound Configuration

The connection to Guido d'Arezzo operates on many levels beyond geographic proximity. His innovations in musical notation—the staff, solmization, and the hexachord system—denoted radical abstractions that translated temporary sound into permanent visual symbols. The stroke rods perform a theoretical inversion: they convert abstract mathematical relationships (rod lengths, nodal points, harmonic ratios) back into physical sound. Both systems reconcile between the conceptual and the experiential, between theory and practice.

The hexachord structure of Guido d'Arezzo and the stroke rods both display methodical advances to the configuration of sound, notwithstanding unique fundamental objectives. Guido d'Arezzo's system was born out of the primary necessity for practical musical instruction and performance. The stroke rods installation provides an artistic and scientific purpose to the discovery of acoustic phenomena. Cook and Pettengill elaborate on the dual artistic-scientific function as a developing important trend in modern sound installations.³⁹

The advancements of Guido d'Arezzo were revolutionary in that the codification of what had previously been learned through an oral practice. This visual representation of pitch relationships and a practice that conceptualized those relationships vocally proposed an apparatus that markedly improved music education. Haar observes these methodical advances embodied important steps in the advancement of Western music's distinguished notational and theoretical traditions.⁴⁰

Similarly, the stroke rods organized acoustic principles building a physical installation wherein calculated connections in sound fabrication can be directly experienced. The lengths of the rods, based on an arithmetic sequence, creates a detailed set of pitch associations that can be comprehended and scrutinized through a filter of acoustics and music theory.⁴¹ The installation illustrates what Born depicts as the “materialization of sonic theory”—physical indicators of fundamental physics principles of vibrating rods that is immediately experienced rather than intellectualized.⁴²

The resonant connection between both the work of Guido d'Arezzo and the stroke rod installation exemplifies the evolving understanding while holding fast to the fundamental acoustic principles. In the words of Benson, “The history of music theory reflects an ongoing dialogue between mathematical ideals and practical musical considerations.”⁴³ These two moments in an ongoing dialogue are represented in both Guido d'Arezzo's system and the stroke rods. As additionally expanded by Christenson, the historical continuity of theoretical innovations on the continuum of Western musical history have steadily connected the opposition between abstract scientific theories and practical musical application.⁴⁴

Cultural and Historical Importance

Musical Legacy of Badia Tedalda

The approach taken in this article is an investigation of the geographical relationships between the work of Guido d'Arezzo and the area of Badia Tedalda as seen via a cultural-geographical viewpoint rather than the usage of conventional historiographical methodology. Recognizing and respecting the historic importance of Guido d'Arezzo's musical systems and notational advances, this investigation centers on the possible connection with his theoretical constructs and his potential residence in Badia Tedalda. Without claiming expertise in historical scholarship, the method used here investigates how the geographical setting may have shaped in some way the establishment of his musical ideas.

Guido d'Arezzo was known by many names some of which were Guido Aretinus, Guido Monico, and Guido Aretino. His innovations became known throughout the region including Rome. Under the command of Pope John XIX, he was asked to travel to Rome to expound on his novel pedagogical methods. It was during this stay in Rome that Guido fell ill. It is documented that he suffered from the intense Roman summer heat. Bishop Teodaldo, a close friend and patron of Guido Aretino, became aware of the monk's advancing health problems and enabled his departure from Rome perhaps to the abbey at Badia Tedalda.

Historians and scholars have speculated alternative locations that include the Abbey of Pomposa and the Hermitage of Fonte Avellana but there is compelling evidence that presents a case that indeed Guido Aretinus made the trip to Badia Tedalda. As Santucci observes, modern interpretation of ancient writings suggests, "*gli faceva rimpiangere I suoi freshi luoghi alpestri*" (made him long for his fresh alpine places).⁴⁵ One source explicitly states, "*nobis alpestribus*" (for us the alpine people). This particular Latin phrase perhaps is a direct reference to Monte dell'Alpe della Luna, situated within the regional boundaries of Badia Tedalda, thus imaginably backing up the claim that Guido Aretinus took refuge and continued his analytical work in this place.

Don Gerico Babini's writings, quoted in Tommaso Regi's *Autopsia della vita di un Genio: Guido d'Arezzo*, gives even more evidence that supports the Badia Tedalda proposition. The text offers even more geographical evidence that could confirm Guido Monico's presence in this location:

Guido Monoco fu esiliato "afinibus septentrionalibus". Stendete una carta geografica sul tavolo e, con il dito da Arezzo, andate verso il settentrione, dove ai confine, ossia entro i confine della Diocesi, troverete Badia Tedalda.

Infatti non dice "extra finibus", ma "a finibus" cioè non fuori dei confine, ma sino ai confine della Diocesi. (Guido Monaco was exiled "to the northern borders." Spread out a geographical map on the table and, with your finger from Arezzo, go toward the north, where at the border, that is within the borders of the diocese, you will find Badia Tedalda. Indeed, he does not say "extra finibus"—outside the borders, but "a finibus"—to the borders; that is, not outside the borders, but up to the borders of the Diocese.)⁴⁶

Guido Monaco was exiled “to the northern borders” (*a finibus septentrionalibus*). The directions of Don Gerico indicate that if you spread a geographical map on a table and trace with your finger from Arezzo to the north, within the borders of the diocese, one will encounter Badia Tedalda. Notably, the writing does not indicate outside the borders, “*extra finibus*” but rather “*a finibus*” within the borders of the diocese.

This subtle distinction that is linguistically presented is crucial in piecing together the location of Guido d’Arezzo. This Latin phrase “*a finibus septentrionalibus*” indicates an expulsion to the northern border of the diocese rather than beyond the jurisdiction of the diocese. This argument establishes the notion that placed at the northern margin of the diocese of Arezzo, that Badia Tedalda was indeed the place of exile for the monk Guido d’Arezzo. The usage of the word “exile” needs further research as it may mean a chosen departure rather than a disciplinary expulsion.

The statement that “the seven musical notes were born in Badia Tedalda” asserted by Alberto Santucci, within this historical context, mirrors the cultural significance connected to the area of Badia Tedalda’s connection with Guido d’Arezzo. Even though he has been associated with the city of Arezzo and not Badia Tedalda, the documented indication regarding the pine forests that are part of Badia Tedalda that is within the province of Arezzo, suggests a concrete regional connection to this musical heritage. Leyshon et al., cultural geographers, have studied how communities develop cultural identities by means of claim-making association with historical innovations.⁴⁷

This social legacy and current significance putting Guido Monaco in the abbey in Badia Tedalda is important. An acknowledgement of this legacy and an extension of it in modern acoustic exploration is manifest in the installation of the stroke rods on Monte Botolino within the boundaries of Badia Tedalda. By placing this sound installation in the same region where Guido Monaco may have developed his progressive musical theories, a dialogue is initiated between past and present viewpoints considering the cognition and arrangement of sound. Kirshenblatt-Gimblett contends that installations like the stroke rods achieve not only artistic goals but also act as “heritage productions” that strengthen local cultural identities.⁴⁸

The location of the installation in a remote area of Monte Botolino that is unreachable to the public unless people actually forge up the hillside, adds yet another element to its regional importance. Very different from other instruments or public sound-art installations, the stroke rods command a planned effort to experience, making an almost pilgrimage-like expedition that highlights their special status as a scientific demonstration and artistic declaration. This three-dimensional seclusive area resonates with a monastic setting where Guido d’Arezzo might have discovered refuge and inspiration, confirming a parallel between medieval contemplative customs and contemporary sound discovery. An environmental trait of the stroke rod installation supports what LaBelle sees as a growing importance of site-specificity in modern sound art.⁴⁹

Connecting Historic Advances

The connection to Guido d'Arezzo operates on multiple levels beyond simple geographic proximity. Guido's innovations in musical notation, the staff, solmization, the hexachord system, represented radical abstractions that changed ephemeral sound into permanent visual symbols. The stroke rods perform a conceptual inversion: they convert abstract mathematical relationships of rod lengths, nodal points, harmonic ratios, back into physical sound. Both systems mediate between the conceptual and the experiential, between theory and practice.

The stroke rod installation on Monte Botolino in the municipality of Badia Tedalda, functions as a connection between medieval musical advances and modern sound exploration. This connection is not only symbolic but substantive—both Guido d'Arezzo's system and the stroke rods work within the fundamental principles of acoustic organization and perception. DeNora takes note that such material ties among chronological points in time serve significant cultural purposes in the advancement and permanency of musical practice throughout time.⁵⁰

Musicologist Richard Taruskin notices that the musical theory of the medieval period, whereas regularly depicted as principally hypothetical, in fact had very realistic relevance in pedagogy and performance. The work of Guido d'Arezzo illustrates this practical direction because his theoretical developments were specifically designed to help musical practice.⁵¹ Likewise, the stroke rods, even though being abstractly sophisticated in their acoustic design, set up a perceptible, physical involvement of sound that surpasses pure theory. The intercourse of theoretical complexity with concrete usage illustrates what Small terms “musicking”—music that is something people do rather than only conceptualize.⁵²

The stroke rod installation in Badia Tedalda is representative of a continuum within the tradition of novelty that mixes the understanding of theory and the application of practice. Recognizing the connection between medieval and contemporary methods to sound, the stroke rods shed light on how basic acoustic principles of physics surpass historical epochs as their applications change to reflect shifting artistic and scientific knowledge. Bohlman claims that these continuities are crucial for the cognition regarding the evolution of musical cultures from period to period.⁵³

A 2025 study on place-based virtual reconstruction of heritage soundscapes at Korean UNESCO sites demonstrated that soundscapes create culturally resonant experiences by mixing ritual, architectural, natural, and visitor-related sonic layers that convey intangible cultural value.⁵⁴ The remote mountaintop placement evokes monastic traditions of mountain hermitages in Italian religious history, areas where contemplation took place in deliberate isolation from worldly concerns. The stroke rods installation renovates this tradition into secular sonic meditation, making available what cultural theorist Michel Foucault might term as “heterotopia”, a space that exists outside normal cultural expectations, governed by its own internal logic and temporal structures.⁵⁵

Conclusion

The stroke rods installation on Monte Botolino in the region of Badia Tedalda and the hexachord system of Guido d' Arezzo, even if disconnected almost by a thousand years, establish corresponding methods with the organization of sound and our understanding and experience. These advances display how mathematical associations in acoustics can be coupled for both artistic and pedagogical uses. These innovations initiate structures that make hypothetical acoustic theories concrete and accessible.

The substantive properties of the aluminum stroke rods that are heliarc welded at their midpoints silencing the fundamental frequency and highlighting upper harmonics, construct an exceptional experience that illustrates the laws of vibration and harmonics. Likewise, Guido d'Arezzo's hexachord innovation offers a structure for insights into the relationships among pitches that revolutionized medieval music instruction and set tenets that continue to inspire Western music theory.

The installation of the stroke rods in Badia Tedalda, inside the province of Arezzo, generates a strong symbolic and conceptual connection between these advances. This resonate connection surpasses plain geographic immediacy and sheds light on how methodical techniques to comprehend sound have progressed while preserving connections to elementary acoustic theories.

This inquiry has analyzed the physical acoustic properties of the stroke rods, their installation in Badia Tedalda, and their theoretical connections to Guido d'Arezzo's innovation with the hexachord. It is in this analysis that one can gain understanding of the mathematical connections into sound fabrication that has nourished music theory for centuries, as also grasping the cultural importance of this installation in an area historically connected with musical innovation.

The stroke rods of Badia Tedalda become evidence as both scientific exhibition and artistic gesture—a modern tribute to the methodical approach to sound forged by people such as Guido d'Arezzo. It is in this way that resonant connections represent the enduring dialogue between science and art that has embodied human encounters with sound over all history.

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Technological Advancements in Hospitality through Python-based Bibliometric Analysis

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This paper presents a bibliometric analysis of academic literature at the intersection of technology and hospitality, using Python-based scripting and VOSviewer. A four-stage methodological framework is employed to identify trends, group research into thematic clusters, and explore key topics and their interconnections. First, co-occurrence analysis reveals seven clusters related to technological innovation, digital transformation, artificial intelligence, and post-COVID-19 strategies. Second, articles are assigned to clusters, and top keywords are extracted using Term Frequency–Inverse Document Frequency (TF-IDF), highlighting the thematic focus of each cluster. Third, Latent Dirichlet Allocation (LDA) identifies five dominant topics per cluster, offering insights into the evolving structure of hospitality research. Finally, a topic-based cluster interaction analysis reveals strong connections, particularly among clusters on digital transformation, sustainability, and technology adoption, while others, such as sustainability and customer satisfaction, appear more isolated. These findings suggest emerging or niche areas within the broader discourse. The study contributes methodologically by offering a replicable, data-driven framework for future bibliometric research and thematically by revealing the multidimensional impact of technology in hospitality. By integrating bibliometric techniques with established theories such as the Technology Acceptance Model and Diffusion of Innovation, this work supports a multidisciplinary approach to understanding technological shifts in hospitality scholarship.

Keywords: *Technology in Hospitality, Digital Transformation, Bibliometric Analysis, Artificial Intelligence in Tourism, Sustainability in Tourism, TAM, DOI.*

Introduction

Bibliometric analysis has become an essential tool for understanding the evolving landscape of scholarly research. Notably, within the Scopus database, the use of the keywords "bibliometric analysis" OR "literature analysis," reveals a significant acceleration in the number of publications from 2019 onward. This growth peaked in 2020 and 2021, with an annual increase rate exceeding 50%. This surge is likely attributable to external factors such as technological advancements and heightened research activity in emerging fields. This growing emphasis on bibliometric and content-based mapping approaches also aligns with previous efforts to assess thematic shifts in tourism scholarship as highlighted by Kyrkilis & Nikolaidis, (2022).

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By systematically examining publication patterns, keyword usage, and thematic developments, researchers can gain valuable insights into prevailing trends and emerging areas of interest within specific fields. Previous studies have effectively employed bibliometric analysis using Python to explore various facets of the research landscape. For instance, Krabokoukis (2023a) utilized Python for keyword-based clustering of papers using terms derived from VOSviewer, thereby facilitating a deeper understanding of research themes. Similarly, Krabokoukis and Polyzos (2023) employed VOSviewer to generate clusters that delineate research foci across different geographic regions, revealing the specific areas of study prevalent in each locale. Furthermore, Krabokoukis et al. (2024) conducted a comprehensive analysis of papers based on their methodologies, specifically identifying relevant keywords, and categorizing the papers into corresponding groups, thus providing insights into the diverse approaches adopted in the literature. Additionally, Zeng et al. (2024) utilized Python, MySQL, AI sentiment analysis, and Tableau to examine tourism safety publications. These methodologies underscore the potential of bibliometric tools in elucidating complex research dynamics and highlight the significance of systematic analysis in mapping the evolving contours of academic inquiry. However, a search in Scopus using the keywords "bibliometric analysis" OR "literature analysis" AND "hospitality" OR "tourism" AND "python" yields only two papers, indicating that Python has not been sufficiently leveraged in related studies within the tourism sector, and that there is a lack of studies grounding their methodological approach in established theoretical frameworks.

Theoretical frameworks play a crucial role in guiding research and interpreting findings. For instance, the Technology Acceptance Model (TAM) is one of the most influential models in explaining technology adoption and has been widely used to this end (Li et al., 2024; Mogaji et al., 2024; Sujood et al., 2024). TAM posits that an individual's acceptance and use of a technology are determined primarily by two factors: perceived usefulness (the degree to which a person believes that using a particular system would enhance their job performance) and perceived ease of use (the degree to which a person believes that using a particular system would be free of effort) (Sujood and Pancy, 2024). In the context of this study, TAM provides a framework for understanding how hospitality and tourism professionals and consumers adopt new technologies, such as AI, digital platforms, and big data tools. Additionally, the Diffusion of Innovation Theory offers insights into how innovations spread within a population and helps explain how new ideas and technologies are disseminated (Babolian & Jaszus, 2024; Xu et al., 2024). This theory describes the process by which an innovation is communicated through certain channels over time among the participants of a social system. Key elements of this theory include the characteristics of the innovation (e.g., relative advantage, compatibility, complexity, trialability, and observability) and the stages of the adoption process (Babolian & Jaszus, 2024; Shin & Baek, 2024; Xu et al., 2024). In the context of this study, the Diffusion of Innovation Theory is particularly relevant for examining the adoption of broader technological trends and innovative practices in the hospitality and tourism industries, such as sustainable practices or virtual tourism experiences. These theories provide valuable frameworks for examining the dynamics of technology integration in the hospitality sector.

The study aims to conduct an in-depth bibliometric analysis by employing a novel and integrated methodology consisting of four key steps. First, a co-occurrence analysis will identify patterns and trends within the literature. Next, the significance of keywords within established clusters will be assessed through Term Frequency–Inverse Document Frequency (TF-IDF) analysis. This will be followed by the implementation of topic modeling techniques, specifically Latent Dirichlet Allocation (LDA), to uncover latent thematic structures within the dataset. Finally, the interrelationships among the extracted topics will be examined to elucidate their broader implications for the research landscape. This systematic integration of diverse bibliometric approaches, transcending the limitations of isolated methods, constitutes a significant methodological contribution to the field.

What distinguishes the present study is its systematically structured, four-stage methodological framework, which offers a distinctive and cohesive thematic synthesis. While prior research may have employed individual techniques such as co-occurrence analysis, TF-IDF, or LDA, this study sequentially integrates these methods to establish connections between emergent technological themes with managerial, operational, and consumer-centered dimensions of the hospitality sector. The novelty lies in this deliberate combination and ordering of analytical techniques, along with their targeted application to the hospitality domain, thereby yielding a more holistic and nuanced understanding than previously available. Furthermore, the automation of key analytical steps through custom-developed Python scripts enhances both the reproducibility and computational efficiency of the study.

Based on this methodological framework, the paper addresses the following four research questions.

1. What patterns and trends can be identified in the literature through keyword co-occurrence analysis? This question helps identify factors that may influence 'perceived usefulness' and 'perceived ease of use' (TAM), or the 'adoption rate' of innovations (DOI).
2. Which keywords are most significant within identified clusters, and how do they contribute to understanding the research landscape?
3. How can topic modeling techniques be applied to extract underlying themes from the literature within the selected database?
4. What relationships exist between identified topics, and how do they inform the overall research landscape in the chosen field?

What distinguishes the present study is not merely its application of bibliometric and topic modeling techniques. While prior research has mapped trends or focused on individual domains, this study introduces a structured thematic synthesis that connects emergent technologies with managerial, operational, and consumer-centered dimensions in a replicable and scalable manner. The remainder of the manuscript is structured as follows. Section 2a comprehensive overview of the database utilized in the analysis, along with a detailed description of the study's methodological framework. Section 3 presents an in-depth examination of the results obtained from the bibliometric analysis, highlighting key patterns and trends. Finally, Section 4 discusses the main findings,

offers critical insights into the evolving research landscape, and proposes directions for future investigation.

Methodology and Data

Dataset

To construct the database for this study, a comprehensive search was conducted within the Scopus database using the keywords "technology" and "hospitality" in the fields of Title, Abstract, and Keywords. The search was limited to articles published between 2010 and 2024, focusing exclusively on English-language journals. Table 1 presents a detailed overview of the search results, including the search string used for data retrieval. The Scopus database was selected due to its reputation for providing high-quality scholarly articles and its capability to export substantial datasets in CSV format.

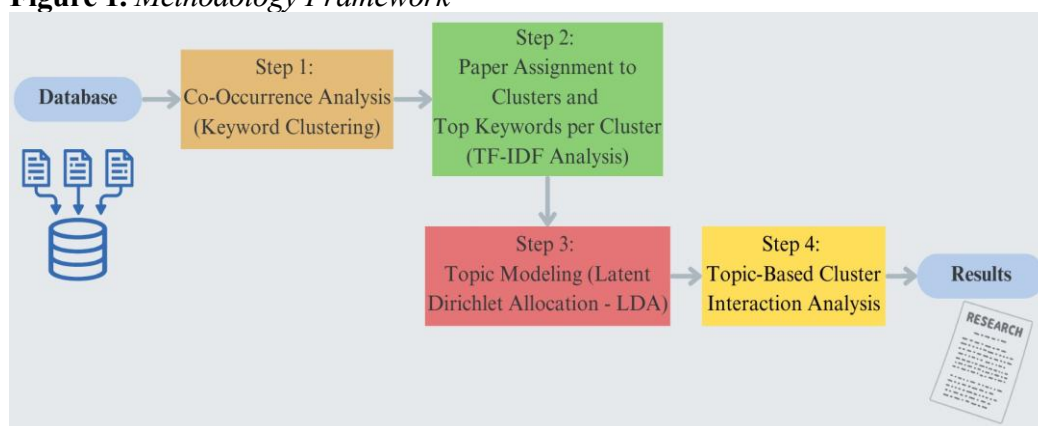
Table 1. *Data Retrieval Constraints and Parameters for the Scopus Database*

Database	Scopus
Search field:	Title, Abstract, Keywords
Keywords:	technology, hospitality
Open access:	All
Years:	2010-2024
Author name:	All
Subject area:	All
Publication stage:	All
Document type:	Article
Source title:	All
Affiliation:	All
Funding sponsor:	All
Country:	All
Source type:	Journal
Language:	English
Search string:	TITLE-ABS-KEY (technology AND hospitality) AND PUBYEAR > 2009 AND PUBYEAR < 2026 AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English"))
Data extracted:	October 2, 2024
Number of publications:	1.485

Source: Authors' own elaboration

Methodological Framework

To address the research questions posed, the analysis is conducted through a systematic four-stage process, as shown in Figure 1, which provides a visual overview of the methodological framework.

Figure 1. Methodology Framework

Source: Authors own elaboration

Each color in the figure corresponds to a specific research question. Research Question 1 is addressed in Stage 1, Research Question 2 is explored in Stage 2. Research Question 3 is analyzed in Stage 3, and Research Question 4 is examined in Stage 4. The four-stage framework is described below:

1. **Co-occurrence Analysis (Keyword Clustering):** A co-occurrence analysis was conducted using VOSviewer to identify thematic clusters of keywords. This step provided an initial mapping of the research field and revealed the most prominent areas of focus.
2. **Paper Assignment and Keyword Extraction (TF-IDF):** Each article was automatically assigned to one or more of the identified clusters, based on the presence of cluster-specific keywords. To highlight the thematic focus of each cluster, Term Frequency–Inverse Document Frequency (TF-IDF) was applied, extracting the most significant keywords.
3. **Topic Modeling (LDA):** Latent Dirichlet Allocation (LDA) was employed to uncover latent thematic structures within each cluster. This allowed for the identification of five dominant topics per cluster, providing deeper insights into the thematic composition of the literature.
4. **Cluster Interaction Analysis:** A topic-based interaction analysis was conducted to examine the degree of similarity and overlap across clusters. By calculating similarity metrics, the study revealed the extent to which research themes are interconnected or remain isolated.

This systematic integration of co-occurrence analysis, keyword weighting, topic modeling, and interaction mapping constitutes a novel methodological approach. The technical details of implementation, including preprocessing steps and Python scripts, are provided in Appendix A and B.

Cluster 1 (red), AI & Automation in Hospitality: This cluster focuses on the integration of artificial intelligence (AI) and automation within the hospitality sector. Key terms include "anthropomorphism," "artificial intelligence," and "robotics," which reflect the increasing reliance on AI technologies to enhance customer experiences and operational efficiency. The presence of terms like "ChatGPT" and "service robots" underscores the trend of utilizing advanced technologies to improve service delivery and customer interaction in hospitality settings. Given this high frequency of these keywords, this cluster is labeled accordingly. Additionally, the keyword "COVID-19 pandemic" indicates the influence of the pandemic on the acceleration of technological adoption in this field. The shift toward automation represents a considerable change in how service work is organized (Tuomi and Ascencao, 2023). Hospitality management literature has begun to conceptualize this transformation, suggesting a move away from mechanical and analytical tasks toward service roles that emphasize intuition and empathy. Furthermore, it is increasingly important for hotels to create distinctive and immersive experiences by leveraging disruptive technologies such as AI, Machine Learning, the Internet of Things (IoT), and Blockchain, while ensuring economic affordability for guests (Aggarwal and Mittal, 2024; Han et al., 2024). Bibliometric analysis shows that the perceived usefulness of AI in increasing operational efficiency and enhancing customer experiences is a major driver of its adoption (TAM). For example, the high weighting of "ChatGPT" and "service robots" suggests that their perceived usefulness in providing 24/7 customer service, automating routine tasks, and personalizing interactions is driving their adoption. Additionally, the sector is in the process of AI adoption, where factors such as technological and organizational complexity can influence the rate and extent of adoption (DOI). For instance, the discussion of 'ChatGPT' and 'service robots' highlights both the relative advantage of these innovations and the potential challenges associated with their implementation.

Cluster 2 (green), Technology Adoption in Hospitality: This cluster highlights the factors influencing the adoption of technology within the hospitality sector and is labeled accordingly. Keywords such as "adoption," "competitive advantage," and "consumer behavior" illustrate the importance of understanding customer preferences and market trends to successfully implement technological solutions. The inclusion of "hospitality education" and "hospitality management" reflects the necessity of ongoing training and development to facilitate effective technology adoption by enhancing both hospitality professionals' and customers' perceived ease of use and perceived usefulness (TAM). Furthermore, the presence of keywords like 'competitive advantage' suggests that technology's perceived relative strategic and operational benefits in enhancing business performance is a significant driver of its adoption (DOI).

Cluster 3 (blue), Digital Transformation in Tourism: Centered on the digital transformation of the tourism industry, this cluster includes terms like "digital technology," "digitalization," and "tourism management" and is labeled accordingly. The presence of "digital transformation" and "online reviews" emphasizes the significance of digital tools and platforms in enhancing customer engagement and streamlining operations. Furthermore, the keywords "Airbnb" and "sharing economy" suggest a shift toward more innovative, technology-driven models within the tourism landscape. The analysis indicates that the adoption of these innovations is transforming how tourism businesses operate, market themselves, and interact with customers.

Specifically, the emphasis on 'online reviews' and 'social media' suggests that tourism businesses perceive these platforms as highly useful for enhancing customer engagement, gathering valuable feedback, and improving marketing effectiveness (TAM). This aligns with broader research showing that digital transformation in tourism spans multiple areas, including city and urban planning, social media, data analytics, and digital destination marketing (Madzik et al., 2023). While TAM helps explain the adoption of specific digital tools, the Diffusion of Innovation Theory (DOI) provides additional context by framing digital transformation as a macro-level innovation diffusing through the tourism sector, driven by factors such as relative advantage and compatibility. However, successfully navigating this transformation also requires addressing challenges such as ensuring that tourism professionals possess the necessary skills to leverage digital tools (Marx et al., 2021) and developing comprehensive strategies that integrate technological advancements with human capital development.

Cluster 4 (yellow), post-COVID-19 Management and Learning: This cluster examines the changes in management practices and learning within the hospitality and tourism sectors following COVID-19. Keywords such as "COVID-19," "learning," and "pandemic" indicate a focus on adapting to new challenges and leveraging lessons learned during the pandemic, and the cluster is labeled accordingly. The inclusion of "management," "performance," and "service quality" highlights the need for enhanced strategies to navigate the evolving landscape of the hospitality industry in a post-pandemic world. The analysis indicates that the urgency and need for contactless solutions spurred by the crisis accelerated the adoption of digital technologies (DOI). This aligns with studies showing how the pandemic boosted the uptake of online learning (Pokhrel & Chhetri, 2021) and forced educators, learners, and managers to re-evaluate how technology could be used to maintain service quality and facilitate learning, shifting perceptions of usefulness and ease of use (TAM).

Cluster 5 (purple), Sustainability and Innovation in Hospitality: This cluster addresses the themes of sustainability and innovation within the hospitality sector. Keywords like "sustainability," "ecotourism," and "innovation" reflect the growing emphasis on sustainable practices and innovative solutions to address environmental concerns, and the cluster is labeled accordingly. The inclusion of terms such as "business" and "customer satisfaction" suggests recognition of the importance of balancing profitability with sustainability in hospitality operations. Results indicate a growing interest in sustainable practices, but their adoption varies depending on perceived relative advantage, complexity, and compatibility (DOI). For example, the perceived usefulness of sustainability practices such as cost savings, enhanced reputation, and increased customer loyalty is a significant factor driving adoption (TAM).

Cluster 6 (light blue), Big Data and IoT in Food Management: Focused on the role of big data and the Internet of Things (IoT) in food management, this cluster includes keywords such as "big data," "food waste," and "technology," and is labeled accordingly. The presence of terms like "decision making" and "food" indicates a strong relationship between data analytics and effective food management practices. Results indicate that food service managers' perceived usefulness of big data and IoT in improving food management and decision-making, such as by reducing food

waste and optimizing resource allocation, is a key driver of their adoption (TAM). This aligns with the emphasis on 'customer satisfaction,' suggesting that leveraging data-driven insights to enhance efficiency in food service can indirectly improve customer experiences. However, the technical and data integration complexities associated with implementing big data and IoT systems may influence the rate of adoption (DOI). The use of smart technologies in other sectors, such as agriculture, where the integration of IoT, cloud computing, machine learning, and artificial intelligence is revolutionizing management practices, offers a model for potential applications in the hospitality industry (Idoje et al., 2021).

Cluster 7 (orange), Enhancing Competitiveness: This cluster explores strategies for enhancing competitiveness within the hospitality and tourism sectors. Keywords such as "competitiveness," "marketing," and "service quality" indicate a focus on differentiating services and improving overall business performance, and the cluster is labeled accordingly. The presence of terms like "customer experience" and "trust" highlights the importance of building strong customer relationships to foster loyalty and drive competitive advantage. Results indicate that hospitality businesses are adopting innovations, such as smart hospitality technologies, to improve their market position and customer satisfaction, driven by the perceived relative advantage and compatibility of these innovations with organizational goals (DOI). For example, the perceived usefulness of technologies that enhance customer satisfaction, such as personalization tools and customer relationship management systems, is a key driver of their adoption (TAM). This aligns with the concept of smart hospitality, which introduces disruptive innovations that reshape the entire hospitality ecosystem by leveraging smart cities and smart tourism to create agile business ecosystems within networked destinations, further enhancing competitiveness and customer engagement (Buhalis et al., 2023). Such thematic isolation echoes earlier observations that certain subfields in tourism, such as rural development or family-run enterprises, often remain disconnected from technological discourses (Koutsou & Milonopoulos, 2021).

To gain a preliminary understanding of the interactions among the clusters, a basic analysis was conducted to identify the common keywords shared between them. This analysis is summarized in Table 2. Among the 112 keywords spanning the seven clusters, the terms "tourism/tourist" and "technology" are particularly noteworthy, as they appeared in multiple clusters. This is expected, given that these keywords served as focal points in the Scopus search used to compile the dataset.

The keyword "management" appears across clusters 2, 3, and 4, underscoring its significance in various contexts within the hospitality and tourism sectors. This highlights the critical role of effective management strategies in navigating the complexities of these industries. Similarly, the recurrence of "COVID-19" in clusters 1 and 4 reflects the profound impact of the pandemic on contemporary research, particularly concerning strategies for recovery in a post-pandemic environment (Krabokoukis, 2023a). The keyword "digital" is present in clusters 3 and 4, emphasizing the essential function of digital technologies in transforming modern management practices and improving service quality following the pandemic (Buhalis et al., 2023; Madzik et al., 2023). Furthermore, the occurrence of "satisfaction" in both clusters 1 and 5 illustrates the increasing recognition of customer satisfaction as a key driver

of success, influencing both technology adoption and sustainability initiatives within the hospitality industry (Veloso et al., 2022; Krabokoukis, 2023b).

Table 2. *Distribution of Common Keywords across Thematic Clusters*

Keyword	Cluster
Management	2, 3, 4
Covid-19	1, 4
Tourism/tourist	1, 2, 3, 5
Technology	1, 2, 3, 4, 5
Digital	3, 4
Satisfaction	1, 5

Source: Authors own elaboration

The uneven distribution of common keywords could be meaningful. For instance, “satisfaction” appears in only two clusters ("AI & Automation", and "Sustainability"), but is absent from the cluster "Digital Transformation", even though TAM emphasizes user perceptions as central to adoption. This could suggest that research in the hospitality sector has yet to systematically link customer satisfaction with the processes of technological adoption. This gap could be an opportunity for future work to integrate consumer psychology with TAM and DOI perspectives.

Step 2: Paper Assignment to Clusters and Top Keywords per Cluster (TF-IDF Analysis)

Building on the methodology outlined by Krabokoukis and Polyzos (2023) in their study "A Bibliometric Analysis of Integrating Tourism Development into Urban Planning", an automated article categorization script was employed to classify the articles into thematic clusters. The script, detailed in Step 2 of the Appendix, utilizes the keywords identified from the VOSviewer analysis to assign each paper in the database to its corresponding cluster. Out of the 1,485 articles in the database, 1,456 were assigned to one or more clusters, revealing a considerable degree of thematic overlap and interaction. This observation aligns with the findings of Step 1, which highlighted shared keywords across clusters. The co-classification of these articles underscores the interconnected nature of the research themes, emphasizing the cross-cutting influence of key topics. The results of this classification are presented in Table 3, which provides a comprehensive overview of the distribution of articles across the thematic clusters.

Table 3. *Distribution of Articles across Thematic Clusters*

Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7
1002	1445	279	1365	753	810	136

Source: Authors own elaboration

Most articles were categorized under Cluster 2 (Green), focusing on Technology Adoption in Hospitality, with a total of 1,445 articles. This was followed by Cluster 4 (Yellow), which addresses post-COVID-19 Management and Learning, comprising 1,365 articles, and Cluster 1 (Red), centered on AI & Automation in Hospitality, which includes 1,002 articles. In contrast, Cluster 3 (Blue), which pertains to Digital

Transformation in Tourism, and Cluster 7 (Orange), focused on Enhancing Competitiveness, garnered the fewest articles, with 279 and 136 papers respectively. Cluster 5 (Purple), Sustainability and Innovation in Hospitality, and Cluster 6 (Light Blue), Big Data and Marketing in Tourism, occupy a middle ground with 753 and 810 articles respectively. To delve deeper into the thematic focus of each cluster, the automated script described in Step 2 was used to extract the top-10 keywords per cluster, along with their corresponding weights. These keywords and their relative importance are summarized in Table 4, offering a clearer insight into the distinctive research themes within each cluster.

Table 4. Top Keywords per Cluster with Weights

Cluster 1		Cluster 2		Cluster 3		Cluster 4	
Keyword	Weight	Keyword	Weight	Keyword	Weight	Keyword	Weight
Tourism	43,26	Tourism	55,63	Tourism	14,92	Tourism	53,05
Study	35,45	Hospitality	47,55	Research	9,82	Study	45,18
Hospitality	34,93	Study	47,35	Study	9,68	Hospitality	44,79
Service	32,16	Research	42,72	Digital	9,54	Research	40,48
Research	31,79	Industry	41,21	Hospitality	9,52	Industry	38,97
Technology	31,29	Technology	40,48	Industry	8,36	Technology	38,92
Industry	28,84	Service	39,73	Hotel	8,32	Service	36,89
Hotel	26,15	Hotel	37,92	Technology	7,79	Hotel	35,61
Ai	24,81	Use	30,21	Technologies	6,64	Use	28,86
Use	23,05	Technologies	27,40	Service	6,50	Data	25,91

Cluster 5		Cluster 6		Cluster 7	
Keyword	Weight	Keyword	Weight	Keyword	Weight
Tourism	30,67	Tourism	39,53	Service	8,08
Study	25,74	Hospitality	28,38	Customer	6,59
Hospitality	25,43	Research	27,74	Study	5,48
Industry	25,05	Study	27,47	Hotel	5,29
Hotel	23,05	Industry	24,65	Satisfaction	5,23
Research	22,75	Technology	23,30	Tourism	4,95
Technology	21,21	Service	20,75	Hospitality	4,74
Service	20,40	Hotel	18,98	Technology	4,61
Innovation	16,79	Data	17,89	Industry	4,52
Business	16,21	Use	17,20	Quality	4,48

Source: Authors' own elaboration

In Cluster 1 (AI & Automation in Hospitality - red), "Tourism" stands as the most prominent keyword, with a weight of 43.26, followed by "Study" (35.45) and "Hospitality" (34.93). This reflects the strong focus on tourism and hospitality research in the context of AI and automation, signifying the sector's emphasis on technological advancements (Tuomi & Ascencao, 2023; Aggarwal & Mittal, 2024; Han et al., 2024). In Cluster 2 (Technology Adoption in Hospitality - green), "Tourism" (55.63) and "Hospitality" (47.55) again dominate, underscoring the integration of technology within these industries. Other keywords such as "Industry" and "Service" highlight the sector's emphasis on operational efficiency and improved service delivery through technology adoption (Buhalis et al., 2023).

Cluster 3 (Digital Transformation in Tourism - blue) displays a more diverse thematic focus. Here "Tourism" (14.92) and "Research" (9.82) are followed by "Digital" (9.54) and "Technology" (7.79), indicating the growing significance of digital technologies in reshaping tourism practices (Marx et al., 2021; Madzik et al., 2023). Cluster 4 (Post-COVID-19 Management and Learning - yellow) features a strong emphasis on "Tourism" (53.05)

and "Study" (45.18), reflecting academic interest in post-pandemic recovery strategies. The presence of "Service" (36.89) and "Technology" (38.92) highlights the critical role of digital adaptation in transformation hospitality services during the post-COVID-19 era (Pokhrel & Chhetri, 2021).

In Cluster 5 (Sustainability and Innovation in Hospitality - purple), the most significant keywords are "Tourism" (30.67) and "Study" (25.74), followed closely by "Hospitality" (25.43) and "Industry" (25.05). The term "Innovation" (16.79) also carries substantial weight, underscoring the sector's increasing commitment to sustainable and innovative practices (Krabokoukis, 2023a). Cluster 6 (Big Data and IoT in Food Management - light blue), is led by "tourism" (39.53) and "hospitality" (28.38), while "technology" (23.30) and "data" (17.89) illustrate the growing reliance on analytics and digital tools for decision-making marketing within tourism and hospitality (Solazzo et al., 2022). Finally, Cluster 7 (Enhancing Competitiveness - orange) is characterized by keywords such as "Service" (8.08), "Customer" (6.59), and "Satisfaction" (5.23). These terms emphasizing the importance of customer-centric strategies in driving competitiveness within the industry (Sharma & Kamble, 2021; Talón-Ballesteros et al., 2022).

Step 3: Topic Modeling (Latent Dirichlet Allocation - LDA)

At this stage, the analysis delves deeper into the clusters to uncover the underlying topics that emerge within each group. In the Table for the Topics of Clusters from Step 3 in the Appendix C, the primary topics for each cluster are presented in detail, alongside their most significant keywords and corresponding weights. Table 5 offers a summary of these topics, showcasing the focus areas and thematic concentrations identified through the LDA analysis.

Table 5. Topics per Cluster

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Topic 0	Understanding technology's role in hospitality	The role of technology in hospitality research	Digital transformation in hospitality	Service innovation through technology in hospitality
Topic 1	Transformative impact of AI and robotics in hospitality services	Innovations in hospitality management	The interplay of tourism and hospitality research	Tourism and hospitality research trends
Topic 2	Technological advances and educational insights in hospitality	Enhancing services delivery through technology	Utilizing technology for business improvement in hospitality	Sustainable practices in hospitality management
Topic 3	Broad implications of technology in the hospitality industry	The intersection of education and hospitality training	Investigating hospitality research methodologies	Technology utilization in hospitality education
Topic 4	Innovation in customer service and management in hospitality	Data-driven insights in hospitality management	Data-driven approaches in hospitality services	Digital transformation in tourism and hospitality

	Cluster 5	Cluster 6	Cluster 7
Topic 0	Technology adoption and service performance in hospitality	Data utilization in tourism and hospitality	Customer satisfaction in hospitality services
Topic 1	Research trends in hospitality and tourism	AI applications in hospitality research	Hotel research and customer insights
Topic 2	Customer perceptions of hotel technology	Implications of research in the hospitality industry	Quality of service in hospitality and tourism
Topic 3	Data-driven innovation in tourism and hospitality	Perceptions of technology use in hospitality	Technology and customer satisfaction in service delivery
Topic 4	Development trends in hospitality technology	Technological advancements in tourism management	Analyzing service quality and customer satisfaction

Source: Authors own elaboration

In Cluster 1 (red), titled "AI & Automation in Hospitality," five distinct topics emerge, each delving into various facets of technology's integration into the hospitality and tourism sectors. Topic 0 is primarily shaped by keywords such as "technology," "study," and "hospitality," which hold the greatest significance, followed by secondary including "tourism," "industry," "research," "customer," "service," "use," and "model." This topic explores how technology is perceived and utilized within the hospitality sector, highlighting the importance of research in understanding its impact (Singh, 2023). Topic 1 is influenced predominantly by the terms "study," "service," "technology," "perceived," "use," and "hospitality," with secondary relevance assigned to "model," "hotel," "intention," and "findings." This topic investigates the role of AI and robotics in hospitality services, focusing on their transformative effects on service delivery and customer interactions (Lu et al., 2024; Fu et al., 2024). Similarly, Topic 2 is primarily shaped by keywords such as "hospitality," "study," and is secondarily influenced by "technology," "tourism," "industry," "research," "findings," "hotel," "students," and "learning." This topic examines how technological advancements intersect with educational aspects and business management within the tourism sector (Akyurek et al., 2024; Gao, 2025; Rong et al., 2025). Topic 3 is significantly influenced by "tourism," "hospitality," "research," "industry," and "technology," with secondary emphasis on "study," "paper," "future," "analysis," and "literature." This topic addresses broader technological implications for the hospitality industry, exploring economic and operational outcomes (Buhalis et al., 2023; León-Gómez et al., 2023; Aggarwal & Mittal, 2024; Han et al., 2024). Finally, Topic 4 is shaped by keywords such as "study," "innovation," "hospitality," "data," "service," "customer," "technology," "tourism," "management," and "students." This topic investigates how technological innovations enhance customer service and operational practices in the hospitality sector, emphasizing the importance of data in driving management strategies and improving customer satisfaction (Bilgihan & Ricci, 2024).

In Cluster 2 (green), titled "Technology Adoption in Hospitality," five distinct topics emerge, each highlighting different dimensions of technology's role in enhancing hospitality education and industry practices. Topic 0: The Role of Technology in Hospitality Research is primarily shaped by keywords such as "study," "hospitality," "research," and "technology," underscoring the significance of academic inquiry into the

adoption and impact of technology in the hospitality sector. Secondary terms such as "findings," "perceived," "use," "value," and "model" provide further context, emphasizing the multifaceted nature of technology's integration in tourism and hospitality (Omran et al., 2024). Topic 1: Innovations in Hospitality Management is influenced mainly by "hospitality," "study," and "technology," with secondary emphasis on "industry," "research," "tourism," "hotel," "data," "innovation," and "findings." This topic investigates how technological advancements drive innovation and operational effectiveness within the hospitality industry (Buhalis et al., 2023; León-Gómez et al., 2023; Aggarwal & Mittal, 2024; Han et al., 2024). Topic 2: Enhancing Service Delivery through Technology revolves around keywords such as "tourism," "hospitality," "service," "research," and "study." It delves into the integration of various technologies, including digital tools and robotics, to improve service delivery and customer experiences (Madzik et al., 2023). Topic 3: The Intersection of Education and Hospitality Training is characterized by keywords such as "learning," "students," and "hospitality," with secondary terms including "education," "study," "technology," "management," "teaching," and "training." This topic highlights the role of technology in shaping hospitality education and professional training methodologies (Akyurek et al., 2024; Gao, 2025). Finally, Topic 4: Data-Driven Insights in Hospitality Management focuses on keyword "hospitality," supported by secondary terms such as "study," "industry," "hotel," "data," "technology," "information," "based," "hotels," and "research." This topic examines how data-driven decision-making contributes to operational efficiency and guest satisfaction within the hospitality sector.

In Cluster 3 (blue), titled "Digital transformation in Tourism," five distinct topics emerge, each examining different aspects of technology's influence within the hospitality and tourism sectors. Topic 0: Digital Transformation in Hospitality is primarily shaped by keywords such as "hospitality," "study," with secondary terms including "technology," "digital," "tourism," "online," "research," "industry," "hotel," and "social." This topic explores the impact of digital innovations on the hospitality landscape and highlights ongoing research efforts aimed at adapting to technological change within the industry. Topic 1: The Interplay of Tourism and Hospitality Research centers on "tourism," "research," and "hospitality," with secondary emphasis on "study," "technology," "industry," "paper," "economy," "service," and "analysis." This topic investigates the interconnectedness of tourism and hospitality research, focusing on how various factors influence service delivery and economic outcomes. Topic 2: Utilizing Technology for Business Improvement in Hospitality is influenced mainly by "hospitality" and "technology," with secondary keywords such as "study," "research," "data," "digital," "tourism," "industry," "use," and "business." It examines how technological tools and data analytics enhance operational efficiency and customer service within hospitality businesses. Topic 3: Investigating Hospitality Research Methodologies centers on "hospitality," "research," and "study," with secondary emphasis given to "service," "technology," "data," "services," "hotels," "industry," and "hotel." This topic focuses on the methodologies employed in hospitality research and their role in advancing domain-specific knowledge. Lastly, Topic 4: Data-Driven Approaches in Hospitality Services is shaped by keywords such as "study," "hotel," "industry," "hospitality," "technology," "research," "service," "data," "digital," and

"online." This topic explores the role of data-driven insights in optimizing service delivery and operational strategies within the hospitality sector.

In Cluster 4 (yellow), titled "Sustainability and Innovation in Hospitality," five distinct topics emerge, each addressing various dimensions of service delivery, technological, integration and environmental considerations in hospitality and tourism. Topic 0: Service Innovation through Technology in Hospitality is primarily influenced by keywords such as "study," "service," "technology," and "hospitality," with secondary terms including "hotel," "research," "use," "findings," and "perceived." This topic examines the role of technological advancements in that enhance service quality and customer satisfaction within the hospitality industry. Topic 1: Tourism and Hospitality Research Trends are shaped mainly by keywords like "tourism," "hospitality," "research," and "industry," with additional emphasis on "technology," "paper," "study," "analysis," and "future." This topic explores emerging research trends that impact both sectors especially regarding technology and future developments. Topic 2: Sustainable Practices in Hospitality Management focuses on keywords such as "food," "waste," "hospitality," "learning," "study," "environmental," "technology," "management," "students," and "green." It examines the environmental implications of hospitality practices, particularly food waste management and integrating sustainable practices into the industry. Topic 3: Technology Utilization in Hospitality Education is influenced primarily by "hospitality," "study," and "technology," with secondary keywords like "industry," "data," "students," "hotel," "management," "use," and "research." This topic focuses on the integration of technology into hospitality education and how it prepares students for the evolving demands of the industry. Finally, Topic 4: Digital Transformation in Tourism and Hospitality is shaped by keywords such as "tourism," "hospitality," "study," "industry," with secondary terms including "technology," "digital," "business," "innovation," "research," and "technologies." This topic investigates the digital transformation in tourism and hospitality, emphasizing the innovative approaches that drive competitiveness and long-term business success.

In Cluster 5 (purple), titled "Sustainability and Innovation in Hospitality," five distinct topics emerge, each highlighting various aspects of the interplay between technology, service delivery, and industry performance in hospitality and tourism. Topic 0: Technology Adoption and Service Performance in Hospitality is primarily influenced by keywords such as "study," "hospitality," "technology," and "service," with secondary terms including "research," "industry," "AI," "performance," "use," and "findings." This topic investigates how the adoption of new technologies, including artificial intelligence, improves service performance and customer experiences within the hospitality sector. Topic 1: Research Trends in Hospitality and Tourism is shaped mainly by keywords like "tourism," "hospitality," "study," and "research," with additional emphasis on "technology," "industry," "innovation," "performance," "analysis," and "hotel." This topic explores emerging research trends that influence both tourism and hospitality industries, particularly in terms of innovative practices and performance metrics (Dowlut & Gobin-Rahimbux, 2023; Fatima & Elbanna, 2023; Luekveerawattana, 2024). Topic 2: Customer Perceptions of Hotel Technology focuses on keywords such as "hotel," "study," "technology," with secondary terms like "research," "hospitality," "use," "tourism," "customer," "industry," and "perceived." It examines customer perceptions of technology used in hotels and its impact on their overall experience.

Topic 3: Data-Driven Innovations in Tourism and Hospitality is influenced primarily by "tourism," "hospitality," "study," "research," "industry," "technology," "data," "analysis," "innovation," and "service." This topic addresses the role of data analytics in driving innovations and improving service delivery within the hospitality sector. Finally, Topic 4: Development Trends in Hospitality Technology is shaped by keywords such as "hospitality," "industry," "tourism," with secondary terms including "technology," "research," "paper," "technologies," "study," "development," and "business." This topic explores technological developments technology development within the hospitality and tourism sectors and their implications for business growth and sustainability.

In Cluster 6 (light blue), titled "Big Data and IoT in Food management," five distinct topics arise, each focusing on different facets of research, technology, and industry dynamics within the hospitality and tourism sectors. Topic 0: Data Utilization in Tourism and Hospitality is primarily influenced by keywords such as "tourism," "data," and "hospitality," with secondary emphasis on "service," "study," "research," "technology," "industry," "services," and "customer." This topic examines the critical role of data in enhancing service delivery and operational efficiency within the tourism and hospitality industries. Topic 1: AI Applications in Hospitality Research centers around keywords like "tourism," "research," "hospitality," and "AI," with additional focus on "service," "study," "industry," "technology," "digital," and "technologies." This topic explores the integration of artificial intelligence in hospitality, analyzing its transformative potential and implications for service and customer interaction. Topic 2: Implications of Research in the Hospitality Industry is shaped by the keywords "hospitality," "tourism," "industry," "research," and "study," along with secondary terms such as "technology," "paper," "value," "findings," and "implications." This topic investigates the impact of research findings on industry practices, emphasizing the importance of applying research to create value in hospitality and tourism. Topic 3: Perceptions of Technology Use in Hospitality focuses on keywords like "study," "tourism," "technology," and "hospitality," with secondary keywords including "use," "research," "social," "perceived," "model," and "findings." This topic examines how perceptions of technology influence its adoption and usage within the hospitality sector. Lastly, Topic 4: Technological Advancements in Tourism Management is influenced by keywords such as "tourism," "study," "hospitality," "research," "technology," "management," "hotel," "technologies," "industry," and "use." This topic delves into the advancements in technology that are shaping tourism management practices, highlighting their relevance to enhancing operational efficiency and customer satisfaction.

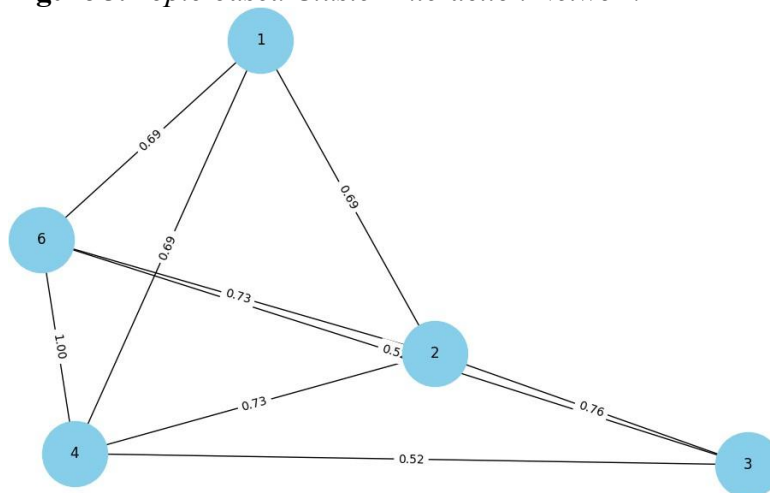
In Cluster 7 (orange), titled "Customer Experience and Service Quality in Hospitality," five distinct topics are identified, each exploring various dimensions of customer satisfaction, service quality, and research. Topic 0: Customer Satisfaction in Hospitality Services is primarily influenced by keywords such as "service," "customer," "satisfaction," and "study," with secondary emphasis on "services," "hospitality," "management," "industry," "technology," and "research." This topic investigates the factors affecting customer satisfaction and the role of service quality in improving experiences. Topic 1: Hotel Research and Customer Insights focuses on keywords like "study," "hotel," "hotels," and "research," with additional emphasis on "hospitality," "customer," "technologies," "technology," "business," and "service." This topic

examines hotel-related research, customer preferences, and the integration of technology to optimize service delivery. Topic 2: Quality of Service in Hospitality and Tourism is shaped by keywords such as "service," "hospitality," "study," "technology," and "industry," with secondary terms including "tourism," "quality," "research," "SST," and "model." This topic explores how service quality contributes to customer satisfaction in both sectors, emphasizing the need for high standards. Topic 3: Technology and Customer Satisfaction in Service Delivery focuses on keywords such as "service," "technology," "study," "customer," and "satisfaction," with secondary emphasis on "hospitality," "industry," "quality," "research," and "tourism." This topic investigates the role of technological tools in enhancing satisfaction and service quality. Lastly, Topic 4: Analyzing Service Quality and Customer Satisfaction is influenced by keywords like "service," "research," "study," "hospitality," and secondary terms such as "quality," "tourism," "technology," "SST," "analysis," and "satisfaction." This topic explores how service quality metrics correlate with customer satisfaction in hospitality settings.

Step 4: Topic-Based Cluster Interaction Analysis

The network density is calculated at 0.90, signifying a high degree of interconnectedness among the various clusters. This elevated density indicates that the topics within the clusters frequently interact and share relevant content, suggesting a rich landscape of relationships in the field of hospitality and tourism research, as evidenced in previous stages of analysis. However, Clusters 5, labeled as AI in Hospitality, and 7, titled Service Quality and Customer Satisfaction, exhibit lower connectivity, both scoring below 0.5. This suggests that these clusters are somewhat isolated, lacking strong links with the others and potentially addressing more niche aspects of the broader topic. These relationships are illustrated in Figure 3, which visually represents the connectivity and interaction strengths among the different clusters.

Figure 3. *Topic-based Cluster Interaction Network*



Source: Authors own elaboration

Clusters 4, known as Sustainable Practices in Hospitality, and 6, referred to as Technological Advancements in Tourism, achieve a perfect density score of 1.

This indicates robust internal cohesion, where topics within the clusters are not only well-connected but also share overlapping discussions. Interaction scores reveal significant relationships involving Cluster 1, (AI & Automation in Hospitality), which shows a connection of 0.69 with both Cluster 6 and Cluster 4, and a slightly stronger score of 0.76 with Cluster 2 (Technological Innovations in Hospitality). These scores suggest that these clusters are closely aligned, contributing to a unified understanding of technology's role in the sector.

Furthermore, Cluster 3, titled Digital Transformation in Hospitality, has moderate interaction scores of 0.52 with both Cluster 4 and Cluster 6, suggesting a degree of connectivity but not as strong as Cluster 1. The interaction between Cluster 2 and Cluster 3 is notably high at 0.76, underscoring a strong thematic alignment between digital transformation and technological innovation in hospitality research. Additionally, the connection between Cluster 2 and Cluster 6 is substantial (0.73), emphasizing the interrelated nature of technological advancements across domains from general adoption to specific applications such as food management. This reinforces the broader trend of technological integration across hospitality subsectors.

Clusters 5, titled Sustainability, and Innovation in Hospitality, and 7, titled Service Quality and Customer Satisfaction, are observed to be relatively isolated, exhibiting lower connectivity with the other clusters. This suggests that they may address more niche aspects of the broader research landscape. In the case of Cluster 5, the relatively lower connectivity might be attributed to a combination of factors. While sustainability is a growing concern within the hospitality industry, its specific applications may constitute a niche subject area, potentially involving specialized methodologies such as environmental science frameworks, life cycle assessments, or green certification systems which are distinct from the more technology-oriented approaches predominant in other clusters. Additionally, sustainability research often emphasizes long-term outcomes and systemic change, which may not directly align with the immediate operational concerns addressed by clusters focused on technology, AI, or digital innovation. It could also be argued that sustainability in hospitality represents an emerging interdisciplinary field, with researchers beginning to fully explore its integration with technology adoption, digital transformation, and operational performance. For example, while there is increasing academic and industry interest in "smart and sustainable" practices, this line of inquiry may still be at a nascent stage of development.

Cluster 7 presents a somewhat different dynamic. While competitiveness and customer satisfaction are central themes in business and management literature, the cluster's emphasis on "customer experience" and "trust" may result in limited interdisciplinary overlap with the technology-centric clusters. Cluster 7 likely draws heavily from disciplines such as marketing, consumer psychology, and behavioral economics, which may have less established links with the technological and operational frameworks that dominate Clusters 1 through 4. Its focus on relational constructs, such as trust and satisfaction, is reflected in its top keywords, which exhibit fewer direct connections to the technological lexicon (e.g., "AI," "robotics," "digital transformation") that drives the connectivity in other clusters. This aligns with the interpretation that customer-centric literature,

while crucial for hospitality, may form a distinct theoretical and methodological domain, somewhat detached from the emergent tech-based research agendas.

These interpretations remain tentative, and further investigation is required to fully elucidate the reasons behind the lower inter-cluster connectivity of Clusters 5 and 7. While the bibliometric analysis provides a valuable macro-level overview, complementary qualitative research, such as systematic reviews, expert interviews, or citation context analysis, could offer deeper insights into the disciplinary boundaries, knowledge flows, and potential integration pathways across the evolving hospitality and tourism research landscape.

The interaction network reveals a highly connected research landscape (density = 0.90), confirming rapid diffusion of technological themes across most subfields. However, Clusters 5 (Sustainability & Innovation) and 7 (Customer Satisfaction & Competitiveness) remain relatively isolated, with interaction scores below 0.5. This isolation could indicate that sustainability research and customer-centered studies operate as parallel domains rather than being integrated into the core technological discourse. From a TAM and DOI perspective, while adoption and efficiency dominate, terms such as perceived usefulness in sustainability or ease of use in customer-facing technologies do not seem to be systematically connected.

Discussion

To enhance clarity and facilitate comparison across clusters, the findings were synthesized, that aligning each cluster with the key constructs of TAM and DOI lens. Table 6 demonstrates that while TAM and DOI explain much of the adoption dynamic in hospitality, several domains remain weakly integrated into the core discourse. These blind spots suggest opportunities for future research and underline the need for theoretical expansion beyond traditional adoption models.

Table 6. *Theoretical Interpretation of Clusters through TAM and DOI*

Cluster	Key Themes	TAM Lens	DOI Lens	Identified Gaps / Implications
<i>AI & Automation</i>	ChatGPT, service robots, automation	Strong perceived usefulness for efficiency and enhanced service delivery.	High relative advantage and observability, but adoption hindered by complexity.	Need for research on balancing automation with personalized service in hospitality.
<i>Technology Adoption</i>	Mobile apps, e-services, customer-facing tools	Reinforces both ease of use and usefulness as key predictors of adoption.	Wide diffusion due to high compatibility with existing practices.	Overemphasis on adoption models; limited exploration of long-term customer impacts.
<i>Digital Transformation</i>	Online reviews, digital platforms, e-tourism	Tools that directly enhance engagement strengthen perceived usefulness.	Rapid diffusion driven by compatibility and observability.	Lack of research connecting digital platforms with broader strategic outcomes.

<i>Post-COVID-19 Management</i>	Contactless tech, crisis-driven adoption	Pandemic shifted perceptions of necessity and ease of use.	Acts as an external shock accelerating diffusion across the sector.	Need for theoretical integration of crisis-driven adoption into long-term frameworks.
<i>Sustainability & Innovation</i>	Green practices, sustainable hotels	Perceived usefulness is less directly visible to managers and customers.	Adoption slowed by complexity and limited observability.	Sustainability remains peripheral to mainstream tech discourse; calls for integration.
<i>Big Data & IoT in Food Management</i>	Data analytics, IoT sensors, waste reduction	High usefulness for resource optimization and efficiency.	Diffusion moderated by technical complexity and integration costs.	Few studies link big data adoption with customer trust and satisfaction.
<i>Customer Satisfaction & Competitiveness</i>	Service quality, trust, competitiveness	Underexplored connection between perceived usefulness and customer experience.	Low connectivity (isolation) suggests weak diffusion links to other clusters.	Highlights a theoretical disconnect: customer-centric constructs not fully tied to adoption theories.

Source: Authors own elaboration

The network density of 0.90 confirms that hospitality technology research is highly interconnected. However, the weaker ties of Clusters 5 and 7 emphasize an uneven diffusion of technological themes across the field. As AI, big data, and digital adoption are examined rapidly, sustainability and customer satisfaction remain partially detached domains.

From this analysis, several key contributions can be identified. First, the findings highlight a lack of integration between sustainability and technology adoption research, suggesting that environmentally oriented innovations remain peripheral to the mainstream technological discourse in hospitality. Second, there is limited theoretical engagement with customer experience literature in the context of digital transformation, despite the centrality of satisfaction and trust in the hospitality domain. Third, while adoption studies dominate the field, relatively few contributions link adoption outcomes to long-term competitiveness and strategic performance. By situating these bibliometric patterns within TAM and DOI, the study shows that hospitality research not only reflects global technological trends but also reveals sector-specific challenges. These include the challenges of integrating sustainability into digital strategies and the theoretical gap between customer-centric approaches and technology adoption models.

Overall, the analysis highlights both the strengths and the shortcomings of current hospitality research. On the strengths side, the high network density confirms that technological adoption is advancing rapidly and in increasingly interconnected ways. However, on the shortcomings side, the marginal position of sustainability and customer satisfaction clusters challenges the comprehensiveness of prevailing theoretical frameworks. While TAM and DOI explain much of the adoption

dynamic, additional theoretical integration is required to capture underexplored but critical domains such as environmental practices and customer experience.

The paper's findings extend TAM by illustrating how perceived usefulness and ease of use vary across technological domains, from AI and automation to big data and digital platforms. Additionally, enrich DOI as the evidence shows that adoption trajectories differ significantly. Some innovations diffuse rapidly due to clear relative advantage and compatibility, while others remain peripheral because of higher complexity and lower observability. This nuanced understanding demonstrates how bibliometric approaches can move beyond methodological contribution to inform and advance theory-building in hospitality.

Closing, the results also offer practical guidance for managers navigating technological transformation. The strong interconnections among clusters indicate opportunities for integrated strategies that simultaneously enhance operational efficiency and customer engagement. Conversely, the relative isolation of sustainability and customer satisfaction clusters serves as a warning for the embodiment of green practices and customer-centric approaches into digital strategies for long-term competitiveness.

Conclusions

Python was employed to conduct an in-depth analysis of the literature concerning the terms "technology" and "hospitality," utilizing a novel four-stage approach. In the first stage, a co-occurrence analysis was performed, which identified seven distinct clusters and highlighted common keywords among them, indicating varying degrees of interconnectivity. In the second stage, the articles were classified into these clusters to determine the primary thematic areas of focus. The top 10 keywords for each cluster were then identified, along with their corresponding weights. This integrated four-stage methodology represents a novel and robust framework for conducting bibliometric analyses in the hospitality domain. In the third stage, Latent Dirichlet Allocation (LDA) was used to identify five primary topics within each cluster, providing a deeper understanding of the thematic structure. This comprehensive process effectively addressed the paper's research questions.

For the first research question, the co-occurrence analysis revealed seven distinct clusters, each representing a key thematic area: AI and automation in Hospitality, Technology Adoption, Digital Transformation in Tourism, Post-COVID-19 Management, Sustainability and Innovation, Big Data and IoT in Food Management, and Service Quality and Customer Satisfaction. The analysis revealed two groups: Clusters 5 and 7 showed interaction scores below 0.5 and demonstrate lower connectivity, suggesting that they represent more niche or disciplinary-isolated domains. In contrast, the remaining clusters exhibited higher interaction scores, suggesting stronger interrelations. The strongest connection was observed between Clusters 4 and 6, followed by notable links between Cluster 2 and Clusters 3, 4, and 6.

For the second research question, TF-IDF was employed to extract the top 10 keywords for each cluster, revealing their unique thematic emphases. For example, Cluster 1 emphasizes terms such as "service," "technology," and "AI," illustrating a strong focus on automation and artificial intelligence, Cluster 3 highlighted terms like

"digital" and "technology," reflecting the significance of digital tools in tourism. Collectively, these findings illustrate the multidisciplinary nature of the research in the domain and the convergence of technological and managerial themes in hospitality studies.

Addressing the third research question, LDA was used to uncover five key topics within each cluster. For instance, within Cluster 1, Topic 1 explored the transformative role of AI and robotics in hospitality operations. In Cluster 2, Topic 0 emphasized the role of technology in advancing hospitality research, particularly through data and innovation. These insights demonstrate the value of topic modeling in identifying sub-themes and specific research trajectories within broader thematic areas.

For the fourth research question, the topic-based cluster interaction analysis revealed a high network density of 0.90, indicating strong interconnectivity among most clusters. Clusters 1, 4, and 6 showed the highest interaction scores, suggesting a shared thematic orientation toward technological transformation. In contrast, Clusters 5 and 7 were relatively isolated, likely reflecting narrower or discipline-specific areas of inquiry such as environmental sustainability or customer experience. Clusters 1, 4, and 6 showed strong interactions, suggesting a unified understanding of technology's transformative role. In contrast, Clusters 5 and 7 showed lower connectivity, indicating more niche areas of focus.

From a methodological standpoint, this study offers a replicable and adaptable framework for conducting large-scale bibliometric and topic modeling analyses in the hospitality and tourism domain. The integration of VOSviewer, Python-based TF-IDF and LDA analysis, and network interaction metrics provides a robust multi-layered approach for exploring research trends, thematic development, and inter-cluster relationships. The identified clusters and associated keywords-topics structures can serve as reference points for future research aiming to identify gaps, emerging themes, or opportunities for interdisciplinary collaboration. From an applied perspective, the findings offer valuable insights for practitioners in the hospitality industry. The identified themes, ranging from AI integration and big data analytics to sustainability practices and customer satisfaction, highlight current technological and managerial trends with direct implications for strategic planning, operations, and workforce training. The emphasis on customer-centric topics such as satisfaction, trust, and perceived value also reinforces the need to align digital innovation with the human aspects of hospitality service delivery.

Throughout this study, the Technology Acceptance Model (TAM) and the Diffusion of Innovation (DOI) theory provided valuable theoretical lenses. TAM was instrumental in explaining technology adoption patterns within Clusters 1, 2, 3, and 6, where perceived usefulness and ease of use were key drivers of acceptance. The findings largely support TAM's assertion but also extend its application by incorporating hospitality-specific factors, such as the balance between automation and personalized service. DOI theory contributed to interpreting the broader diffusion patterns observed in Clusters 3, 4, 5, and 7, where factors like relative advantage, complexity, and external shocks, such as the COVID-19 pandemic, played a role in accelerating or constraining innovation adoption. These frameworks collectively enriched the analysis and provided structure to the interpretation of findings across clusters. In conclusion, this study

contributes both methodologically and thematically to the hospitality and tourism literature. It advances a hybrid bibliometric topic modeling approach that enables scalable and systematic reviews of academic corpora. Thematically, it reveals how the sector has organized around emergent technologies, and digital transformation with clusters reflecting varying degrees of adoption, innovation, and customer integration. These findings carry theoretical implications, suggesting that uneven integration across subfields reflects different stages of technology diffusion and adoption maturity. Future research could build upon this framework by applying similar methods across time series datasets, expanding the scope of analysis, or delving deeper into specific clusters to investigate how academic and industry discourses evolve in response to technological change.

This study demonstrates that a bibliometric framework is not merely a technical exercise but a means of advancing hospitality scholarship. By situating large-scale text mining within TAM and DOI, the research reveals both the strengths of current adoption trajectories and the blind spots where theoretical integration is lacking. Future work could continue to bridge methodology frameworks with theory, building and ensuring that bibliometric tools serve as catalysts for developing richer understandings of technology, sustainability, and customer experience in hospitality. For practitioners, the results highlight the need to align technological adoption with strategic objectives that balance efficiency, innovation, and customer value.

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Appendix

A. Technical Implementation

Tools and Environment	<ul style="list-style-type: none"> • Software: VOSviewer (for keyword co-occurrence analysis) • Programming Language: Python (executed in Google Colab) • Libraries: pandas, scikit-learn (TF-IDF, TfidfVectorizer), gensim (LDA topic modeling), nltk (text preprocessing), networkx (network analysis)
Data Preprocessing	<ul style="list-style-type: none"> • Conversion of text to lowercase • Removal of punctuation, special characters, and stopwords • Tokenization of abstracts and keywords • Construction of a document-term matrix for subsequent analysis
Step 2 – Paper Assignment & TF-IDF	<ul style="list-style-type: none"> • Cluster assignment: Articles were matched to clusters based on keyword presence in titles and abstracts. • TF-IDF extraction: The TfidfVectorizer function from scikit-learn was used to compute keyword weights, allowing the identification of the top-10 keywords per cluster.
Step 3 – Topic Modeling (LDA)	<ul style="list-style-type: none"> • The gensim library was applied to perform Latent Dirichlet Allocation. • Parameters: 5 topics per cluster. • The model was trained on the processed abstracts to extract latent thematic structures.
Step 4 – Cluster Interaction Analysis	<ul style="list-style-type: none"> • Cosine similarity was applied to compare keyword sets across clusters. • A similarity threshold of 0.5 was used to filter meaningful connections. • Network visualization was generated using networkx, representing clusters as nodes and their similarity relationships as edges.

B. Python Scripts

Step 1: Data Reading and Cluster Assignment

```
import pandas as pd
from sklearn.feature_extraction.text import TfidfVectorizer
import numpy as np

# Reading the data
df = pd.read_csv('scopus.csv')

# List of clusters and their associated keywords
clusters = {
    "Cluster 1": ["anthropomorphism", "artificial intelligence", "artificial intelligence (ai)",
"augmented reality", "automation",
"behavioral intention", "bibliometric analysis", "chatgpt", "consumption
behavior", "covid-19 pandemic", "customer experience",
"higher education", "hospitality and tourism", "hospitality technology",
"innovativeness", "machine learning", "metaverse",
"perception", "pls-sem", "robotics", "robots", "satisfaction", "self-efficacy",
"service robot", "service robots",
"structural equation modeling", "systematic review", "tam", "technology
acceptance", "technology acceptance model",
"technology adoption", "tourism and hospitality", "trust", "virtual reality"],

    "Cluster 2": ["adoption", "competitive advantage", "hospitality", "hospitality education",
```

```
"hospitality management", "hospitality services",
    "hotel", "hotels", "human resources management", "ict", "india", "information
and communication", "information systems",
    "information technology", "knowledge management", "literature review",
"malaysia", "mobile technology", "service innovation",
    "smart tourism", "tourism industry"],
```

```
"Cluster 3": ["airbnb", "china", "digital technology", "digital transformation",
"digitalization", "digitization", "empirical analysis",
    "hospitality industry", "internet", "online reviews", "research work", "sharing
economy", "social media", "tourism development",
    "tourism economics", "tourism management", "tourism market", "tourist
behavior", "tourist destination"],
```

```
"Cluster 4": ["article", "consumer behavior", "covid-19", "digital technologies",
"education", "food", "food waste", "human",
    "humans", "learning", "management", "pandemic", "restaurant", "technology"],
```

```
"Cluster 5": ["business", "ecotourism", "hotel industry", "innovation", "knowledge",
"performance", "service sector", "sustainability",
    "sustainable development", "technological development"],
```

```
"Cluster 6": ["big data", "blockchain", "commerce", "decision making", "internet of
things", "marketing", "sales", "tourism"],
```

```
"Cluster 7": ["competitiveness", "customer satisfaction", "self-service technology",
"service quality"]
}
```

```
# Function to check which clusters each paper belongs to
```

```
def assign_cluster(title, abstract):
    assigned_clusters = []
    for cluster_name, keywords in clusters.items():
        for keyword in keywords:
            if keyword.lower() in title.lower() or keyword.lower() in abstract.lower():
                assigned_clusters.append(cluster_name)
                break
    return assigned_clusters
```

```
# Create a new column 'Assigned Clusters' with the cluster assignment for each paper
df['Assigned Clusters'] = df.apply(lambda row: assign_cluster(row['Title'],
row['Abstract']), axis=1)
```

```
# Result: Number of papers per cluster
```

```
cluster_counts = {cluster_name: 0 for cluster_name in clusters.keys()}
multiple_clusters = 0
```

```
for assigned_clusters in df['Assigned Clusters']:
    if len(assigned_clusters) > 1:
        multiple_clusters += 1
```

```

for cluster in assigned_clusters:
    cluster_counts[cluster] += 1

# Print the number of papers assigned to each cluster
print("Number of papers assigned to each cluster:")
for cluster, count in cluster_counts.items():
    print(f"{cluster}: {count}")

print(f"\nNumber of papers assigned to multiple clusters: {multiple_clusters}")

```

Step 2: Extracting Top Keywords Using TF-IDF

```

# Function to extract the top keywords for each cluster using TF-IDF
def get_top_keywords(cluster_abstracts, top_n=10):
    vectorizer = TfidfVectorizer(stop_words='english')
    tfidf_matrix = vectorizer.fit_transform(cluster_abstracts)
    feature_names = vectorizer.get_feature_names_out()
    tfidf_scores = tfidf_matrix.sum(axis=0).A1
    sorted_indices = tfidf_scores.argsort()[::-1][:top_n]
    top_keywords = [(feature_names[i], tfidf_scores[i]) for i in sorted_indices]
    return top_keywords

# Example: Extracting top keywords for each cluster
for cluster in df['Assigned Clusters'].explode().unique():
    cluster_papers = df[df['Assigned Clusters'].apply(lambda x: cluster in x)]
    if len(cluster_papers) > 0:
        top_keywords = get_top_keywords(cluster_papers['Abstract'])
        print(f"\nTop keywords for {cluster}: {top_keywords}")

```

Step 3: Latent Dirichlet Allocation (LDA) Topic Modeling

```

import pandas as pd
from gensim import corpora
from gensim.models import LdaModel
import nltk
from nltk.corpus import stopwords
import re

# Ensure stopwords are downloaded
nltk.download('stopwords')

# List of stopwords
stop_words = set(stopwords.words('english'))

# Function for text preprocessing
def preprocess_text(text):
    # Remove special characters and convert to lowercase
    text = re.sub(r'\W+', '', text.lower())
    # Remove stopwords
    text = ''.join([word for word in text.split() if word not in stop_words])
    return text

# Function for LDA Topic Modeling
def lda_topic_modeling(cluster_abstracts, num_topics=5):

```

```

# Data preparation
processed_abstracts = [preprocess_text(abstract) for abstract in cluster_abstracts]
tokenized_abstracts = [doc.split() for doc in processed_abstracts]

# Create dictionary and corpus
dictionary = corpora.Dictionary(tokenized_abstracts)
corpus = [dictionary.doc2bow(text) for text in tokenized_abstracts]

# Train the LDA model
lda_model = LdaModel(corpus, num_topics=num_topics, id2word=dictionary,
passes=15)

return lda_model

# Example: Apply LDA for each cluster
for cluster in df['Assigned Clusters'].explode().unique():
    cluster_papers = df[df['Assigned Clusters'].apply(lambda x: cluster in x)]
    if len(cluster_papers) > 0:
        lda_model = lda_topic_modeling(cluster_papers['Abstract'], num_topics=5)
        print(f"\nTopics for {cluster}:")
        for idx, topic in lda_model.print_topics(-1):
            print(f"Topic {idx}: {topic}")

```

Step 4: Topic-Based Cluster Interaction Analysis

```

from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.metrics.pairwise import cosine_similarity
import networkx as nx
import matplotlib.pyplot as plt

# Create keyword lists for each cluster
cluster_keywords = {
    1: 'tourism study hospitality service research technology industry hotel ai use',
    2: 'tourism hospitality study research industry technology service hotel use
technologies',
    3: 'tourism research study digital hospitality industry hotel technology technologies
service',
    4: 'tourism study hospitality research industry technology service hotel use data',
    5: 'tourism study hospitality industry hotel research technology service innovation
business',
    6: 'tourism hospitality research study industry technology service hotel data use',
    7: 'service customer study hotel satisfaction tourism hospitality technology industry
quality'
}

# Vectorization for cosine similarity calculation
vectorizer = TfidfVectorizer()
X = vectorizer.fit_transform(cluster_keywords.values())

# Cosine similarity between clusters
similarity_matrix = cosine_similarity(X)

```

```

# Print similarity matrix
print("Cosine Similarity Matrix between clusters:")
print(similarity_matrix)

# Create a graph from the similarity matrix
G = nx.Graph()

# Add nodes and edges based on similarity
clusters = list(cluster_keywords.keys())
for i in range(len(clusters)):
    for j in range(i + 1, len(clusters)):
        if similarity_matrix[i, j] > 0.5: # Threshold increased to avoid irrelevant connections
            G.add_edge(clusters[i], clusters[j], weight=similarity_matrix[i, j])

# Plot the similarity network
pos = nx.spring_layout(G)
plt.figure(figsize=(10, 6))
nx.draw(G, pos, with_labels=True, node_size=3000, node_color='skyblue', font_size=12)
labels = nx.get_edge_attributes(G, 'weight')
nx.draw_networkx_edge_labels(G, pos, edge_labels={k: f'{v:.2f}' for k, v in
labels.items()})
plt.title("Cluster Similarity Network")
plt.show()

# Network density analysis
density = nx.density(G)
print(f"Network density: {density:.4f}")

```

B. Table for the Topics of clusters from Step 3

Cluster 1	
Topic 0	0.012*"technology" + 0.011*"study" + 0.010*"hospitality" + 0.008*"tourism" + 0.007*"industry" + 0.007*"research" + 0.007*"customer" + 0.006*"service" + 0.006*"use" + 0.005*"model"
Topic 1	0.018*"study" + 0.017*"service" + 0.013*"technology" + 0.012*"perceived" + 0.011*"use" + 0.010*"hospitality" + 0.008*"model" + 0.008*"hotel" + 0.008*"intention" + 0.008*"findings"
Topic 2	0.015*"hospitality" + 0.014*"study" + 0.009*"technology" + 0.008*"tourism" + 0.007*"industry" + 0.006*"research" + 0.006*"findings" + 0.006*"hotel" + 0.006*"students" + 0.006*"learning"
Topic 3	0.025*"tourism" + 0.020*"hospitality" + 0.017*"research" + 0.012*"industry" + 0.010*"technology" + 0.009*"study" + 0.008*"paper" + 0.006*"future" + 0.006*"analysis" + 0.005*"literature"
Topic 4	0.009*"study" + 0.008*"innovation" + 0.006*"hospitality" + 0.006*"data" + 0.006*"service" + 0.006*"customer" + 0.005*"technology" + 0.004*"tourism" + 0.004*"management" + 0.004*"students"
Cluster 2	
Topic 0	0.015*"study" + 0.014*"hospitality" + 0.012*"research" + 0.012*"technology" + 0.008*"findings" + 0.008*"perceived" + 0.007*"use" + 0.007*"value" + 0.007*"model" + 0.007*"tourism"
Topic 1	0.016*"hospitality" + 0.013*"study" + 0.011*"technology" + 0.010*"industry"

	+ 0.007*"research" + 0.007*"tourism" + 0.007*"hotel" + 0.007*"data" + 0.006*"innovation" + 0.005*"findings"
Topic 2	0.021*"tourism" + 0.015*"hospitality" + 0.012*"service" + 0.011*"research" + 0.011*"study" + 0.010*"industry" + 0.009*"technology" + 0.006*"digital" + 0.005*"technologies" + 0.005*"robots"
Topic 3	0.018*"learning" + 0.017*"students" + 0.010*"hospitality" + 0.009*"education" + 0.008*"study" + 0.007*"technology" + 0.006*"management" + 0.006*"teaching" + 0.005*"training" + 0.005*"research"
Topic 4	0.010*"hospitality" + 0.007*"study" + 0.007*"industry" + 0.007*"hotel" + 0.006*"data" + 0.005*"technology" + 0.005*"information" + 0.005*"based" + 0.005*"hotels" + 0.004*"research"
Cluster 3	
Topic 0	0.012*"hospitality" + 0.011*"study" + 0.009*"technology" + 0.009*"digital" + 0.008*"tourism" + 0.008*"online" + 0.008*"research" + 0.007*"industry" + 0.006*"hotel" + 0.006*"social"
Topic 1	0.027*"tourism" + 0.011*"research" + 0.010*"hospitality" + 0.008*"study" + 0.007*"technology" + 0.006*"industry" + 0.005*"paper" + 0.004*"economy" + 0.004*"service" + 0.004*"analysis"
Topic 2	0.012*"hospitality" + 0.011*"technology" + 0.009*"study" + 0.008*"research" + 0.007*"data" + 0.007*"digital" + 0.006*"tourism" + 0.006*"industry" + 0.005*"use" + 0.005*"business"
Topic 3	0.015*"hospitality" + 0.012*"research" + 0.012*"study" + 0.007*"service" + 0.007*"technology" + 0.007*"data" + 0.007*"services" + 0.006*"hotels" + 0.006*"industry" + 0.006*"hotel"
Topic 4	0.012*"study" + 0.009*"hotel" + 0.008*"industry" + 0.008*"hospitality" + 0.007*"technology" + 0.007*"research" + 0.006*"service" + 0.006*"data" + 0.006*"digital" + 0.005*"online"
Cluster 4	
Topic 0	0.017*"study" + 0.014*"service" + 0.012*"technology" + 0.011*"hospitality" + 0.009*"hotel" + 0.009*"research" + 0.008*"use" + 0.007*"findings" + 0.007*"perceived" + 0.007*"customer"
Topic 1	0.018*"tourism" + 0.018*"hospitality" + 0.016*"research" + 0.010*"industry" + 0.009*"technology" + 0.007*"paper" + 0.006*"study" + 0.006*"analysis" + 0.005*"technologies" + 0.005*"future"
Topic 2	0.008*"food" + 0.008*"waste" + 0.007*"hospitality" + 0.007*"learning" + 0.007*"study" + 0.006*"environmental" + 0.005*"technology" + 0.005*"management" + 0.004*"students" + 0.004*"green"
Topic 3	0.015*"hospitality" + 0.013*"study" + 0.011*"technology" + 0.008*"industry" + 0.007*"data" + 0.007*"students" + 0.006*"hotel" + 0.006*"management" + 0.006*"use" + 0.005*"research"
Topic 4	0.014*"tourism" + 0.011*"hospitality" + 0.011*"study" + 0.010*"industry" + 0.009*"technology" + 0.007*"digital" + 0.006*"business" + 0.006*"innovation" + 0.005*"research" + 0.004*"technologies"
Cluster 5	
Topic 0	0.015*"study" + 0.011*"hospitality" + 0.010*"technology" + 0.010*"service" + 0.008*"research" + 0.007*"industry" + 0.007*"ai" + 0.006*"performance" + 0.006*"use" + 0.006*"findings"
Topic 1	0.014*"tourism" + 0.012*"hospitality" + 0.012*"study" + 0.010*"research" + 0.009*"technology" + 0.007*"industry" + 0.006*"innovation" +

Topic 2	0.005*"performance" + 0.005*"analysis" + 0.005*"hotel" 0.013*"hotel" + 0.012*"study" + 0.010*"technology" + 0.009*"research" + 0.008*"hospitality" + 0.007*"use" + 0.006*"tourism" + 0.006*"customer" + 0.006*"industry" + 0.006*"perceived"
Topic 3	0.009*"tourism" + 0.009*"hospitality" + 0.008*"study" + 0.007*"research" + 0.006*"industry" + 0.006*"technology" + 0.005*"data" + 0.004*"analysis" + 0.004*"innovation" + 0.004*"service"
Topic 4	0.020*"hospitality" + 0.017*"industry" + 0.015*"tourism" + 0.008*"technology" + 0.008*"research" + 0.007*"paper" + 0.007*"technologies" + 0.006*"study" + 0.006*"development" + 0.006*"business"
Cluster 6	
Topic 0	0.017*"tourism" + 0.012*"data" + 0.010*"hospitality" + 0.009*"service" + 0.008*"study" + 0.008*"research" + 0.007*"technology" + 0.006*"industry" + 0.005*"services" + 0.005*"customer"
Topic 1	0.028*"tourism" + 0.016*"research" + 0.015*"hospitality" + 0.012*"ai" + 0.008*"service" + 0.008*"study" + 0.007*"industry" + 0.007*"technology" + 0.007*"digital" + 0.006*"technologies"
Topic 2	0.020*"hospitality" + 0.019*"tourism" + 0.012*"industry" + 0.012*"research" + 0.010*"study" + 0.008*"technology" + 0.007*"paper" + 0.006*"value" + 0.005*"findings" + 0.005*"implications"
Topic 3	0.017*"study" + 0.012*"tourism" + 0.012*"technology" + 0.011*"hospitality" + 0.009*"use" + 0.008*"research" + 0.007*"social" + 0.007*"perceived" + 0.007*"model" + 0.007*"findings"
Topic 4	0.009*"tourism" + 0.008*"study" + 0.007*"hospitality" + 0.007*"research" + 0.007*"technology" + 0.006*"management" + 0.005*"hotel" + 0.005*"technologies" + 0.005*"industry" + 0.004*"use"
Cluster 7	
Topic 0	0.016*"service" + 0.015*"customer" + 0.010*"satisfaction" + 0.010*"study" + 0.008*"services" + 0.008*"hospitality" + 0.007*"management" + 0.007*"industry" + 0.007*"technology" + 0.006*"research"
Topic 1	0.013*"study" + 0.013*"hotel" + 0.011*"hotels" + 0.010*"research" + 0.009*"hospitality" + 0.008*"customer" + 0.007*"technologies" + 0.007*"technology" + 0.006*"business" + 0.006*"service"
Topic 2	0.016*"service" + 0.014*"hospitality" + 0.011*"study" + 0.010*"technology" + 0.010*"industry" + 0.008*"tourism" + 0.007*"quality" + 0.006*"research" + 0.006*"sst" + 0.005*"model"
Topic 3	0.023*"service" + 0.014*"technology" + 0.012*"study" + 0.012*"customer" + 0.010*"satisfaction" + 0.009*"hospitality" + 0.009*"industry" + 0.008*"quality" + 0.007*"research" + 0.007*"tourism"
Topic 4	0.014*"service" + 0.013*"research" + 0.011*"study" + 0.010*"hospitality" + 0.008*"quality" + 0.008*"tourism" + 0.007*"technology" + 0.007*"sst" + 0.006*"analysis" + 0.006*"satisfaction"

The Challenge of Renewing Djerba as a Destination in the Age of Sustainable Development and Digital Technology

By Mohamed Hellal & Taha Bouchaddakh[‡]*

Over time, tourism has changed its relationship with the island of Djerba. At the start of its development, tourism to this island in south-east Tunisia was more territorial than the mass beach tourism of today, which is concentrated in the eastern coastal area of the island. This has had consequences for the destination itself, which has shown little resilience in the face of crises (Hellal, 2021), and has been responsible for the permanent closure of several hotels in Djerba, which are signs of the end of the tourism cycle (Butler, 1980). So, after the upheaval of the island's economic system under the crushing weight of tourism, the latter is now tending to renew itself in order to survive. This is reflected in the attempt to upgrade the existing tourism product by diversifying it and renewing the image of the island, which is overflowing with heritage assets. With a view to developing tourism in Djerba on a regional basis, local stakeholders are being encouraged to develop events and to promote the island's cultural assets as a way of enhancing its appeal. In the age of digital technology and m-tourism, mobile applications are helping to develop a form of tourism that is more local and more sustainable. By way of problem, we ask here: how can Djerba's tourism system, which is reputed to be a mass tourism destination, meet the challenge of renewing its image in the age of sustainable development and digital technology? To answer this question, we use direct observations and interviews in the field, supported by official statistics on the development of tourism in Djerba and webgraphic research, which are compared with theory and literature.

Keywords: *Djerba, tourism, image, renewal, sustainable and digital development*

Introduction

Djerba has been an established tourist destination since the 1960s. It has benefited from its island location and rather rural lifestyle to forge its own specific image: 'Djerba la douce'. However, it has also fallen victim to the development of mass tourism, which has had a detrimental effect, particularly on the environment: erosion of the coastline, pollution from solid waste, depletion of water resources, and so on. This has had consequences for the destination itself, which has shown little resilience in the face of crises, and has been responsible for the permanent closure of several hotels, which are signs of the end of the tourism cycle (Butler 1980) in Djerba. So, after the upheaval of the island's economic system under the crushing weight of tourism, the latter is now tending to renew itself in order to survive. This is reflected in the attempt to regenerate the existing tourist activity by diversifying it and renewing the image of the island, which is overflowing with heritage assets.

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With the change in international demand, island destinations such as Mallorca (Segui Llinas 2000) and French Polynesia (De Barnier et al. 2024) have been forced to develop new products other than seaside tourism. The development and governance of tourism across the entire destination contributes to its resilience (Gardère 2022, Delaplace et al. 2018). Thus, the use of digital technology and artificial intelligence contributes to the spread of tourism across the territory and to improving interaction between tourists and locals (Larbi et al. 2021, Viallon and Merah 2025).

What's more, today's 'tourism experience' can only be envisaged through encounters with the societies and individuals who evolve in the environments visited and who become objects of discovery. This approach to deploying inclusive tourism makes it possible to envisage territorial development processes based on the income generated by more carefully thought-out and organised tourist consumption (Blamey 2001, quoted by Dehorne 2011). In this context of the 're-territorialisation' of tourism in Djerba (Binkhorst and Den Dekker 2009, Neuhofer et al. 2012), local stakeholders have the opportunity to develop events and brand the island's cultural assets to enhance its appeal. In the age of digital technology and m-tourism, mobile applications are helping to develop a form of tourism that is more local and more sustainable.

The tourism system (Hellal 2020, Knafou and Fournier 2023) of Djerba, recognised as a mass tourism destination, faces the challenge of renewing its image in the context of sustainable development and digital transformation. Thus, the central question of this article is: how does Djerba's tourism system, which is reputed to be a mass tourism destination, meet the challenge of renewing its image in the era of sustainable development and digital transformation? To answer this question, we use direct observations and interviews in the field, supported by official statistics on the development of tourism in Djerba and webgraphic research, all of which are compared with theories in the literature.

To better explore governance issues in the island territory of Djerba, we analyzed local statistical data and conducted 22 semi-structured interviews with 13 municipal officials and 9 local elected representatives from the municipality of Houmt Souk in 2021, supplemented by 12 additional semi-structured interviews conducted in 2024 with experts in local governance and decentralization and local officials (mayors and municipal councilors).

Djerba: A Mass Tourism Destination at the End of the Cycle

Over time, tourism has changed its relationship with the island of Djerba. At the start of its development, tourism to this island in south-east Tunisia was more territorial than the mass seaside tourism of today, which is concentrated in the coastal area around the commune of Midoun, and which turns its back on the island's built-up areas.

Kassah and Bourgou (2008) consider foundouks to be the first tourist establishments in Djerba. These establishments were designed to accommodate foreigners passing through, whatever their reason for coming to Djerba: merchants, civil servants, craftsmen, fishermen, missionaries and others. These foundouks, of which there were around twenty, are concentrated in the main town of Djerba: Houmet Essouk. These are

traditional 2-storey structures with a patio serving as an inn for travellers, a shop for goods and a stable for draught animals.

The location of these fondouks in the old urban centre, Houmet Essouk, reflected its multiple functions as the 'capital of the island', fishing port and commercial centre for the whole island. In modern times, urban development was gradually grafted onto this ancient core, before the socio-economic system was turned upside down by the development of mass tourism.

The first modern hotel dates back to the early 1930s. It had just 25 rooms and was paradoxically called 'the Grand Hotel'. The arrival on the scene of an international tourism player was to give a new impetus to tourism and give it its current character of seaside tourism geared towards a large clientele. This was Club Méditerranée, which set up a holiday village in Djerba in 1954. This club represented the start of international mass tourism on the island. Since then, tourism in Djerba has developed as an extroverted sector geared towards satisfying the needs and expectations of a European clientele. The main attractions that fascinated this European clientele at the time were the oasis landscape, the fine sandy beaches and the peaceful lifestyle. To these resources, we must add a major asset for Djerba: its island character.

In the early 1960s, the role of the state after independence was paramount in the development and establishment of a modern infrastructure: hotels, roads, drinking water supply, electricity and telephone network, sewage treatment plant, airport, in addition to encouraging private investment.

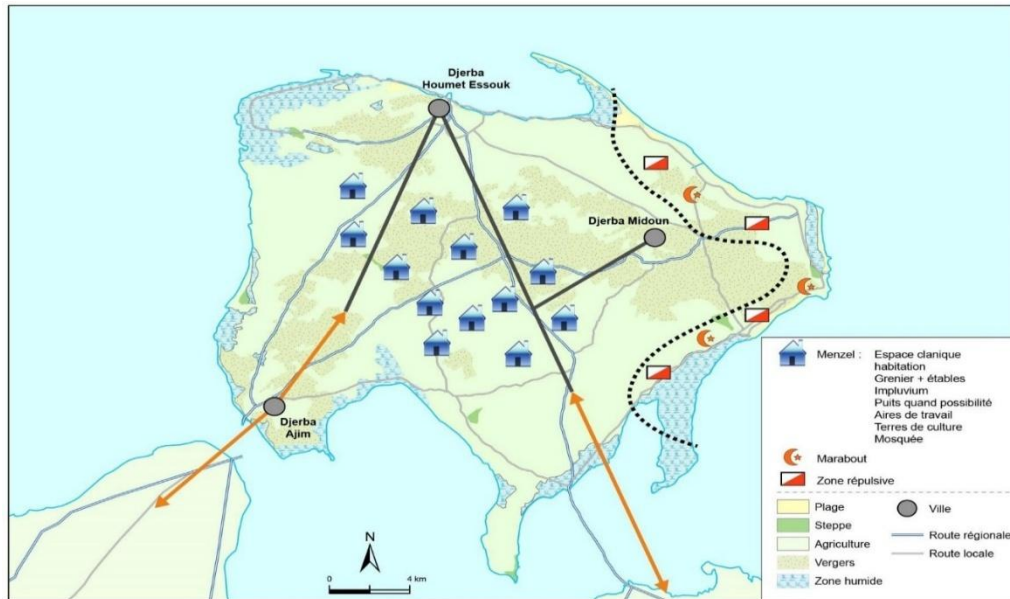
After Club-Med, El Jazira was the result of the initiative of a tourism promoter who set up a hotel on the island's eastern coastline. This unit was built very close to the beach and on the edge of the dune. This was the first attack on the fragile coastal ecosystem. The beach quickly deteriorated and the waves attacked the hotel.

Since the 1960s, with the development of mass seaside tourism and the emergence of Djerba as a destination, tourist accommodation has continued to grow at a steady pace. In 1967, tourist accommodation capacity in the south-east, including Djerba, which accounts for most of the capacity, was 3,349 beds, or 18% of the accommodation capacity of the whole of Tunisia. Between 1962 and 1971, more than 6,000 beds were created in 20 hotels. In 1973, the island of Djerba already had around 7,500 beds. Ten years later, capacity had risen to 8,650 beds (Kassah and Bourgo 2008).

In 2003, the Jerba-Zarzis-Gabès tourist zone had a total of 49,317 beds, accounting for 22% of national capacity. In 2019, the Djerba-Zarzis zone had 53,079 beds spread over 144 hotel establishments. During the same year, it recorded 1,214,495 tourist arrivals and 7,222,833 overnight stays (ONTT 2019). In addition to hotels, Djerba also has other types of tourist establishments: apartment hotels, guest houses, etc. There are also thousands of second homes on the island of Djerba, especially near the coast.

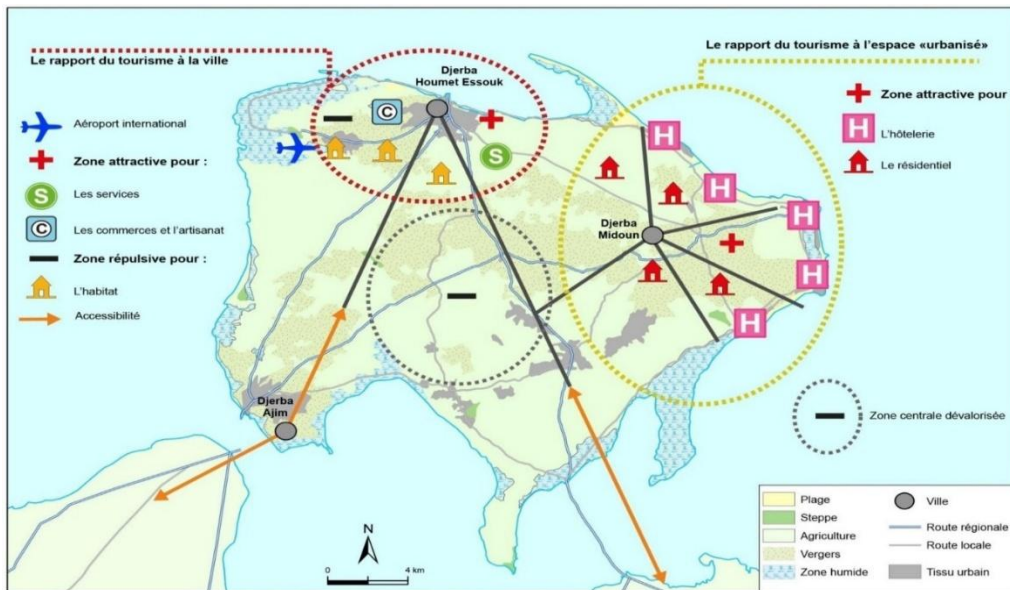
In Djerba, the majority of hotels are located on the eastern and southern coasts, which fall within the municipality of Midoun. Tourist establishments occupy the entire seafront over a length of around 30 km. The entire island is thus influenced by the expansion of the tourism sector. On the other hand, the centre of the island is marginalised from this sector. As a result, the island's territory, which is by definition fragile, is under strain and suffering irreversible damage. This territorial and ecological imbalance even threatens tourism, whose future depends on the quality of the surrounding environment (see Figure 1 and 2).

Figure 1. The Organisation of the Djerbian Territory before the Development of Mass Tourism



Source: UNEP/MAP2011, reproduced by M. HELLAL

Figure 2. The Organisation of the Island Territory after the Development of Mass Tourism



Source: PNUE /PAM2011, reproduced M. HELLAL

In her doctoral thesis, Dribek A. (2013) clearly shows that human action linked to the establishment of tourist activity in Djerba, as well as the island's specific natural features, are gradually weakening the balance of the natural coastal environment. The beach at the El Jazira hotel has disappeared due to coastal erosion. Between the Sirène and Dar Midoun hotels, the beautiful beaches have also begun to deteriorate. Then, at the Club Med Djerba la Fidèle, the beach has retreated significantly and outcrops are

visible. However, action is being taken to deal with the damage. Most often, these involve the construction of defence works using large boulders on the foreshore or the creation of groins and riprap by the APAL (Agence de Protection et d'Aménagement du Littoral - Coastal Protection and Development Agency). But as well as being unsightly, these structures sometimes pose an additional threat by exacerbating erosion.

In addition to the saturation of the tourist zone, the interior of the island has also suffered the effects of the expansion of the urban fabric. In addition to the urban sprawl of farmland, the high demand for building materials has led to the uncontrolled and illegal quarrying of sand and stone. Similarly, the island's territory has been invaded by uncontrolled rubbish dumps as a result of the explosion in the number of holidaymakers, tourists and secondary residents during the summer season.

Finally, the island of Djerba has suffered the full impact of mass beach tourism. In the new climate of sustainable development, tourism on the island is forced to renew itself if it is to survive.

Attempts by Local Stakeholders to Renew the 'Djerba Destination' through Labelling and Events

The island of Djerba boasts a rich and varied architectural, archaeological and craft heritage, with the island's specific human settlement pattern centred around the *menzels*, the traditional rural houses (Bourgou & Kasah, 2008). These are mainly structures that have fostered traditional economic activities around underground oil mills, weaving workshops, lime kilns and potters' kilns, but above all thanks to a varied agriculture, despite an arid climate, producing unique local products such as the Djerba sweet apple, the Meski grape, the Baccour apricot tree, the Djerba fig, the "sakasli" lime, and the "Lemsi" and "Metata" dates.

Thanks to its coastline and position in the Gulf of Gabès, the island of Djerba benefits from a certain wealth of fishery resources, which has led to significant fishing activity, particularly through the fixed 'zrayeb' fisheries (which have nothing to envy the Cherfia of Kerkenah, a UNESCO World Heritage site), sponge fishing and octopus fishing (Tlatli 1967).

Sixty years on from the development of this one-size-fits-all economic model, the area is overexploited and the island ecosystem is under threat (Mansour L., 2017). Faced with this situation, civil society organisations such as the Association for the protection of the island of Djerba (ASSIDJE founded in 1975), and other younger organisations that emerged just after the Revolution, are raising awareness of the environmental (waste management) and heritage (preservation of vernacular architecture) issues. This mobilisation is part and parcel of citizen participation in environmental management, which has been encouraged by the climate of climatic transition since the outbreak of the Tunisian revolution on 17 December 2010.

Since then, Djerba has seen a number of sustainable development initiatives, such as the Djerba Smart Island. This idea, promoted by the Tunisian Smart Cities

association¹, aims to boost the island's capacity to produce renewable energy, optimise waste management and facilitate land access to the island as part of an inter-communal approach.

Green Djerba is another societal initiative, the aim of which is to develop a strategic vision for establishing a sustainable development label for the island of Djerba. The aim is to ensure better sectoral and territorial organisation, as well as efficient mobilisation of residents and tourists. The initiative seeks to strengthen the capacities of local authorities in terms of decentralisation and local governance, by rehabilitating the brand image of the island of Djerba as a distinguished tourist destination on a national and international scale, and by ensuring greater resilience of the natural and cultural heritage in the face of environmental degradation and the risks associated with the impacts of climate change.

Figure 3. Logo Green Djerba



Source: <https://www.green-djerba.net/>

Another initiative aimed at raising Djerba's profile is the preparation of a file for its inclusion on UNESCO's World Heritage List as a unique living environment. The island boasts 250 archaeological sites, including Mininx, which was originally a Phoenician trading post before becoming a prosperous city in Roman times. The built heritage of other eras (Menzel, Houch, mosques, fondouks, oil mills, etc.) also constitutes an Outstanding Universal Value (OUV) selected for Djerba's application. This approach is in line with the criteria defined by UNESCO for the recognition of World Heritage sites, which include historical, cultural and architectural significance (UNESCO 2008).

Studies on heritage enhancement and its impact on local development argue that World Heritage listing can have significant effects on heritage conservation and promotion, while strengthening local identity and stimulating tourism (Labadi, 2013; Ashworth, 1994). Indeed, the inscription of sites on the World Heritage List is often associated with an increase in international visibility and economic and social benefits for local communities (Fyall and Rakic 2006).

The preparation of Djerba's nomination dossier also involves close collaboration with local communities and authorities, an approach advocated by heritage management experts to ensure inclusive participation and sustainable management of heritage sites.

Finally, on 18 September 2023, Djerba was officially included on the World Heritage List at the 45th enlarged session of the World Heritage Committee in Saudi Arabia. This international label is a useful advertising tool for renewing Djerba's tourist image.

¹L'association Tunisian Smart Cities est une association nationale de prospection, porteuse du programme qui sera matérialisé à terme par un réseau national des villes intelligentes. <https://www.tunisiansmartcities.com/whoarewe.php>.

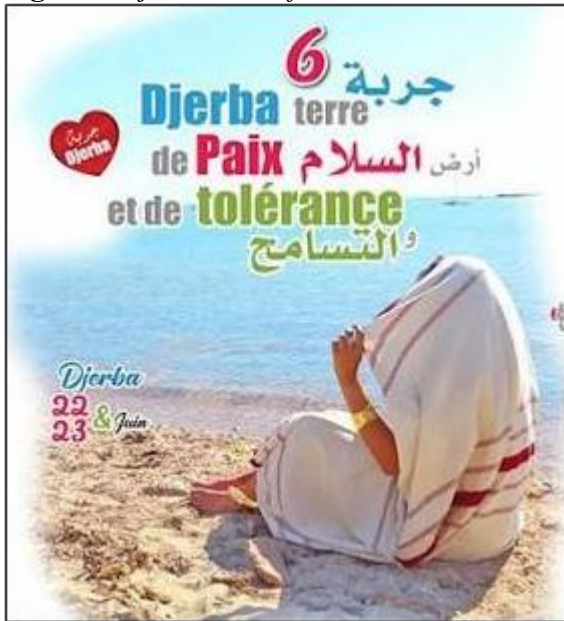
Figure 4. Logo Djerba World Heritage Site

Source: <https://www.facebook.com/Djerba.UNESCO/>

Local stakeholders are trying to improve the image of their island through events linked to its heritage. In fact, ‘Djerba land of peace and tolerance’ is an event organised every first Sunday in June since 2014 by the Hibiscus Association² with the aim of promoting tourism in Tunisia and Djerba through one of Djerba's special features: tolerance and peace between the island's inhabitants. In this island territory, the three monotheistic religions (Islam, Christianity and Judaism) have always coexisted in exceptional social peace. This ‘Djerba - Land of Peace and Tolerance’ events initiative is part of a wider strategy of territorial marketing and image management, essential for attracting tourists and strengthening local identity (Kotler et al. 1993). Here, in the case of Djerba, territorial marketing uses cultural events to create a positive and distinctive image of a place, which can have significant effects on tourist appeal and social cohesion (Hospers 2011).

By highlighting religious tolerance and social peace, this type of event helps to reinforce a sense of belonging and identity among local residents, while drawing tourists' attention to the unique cultural and heritage aspects of Djerba. The result is a climate of tolerance and security that encourages the spread of tourism throughout the island.

²<https://www.facebook.com/hibiscus.djerba/>

Figure 5. *Djerba Land of Peace and Tolerance Poster*

Source: <http://kapitalis.com/tunisie/2019/06/21/hibiscus-djerba-organise-djerba-terre-de-paix-et-de-tolerance>

The XVIIIth Summit of the Francophonie, to be held in November 2021, is the most important event on which local stakeholders are betting to give a new lease of life to the destination of Djerba following the tourism crisis linked to the COVID-19. The member countries of the Francophonie meet every two years and their Heads of State are present, making it a high-profile event.

In Tunisia, at least in the case of Djerba, the transition to a more decentralized form of governance, despite being enshrined in the 2022 Constitution, remains incomplete. Many respondents cited an institutional context marked by instability, persistent centralization, and opaque decision-making processes. Seventy-five percent of respondents (9 out of 12) consider that the absence of regulatory texts implementing Organic Law No. 2018-29 is the main obstacle to the effective implementation of local autonomy. This legal recognition of local authorities as the fourth branch of government therefore remains largely theoretical, which weakens their ability to promote appropriate territorial development policies.

Finally, 20 respondents (90.9%) emphasize the lack of a collective and coherent narrative around Djerba. The image of the destination remains fragmented, trapped in stereotypical representations (beach, sun, folklore), without strong links to contemporary issues of sustainability, social justice, or digital transition.

Using Digital Technology to attract Tourists to Djerba

Today, digital marketing is emerging as a response to the need to enhance the attractiveness of regions (Cova and Cova 2009). Digital communication, particularly via the social web, is emerging as a means of diversifying the brand's message, going beyond its traditional role. Consumer-citizens, referred to as 'consom'actors' (Aubry, C.

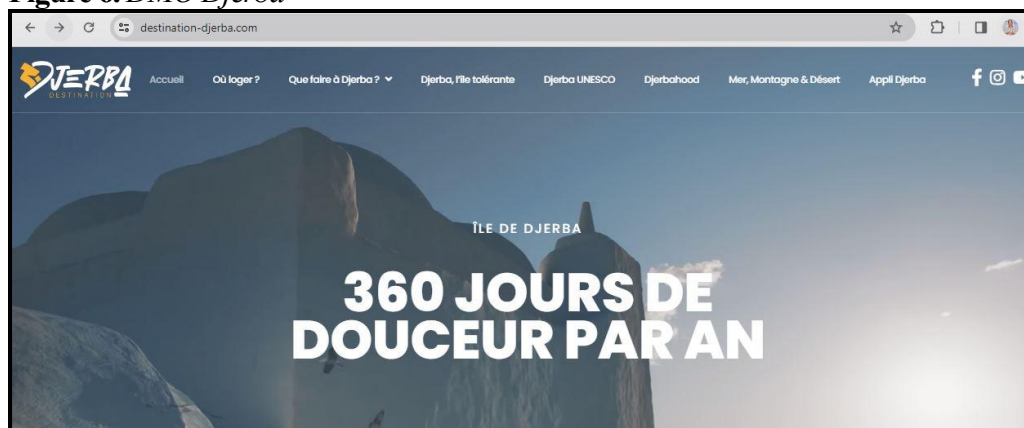
Ibid), are playing an increasingly active role in promoting the area and improving municipal services (Cova and Cova 2009, Kaplan and Haenlein 2010).

In our case study, the town of Houmt Souk, the capital of the island of Djerba, is part of this dynamic approach to territorial and digital communication. Implementing digital marketing strategies enables local authorities to reach a wider audience and create meaningful interactions with residents and visitors (tourists and non-tourists). Digital initiatives, such as the creation of online platforms and the use of social networks, are essential for engaging local communities in a process of developing a new image for the island by promoting its tourism and cultural assets (Buhalis and Law 2008, Xiang and Gretzel 2010).

The creation of Djerba's Destination Management Organization (DMO)³, which involves local stakeholders (local authorities, civil society, local promoters in tourism and para-tourism projects), marks a decisive turning point in Djerba's tourism development strategy. By resolutely embracing digital technology, the DMO is orchestrating a holistic transformation aimed at reinventing Djerba as a destination through a sustainable and intelligent approach (in relation to digital technology). This transition is marked by environmental, cultural and technological awareness (Gretzel et al. 2015, Xiang and Gretzel 2010).

Djerba's DMO is part of this dynamic, focusing on enhancing the island's rich tangible and intangible heritage. The preservation and promotion of archaeological sites, historical monuments and traditional architecture are supported by digital initiatives such as virtual tours and interactive applications (Huang et al. 2013, Tussyadiah and Fesenmaier 2009). At the same time, the DMO is committed to highlighting intangible heritage, disseminating craft traditions, distinctive local cuisine, festivals, and other unique cultural practices via its website, social networks, blogs, interactive platforms and mobile applications.

Figure 6. *DMO Djerba*



Source: destination-djerba.com

A concrete example of this trend is the Djerba Guide application⁴, initiated by the DMO (Djerba Management Organisation). This application is being developed as part

³<https://www.destination-djerba.com/>

⁴<https://apps.apple.com/tt/app/djerba-guide/id1563972993>

of the 'Destination Sud-Est Tunis' project, supported by the Swiss State Secretariat for Economic Affairs (SECO) and implemented by Swisscontact, in collaboration with the Ministry of Tourism and the Tunisian National Tourist Office. Free of charge and operating in offline mode, it offers users the opportunity to geolocate and guide themselves as they discover and enjoy their destination (Swisscontact 2020, SECO 2021).

Customisable and interactive, the Djerba Guide application lets users explore the labyrinths of the island's medinas, discover the colourful markets and lively café terraces, or explore the centuries-old workshops of potters, basket-makers and others. By offering an immersive and enriching experience, it encourages the discovery and promotion of Djerba's cultural riches to a wider audience. This application embodies the convergence between the search for information located in the urban space and the judicious use of mobile technologies to offer a personalised and enriching tourist experience.

Figure 7. *Djerba Guide*



Source: Djerba 360°

Although the Djerba Guide application seems to be regaining ground, competing with Tunisia's Routard thanks to its reliability and its exhaustive flow of information on the island, it does have a shortcoming in terms of the immediacy of some crucial information, particularly for ferry users. In fact, the interminable queues and the resulting loss of time and stress on the Ajim and Jorf sides remain one of the thorniest issues for the mobility of visitors entering and leaving the island. To remedy this shortcoming, Djerbabus, a private initiative launched by young start-up entrepreneurs, represents a revolutionary advance in the field of public transport, both nationally and in Djerba in particular. The application, used by more than 2.5K users, including locals and visitors from Tunisia and abroad, is the first of its kind on Messenger. Djerbabus is

unique in that it combines data from different means of transport to provide users with a complete overview of their journey, including itinerary, timetables, lines, stations, buses, ferries, taxis, and so on. This approach allows users to save time and travel more comfortably.

Currently operational on the island of Djerba, Djerbabus plans to extend its coverage to the whole of Tunisia. This expansion promises to bring significant benefits to users by simplifying access to transport information, contributing to a smoother and more efficient travel experience for local residents and visitors alike.

Figure 8. *Djerbabus*



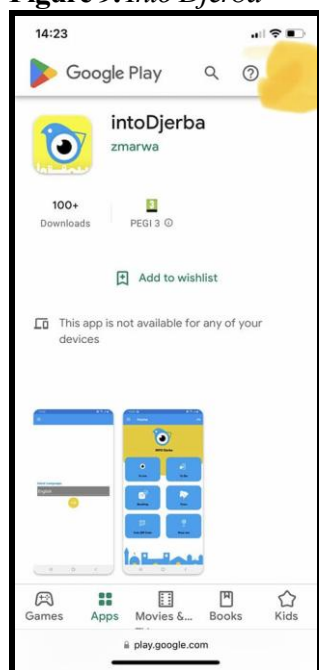
Source: Application Djerbabus

Heritage sites are omnipresent in most of the applications operating on the island, including one such as Into Djerba⁵. Launched by the Djerba Insolite association⁶, this application aims to raise awareness among the local population and visitors to the island of Djerba's tangible and intangible heritage, as well as its preservation. This is being achieved by digitising and presenting fifteen historic monuments, with financial support from the Normandy Region and the Tunis International Center for Digital Cultural Economy (TICDCE) (Normandy 2020, TICDCE 2021).

The application Djerbabus offers visitors to Djerba, as well as local residents, an unusual way to discover the island through six distinct sections: 'things to see', 'things to do', 'bike booking', 'tours', 'augmented reality' and an 'online craft shop'. This innovative application allows users to view the monuments in 3D and listen to the history of each site through voice-over narration.

⁵https://play.google.com/store/apps/details?id=com.djerba_insolite.guide&fbclid=IwAR2kARtphtE49we-rZpDofw4Wt7RSK5ZFsm0Wqhqhunc9wbHmSYyohhywloE.

⁶<https://djerba-insolite.com/>.

Figure 9. *Into Djerba*

Source: Into Djerba

The Into Djerba app appears to be an extension of ‘Djerba Guide’, offering a variety of new sites and historical monuments, including an eco-tourism dimension with bike tours. However, on a technical level, it is imperative that the designers revise the application, as some of its features, such as the voice-over, no longer seem to work. In addition, a major point of concern is that the application seems to focus on a foreign clientele, using mainly English and French as the languages of communication. This approach may be disappointing for the local population, which is mainly Arabic-speaking. It would make sense to include Arabic in the languages available, to ensure equitable accessibility for all users, while recognising and valuing the cultural and linguistic richness of the region (Hassan et al. 2019, *ibid*). It follows that although the app offers interesting and diverse features, technical and linguistic adjustments are needed to ensure an optimal and inclusive experience for all users, whether local or foreign.

Another application has also just seen the light of day thanks to the good offices of the Association for the Safeguarding of the Island of Djerba, known as ASSIDJE, which recently unveiled an innovative new mobile application entitled ‘Djerba Kids Tour’⁷. This application is specially designed for children, offering a magical journey through the island of Djerba.

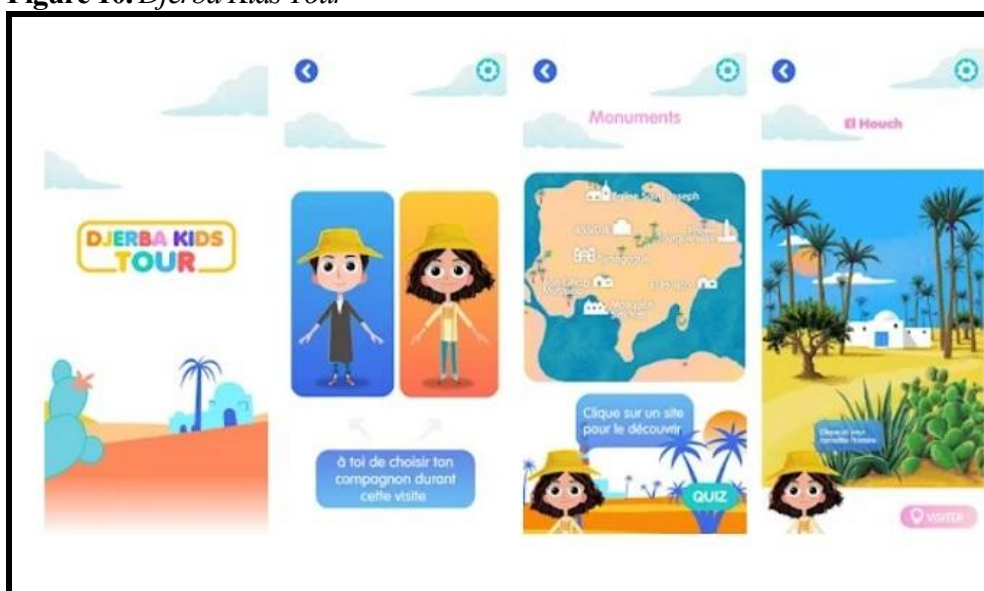
Through Djerba Kids Tour, young visitors are invited on an exciting adventure to discover the island's museums, monuments, picturesque villages, enchanting parks and magnificent beaches. The main aim of the application is to highlight Djerba's rich natural, cultural and historical heritage, offering an experience that is both educational and entertaining.

⁷<https://www.facebook.com/profile.php?id=100087569901849>

Guided by the two endearing companions, Djerbi and Djerbia, children enjoy a specially designed journey highlighting the island's must-sees through simple stories and playful illustrations. The illustrators have opted for a colourful, fairytale style, paying particular attention to detail and presentation to capture the attention of visitors young and old.

The application is the result of a fruitful collaboration between the Association pour la Sauvegarde de l'Île de Djerba (ASSIDJE) and the Tunis International Center for Digital Cultural Economy (TIC DCE), in association with talented young artists. This joint initiative illustrates ASSIDJE's commitment to preserving the heritage of the island of Djerba by taking advantage of the opportunities offered by digital technology and the cultural economy. TIC DCE's contribution, as a public incubator, underlines the importance of supporting innovative and creative projects that merge digital technology with local cultural wealth.

Figure 10. *Djerba Kids Tour*



Source: Application of Djerba Kids Tour

This application, although appreciated by many Francophiles for its educational and recreational value, is causing a certain amount of frustration among the Arabic-speaking population because of its exclusive use of the French language. What's more, the voice-over accompanying the dialogue of the characters Djerbi and Djerbia seems unnatural and rather artificial.

In the search for alternative strategies to propel Djerba Houmt Souk towards Mediterranean and international appeal, the growing use of mobile platforms and applications is proving to be a modern and effective approach. In a world where the majority of the population owns a mobile phone, this strategy is particularly relevant. The active participation of contemporary tourists, who are intrinsically connected, in the co-creation of destinations through online communities, illustrates a significant change. This collaborative dynamic even extends to destination management organisations, such as Djerba's DMO, which are adopting innovative approaches to co-creating personalised

experiences, reflecting the evolution of the contemporary tourist into an autonomous and sometimes 'participative' player.

Despite all the efforts made by local stakeholders to improve Djerba's tourism image and environmental resilience by promoting tourism practices throughout the region, we note that there are still areas of weakness. The 18 people interviewed in local administrations (81.8%) point out that the digital tools used by the municipality or tourist offices are mainly used for administrative management or top-down communication. They believe that very few digital applications are geared towards the visitor experience or interactive cultural mediation.

Conclusion

This article highlights the challenges and transformations facing the tourist destination of Djerba. Since the 1960s, Djerba has evolved into a mass tourism destination, with significant environmental and territorial consequences. Coastal erosion, pollution and the over-exploitation of natural resources have weakened the island's ecosystem, compromising the long-term sustainability of tourism.

Faced with these challenges, local initiatives are emerging to diversify and renew Djerba's image by highlighting its rich heritage and cultural assets. Reconciling tourism with the island's territory involves promoting its architectural, archaeological and craft heritage, as well as sustainable development projects such as Djerba Smart Island and Green Djerba. These initiatives aim to renew the destination's image and strengthen the island's resilience in the face of environmental and economic crises, while promoting local and participatory governance.

Djerba's application for inclusion on UNESCO's World Heritage List and the organisation of events such as the 18th Francophonie Summit are part of a strategy to enhance its appeal and international visibility. These efforts reflect a desire to improve the island's image by fully integrating local communities and promoting the island's cultural assets.

Digital technology plays a crucial role in this process of renewal. Digital technologies and mobile applications can be used to disseminate an integrated tourism offer that covers the whole of the island, promoting more sustainable and inclusive tourism. These digital tools are essential for attracting a new category of tourists looking for authentic and personalised experiences (Kotler et al. 1993, Hospers 2011, *ibid*).

By examining the opportunities offered by digital technologies, we see that they play a crucial role in transforming the tourism experience. Digital initiatives implemented by local stakeholders offer tools for active collaboration between individual travellers and destination management organisations, fostering the co-creation of personalised tourism offers and experiences. In this way, the transformation of Djerba into a sustainable and resilient tourist destination is based on an integrated approach combining heritage enhancement, ecological initiatives and the strategic use of digital technologies.

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