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Firm Characteristics and Industry 4.0 Adoption: A Study on Hotel Businesses

Abstract

This study examines the relationship between firm characteristics and the adoption of Industry 4.0 (I4.0) technologies across near-, medium-, and long-term timeframes. A chi-square analysis was conducted on data collected from 208 hotel businesses. The findings reveal a statistically significant association between adopting I4.0 technologies and business type, star rating, ownership structure, business age, business size, service type, and customer segment. The results indicate that five-star hotels, older businesses, large-scale enterprises, and luxury hotels are more likely to adopt face recognition systems in the near future (1-5 years). The study challenges prevailing discussions in the literature by demonstrating that older businesses play a more prominent role in the early adoption of I4.0 technologies.

Keywords: industry 4.0 adoption, firm characteristics, technology adoption

1. Introduction

The Industry 4.0 (I4.0) revolution has accelerated transformations in social and economic domains through automation, digitalisation, new production and consumption models, and novel business paradigms. Even in the tourism and hospitality industry, which is typically characterised by the late adoption of technology, the delivery of products and services is increasingly driven by the opportunities afforded by technological advancements. This has even culminated in the concept of Hotel 4.0, a term that reflects the I4.0 (Gomes et al., 2024).

The I4.0 technologies have significantly enhanced service operations by reducing fixed costs and increasing operational flexibility (Osei & Cheng, 2024). As a desirable aspect of benchmarking operations (Kozak, 2002), the Marriott Hotel in China remarkably reduced check-in times from three minutes to one minute by implementing a facial recognition system (Gupta et al., 2023). Furthermore, the Hyatt Inclusive Collection reported a substantial increase in revenue attributed to its mobile application, which provides in-app room keys, personalized check-in, and travel planning services. Notably, 80-90% of guests regularly utilize the app (Zheldak, 2026). The transformative impact of I4.0 technologies has made technology adoption and usage a prominent research topic (Soares et al., 2021). Despite the growing interest in technology research focused on tourism and hospitality (Osei & Cheng, 2024), only a limited number of these studies have been conducted from a firm-level perspective (Ma et al., 2024). Consequently, several critical issues have been overlooked. In particular, the effects of firm characteristics on the adoption of technology remain a significant area of neglect.

Existing research on I4.0 technologies, such as blockchain, the metaverse, and the Internet of Things, has primarily focused on small and medium-sized enterprises as a firm characteristic (Ledesma-Chaves et al., 2024; Pappas et al., 2021; Van Huy et al., 2024). On the other hand, researchers employed theories such as the

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technology-organisation-environment framework, the tri-core model, and the diffusion of innovation theory to examine the adoption, utilisation, and diffusion of various I4.0 technologies in the hotel industry, including mobile reservation systems (Wang et al., 2016), cloud computing (Ayoobkhan & Kaldeen, 2020), robotics (Pizam et al., 2022), AI (Chen et al., 2023), and blockchain (Acikgoz et al., 2024). Instead of focusing on business-specific characteristics, most research emphasises broader organisational factors such as innovation, management support, and organisational readiness. Some research has also discussed how firm characteristics, such as hotel type, customer segment (Osei & Cheng, 2024), hotel size, and the degree of geographic distribution of hotel operations (Ezzaouia & Bulchand-Gidumal, 2020), influence the adoption of I4.0 technologies. However, the results indicate that business characteristics may play an ambiguous role in adoption.

For instance, research investigating foundational technologies, including information and communication technologies and radio frequency identification, has revealed that, more significantly, luxury and franchise hotels exhibit a higher propensity for adopting these technologies (Ozturk & Hancer, 2014; Siguaw et al., 2000). Regarding I4.0, Milohnić and Kapeš (2024) concluded that hotel managers are less inclined to consider robotisation as a suitable option for luxury hotels due to concerns about a potential diminution of personal touch and customer satisfaction. Yang et al. (2024) observed that high-star hotels tend to prioritise maintaining traditional service models during their digital transformation efforts involving I4.0 technologies, resulting in a cautious approach. Conversely, budget hotels demonstrate a greater inclination to embrace technology to enhance their competitiveness and efficiency, as it facilitates the establishment of fair business models. Consequently, comprehending the interplay between hotel business characteristics and adopting I4.0 technologies remains a pressing research area.

In addition to the aforementioned discussions, various industry reports indicate that lodging businesses increasingly allocate a growing share of their budgets to I4.0 technologies (Hospitality Technology, 2024). This digital transformation is anticipated to manifest through specific technologies at specific junctures. For instance, the "Travel Technology Investment Trends" report by Amadeus (2024) reveals that 24% of hoteliers intend to make substantial investments in technology, 70% plan to invest moderately, and 6% anticipate a conservative approach over the next twelve months. Branded hotels are positioned ahead of individual and group hotels in these metrics, with 97% planning moderate to aggressive technology investments. In the short term, AI and digital payments are emerging as pivotal technologies, while machine learning and extended reality are anticipated to gain prominence in the long term. However, aside from a few studies (e.g., Ivanov et al., 2020), there is a lack of evidence on when the hotel business will adopt I4.0 technologies. This study addresses this gap by investigating the relationship between firm characteristics and the adoption of I4.0 technologies across various timeframes (near, medium, and long-term). By holistically examining I4.0 technologies, this study goes beyond previous research, which typically focused on specific technologies and firm characteristics, while addressing the call for investigations into firm characteristics such as hotel type, size, location, and star rating that influence the adoption of I4.0 technologies (Alsetoohy et al., 2019; Buhalis et al., 2024; Iranmanesh et al., 2022; Jabeen et al., 2022; Rodrigues et al., 2024).

2. Literature review

The concept of I4.0 was first introduced in Germany as a manufacturing strategy associated with a range of technical, physical, and biological domains. Eventually, connecting people and machines, I4.0 has evolved into a comprehensive collection of technologies that has gained global prominence (Bai et al., 2026). Although the context of I4.0 technologies varies across industries, innovations such as artificial intelligence (AI), virtual and augmented reality (AR/VR), the internet of things (IoT), machine learning, big data, service robots, cloud computing, and blockchain are among the leading technologies in the hotel industry (Law & Chen, 2025; Ionescu & Sârbu, 2024; Osei et al., 2020). The I4.0 technologies addressed in the present study are outlined below.

Chatbots. It refers to computer programs that respond to verbal or text-based questions and commands while providing recommendations (Lukanova & Ilieva, 2019). The chatbot Edward, introduced by Radisson Blu Edwardian Hotels, a luxury hotel chain based in the United Kingdom, offers guests text-based responses to inquiries on various topics, including travel tips, route information, and hotel amenities (Huang et al., 2022).

Service robots. It is defined as a partially or wholly automated, AI-enabled agent capable of interacting and communicating with customers (Rana et al., 2025). Henn Na Hotel uses robots to perform various services, such as delivering guests' luggage to their rooms (Yağmur et al., 2024).

Virtual/augmented reality. Virtual and augmented reality allow users to experience artificially created environments. Augmented reality, an advanced virtual reality version, delivers layered experiences through portable devices such as wearable technology and smart glasses (Buhalis et al., 2019). Holiday Inn offers its guests an augmented reality experience that allows them to see lifelike virtual representations of celebrities (Zheldak, 2026). Using interactive maps, the augmented reality feature in rooms at the London-based Premier Inn chain helps guests find local information, such as online reviews of nearby restaurants and bars (Huang et al., 2022).

IoT. It refers to integrating physical and virtual objects (things) through a unified platform via the Internet, enabling information collection, sharing, and exchange (Osei et al., 2020). Hilton Hotels & Resorts employs an IoT-enabled smartphone application that allows guests to control room settings such as lighting and temperature (Singh, 2024). Hilton Worldwide Holdings Inc. has also developed a "digital key" feature, enabling guests to check in and out independently without interacting with front desk staff (Yağmur et al., 2024).

Facial recognition. Facial recognition is a technology that identifies human faces in images and videos, captures facial features to process information into digital data, and facilitates identity verification through face matching (Gupta et al., 2023). Marriott International has initiated the trial of facial recognition-enabled check-in kiosks at two locations in China: these kiosks offer identification documents, capture photos and complete service agreement forms. The facial recognition software verifies reservation and personal information, facilitating the distribution of room keys (Huang et al., 2022).

Big data. It refers to digital techniques ranging from aggregating and integrating large volumes of digital data to uncovering patterns related to human behaviour (Favaretto et al., 2020). It encompasses collecting, processing, analysing, and managing digital data (Osei et al., 2020). Marriott Hotels utilises big data to boost customer loyalty and revenue. The company monitors events and adjusts prices at nearby hotels based on increasing demand. Additionally, Marriott gathers insights into customer needs and preferences through Amazon Echo devices installed in guest rooms, which allows for the personalisation of services (Tymoshchenko, 2025).

Metaverse. It is a technology that enables the convergence of physical and digital universes, allowing users to explore their areas of interest, such as education, work, and health, interact with others, and seamlessly transition between them (Buhalis et al., 2023). RendezVerse, in collaboration with Atlantis and Marriott, is creating metaverse replicas of real-world hotels. Establishing a metaverse-based community that includes hotel owners and event organizers aims to explore innovative marketing strategies and offer digital twins of iconic hotels. Similarly, Millennium Hotels and Resorts has launched the M Social Hotel concept on the Decentraland platform, allowing guests to rent or purchase virtual spaces (Barten, 2024).

Blockchain. It is a distributed ledger technology in which transactions are recorded on a decentralised network and made publicly accessible (Valeri & Baggio, 2021). The TUI Group has developed the BedSwap project to record hotel bed inventories in real-time and ensure accurate tracking (Valeri & Baggio, 2021).

Cloud computing. It refers to infrastructure, data resources, and applications made accessible over the Internet. This technology enables the use of technological infrastructure and applications through the Internet instead of relying on physical resources (Osei et al., 2020). The Thon Hotels chain leverages the OPERA Cloud platform, cloud computing technology, to streamline check-in and check-out processes and enable real-time data analysis (Zheldak, 2026).

2.1. Firm characteristics and I4.0 adoption

The characteristics of hotel businesses significantly influence the adoption of various technologies, including the Internet, ICTs, and the latest I4.0 technologies. Researchers have established a correlation between the quality of hotel services (e.g., economy, luxury) and the extent of technology utilisation. Luxury hotels tend to employ more technologies to enhance guest experience (Siguaw et al., 2000). Considering the age of establishment, older hotels generally exhibit less inclination to adopt novel technologies compared to newer establishments. This reluctance stems from their reliance on legacy systems that are challenging to replace and their established reputations, which diminish the urgency to expand their market share (Sahadev & Islam, 2005).

Another characteristic linked to technology adoption in hotel establishments is the star rating (Peña & Jamilena., 2010). Nam et al. (2021) identified star ratings as a key factor influencing the adoption of advanced technologies, such as artificial intelligence. Hotels with high star ratings prioritising the guest experience are more inclined to adopt technology, as they perceive it to enhance services through personalisation and optimising operations.

Firm size is another organizational characteristic that plays a significant role in the technology adoption of the hotel business (Wang et al., 2016; Nikopoulou et al., 2024). In their study on the reasons for low technology adoption in hotels, Osei et al. (2024) observed that independent hotels with limited rooms often regard the implementation of I4.0 technologies as an unprofitable investment. The authors indicate that small hotel businesses face challenges in adopting advanced technologies due to budget constraints that hinder their investment capabilities. In line with this, Dhakal and Tjokro (2024) concluded that larger tourism businesses (concerning staff size) are more likely to adopt I4.0 technologies.

Last but not least, the type of hotel and the customer segment are significant characteristics that influence technology implementation. Accordingly, the extent of investment in technology can be different for holiday hotels and business hotels. For example, a business hotel may prioritise big data due to the importance of customer data, while a luxury holiday hotel may focus on artificial intelligence and room automation. Additionally, business travellers may tend to rely heavily on technology, unlike leisure travellers. Thus, customer segments (e.g., business) may delay or accelerate the adoption of these technologies in hotel businesses (Osei & Cheng, 2024).

3. Methodology

The snowball sampling method was employed to reach lodging businesses with diverse characteristics for the study. Initially, tourism academics were contacted to obtain participant recommendations. Subsequently, the lodging businesses referred to by each participant were reached. To ensure representation of each business, the focus was placed on one manager from each establishment. Consequently, data were collected from 208 lodging businesses via email and WhatsApp between 30 November 2024 and 16 January 2025.

The questionnaire on firm characteristics was developed based on existing literature. The literature suggests that the adoption of technologies, such as information and communication technologies, radio frequency identification, mobile reservation systems, artificial intelligence, and robotics, by hotel businesses is influenced by various factors, including service type (Siguaw et al., 2000), age (Sahadev & Islam, 2005), ownership structure (Ozturk & Hancer, 2014), size (Wang et al., 2016), star rating (Nam et al., 2021), and type of business (Osei & Cheng, 2024). While no significant impact is evident, location and customer segment may influence technology adoption (Ivanov et al., 2020). These firm characteristics have been utilized as the foundation of the current study. Furthermore, to measure adoption within a temporal framework, the future periods defined by Joseph (1974), short-range (1-5 years), median range (5-20 years), and long-range (20-50 years), have been employed (Acar, 2019). Finally, nine distinct technologies, identified in the literature review as representative of I4.0 technologies, were used as the foundation for this study.

The data obtained in this study were analysed using SPSS (Statistical Package for the Social Sciences) 25.0 and DataBeeg 1.0. Descriptive statistical methods were employed for data evaluation, including frequency and percentage analyses. Additionally, a chi-square analysis was conducted to examine the relationships between variables.

4. Results

Table 1 presents a comprehensive profile of the businesses. Table 2 presents the percentages related to the time frame for adopting I4.0 technologies. Accordingly, it has been observed that all I4.0 technologies are expected to have higher adoption rates in the medium-term future (6-20 years). Table 3 presents the relationship between business type and adoption of I4.0 technologies. The findings indicate that business type has a statistically significant relationship with all I4.0 technologies except for cloud computing ($\chi 2$ = 28.477, p>.05). Additionally, the results suggest that resort hotels are expected to have higher adoption rates for all I4.0 technologies shortly. Face recognition (93.3%) was the most highly adopted technology by resort hotels shortly. In the distant future, motels are expected to have higher adoption rates for chatbots (22.2%), service robots (27.8%), and the metaverse (27.8%). In comparison, hostels are likely to adopt AR/VR (31.6%), Internet of Things (26.3%), face recognition (26.3%), big data (26.3%), and Blockchain (31.6%) at higher rates.

Table 1
Sample characteristics

Variables	Category	Frequency (N =208)	Percentage (%)
Business type	Hotel	109	52.4
	Resort	15	7.2
	Thermal hotel	20	9.6
	Boutique hotel	18	8.7
	Motel	18	8.7
	Hostel	19	9.1
	Other	9	4.3
Market type	5 Stars	77	37.0
	4 Stars	32	15.4
	3 Stars	54	26.0
	2 Stars	31	14.9
	1 Star	6	2.9
	Other	8	3.8
Ownership status	Independent	126	60.6
	Chain/group	55	26.4
	Franchise	13	6.3
	Management agreement	14	6.7
Location	Urban	95	45.7
	Coastal	49	23.6
	Mountain	24	11.5
	Rural	40	19.2
Year of establishment	1984 and before	13	6.3
	1985-2000	27	13.0
	2001-2010	50	24.0
	2010 and after	118	56.7
Business size	Small (10-49 rooms)	73	35.1
	Medium (50-99 rooms)	73	35.1
	Large (101 rooms and above)	62	29.8
Operational status	Year-round	172	82.7
	Seasonal	36	17.3

Table 1 ***(continued)***

Service type	Economic	88	42.3
	Mid-range	63	30.3
	Luxury	57	27.4
Customer segment	Business	67	32.2
	Leisure	83	39.9
	MICE	34	16.3
	Health and wellness	24	11.5

Table 2
I4.0 technologies and adoption time

	Near future (1-5)		Medium-term future (6-20)		Distant future (21-50)		Never	
	n	%	n	%	n	%	n	%
Chatbot	65	31.3	106	51.0	28	13.5	9	4.3
Service robot	66	31.7	100	48.1	34	16.3	8	3.8
Virtual/augmented reality	67	32.2	93	44.7	39	18.8	9	4.3
Internet of things	72	34.6	91	43.8	37	17.8	8	3.8
Voice/face recognition	77	37.0	98	47.1	26	12.5	7	3.4
Big data	72	34.6	98	47.1	29	13.9	9	4.3
Metaverse	65	31.3	93	44.7	40	19.2	10	4.8
Blockchain	70	33.7	94	45.2	36	17.3	8	3.8
Cloud computing	76	36.5	92	44.2	33	15.9	7	3.4

Table 3
Chi-square test of the relationship between business type and the adoption of I4.0 technologies

Technology	Time frame	Hotel		Resort		Thermal		Boutique		Motel		Hostel		Other		X^2	p
		n	%	n	%	n	%	n	%	n	%	n	%	n	%		
Chatbot	Near future	36	33.0	12	80.0	4	20.0	4	22.2	3	16.7	3	15.8	3	33.3	34.1666	**0.012***
	Medium-term future	51	46.8	3	20.0	13	65.0	12	66.7	11	61.1	12	63.2	4	44.4		
	Distant future	13	11.9	0	0.0	3	15.0	2	11.1	4	22.2	4	21.1	2	22.2		
	Never	9	8.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0		
Service robot	Near future	37	33.9	11	73.3	4	20.0	6	33.3	3	16.7	3	15.8	2	22.2	33.152	**0.016***
	Medium-term future	45	41.3	4	26.7	15	75.0	10	55.6	10	55.6	11	57.9	5	55.6		
	Distant future	19	17.4	0	0.0	1	5.0	2	11.1	5	27.8	5	26.3	2	22.2		
	Never	8	7.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0		
AR/VR	Near future	40	36.7	10	66.7	6	30.0	5	27.8	2	11.1	2	10.5	2	22.2	31.393	**0.026***
	Medium-term future	39	35.8	5	33.3	11	55.0	11	61.1	11	61.1	11	57.9	5	55.6		
	Distant future	22	20.2	0	0.0	3	15.0	2	11.1	5	27.8	6	31.6	1	11.1		
	Never	8	7.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	11.1		
Internet of things	Near future	42	38.5	11	73.3	5	25.0	5	27.8	3	16.7	2	10.5	4	44.4	34.011	**0.013***
	Medium-term future	38	34.9	3	20.0	12	60.0	12	66.7	11	61.1	12	63.2	3	33.3		
	Distant future	22	20.2	1	6.7	3	15.0	1	5.6	4	22.2	5	26.3	1	11.1		
	Never	7	6.4	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	1	11.1		
Face recognition	Near future	46	42.2	14	93.3	4	20.0	6	33.3	3	16.7	1	5.3	3	33.3	50.676	**0.000***
	Medium-term future	42	38.5	1	6.7	14	70.0	12	66.7	11	61.1	13	68.4	5	55.6		
	Distant future	14	12.8	0	0.0	2	10.0	0	0.0	4	22.2	5	26.3	1	11.1		
	Never	7	6.4	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0		
Big data	Near future	41	37.6	12	80.0	5	25.0	5	27.8	3	16.7	3	15.8	3	33.3	33.842	**0.013***
	Medium-term future	44	40.4	3	20.0	12	60.0	12	66.7	11	61.1	10	52.6	6	66.7		
	Distant future	16	14.7	0	0.0	3	15.0	1	5.6	4	22.2	5	26.3	0	0.0		
	Never	8	7.3	0	0.0	0	0.0	0	0.0	0	0.0	1	5.3	0	0.0		

Table 3 ***(continued)***

Metaverse	Near future	34	31.2	10	66.7	5	25.0	6	33.3	4	22.2	3	15.8	3	33.3	29.617	**0.041***
	Medium-term future	40	36.7	5	33.3	12	60.0	11	61.1	9	50.0	11	57.9	5	55.6		
	Distant future	25	22.9	0	0.0	3	15.0	1	5.6	5	27.8	5	26.3	1	11.1		
	Never	10	9.2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0		
Blockchain	Near future	35	32.1	13	86.7	7	35.0	6	33.3	4	22.2	2	10.5	3	33.3	38.142	**0.004***
	Medium-term future	44	40.4	2	13.3	11	55.0	11	61.1	10	55.6	11	57.9	5	55.6		
	Distant future	22	20.2	0	0.0	2	10.0	1	5.6	4	22.2	6	31.6	1	11.1		
	Never	8	7.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0		
Cloud computing	Near future	39	35.8	12	80.0	7	35.0	6	33.3	5	27.8	3	15.8	4	44.4	28.477	0.055
	Medium-term future	43	39.4	3	20.0	11	55.0	11	61.1	9	50.0	11	57.9	4	44.4		
	Distant future	20	18.3	0	0.0	2	10.0	1	5.6	4	22.2	5	26.3	1	11.1		
	Never	7	6.4	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0		

Note. *: $p < 0.05$.

Table 4
Chi-square test of the relationship between star rating and the adoption of I4.0 technologies

Technology	Time frame	5-star		4-star		3-star		2-star		1-star		Other		X^2	p
		n	%	n	%	n	%	n	%	n	%	n	%		
Chatbot	Near future	33	42.9	9	28.1	11	20.4	6	19.4	1	16.7	5	62.5	40.867	**0.000***
	Medium-term future	33	42.9	20	62.5	35	64.8	14	45.2	2	33.3	2	25.0		
	Distant future	5	6.5	2	6.3	6	11.1	11	35.5	3	50.0	1	12.5		
	Never	6	7.8	1	3.1	2	3.7	0	0.0	0	0.0	0	0.0		
Service robot	Near future	33	42.9	11	34.4	11	20.4	5	16.1	1	16.7	5	62.5	42.611	**0.000***
	Medium-term future	31	40.3	15	46.9	36	66.7	15	48.4	1	16.7	2	25.0		
	Distant future	7	9.1	5	15.6	6	11.1	11	35.5	4	66.7	1	12.5		
	Never	6	7.8	1	3.1	1	1.9	0	0.0	0	0.0	0	0.0		
Virtual/ augmented reality	Near future	33	42.9	11	34.4	12	22.2	6	19.4	1	16.7	4	50.0	30.896	**0.009***
	Medium-term future	28	36.4	14	43.8	34	63.0	12	38.7	2	33.3	3	37.5		
	Distant future	12	15.6	5	15.6	5	9.3	13	41.9	3	50.0	1	12.5		
	Never	4	5.2	2	6.3	3	5.6	0	0.0	0	0.0	0	0.0		
Internet of things	Near future	39	50.6	10	31.3	14	25.9	5	16.1	1	16.7	3	37.5	34.712	**0.003***
	Medium-term future	23	29.9	15	46.9	33	61.1	14	45.2	2	33.3	4	50.0		
	Distant future	11	14.3	5	15.6	5	9.3	12	38.7	3	50.0	1	12.5		
	Never	4	5.2	2	6.3	2	3.7	0	0.0	0	0.0	0	0.0		
Face recognition	Near future	46	59.7	12	37.5	10	18.5	5	16.1	1	16.7	3	37.5	57.909	**0.000***
	Medium-term future	23	29.9	18	56.3	36	66.7	15	48.4	2	33.3	4	50.0		
	Distant future	4	5.2	1	3.1	6	11.1	11	35.5	3	50.0	1	12.5		
	Never	4	5.2	1	3.1	2	3.7	0	0.0	0	0.0	0	0.0		
Big data	Near future	40	51.9	11	34.4	12	22.2	5	16.1	1	16.7	3	37.5	46.634	**0.000***
	Medium-term future	26	33.8	17	53.1	34	63.0	14	45.2	2	33.3	5	62.5		
	Distant future	6	7.8	2	6.3	6	11.1	12	38.7	3	50.0	0	0.0		
	Never	5	6.5	2	6.3	2	3.7	0	0.0	0	0.0	0	0.0		
Metaverse	Near future	31	40.3	12	37.5	11	20.4	5	16.1	2	33.3	4	50.0	31.496	**0.008***
	Medium-term future	26	33.8	14	43.8	35	64.8	14	45.2	1	16.7	3	37.5		
	Distant future	14	18.2	4	12.5	6	11.1	12	38.7	3	50.0	1	12.5		
	Never	6	7.8	2	6.3	2	3.7	0	0.0	0	0.0	0	0.0		
Blockchain	Near future	35	45.5	11	34.4	13	24.1	5	16.1	2	33.3	4	50.0	31.214	**0.008***
	Medium-term future	25	32.5	16	50.0	33	61.1	15	48.4	1	16.7	4	50.0		
	Distant future	12	15.6	4	12.5	6	11.1	11	35.5	3	50.0	0	0.0		
	Never	5	6.5	1	3.1	2	3.7	0	0.0	0	0.0	0	0.0		
Cloud computing	Near future	39	50.6	10	31.3	15	27.8	6	19.4	2	33.3	4	50.0	38.601	**0.001***
	Medium-term future	22	28.6	19	59.4	33	61.1	14	45.2	1	16.7	3	37.5		
	Distant future	11	14.3	2	6.3	5	9.3	11	35.5	3	50.0	1	12.5		
	Never	5	6.5	1	3.1	1	1.9	0	0.0	0	0.0	0	0.0		

Note. *: $p < 0.05$.

Table 5
Chi-square test of the relationship between ownership structure and the adoption of I4.0 technologies

Technology	Time frame	Independent		Chain		Franchise		Management		X^2	p
		n	%	n	%	n	%	n	%		
Chatbot	Near future	24	19.0	25	45.5	6	46.2	10	71.4	31.373	**0.000***
	Medium-term future	71	56.3	26	47.3	5	38.5	4	28.6		
	Distant future	25	19.8	2	3.6	1	7.7	0	0.0		
	Never	6	4.8	2	3.6	1	7.7	0	0.0		
Service robot	Near future	28	22.2	27	49.1	4	30.8	7	50.0	21.764	**0.010***
	Medium-term future	68	54.0	21	38.2	5	38.5	6	42.9		
	Distant future	26	20.6	5	9.1	2	15.4	1	7.1		
	Never	4	3.2	2	3.6	2	15.4	0	0.0		
AR/VR	Near future	23	18.3	28	50.9	8	61.5	8	57.1	31.825	**0.000***
	Medium-term future	66	52.4	20	36.4	2	15.4	5	35.7		
	Distant future	30	23.8	6	10.9	2	15.4	1	7.1		
	Never	7	5.6	1	1.8	1	7.7	0	0.0		
IoT	Near future	28	22.2	27	49.1	9	69.2	8	57.1	26.396	**0.002***
	Medium-term future	64	50.8	19	34.5	2	15.4	6	42.9		
	Distant future	28	22.2	7	12.7	2	15.4	0	0.0		
	Never	6	4.8	2	3.6	0	0.0	0	0.0		
Face recognition	Near future	30	23.8	32	58.2	8	61.5	7	50.0	29.045	**0.001***
	Medium-term future	68	54.0	19	34.5	4	30.8	7	50.0		
	Distant future	23	18.3	2	3.6	1	7.7	0	0.0		
	Never	5	4.0	2	3.6	0	0.0	0	0.0		
Big data	Near future	29	23.0	27	49.1	6	46.2	10	71.4	26.204	**0.002***
	Medium-term future	66	52.4	24	43.6	4	30.8	4	28.6		
	Distant future	24	19.0	3	5.5	2	15.4	0	0.0		
	Never	7	5.6	1	1.8	1	7.7	0	0.0		
Metaverse	Near future	25	19.8	23	41.8	6	46.2	11	78.6	28.818	**0.001***
	Medium-term future	69	54.8	19	34.5	3	23.1	2	14.3		
	Distant future	26	20.6	10	18.2	3	23.1	1	7.1		
	Never	6	4.8	3	5.5	1	7.7	0	0.0		
Blockchain	Near future	28	22.2	25	45.5	6	46.2	11	78.6	26.237	**0.002***
	Medium-term future	65	51.6	22	40.0	4	30.8	3	21.4		
	Distant future	27	21.4	7	12.7	2	15.4	0	0.0		
	Never	6	4.8	1	1.8	1	7.7	0	0.0		
Cloud computing	Near future	29	23.0	27	49.1	7	53.8	13	92.9	26.126	**0.000***
	Medium-term future	68	54.0	20	36.4	3	23.1	1	7.1		
	Distant future	24	19.0	7	12.7	2	15.4	0	0.0		
	Never	5	4.0	1	1.8	1	7.7	0	0.0		

Note. *: $p < 0.05$.

Table 4 presents the relationship between hotel business star ratings and the adoption of I4.0 technologies. The findings indicate a statistically significant relationship between star ratings and I4.0 technologies ($p<.05$). Accordingly, all I4.0 technologies will soon have higher adoption rates in five-star establishments. Moreover, face recognition (59.7%) was soon identified as the most highly adopted technology among five-star businesses. In the distant future, all I4.0 technologies will have higher adoption rates in one-star establishments. Among these technologies, service robots (66.7%) emerged as the most highly adopted technology by one-star businesses in the distant future.

Table 5 presents the relationship between the ownership structure of hotel businesses and the adoption of I4.0 technologies. The findings indicate a statistically significant relationship ($p<.05$) between ownership structure and adopting all I4.0 technologies. Accordingly, the adoption likelihood of chatbots (71.4%), service robots

(50%), big data (71.4%), metaverse (78.6%), Blockchain (78.6%), and cloud computing (92.9%) is higher among businesses operating under management agreements. In contrast, AR/VR (61.5%) and IoT (69.2%) are more likely to be adopted by franchise-based hotel businesses. Among these technologies, cloud computing (92.9%) emerged as businesses' most highly adopted technology, with a short management agreement. In the long-term future, the findings suggest that independent hotel businesses are expected to adopt all I4.0 technologies at higher rates, except for the metaverse.

Table 6
Chi-square test of the relationship between location and the adoption of I4.0 technologies

Technology	Time frame	City		Coastal		Mountain		Rural		X^2	p
		n	%	n	%	n	%	n	%		
Chatbot	Near future	28	29.5	19	38.8	6	25.0	12	30.0	10.503	0.311
	Medium-term future	51	53.7	21	42.9	15	62.5	19	47.5		
	Distant future	11	11.6	5	10.2	3	12.5	9	22.5		
	Never	5	5.3	4	8.2	0	0.0	0	0.0		
Service robot	Near future	30	31.6	18	36.7	6	25.0	12	30.0	7.372	0.598
	Medium-term future	44	46.3	24	49.0	13	54.2	19	47.5		
	Distant future	15	15.8	5	10.2	5	20.8	9	22.5		
	Never	6	6.3	2	4.1	0	0.0	0	0.0		
AR/VR	Near future	27	28.4	21	42.9	6	25.0	13	32.5	13.190	0.154
	Medium-term future	42	44.2	22	44.9	11	45.8	18	45.0		
	Distant future	18	18.9	5	10.2	7	29.2	9	22.5		
	Never	8	8.4	1	2.0	0	0.0	0	0.0		
Internet of things	Near future	33	34.7	21	42.9	6	25.0	12	30.0	10.204	0.334
	Medium-term future	41	43.2	18	36.7	13	54.2	19	47.5		
	Distant future	14	14.7	9	18.4	5	20.8	9	22.5		
	Never	7	7.4	1	2.0	0	0.0	0	0.0		
Face recognition	Near future	32	33.7	25	51.0	8	33.3	12	30.0	12.249	0.200
	Medium-term future	49	51.6	17	34.7	12	50.0	20	50.0		
	Distant future	10	10.5	4	8.2	4	16.7	8	20.0		
	Never	4	4.2	3	6.1	0	0.0	0	0.0		
Big data	Near future	30	31.6	21	42.9	8	33.3	13	32.5	11.022	0.274
	Medium-term future	49	51.6	22	44.9	9	37.5	18	45.0		
	Distant future	10	10.5	4	8.2	6	25.0	9	22.5		
	Never	6	6.3	2	4.1	1	4.2	0	0.0		
Metaverse	Near future	30	31.6	15	30.6	7	29.2	13	32.5	6.640	0.675
	Medium-term future	43	45.3	21	42.9	10	41.7	19	47.5		
	Distant future	15	15.8	10	20.4	7	29.2	8	20.0		
	Never	7	7.4	3	6.1	0	0.0	0	0.0		
Blockchain	Near future	27	28.4	19	38.8	10	41.7	14	35.0	7.011	0.636
	Medium-term future	47	49.5	20	40.8	9	37.5	18	45.0		
	Distant future	15	15.8	8	16.3	5	20.8	8	20.0		
	Never	6	6.3	2	4.1	0	0.0	0	0.0		
Cloud computing	Near future	31	32.6	21	42.9	8	33.3	16	40.0	5.854	0.754
	Medium-term future	45	47.4	19	38.8	12	50.0	16	40.0		
	Distant future	14	14.7	7	14.3	4	16.7	8	20.0		
	Never	5	5.3	2	4.1	0	0.0	0	0.0		

Note. *: $p < 0.05$.

According to Table 6, no statistically significant relationship was found between location and adopting I4.0 technologies (p>.05). Table 7 presents the relationship between the age of the business and adopting I4.0 technologies. The findings indicate that there is a significant relationship between business age and the adoption

of I4.0 technologies (p<.05). The results suggest that, shortly, all I4.0 technologies, except for Metaverse and Cloud Computing, are expected to have higher adoption rates among businesses established in 1984 or earlier. Among these technologies, Face recognition (92.3%) had the highest adoption rate among I4.0 technologies in businesses founded before 1984. Furthermore, the findings suggest that, in the distant future, except for Metaverse and Cloud Computing, all I4.0 technologies are more likely to be adopted by businesses established in 2010 or later. In particular, AR/VR (24.6%) and the Internet of Things (24.6%) were identified as the I4.0 technologies expected to be adopted the most by hotel businesses founded after 2010 in the long-term future.

The findings indicate a statistically significant relationship (p<.05) between business size and the adoption of I4.0 technologies (Table 8). Accordingly, shortly, all I4.0 technologies are expected to have a higher likelihood of adoption by large-scale hotel businesses (101+ rooms). Among these technologies, face recognition (61.3%) emerged as the most likely to be adopted by large-scale hotel businesses shortly. In the distant future, all I4.0 technologies will have higher adoption rates among small-scale hotel businesses (10-49 rooms). Specifically, chatbots (28.8%) and AR/VR (28.8%) were identified as the technologies most likely to be adopted by small-scale businesses in the long term.

Table 7
Chi-square test of the relationship between business age and the adoption of I4.0 technologies

Technology	Time frame	-1984		1985-2000		2001-2010		2010-		X^2	p
		n	%	n	%	n	%	n	%		
Chatbot	Near future	9	69.2	13	48.1	19	38.0	24	20.3	27.585	**0.001***
	Medium-term future	3	23.1	11	40.7	27	54.0	65	55.1		
	Distant future	1	7.7	1	3.7	2	4.0	24	20.3		
	Never	0	0.0	2	7.4	2	4.0	5	4.2		
Service robot	Near future	9	69.2	14	51.9	19	38.0	24	20.3	24.359	**0.004***
	Medium-term future	3	23.1	9	33.3	25	50.0	63	53.4		
	Distant future	1	7.7	3	11.1	4	8.0	26	22.0		
	Never	0	0.0	1	3.7	2	4.0	5	4.2		
AR/VR	Near future	10	76.9	13	48.1	21	42.0	23	19.5	32.502	**0.000***
	Medium-term future	3	23.1	7	25.9	21	42.0	62	52.5		
	Distant future	0	0.0	4	14.8	6	12.0	29	24.6		
	Never	0	0.0	3	11.1	2	4.0	4	3.4		
Internet of things	Near future	9	69.2	14	51.9	23	46.0	26	22.0	27.791	**0.001***
	Medium-term future	3	23.1	8	29.6	20	40.0	60	50.8		
	Distant future	1	7.7	3	11.1	4	8.0	29	24.6		
	Never	0	0.0	2	7.4	3	6.0	3	2.5		
Face recognition	Near future	12	92.3	12	44.4	22	44.0	31	26.3	29.652	**0.001***
	Medium-term future	0	0.0	12	44.4	22	44.0	64	54.2		
	Distant future	1	7.7	1	3.7	4	8.0	20	16.9		
	Never	0	0.0	2	7.4	2	4.0	3	2.5		
Big data	Near future	9	69.2	11	40.7	23	46.0	29	24.6	19.909	**0.018***
	Medium-term future	2	15.4	12	44.4	22	44.0	62	52.5		
	Distant future	2	15.4	2	7.4	3	6.0	22	18.6		
	Never	0	0.0	2	7.4	2	4.0	5	4.2		
Metaverse	Near future	7	53.8	15	55.6	18	36.0	25	21.2	22.194	**0.008***
	Medium-term future	3	23.1	7	25.9	21	42.0	62	52.5		
	Distant future	3	23.1	2	7.4	9	18.0	26	22.0		
	Never	0	0.0	3	11.1	2	4.0	5	4.2		
Blockchain	Near future	10	76.9	12	44.4	21	42.0	27	22.9	24.040	**0.004***
	Medium-term future	3	23.1	8	29.6	22	44.0	61	51.7		
	Distant future	0	0.0	5	18.5	5	10.0	26	22.0		
	Never	0	0.0	2	7.4	2	4.0	4	3.4		

Table 7 ***(continued)***

Cloud computing	Near future	8	61.5	19	70.4	20	40.0	29	24.6	29.608	**0.001***
	Medium-term future	2	15.4	5	18.5	22	44.0	63	53.4		
	Distant future	3	23.1	2	7.4	5	10.0	23	19.5		
	Never	0	0.0	1	3.7	3	6.0	3	2.5		

Note. *: $p < 0.05$.

The findings indicate that there is no statistically significant relationship (p>.05) between the operational status of hotel businesses and the adoption of I4.0 technologies (Table 9). However, a statistically significant relationship (p<.05) was found between service type and adopting I4.0 technologies. As shown in Table 10, the results reveal that all I4.0 technologies are expected to have higher adoption rates among luxury hotel businesses shortly. Among these technologies, face recognition (64.9%) emerged as the most likely to be adopted by luxury hotel businesses shortly. In the long term, all I4.0 technologies will have higher adoption rates among budget hotel businesses. Specifically, chatbots (26.1%) were identified as the most likely to be adopted by budget hotel businesses in the distant future.

Table 8
Chi-square test of the relationship between business size and the adoption of I4.0 technologies

Technology	Time frame	Small (10-49 rooms)		Medium (50-99 rooms)		Large (101+ rooms)		X^2	p
		n	%	n	%	n	%		
Chatbot	Near future	16	21.9	21	28.8	28	45.2	31.610	**0.000***
	Medium-term future	34	46.6	47	64.4	25	40.3		
	Distant future	21	28.8	2	2.7	5	8.1		
	Never	2	2.7	3	4.1	4	6.5		
Service robot	Near future	15	20.5	24	32.9	27	43.5	20.007	**0.003***
	Medium-term future	37	50.7	39	53.4	24	38.7		
	Distant future	20	27.4	8	11.0	6	9.7		
	Never	1	1.4	2	2.7	5	8.1		
AR/VR	Near future	18	24.7	22	30.1	27	43.5	17.518	**0.008***
	Medium-term future	32	43.8	41	56.2	20	32.3		
	Distant future	21	28.8	8	11.0	10	16.1		
	Never	2	2.7	2	2.7	5	8.1		
Internet of things	Near future	18	24.7	22	30.1	32	51.6	25.473	**0.000***
	Medium-term future	34	46.6	42	57.5	15	24.2		
	Distant future	19	26.0	8	11.0	10	16.1		
	Never	2	2.7	1	1.4	5	8.1		
Face recognition	Near future	15	20.5	24	32.9	38	61.3	39.778	**0.000***
	Medium-term future	38	52.1	42	57.5	18	29.0		
	Distant future	19	26.0	4	5.5	3	4.8		
	Never	1	1.4	3	4.1	3	4.8		
Big data	Near future	17	23.3	25	34.2	30	48.4	22.064	**0.001***
	Medium-term future	36	49.3	41	56.2	21	33.9		
	Distant future	18	24.7	5	6.8	6	9.7		
	Never	2	2.7	2	2.7	5	8.1		
Metaverse	Near future	15	20.5	22	30.1	28	45.2	20.365	**0.002***
	Medium-term future	38	52.1	38	52.1	17	27.4		
	Distant future	19	26.0	10	13.7	11	17.7		
	Never	1	1.4	3	4.1	6	9.7		

Table 8 ***(continued)***

Blockchain	Near future	17	23.3	22	30.1	31	50.0	23.402	**0.001***
	Medium-term future	37	50.7	41	56.2	16	25.8		
	Distant future	18	24.7	8	11.0	10	16.1		
	Never	1	1.4	2	2.7	5	8.1		
Cloud computing	Near future	19	26.0	28	38.4	29	46.8	15.912	**0.014***
	Medium-term future	33	45.2	37	50.7	22	35.5		
	Distant future	19	26.0	7	9.6	7	11.3		
	Never	2	2.7	1	1.4	4	6.5		

Note. *: $p < 0.05$.

Table 11 presents the relationship between the customer segment and adopting I4.0 technologies. The findings indicate a statistically significant relationship ($p<.05$) between the customer segment and all I4.0 technologies, except chatbots. The results suggest that, shortly, I4.0 technologies will have higher adoption rates among hotel businesses serving the MICE (Meetings, Incentives, Conferences, and Exhibitions) customer segment. In contrast, in the distant future, hotel businesses catering to the business customer segment are expected to have higher adoption rates of I4.0 technologies. Among these technologies, Blockchain (29.9%) was identified as the most likely to be adopted by these businesses in the long term.

Table 9
Chi-square test of the relationship between operational status and the adoption of I4.0 technologies

Technology	Time frame	Continuous		Seasonal		X^2	p
		n	%	n	%		
Chatbot	Near future	52	30.2	13	36.1	2.914	0.405
	Medium-term future	89	51.7	17	47.2		
	Distant future	25	14.5	3	8.3		
	Never	6	3.5	3	8.3		
Service robot	Near future	52	30.2	14	38.9	1.569	0.667
	Medium-term future	83	48.3	17	47.2		
	Distant future	30	17.4	4	11.1		
	Never	7	4.1	1	2.8		
AR/VR	Near future	50	29.1	17	47.2	4.556	0.207
	Medium-term future	80	46.5	13	36.1		
	Distant future	34	19.8	5	13.9		
	Never	8	4.7	1	2.8		
Internet of things	Near future	54	31.4	18	50.0	4.869	0.182
	Medium-term future	80	46.5	11	30.6		
	Distant future	31	18.0	6	16.7		
	Never	7	4.1	1	2.8		
Face recognition	Near future	59	34.3	18	50.0	3.980	0.264
	Medium-term future	83	48.3	15	41.7		
	Distant future	24	14.0	2	5.6		
	Never	6	3.5	1	2.8		
Big data	Near future	55	32.0	17	47.2	3.520	0.318
	Medium-term future	85	49.4	13	36.1		
	Distant future	25	14.5	4	11.1		
	Never	7	4.1	2	5.6		
Metaverse	Near future	52	30.2	13	36.1	3.617	0.306
	Medium-term future	81	47.1	12	33.3		
	Distant future	30	17.4	10	27.8		
	Never	9	5.2	1	2.8		

Table 9 ***(continued)***

Blockchain	Near future	53	30.8	17	47.2	3.599	0.308
	Medium-term future	81	47.1	13	36.1		
	Distant future	31	18.0	5	13.9		
	Never	7	4.1	1	2.8		
Cloud computing	Near future	57	33.1	19	52.8	5.135	0.162
	Medium-term future	81	47.1	11	30.6		
	Distant future	28	16.3	5	13.9		
	Never	6	3.5	1	2.8		

Table 10
Chi-square test of the relationship between service type and the adoption of I4.0 technologies

Technology	Time frame	Budget		Mid-range		Luxury		X^2	p
		n	%	n	%	n	%		
Chatbot	Near future	18	20.5	20	31.7	27	47.4	31.152	**0.000***
	Medium-term future	45	51.1	37	58.7	24	42.1		
	Distant future	23	26.1	1	1.6	4	7.0		
	Never	2	2.3	5	7.9	2	3.5		
Service robot	Near future	19	21.6	22	34.9	25	43.9	16.768	**0.010***
	Medium-term future	47	53.4	32	50.8	21	36.8		
	Distant future	21	23.9	5	7.9	8	14.0		
	Never	1	1.1	4	6.3	3	5.3		
AR/VR	Near future	18	20.5	18	28.6	31	54.4	20.713	**0.002***
	Medium-term future	46	52.3	31	49.2	16	28.1		
	Distant future	21	23.9	10	15.9	8	14.0		
	Never	3	3.4	4	6.3	2	3.5		
Internet of things	Near future	18	20.5	21	33.3	33	57.9	28.247	**0.000***
	Medium-term future	46	52.3	30	47.6	15	26.3		
	Distant future	22	25.0	7	11.1	8	14.0		
	Never	2	2.3	5	7.9	1	1.8		
Face recognition	Near future	16	18.2	24	38.1	37	64.9	35.642	**0.000***
	Medium-term future	51	58.0	30	47.6	17	29.8		
	Distant future	18	20.5	6	9.5	2	3.5		
	Never	3	3.4	3	4.8	1	1.8		
Big data	Near future	18	20.5	23	36.5	31	54.4	23.464	**0.001***
	Medium-term future	47	53.4	31	49.2	20	35.1		
	Distant future	20	22.7	5	7.9	4	7.0		
	Never	3	3.4	4	6.3	2	3.5		
Metaverse	Near future	15	17.0	21	33.3	29	50.9	19.865	**0.003***
	Medium-term future	47	53.4	29	46.0	17	29.8		
	Distant future	22	25.0	10	15.9	8	14.0		
	Never	4	4.5	3	4.8	3	5.3		
Blockchain	Near future	16	18.2	22	34.9	32	56.1	23.501	**0.001***
	Medium-term future	49	55.7	27	42.9	18	31.6		
	Distant future	20	22.7	11	17.5	5	8.8		
	Never	3	3.4	3	4.8	2	3.5		
Cloud computing	Near future	21	23.9	23	36.5	32	56.1	17.792	**0.007***
	Medium-term future	46	52.3	29	46.0	17	29.8		
	Distant future	19	21.6	8	12.7	6	10.5		
	Never	2	2.3	3	4.8	2	3.5		

Note. *: $p < 0.05$.

Table 11
Chi-square test of the relationship between customer segment and the adoption of I4.0 technologies

Technology	Time frame	Business		Leisure		MICE		Health		X^2	p
		n	%	n	%	n	%	n	%		
Chatbot	Near future	18	26.9	25	30.1	17	50.0	5	20.8	15.596	**0.076**
	Medium-term future	32	47.8	42	50.6	16	47.1	16	66.7		
	Distant future	14	20.9	11	13.3	0	0.0	3	12.5		
	Never	3	4.5	5	6.0	1	2.9	0	0.0		
Service robot	Near future	19	28.4	27	32.5	17	50.0	3	12.5	22.764	**0.007***
	Medium-term future	26	38.8	42	50.6	16	47.1	16	66.7		
	Distant future	17	25.4	12	14.5	0	0.0	5	20.8		
	Never	5	7.5	2	2.4	1	2.9	0	0.0		
AR/VR	Near future	13	19.4	32	38.6	18	52.9	4	16.7	24.750	**0.003***
	Medium-term future	30	44.8	35	42.2	14	41.2	14	58.3		
	Distant future	18	26.9	14	16.9	1	2.9	6	25.0		
	Never	6	9.0	2	2.4	1	2.9	0	0.0		
Internet of things	Near future	16	23.9	33	39.8	19	55.9	4	16.7	22.155	**0.008***
	Medium-term future	31	46.3	31	37.3	14	41.2	15	62.5		
	Distant future	15	22.4	16	19.3	1	2.9	5	20.8		
	Never	5	7.5	3	3.6	0	0.0	0	0.0		
Face recognition	Near future	16	23.9	38	45.8	19	55.9	4	16.7	29.779	**0.000***
	Medium-term future	31	46.3	35	42.2	15	44.1	17	70.8		
	Distant future	16	23.9	7	8.4	0	0.0	3	12.5		
	Never	4	6.0	3	3.6	0	0.0	0	0.0		
Big data	Near future	14	20.9	34	41.0	19	55.9	5	20.8	25.518	**0.002***
	Medium-term future	32	47.8	38	45.8	14	41.2	14	58.3		
	Distant future	16	23.9	8	9.6	0	0.0	5	20.8		
	Never	5	7.5	3	3.6	1	2.9	0	0.0		
Metaverse	Near future	13	19.4	28	33.7	19	55.9	5	20.8	22.707	**0.007***
	Medium-term future	31	46.3	35	42.2	14	41.2	13	54.2		
	Distant future	18	26.9	16	19.3	0	0.0	6	25.0		
	Never	5	7.5	4	4.8	1	2.9	0	0.0		
Blockchain	Near future	13	19.4	32	38.6	18	52.9	7	29.2	25.722	**0.002***
	Medium-term future	29	43.3	36	43.4	15	44.1	14	58.3		
	Distant future	20	29.9	13	15.7	0	0.0	3	12.5		
	Never	5	7.5	2	2.4	1	2.9	0	0.0		
Cloud computing	Near future	18	26.9	33	39.8	18	52.9	7	29.2	19.438	**0.022***
	Medium-term future	28	41.8	34	41.0	15	44.1	15	62.5		
	Distant future	17	25.4	14	16.9	0	0.0	2	8.3		
	Never	4	6.0	2	2.4	1	2.9	0	0.0		

Note. *: $p < 0.05$.

5. Conclusion and implications

The present study examines the relationship between hotel business characteristics and the adoption of I4.0 technologies within the context of the near, medium, and distant future. In this regard, it investigates nine different hotel business characteristics and nine distinct I4.0 technologies. The findings reveal a statistically significant relationship between adopting I4.0 technologies and business type, star rating, ownership structure, business age, business size, service type, and customer segment. Conversely, the results indicate no significant relationship between adopting I4.0 technologies and location or operational status. The findings are discussed below.

First, the study indicates that in the near future, the adoption of I4.0 technologies is expected to be higher among resort hotels, whereas in the distant future, motels and hostels are projected to adopt these technologies at higher rates. This finding supports those of previous research suggesting that smaller hotels face difficulties in adopting advanced technologies due to budget constraints (Dhakal & Tjokro, 2024; Osei et al., 2024). Moreover, we found that five-star hotels are more likely to adopt I4.0 technologies in the near term, while one-star hotels are expected to have higher adoption rates in the distant future. Similarly, Nam et al. (2021) highlight that higher-star-rated hotels perceive advanced technologies as tools for enhancing guest experiences through personalisation and operational optimisation. Thus, higher-star-rated hotels are more willing to adopt advanced technologies. The study, on the other hand, reveals that businesses operating under management agreements and franchise models are expected to lead the adoption of I4.0 technologies in the near term. Independent hotel businesses are projected to adopt them in the distant future. According to Ozturk and Hancer (2014), one of the primary objectives of franchisors is to ensure consistent service delivery across all franchise units. Thus, authors highlight that hotels that are part of franchise systems are more likely to adopt new technologies.

We observed that large-scale hotel businesses (101+ rooms) are expected to lead the adoption of I4.0 technologies in the near term. In contrast, small-scale hotel businesses (10–49 rooms) are projected to adopt these technologies at higher rates in the distant future. This finding supports the existing debate suggesting that micro, small, and medium-sized accommodation enterprises have historically been slower in adopting digital technologies due to barriers such as limited infrastructure, financial resources, and training (Buhalis et al., 2024; Nikopoulou et al., 2023). Also, results show that the adoption rate of I4.0 technologies will be higher among luxury hotel businesses in the near term. Budget hotels are expected to adopt these technologies at a higher rate in the distant future. This supports the current body of literature indicating that hotel owners in budget segments tend to reject or postpone technological investments. Because they don't perceive technology as necessary or prioritised within their operational strategies (Chan et al., 2018).

The findings further reveal that hotel businesses serving the MICE (Meetings, Incentives, Conferences, and Exhibitions) consumer segment are expected to adopt I4.0 technologies at higher rates in the near term. Moreover, those catering to the business customer segment are projected to have higher adoption rates in the more distant future. This finding is consistent with prior research (Osei & Cheng, 2024) and the mission of the task–technology fit theory (Schrier et al., 2010). According to the theory, when the functionality of a technology matches users' task requirements, technology adoption increases. MICE (Meetings, Incentives, Conferences, and Exhibitions) activity has task requirements such as time sensitivity or data intensity. As technology fits the task requirements of MICE, hotels are more inclined to adopt advanced technologies to manage them.

The findings showed that older hotel businesses (established in 1984 or earlier) will likely adopt I4.0 technologies in the near term, while younger businesses (established in 2010 or later) are expected to have higher adoption rates in the distant future. Although this finding contradicts what we discussed in this study, it is parallel to previous research findings. Van Ta et al. (2024) observed no relationship between firm age and technology adoption. The reason is that young businesses are already equipped with technological infrastructure when they are established and do not require additional technological investments. The inverse relationship between firm age and technology adoption can also be interpreted through the lens of dynamic capabilities theory (Ziyae et al., 2022). In this theory, firms' abilities to reconfigure resources and respond to environmental changes reflect their dynamic capabilities. Business develops dynamic capabilities over time. Thus, older hotels may have stronger dynamic capabilities, thus facilitating them to recognize technological underdevelopment.

Lastly, the results indicate no significant relationship between the adoption of I4.0 technologies and either location or operational status. This finding is consistent with previous research (Ivanov et al., 2020). The reason can be explained through the lens of institutional theory (Soares et al., 2021). According to institutional

theory, firms' technology adoption decisions are influenced by external pressures. One of these is mimetic pressure. Accordingly, firms imitate the practices of successful businesses to gain legitimacy. Based on this, in the current location where accommodation businesses are situated, as other businesses have not adopted the technology, it may be hindering its adoption. Also, coercive pressure reflects that consumer pressure influences businesses' technology decisions. From this perspective, the non-significant relationship between operational status (year-round and seasonal) and I4.0 technology adoption may arise from the lack of consumer technological demands.

5.1. Contributions and implications

The present study makes several contributions to literature. First, despite various studies examining the relationship between the characteristics of hotel businesses and the adoption of foundational technologies such as information and communication technologies (Ozturk & Hancer, 2014), research within the scope of I4.0 technologies remains limited. By analysing nine different I4.0 technologies, this study contributes to the literature by identifying how different business characteristics influence the adoption of specific I4.0 technologies.

Second, the relationship between business characteristics and adoption of technology has often been examined within the context of an uncertain future. The present study advances the literature by investigating the adoption of I4.0 technologies within the frameworks of the near, medium, and distant future. For instance, industry reports, such as Amadeus (2024), suggest that branded hotels are more likely than independent properties to invest in technology and adopt AI and digital payments in the short term. This study extends this understanding by revealing that resorts, five-star hotels, older businesses, large-scale hotel enterprises, and luxury hotels are more likely to adopt face recognition systems shortly. This study enhances the understanding of technology adoption trends in the hotel industry by identifying which business types are more inclined to adopt specific technologies across different time horizons.

Third, the present study advances widely accepted discussions on the relationship between various business characteristics and technology adoption. For instance, previous research has observed that older hotels tend to be less inclined to adopt technology than newer establishments (Sahadev & Islam, 2005). However, the findings of this study extend this discussion by demonstrating an inverse relationship between business age and adoption of I4.0 technology, revealing that older hotel businesses will be more prominent in the early adoption of I4.0 technologies shortly. Through the principles of the dynamic capabilities' theory, this study contributes to the literature by showing that older businesses are more enthusiastic than younger businesses in renewing their infrastructure in response to environmental change.

Fourth, earlier studies suggested no significant relationship exists between customer segment and technology adoption (Ivanov et al., 2020). Moreover, it has been argued that business hotels may prioritise big data due to privacy concerns, while leisure hotels may focus more on AI for entertainment and uniqueness (Osei & Cheng, 2024). This study, in contrast, identifies a statistically significant relationship between the customer segment and I4.0 technology adoption, showing that, shortly, business hotels are more likely to adopt service robots, while leisure hotels prioritise face recognition. Furthermore, this result aligns with previous findings suggesting that managers perceive robots as more suitable for business hotels (Milohnić & Kapeš, 2024) and contributes to the existing literature by providing empirical support. From a task–technology fit perspective, the study also broadens the current body of literature by revealing that the customer segment is associated with early technology adoption in terms of the requirements of the tasks.

The study also lists a handful of implications for hotel businesses and technology providers. To prioritise their technology investments, the hotel authorities may benefit from such insights while making decisions about technology investments, considering their firm characteristics. Technology providers can use this

information to better approach their specific target markets, which need technology-based products and services to operate in a technology-driven environment. Among such products or services may be adopting technologies such as face recognition by luxury and/or five-star hotels to enhance service quality and customer experience, increasing customer satisfaction and loyalty. Older hotel businesses can also be considered in this segment, which may be desperate to leverage their technological infrastructure to modernize and remain competitive. Considering the influence of business size, large-scale businesses may have a higher inclination to adopt such technologies in their medium and long-term innovative investment strategies. All these operations also require hotel businesses to invest in staff training to develop their skills and competencies in collaboration with technology providers responsible for offering robust customer support and tailored-based training programs.

5.2. Limitations

The present study has several limitations that should be addressed in future research. First, this study focuses on a limited number of business characteristics based on widely accepted classifications. Future research could consider socioeconomic contextual characteristics that allow for a more in-depth examination. For example, technological investment levels, annual revenues, and service offerings (e.g., all-inclusive services) could be explored. Second, this study examines the adoption of I4.0 technologies within a future-oriented timeframe, providing forward-looking insights into technology adoption. However, this approach imposes limitations on understanding the relationship between business characteristics and the current adoption of technologies. Therefore, future research could conduct comparative analyses between businesses that have adopted specific technologies and those that have not. Third, although this study focuses on hotel businesses, technological transformation in the tourism and hospitality industry extends to other stakeholders, including food and beverage, travel, and entertainment. Therefore, future research could explore technological transformation in tourism and hospitality from different perspectives by focusing on various industry stakeholders. Finally, the findings of this study are based on primary data. Future research could incorporate secondary data sources to advance both this research and previous studies on business characteristics and technology adoption. For instance, businesses that actively use various technologies in their operational processes could be identified, and their size, location, and other characteristics could be analyzed.

Declaration of Competing Interests

The authors declare that they have no known competing interests that could have appeared to influence the work reported in this paper.

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