



Review

Overviews of Internet of Things Applications in China's Hospitality Industry

Mengyuan Chen ¹, Zheng Jiang ² , Zezheng Xu ³, Aihua Shi ⁴, Mingyan Gu ⁵ and Yuanzhe Li ^{6,*} 

¹ School of Tourism and Hospitality, Management Development Institute of Singapore, Singapore 148951, Singapore; cmy677@126.com

² Faculty of Computing & Informatics, Persiaran Multimedia, Cyberjaya 63100, Malaysia; jiangzheng292679@gmail.com

³ Department of Diplomacy, China Foreign Affairs University, Beijing 100037, China; benjaminxzz@163.com

⁴ School of Economics and Management, Hebei College of Science and Technology, Baoding 071000, China; s1522621455@163.com

⁵ School of Business and Management, University of South Wales, Cardiff CF37 1DL, UK; gumingyan@outlook.com

⁶ School of Materials Science & Engineering, Nanyang Technological University, Singapore 639798, Singapore

* Correspondence: yuanzhe001@e.ntu.edu.sg

Abstract: During the current post-epidemic period, hygiene requirements and health needs in the hospitality industry keep increasing, and consumers become more concerned about the cleanliness of hotels and have stronger demands for contactless services in hotels. The growth and popularity of IoT technology in China make it more accessible to a wider range of service industries and provides the basis for the application of IoT in the hospitality industry. The application of IoT devices in hotels mainly includes intelligent robots, intelligent guest control, systems, etc., which helps to realize contactless services in hotels. This research reviews the entire development cycle of the application of IoT in the hospitality industry, from the founding, development, and expansion of companies to their IPO and post-IPO maturity. From a perspective combined with IoT technology, we can cope with the changing industry models, business models, and operation modes in the hospitality industry more efficiently. The development of IoT in hotels will move towards humanization and service-orientation. Through the role of human-machine linkage and the reasonable management of IoT equipment, IoT technology can reasonably promote the efficiency of manual work, while injecting "warmth" and "quality" into IoT equipment.

Keywords: internet of things (IoT); smart hotels; efficiency; cost reduction



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1. Introduction

The Internet of Things (IoT) is a phrase that refers to the inclusion of internet connectivity in everyday devices and appliances that do not usually have such functionality. Examples of these devices may range from thermostats and energy meters to vehicles and large machines (Mercan, S. et al. 2021). In essence, the IoT is able to turn these devices or appliances into 'smart' objects that can send and receive data and communicate with each other. This also can improve data collection, increase automation, and allow multiple devices to be controlled or monitored from a centralized location (such as a mobile phone or tablet) [1].

IoT hotels have recently been widely discussed in the hospitality industry. With the development of China's communication industry and internet coverage, the smartening of hotels is an inevitable trend. The industry chain of IoT application in hotels in China is relatively distinct, with the upstream of the industry chain being raw materials for IoT devices, the midstream being hotel IoT service providers, and the downstream being hotels. In the upstream, although China's independent research and development of chip

enthusiasm is high and the chip design is developing rapidly, China's chip market still relies heavily on overseas imports. The midstream of IoT comprehensive service providers and software service providers are mainly under a cooperation-based relationship. The downstream is mainly for hotel applications. From 2016 to 2020, the market size of IoT in hotels in China has grown from 51.74 billion RMB to 67.18 billion RMB, with a compound annual growth rate of 5.4% [2].

Many hospitality companies are already successfully deploying IoT applications in their hotels to improve guest satisfaction, staff productivity, and environmental sustainability, while reducing unnecessary costs and labor [3]. Included below are five current trends relating to the IoT technology in the hospitality industry:

1.1. Room Automation

Room automation sets hotels apart from their competitors by making guests feel more comfortable and modern. For example, Starwood Hotels & Resorts uses a technology called Daylight Harvesting to save energy and improve the consistency of in-room lighting by automatically adjusting LED lighting based on the natural light in the room [4].

1.2. Predictive Maintenance

Predictive maintenance uses sensors' activity data to identify dangerous trends and notify the appropriate maintenance engineer before problems escalate, allowing for further preventative maintenance. For example, manually tracking 16 m at a labor cost of \$16/h and checking the meters once a day may cost \$3840 per year. With the implementation of sensors, the systematic checking of all the meters can be conducted in seconds. Predictive maintenance allows you to make a highly accurate forecast of when and where repairs may need be carried out. It focuses people's attention on where and when they need maintenance most [5].

1.3. Mobile Interaction

There are 6.8 billion mobile phones and more than 85% of the global population has access to cellular coverage as of December 2021. Guests can use their mobile phones as room keys or submit requests to the front desk. Mobile engagement is also backed up by in-house tools through the use of the Enterprise asset management (EAM) and computerized maintenance management systems (CMMS) applications. Engineers can access work requests or work instructions that need to be carried out on the property to eliminate written requests to guests, thus increasing guest satisfaction.

1.4. Hyper-Personalization

Personal data can be used to personalize hotel guests and make a difference to their stay [6]. For example, as time passes, IoT platforms can remember guests' specific comfort preferences, such as temperature, lighting, and TV channels, and automatically set the room for the next stay.

1.5. APIs and Third-Party Integrations

As the IoT market matures, suppliers are likely to merge, resulting in a smaller number of suppliers with more cohesive system offerings. Until then, APIs (Application Programming Interfaces) that integrate with standard data communication protocols will be the focus of integrated IoT systems.

The concept of the Internet of Things (IoT) is no longer difficult to imagine, as it is used in our homes, businesses, and in multiple industries around the world to automate processes, increase productivity, and reduce unnecessary labor costs [7]. In the racing advancement of the industrial and internet revolutions, companies like General Electric are calling the Industrial Internet of Things (IIoT) the "third wave of innovation".

2. Background on the Foundation of Internet of Things (IoT)

2.1. Architecture of Internet of Thing

The IoT can be broadly divided into the following four layers (Figure 1): a Perception Layer, a Network Layer, a Platform Layer, and an Application Layer [8,9].

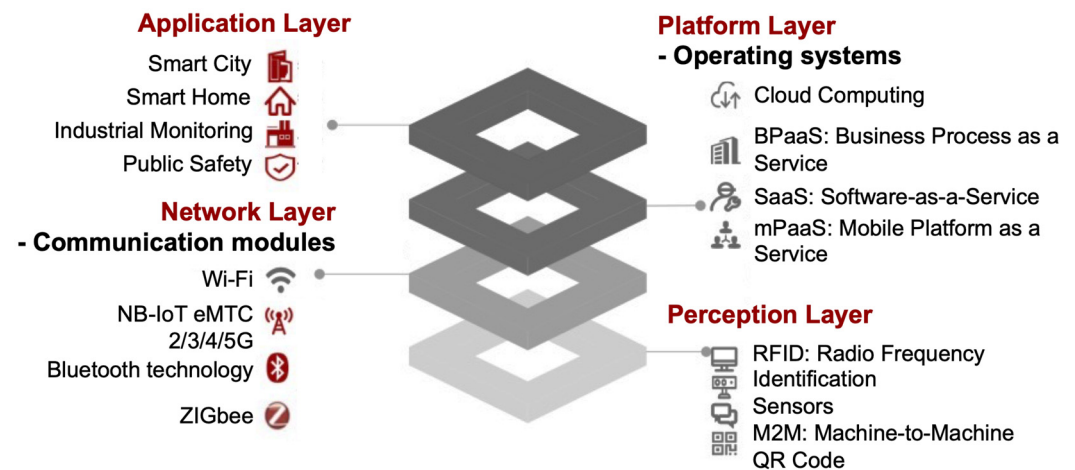


Figure 1. Architecture of Internet of Thing (IoT).

1. **Perception Layer:** The perception layer is responsible for the collection and acquisition of IoT information and is the foundation of the overall IoT architecture. In the sensing layer, sensors sense information about the object itself and its surroundings, so the object also has the ability to speak and publish information.

2. **Network Layer:** The network layer transmits the information collected by the perception layer to the IoT cloud platform and is also responsible for transmitting the commands issued by the IoT cloud platform to the application layer, which has a linking effect. The network layer transmits a large amount of information mainly through the IoT, the Internet, and mobile communication networks.

3. **Platform Layer:** Platform management mainly addresses issues such as data storage, retrieval, use, and data security and privacy protection.

4. **Application Layer:** The ultimate purpose of IoT is to be applied to various scenarios. After processing the information transmitted by objects on the IoT cloud platform, the valuable mined information will be applied to practical life and work such as smart logistics, smart medical care, and food safety.

If the human neural network is taken as an analogy, then human sense organs are the perception layer of IoT, such as eyes that can collect visual information, a nose that collects smell information, a mouth that collects taste information, and ears that collect sound information. This information is transmitted to the brain center through neurons, and the neural transmission channels formed by these neurons are equivalent to the network layer in the IoT, whose role is to transmit the information to the processing center. When it receives information from the eyes, nose, mouth, ears, etc., it can synthesize it to draw some useful conclusions, such as determining whether there is danger now, acquiring the ability to read a book or watch a movie, etc. [10]. This is equivalent to it applying the information from the perception layer and generating value.

2.2. Technical Support for Internet of Thing

The IoT architecture can be divided into three layers: the sensing layer, the network layer, and the application layer [11]. The roles and responsibilities of these layers in the IoT system are explained below (Figure 2).

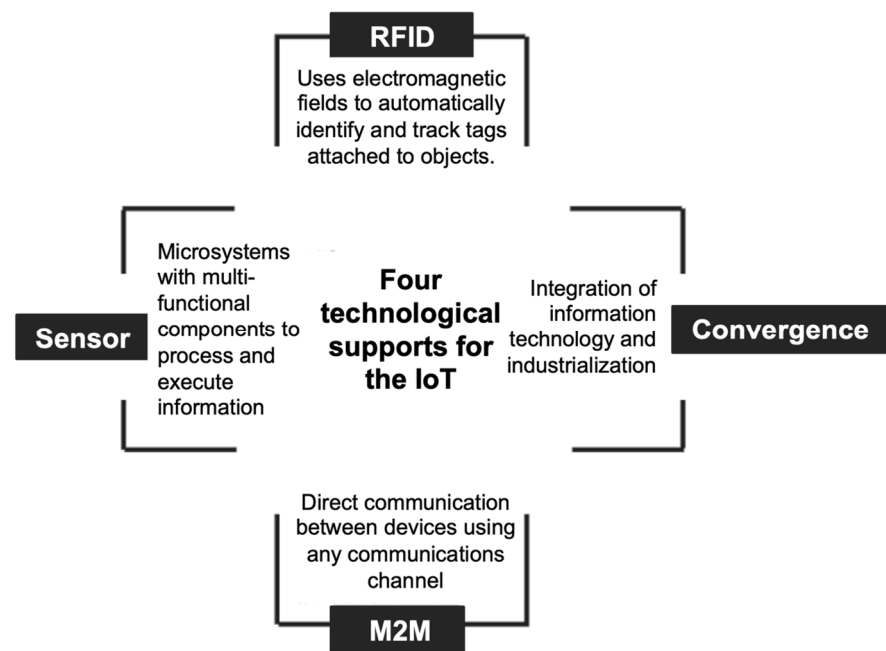


Figure 2. Technical support for the Internet of Things.

The application of network technology to everything, forming the “Internet of Things”, involves processes such as embedding sensors into equipment, and then integrating the “Internet of Things” with the “Internet” to achieve the integration of human society and physical systems. Supercomputer clusters manage and control the people, machines, and infrastructure of the ‘integrated network’ in real time to manage production and life in a fine-grained and dynamic way, to improve the utilization of resources and productivity, and to improve the relationship between man and nature [12].

There are four main technologies supporting the IoT, namely RFID, sensor networks, M2M, and the convergence of two technologies, which are fully applied in various scenarios of IoT use and are the basic elements for the realization of the IoT [13].

1. **RFID:** Electronic tags belong to the category of smart cards. The concept of the Internet of Things was proposed by Professor Ashton, Director of the MIT Auto-ID Centre in 1999. With respect to the Internet of Things, RFID mainly plays an “enabling” role. RFID technology is a fusion of radio frequency technology and embedded technology as a comprehensive technology, and RFID in automatic identification and goods logistics management has broad application prospects.

2. **Sensor Network:** A network that detects and integrates material phenomena including temperature, humidity, pressure, speed, etc., with the help of various sensors, and is one of the main bases of Premier Wen’s “Sensing China”. Through the sensing network, the required information can be collected. The customer in practice can use RFID readers and related sensors, etc., to collect the required data information, and when the gateway terminal opens for convergence, the data can be smoothly transmitted to the designated application system through wireless network transport [14]. In addition, sensors can also use ZigBee and Bluetooth technologies to achieve the purpose of effective communication with the sensor gateway.

3. **M2M:** This term is more commonly used abroad, which focuses on the interconnection and centralized management of end devices, the X-Internet, and the three major Chinese communications operators, who are promoting the M2M concept. The M2M platform has a certain level of authentication, so it can provide the necessary terminal management services to customers, and it can be accessed smoothly by different access methods [15]. In addition, the M2M platform has certain management functions, such as user authentication and data routing, which can be managed effectively. The BOSS system is widely used in IoT services because of its strong billing management capabilities [16].

4. Convergence of Two Technologies: Industrial informatization is also one of the main driving forces of the IoT industry, with the automation and control industry being the main force, but there are relatively few voices from this industry.

2.3. China’s Development of the Internet of Things

China is set to become one of the world’s largest markets for IoT, with a broad market outlook and an upward trend in IoT spending in China, with a CAGR of 5.5% from 2017–2020. As indicated in Figure 3, from 2017–2018, China’s IoT spending grew at a fast rate, with a growth rate of 13.3%, and from 2018–2020 the growth rate slowed down to an average of 5.4%, with China’s IoT entering a development bottleneck and waiting for new technology breakthroughs and new applications. IoT spending in China has grown from US\$136.45 billion in 2017 to US\$168.89 billion in 2020, with a CAGR of 5.5% from 2017 to 2020 [17].

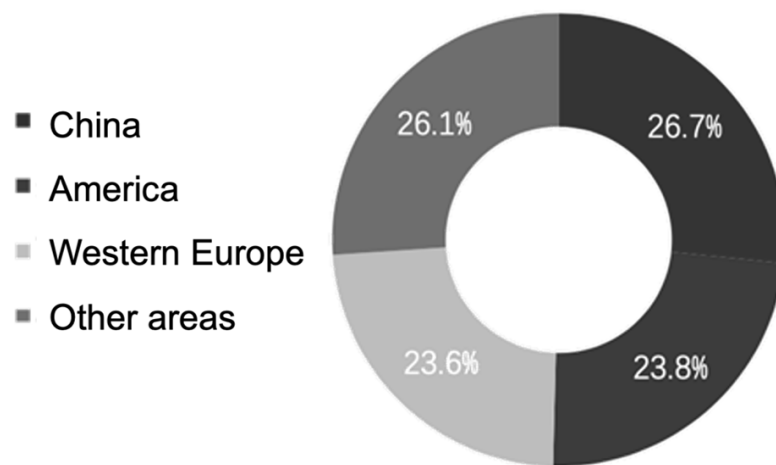


Figure 3. Forecast to 2024 for Global IoT spending.

According to the IDC forecasts for 2021 in Figure 4, China, the US, and Western Europe are expected to be the world’s top three IoT spending regions in 2024, with the three accounting for over 70% of global spending, and with the US accounting for 23.8% of global spending and Western Europe for 23.6%. In 2024, China will account for 26.7% of the world’s IoT spending, making it the world’s largest country in terms of IoT spending.

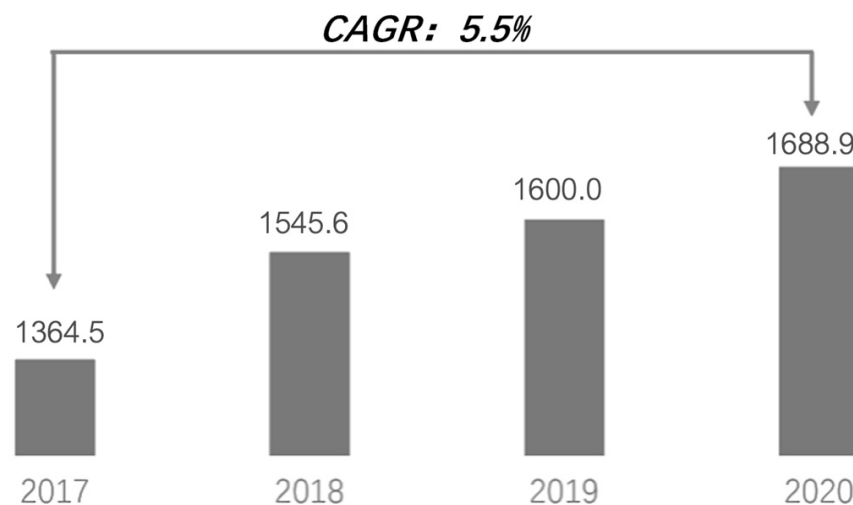


Figure 4. IoT spending in China from 2017 to 2020 (Unit: USD/billion).

2.4. Hospitality Industry Reform

The pandemic has had a major impact on the hotel accommodation industry. After the epidemic, hygiene requirements and health needs in the hospitality industry have increased, consumers are more concerned about the cleanliness of hotels, and there is a stronger demand for contactless services in hotels; therefore, the intelligent application of IoT in hotels has become an inevitable trend [18].

From 2015–2019, the number of tourists in China has been rising (Figure 5). Tourism arrivals rose from 3.99 billion in 2015 to 6.01 billion in 2019, a CAGR of 8.5% was reported over the five-year period, and total tourism revenue increased from RMB 3.4 trillion in 2015 to RMB 570 million in 2018. The number of rooms in China’s accommodation sector climbed from 2.655 million in 2013 to 4.228 million in 2019, with the occupancy rate of star-rated hotels in China remaining at approximately 58–61% during the peak season and 48–50% during the low season from 2014 to the second half of 2019. Overall, the hotel accommodation industry in China was developing steadily before the epidemic, with a stable demand [19,20].

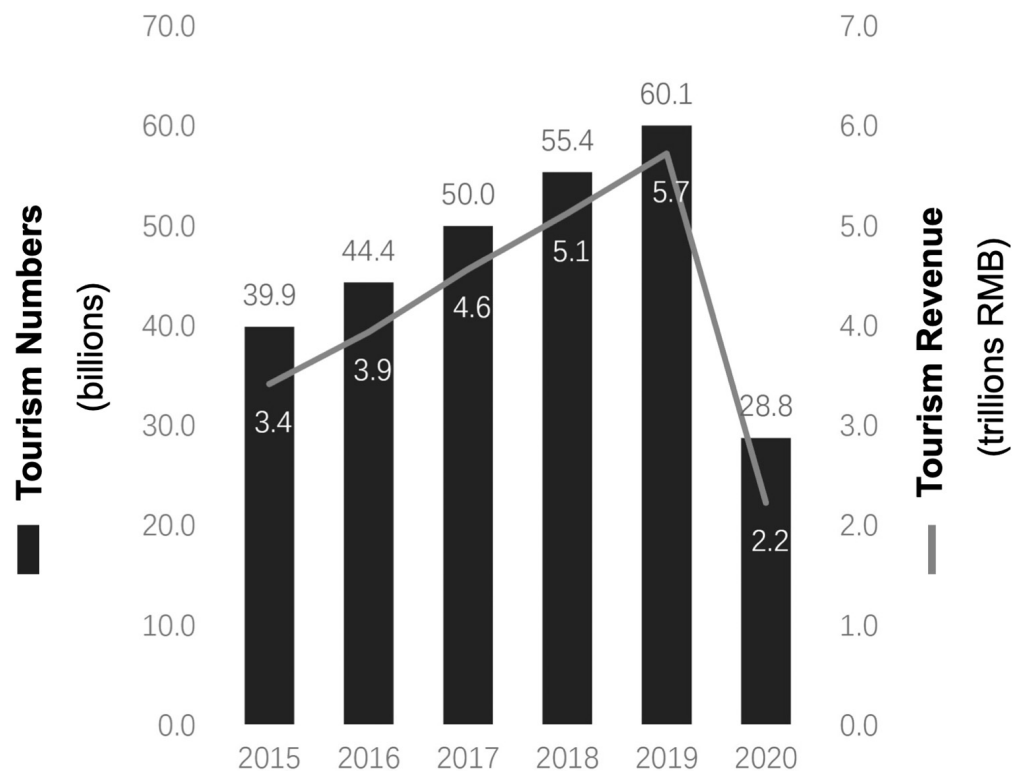


Figure 5. Tourism numbers and total tourism revenue in China from 2015 to 2020.

In 2020, China’s tourism sector was affected, with the number of visitors falling to 2.88 billion and total tourism revenue falling to RMB 2.2 trillion (Figure 6a), down 61.1% YoY. Occupancy rates for star-rated hotels in China fell to 22.8% at the beginning of 2020, but then the decline narrowed rapidly, with occupancy rates for star-rated hotels in China recovering to approximately 49% by Q3 2020 (Figure 6b).

As the pandemic continues to be contained, China’s tourism industry is gradually recovering and the hotel accommodation industry is gradually picking up, but the post-epidemic period has seen an increase in hygiene requirements and health needs in the hospitality industry, with consumers paying more attention to the cleanliness of hotels and a stronger demand for contactless services in hotels. The main applications of IoT in hotels include smart robots and intelligent guest control systems, which will help to realize contactless services in hotels.

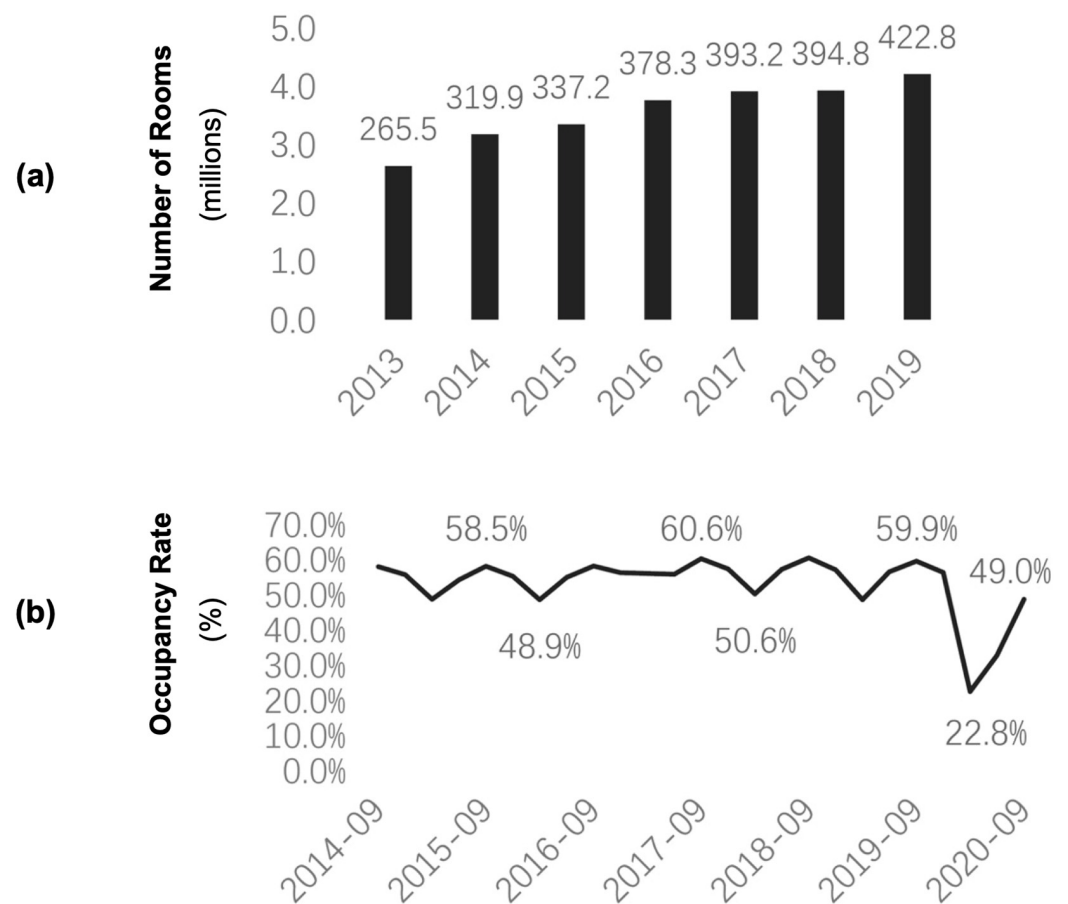


Figure 6. (a) Number of rooms in the accommodation sector in China from 2013 to 2019, and (b) occupancy rate of star-rated hotels in China from 2014 to 2020 Q3.

2.5. Application of IoT in the Hospitality Industry—Chain Analysis

The upstream of China's IoT hotel applications are raw materials for IoT devices, of which chips are highly dependent on imports, the midstream for hotel IoT service providers, and the downstream for hotels.

2.5.1. Upstream of Hospitality Industry Chain—Chips

The current Chinese chip market is heavily reliant on overseas imports, with independent development capabilities continuing to grow and midstream producers having low bargaining power over chip prices. However, China's independent chip research and development enthusiasm is high, and the chip design industry is developing rapidly [21].

2.5.2. Upstream of Hospitality Industry Chain—IoT Modules

The overall supply of IoT modules is rising, the industry is developing well, and the bargaining power is moderate, which will help the cost control of the production of IoT hotel equipment, which will bring certain benefits to the production and sales of IoT hotel equipment [22,23].

The IoT module is a key component of the IoT device; it is an important link between the cognitive layer and the transmission layer of the IoT, and it is a necessary hardware configuration and cannot be replaced. Common IoT modules are LORA control modules, RF control modules, wireless control modules, etc.

From 2015 to 2019 (Figure 7), global IoT module shipments continued to rise, from 110 million units in 2015 to 310 million units in 2019, with a compound annual growth rate of 23.0%. The overall supply of IoT modules is on the rise and the industry is developing well, providing a guaranteed raw material supply base for the production of IoT smart

devices, which will benefit the production and supply of IoT smart device manufacturers in the midstream of the industry chain.

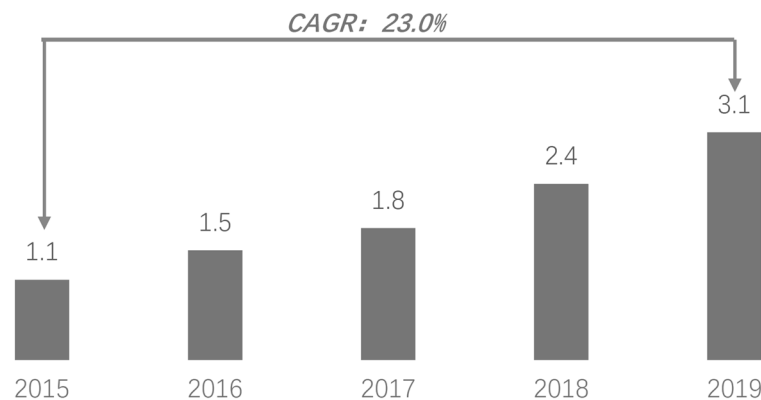
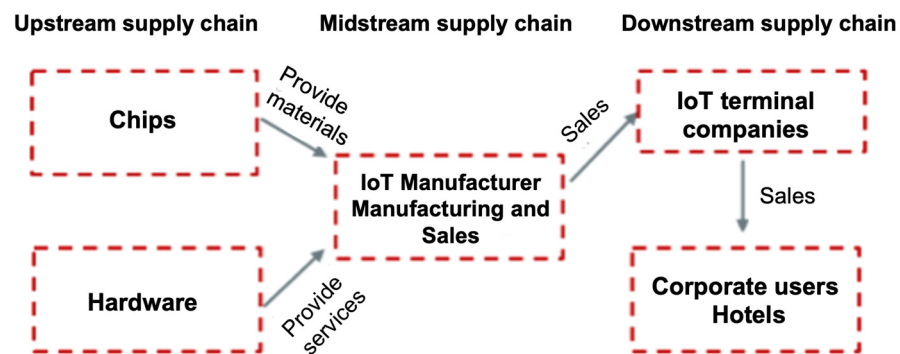


Figure 7. Global IoT module shipments from 2015 to 2019.

As summarized in Figure 8, the upstream of the overall industry chain of IoT modules in China is mainly composed of chip and other component manufacturers, the midstream is mainly composed of wireless communication module manufacturers, the downstream is for hotels and other IoT terminal enterprises, and then the IoT terminal enterprises will sell their devices to enterprise customers. The technical difficulty of module manufacturing is low, so IoT equipment manufacturers in the middle of the industry chain have moderate bargaining power over IoT modules. This will help the cost control of the production of IoT hotel equipment and the stability of the IoT's terminal price. This will bring certain benefits to the production and sales of IoT hotel equipment.



PERSONALIZATION & CUSTOMIZATION

Figure 8. IoT module business model in China.

2.5.3. Midstream of Hospitality Industry—Chain-Industry Cooperation and Integration

The midstream of hotel IoT application is mainly for hotel IoT integrated service providers, hardware equipment manufacturers, and software equipment providers, of which the midstream integrated service providers and hardware equipment manufacturers integrate with each other, and IoT integrated service providers and software service providers are mainly cooperative relationships.

The midstream of hotel IoT application is mainly composed of three parts, namely, a hotel IoT integrated service provider, a hardware equipment manufacturer, and a software equipment provider (Figure 9). On the one hand, the integrated service providers and hardware equipment manufacturers have reached a win-win cooperation and procurement agreement, and on the other hand, hardware equipment manufacturers provide IoT solutions for their customers in specialized areas.

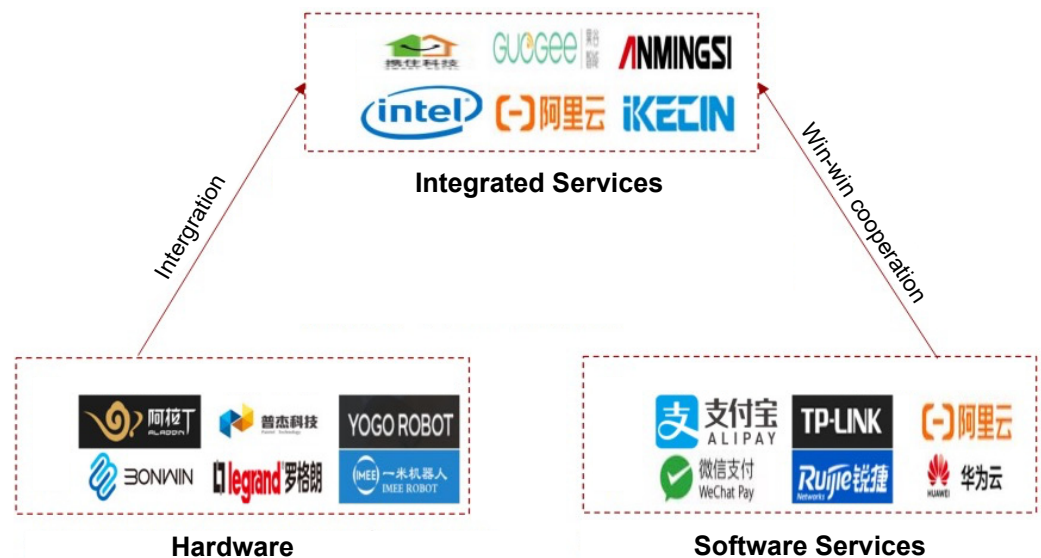


Figure 9. Midstream of the hospitality industry chain of hotel IoT applications.

The midstream of the supply chain is characterized by a high degree of concentration and professional differentiation. High-quality enterprises have emerged in various fields, such as Pujia Technology and Rogeland for intelligent control systems, Yogo Robot and Yimi Robot for intelligent robots, etc. Enterprises in the segment not only provide products for customers, but also provide IoT solutions for customers in the segment.

There are two main forms of IoT applications in the market for hotels: (1) the use of different API products from different manufacturers—the disadvantage of this model is that the operation effect after integration is relatively unstable, and the flow is not as smooth as the unified API; (2) the use of unified API products from unified manufacturers to form an IoT device ecology. The advantages of this form of operation of the IoT system are smooth operation, fewer failures, and higher efficiency. As a result, major vendors are actively building their own IoT ecosystems to boost sales of their own IoT products and maintain customer brand repurchase rates.

2.5.4. Downstream of Hospitality Industry Chain—Improving Hotel Operations

At this stream, the hospitality industry will benefit most from IoT in the areas of security and asset management; in the future, IoT will have the greatest scope and the best results in helping hotels to improve customer experience and increase revenue. According to PwC 2020 research, the hospitality industry has a high level of interest and investment in IoT applications. At this stage, the IoT has made significant improvements in enhancing guest experience, security, and asset management, with current optimization levels of 53%. In addition, the use of IoT in revenue enhancement, cost control, and big data decision making has also made a significant contribution to hotels, with 47% efficiency improvement.

In the future, the IoT will have significant room for growth in terms of enhancing the customer experience and increasing revenue. Hotels can enhance the customer experience through smart homes, robotic services, and convenient check-in and check-out options, with an estimated 33% improvement. The IoT will also increase revenue for the hospitality industry, as the smart experience of the IoT will increase the attractiveness of hotels and boost customer numbers, while the IoT system will reduce costs in terms of energy, labor, and management, and is expected to increase revenue for hotels by 37% by 2030.

The optimization effect of the IoT on the hospitality industry is relatively outstanding. At this stage, the efficiency of the IoT in all aspects of the hospitality industry is over 40%, and the overall efficiency improvement is expected to reach 70–85%. The efficiency of IoT in the hospitality industry is obviously improving the operation of hotels [24].

2.5.5. Downstream of Hospitality Industry Chain—Enhance Hotel User Experience

The use of the Internet of Things in hotels is conducive to enhancing user experience. The Internet of Things gives hotel users a more comfortable consumer experience by regulating room temperature, providing intelligent lighting, enabling smart home services, enabling supply chain management, and greening control as illustrated in Figure 10. The IoT is used to improve user experience in three main stages: before the guest checks in, after the guest checks in, and after the guest checks out [25].

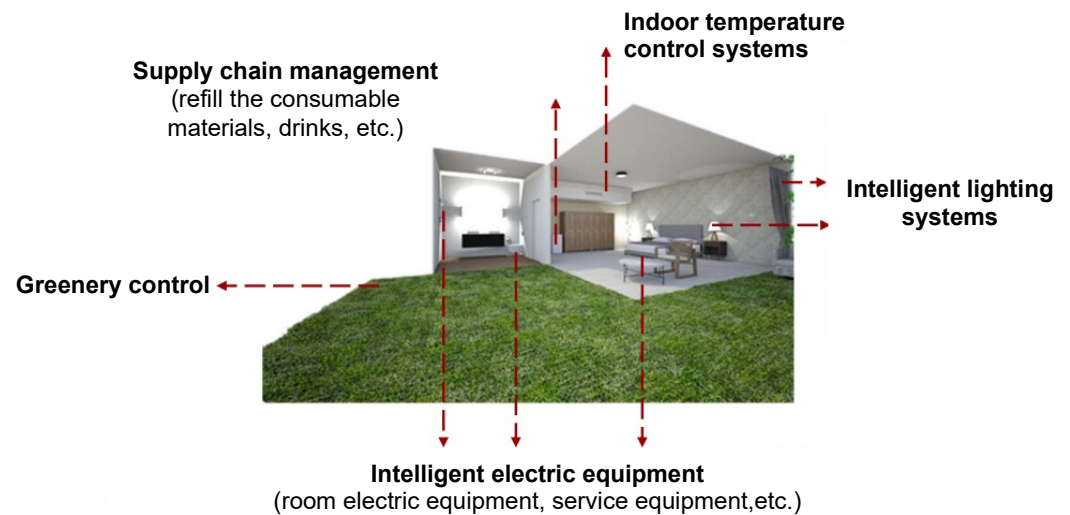


Figure 10. IoT improvements to the hotel user experience.

- Before check-in

Prior to check-in, users can use the OTA or the hotel's own booking system to book a room, and guests will receive relevant information automatically sent to the hotel, including resident information, network login information, hotel services, etc., to facilitate the use of guests. Some hotels are equipped with a self-check-in registration system, making a user's check-in more convenient.

- After check-in

The temperature control and lighting systems in the rooms can be used and deployed according to the user's actual usage and habits, making the stay more comfortable. Smart devices are flexible and easy to operate, and real-time monitoring of inventory and product quality ensures the quality of service and a smooth supply chain. The IoT is also used in the maintenance of the hotel environment, saving a lot of manpower costs and maintaining a good environment in the hotel.

- After check-out

When the user leaves the hotel, the hotel will use intelligent robots and other types of equipment to help the customer carry their luggage and quickly settle the bill through the payment channel. After the customer has left the hotel, the hotel will quickly notify the cleaning staff through the intelligent system to clean the room, which will improve the operational efficiency of the hotel and reduce the waiting time of the customer when the room is in peak use.

3. Hypothesis

3.1. IoT Can Help Hospitality Industry Revolutionize the Supply Chain to Reduce Hotel Costs

The application of the Internet of Things in the hospitality industry will revolutionize the hotel supply chain system, making it more timely, intelligent, unmanned, efficient, and cost effective. The use of the IoT in hotels will facilitate the cost control of energy, labor, and management in the hotel business process, with savings of up to 25–80%. The hospitality

industry is mainly service-oriented, so a heap of advanced IoT equipment is not conducive to the operation of the hotel. The development of the IoT in the hotel will be towards the humanization of equipment, service, the integration of technology, data, and services that will promote the development of the hotel.

3.2. The Drivers of IoT Adoption in the Hospitality Industry Depend on the Development of the Communications Industry and the Pandemic

The popularization of Wi-Fi provides a platform for IoT applications. Smartphones are the main client access points for IoT hotel equipment, and the rapid development of mobile communications and the Internet has built the foundation for the development and application of IoT in hotels. In the post-epidemic period, users and guests are demanding higher levels of pandemic prevention and cleanliness in hotels, and the demand for contactless services has increased, so there are new growth opportunities for IoT applications in hotels.

3.3. Factors Limiting the Development of IoT in the Hospitality Industry May Be due to Lack of Intelligence, Lack of Serviceability, Privacy Issues, and Lack of Financial Follow-Up

The lack of intelligence limits the use of IoT in the hospitality industry, mainly because current algorithms limit the development of IoT smart devices applications, so artificial intelligence devices are in their infancy and the capabilities of service-oriented robots are not outstanding. Privacy is currently also a hot topic in the IoT hotel and even in the IoT industry, where user data is collected in the course of use and the legality of such user data collection is debatable [26].

4. China's IoT Hospitality Industry Policy Analysis

As summarized in Table 1, in May 2020, the Notice on Furthering the Comprehensive Development of Mobile Internet of Things announced by the Ministry of Industry and Information Technology promoted the incorporation of NB-IoT standards into the ITUIMT-2020 5G standard. It targeted the key areas such as smart home, smart agriculture, industrial manufacturing, energy metering, smoke sensing, logistics tracking, and financial payment [27,28].

Table 1. List of China IoT Hospitality industry Policy from 2020 to 2021.

Policy Title	Date of Issue	Issue Department
Notice on Furthering the Comprehensive Development of Mobile Internet of Things	2020-05	Ministry of Industry and Information Technology
Three-Year Action Plan to Expand and Upgrade Information Consumption (2018–2020)	2018-07	Ministry of Industry and Information Technology
Three-Year Action Plan to Promote the Development of a New Generation of Artificial Intelligence Industries (2018–2020)	2017-12	Ministry of Industry and Information Technology
The 13th Five-Year Plan for the Internet of Things (2016–2020)	2016-12	State Council of China
Smart Manufacturing Development Plan (2016–2020)	2016-12	Ministry of Industry and Information Technology & Ministry of Finance
The 12th Five-Year Plan for the Development of the Internet of Things	2011-12	Ministry of Industry and Information Technology

Tracing back to the Three-Year Action Plan for Expanding and Upgrade Information Consumption (2018–2020), the Ministry of Industry and Information Technology also mentioned the acceleration of the development of new display products. The government would also support enterprises to increase investment in technological innovation and breakthroughs in mass production technologies such as new back panels, ultra-high definition, and flexible panels to drive product innovation and achieve product restructuring. Moreover, promoting panel enterprises and terminal enterprises to expand applications

in different fields such as the Internet, the Internet of Things, and artificial intelligence; to cultivate new growth points in the mid-to-high-end consumer sector; and to further expand the scope of applications in online health care, security, and surveillance, smart home and other fields had already become the new mission of the government work.

Similarly, the Three-Year Action Plan for Promoting the Development of a New Generation of Artificial Intelligence Industry (2018–2020) took market demand as the driving force, actively fostered innovative AI products and services, and promoted the industrialization of AI technologies and the integrated application of intelligent products in industry, healthcare, transportation, agriculture, finance, logistics, education, culture, tourism, and other fields. The development of intelligent control products was undertaken to promote the popularization of intelligent hardware; deepen the applications of artificial intelligence technology in smart homes, health management, mobile intelligent terminals, and vehicle products; and enrich the intelligent functions of terminal products.

The State Council of China had also announced the 13th Five-Year Plan for the Internet of Things (2016–2020) in order to promote innovation in the application of IoT in the consumer sector; encourage technological innovation, business innovation, and model innovation regarding the Internet of Things; and to actively cultivate new technological models and new business models and promote the rapid growth of applications in the consumer sector such as the Internet of Vehicles, smart homes, and health services. The Internet of Things has grown rapidly; hence, the strengthening in technological innovation and demonstrated applications of the Internet of Vehicles may also contribute to the larger scale of home security, intelligent control of home appliances, home environment management, and other smart home applications.

The IoT may also enhance the integration and application of a new generation of information and communication technologies in equipment (products), and promote the development, design, and industrialization of products such as intelligent network-connected vehicles and service robots. This relies on advantageous enterprises to carry out the integrated innovation and applicable demonstration of intelligent manufacturing sets of equipment and accelerate industrialization [29]. The IoT may also promote intelligent network-connected vehicles, intelligent construction machinery, and intelligent ships. Such developments may focus on supporting public security, medical and health care, and smart home and other areas of the Internet of Things-related demonstrative application projects. These developments leverage the advantages of IoT technology towards improving the quality of people's lives and the level of social public management and promote the innovation of application in the field of people's livelihood services.

5. IoT Has Been Revolutionizing the Supply Chain of Hospitality Industry to Reduce Costs

5.1. IoT Improve the Efficiency and Reduce the Cost of the Hotels Supply Chain

In the upstream of hotels' supply chain (Figure 11), the IoT system records the current product data in the warehouse in real time, and the hotel grants the rights to the supplier, who can replenish the stock in time according to the stock situation. At the same time, the supplier can also change the type and quantity of the products supplied by the hotel based on the user usage data returned by the IoT system and improve the quantity of its own products to meet market demand. The IoT equipment can be used to efficiently and quickly check the logistics and goods data through sensors and RFID technology, thus making the transport and logistics more personalized and improving the operational efficiency of the hotel.

In the midstream of the supply chain, enabling inventory management and flow detection through smart IoT devices may ensure the usual up-and-down of the supply chain, guarantee the quality of service and resource reserves in the hotel, and over time, will allow the business to predict seasonal highs and lows and raise or lower inventory levels accordingly [30].

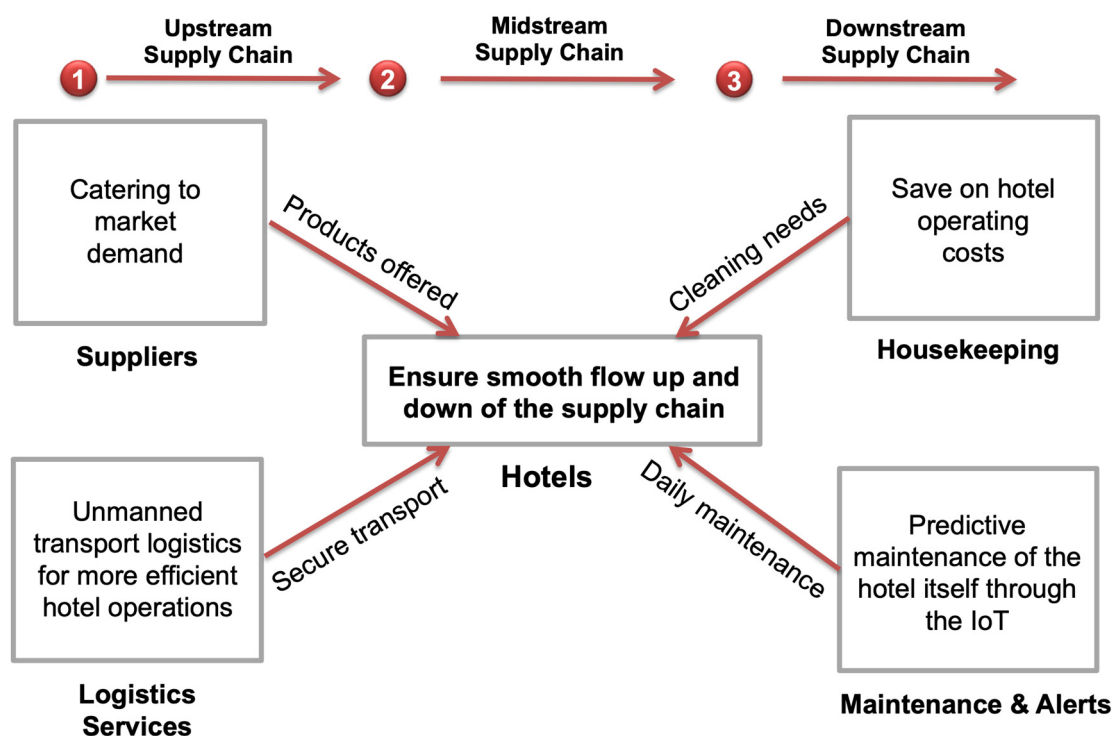


Figure 11. The use of the Internet of Things in the hotel supply chain.

In the downstream of the supply chain, regarding the aftermath of cleaning, once the guest leaves the hotel, the IoT device will instantly notify the third-party service procured by the hotel, which posts the task on the platform and the hotel cleaning professionals will take the order on the service side. In this way, hotels can share their service staff to save on operational costs. Regarding the maintenance and security, the hotel itself is subject to predictive maintenance through the Internet of Things [31]. Sensors connected to the ERP system monitor the parts of the hotel that need to be replaced and automatically send alerts before breakdowns occur or before equipment runs out of critical consumables, which reduces the need to hold excess stock and helps with maintenance planning.

5.2. IoT Improvements to Hotel Costs in 2021

In terms of energy costs, IoT hotel applications use wireless controllers and sensors to detect the usage of customer rooms and adjust the control systems of air conditioning and lighting in the room according to the actual needs, so as to maximize the rational allocation of energy usage and achieve energy savings and cost reduction.

As summarized in Table 2, the IoT is effective in controlling labor costs and staff costs will be saved by 40%. According to the National Bureau of Statistics, the average salary of a service worker in China's hospitality industry in 2020 will be RMB 48,260/year, while the rent of an intelligent robot will be RMB 24,000–36,000/year, representing an overall reduction in costs of approximately 40%. With the application of the Internet of Things in hotels, some of the work will be converted from human management to intelligent detection, the addition of intelligent robots and self-check-in machines will extend the length of hotel services, and the use of intelligent delivery machines in restaurants will improve the efficiency of hotel restaurant services. In general, energy accounts for around 6% of the hotel's operating costs. With the use of the IoT, it is expected that energy costs will be reduced to 4% of the operating costs and the hotel's public service expenditure will be reduced by 25% [32].

In terms of management costs, the IoT saves costs in transport and distribution, stock turnover, and laundry. Transport costs are reduced through the unmanned delivery of

goods via RFID. Inventory and turnover are monitored in real time through the IoT to rationalize the scheduling of hotel equipment and supplies.

Table 2. IoT improvements to hotel costs in 2021.

Major Categories	Subdivision	Market Costs	Cost Breakdown	Solutions	Costs after Optimization	Savings
Energy costs	Energy	6% of operating costs	Water, electricity, gas, etc.	Using the wireless controller	4% of operating costs	≈25%
	Staff	48,260 RMB/year	Salaries, social security, overheads	Robotic assistance	24,000–36,000 RMB/year	≈40%
Labor costs	Room Distribution	Approx. 16.8 RMB per hour	Labor costs	Robot-assisted delivery	Approx. 2.7–4.2 RMB per hour	≈80%
	Restaurant Services	Per 6 people	Labor costs	Robots instead of manual labor	1 unit	≈80%
Management costs	Transport delivery	Approx. 2–2.5 RMB/set	Vehicles, drivers, fuel costs	RFID chip implantation without handover	Approx. 0.6–0.7 RMB/set	≈65%
	Stock Turnaround	360 RMB/set	Towel replacement cycle 1 year, bedding 1.5 years	Scheduling of cloths via app, on demand	250 RMB/set	≈30%
	Laundry	360 RMB/set	3 times stock availability	Three levels of procurement based on demand	220 RMB/set	≈70%

6. Drivers of IoT Adoption in Hospitality Industry Depend on the Development of the Communications Industry and the Pandemic

6.1. Communications Development Drives IoT in the Hospitality Industry

The rapid development of mobile communications and the Internet is the basis for the development and application of the IoT. From 2014 to 2020, the number of smartphones in China has increased year after year in terms of ownership and penetration, and the number of base stations is also growing rapidly. It is the development of the Internet and communications industry that is driving the development and application of the IoT in the hospitality industry [33,34].

Smartphone ownership in China continues to rise from 800 million units in 2014 to 1.3 billion units in 2020, a compound growth rate of 7.2% over seven years. The smartphone penetration rate is also increasing, from 46.4% in 2014 to 58.7% in 2020, a 12.3% increase over seven years. The growth and popularity of smartphones as client access points for the IoT has contributed to the increase in users, making IoT applications more accessible to a wider range of people and easier and faster to operate, facilitating the application of the IoT in the hospitality industry [35].

The popularity of mobile networks and Wi-Fi is also an important factor in the development of IoT applications in the hospitality industry. Between 2014 and 2020, there was a rapid rise in the number of base stations in China, from 3.51 million in 2014 to 9.338 million in 2020, with a compound annual growth rate of 15% over seven years. The increase in the number of base stations is conducive to the laying of a network environment, and the full coverage of Wi-Fi in hotels and the increase in network speed provide the foundation for the use of the IoT in hotels.

6.2. Epidemic Drives the Development of IoT in Hospitality Industry

From 2014 to Q3 2019 (Figure 12), the occupancy rate of star-rated hotels in China remained between approximately 45% and 60%, but the operating income of star-rated hotels continued to decline, mainly due to (1) the impact of OTAs on traditional hotels. As a result of the impact of OTAs, traditional hotels have no advantage in terms of price and booking methods, which has led to a certain degree of decline in hotel revenue. (2) The industry is highly competitive, focusing on low-price competition, but the application of IoT in hotels will break this dilemma. On the one hand, the use of IoT in hotels no longer

insists on low price competition but creates differentiation and comfort through IoT hotel systems and equipment to attract users [36].

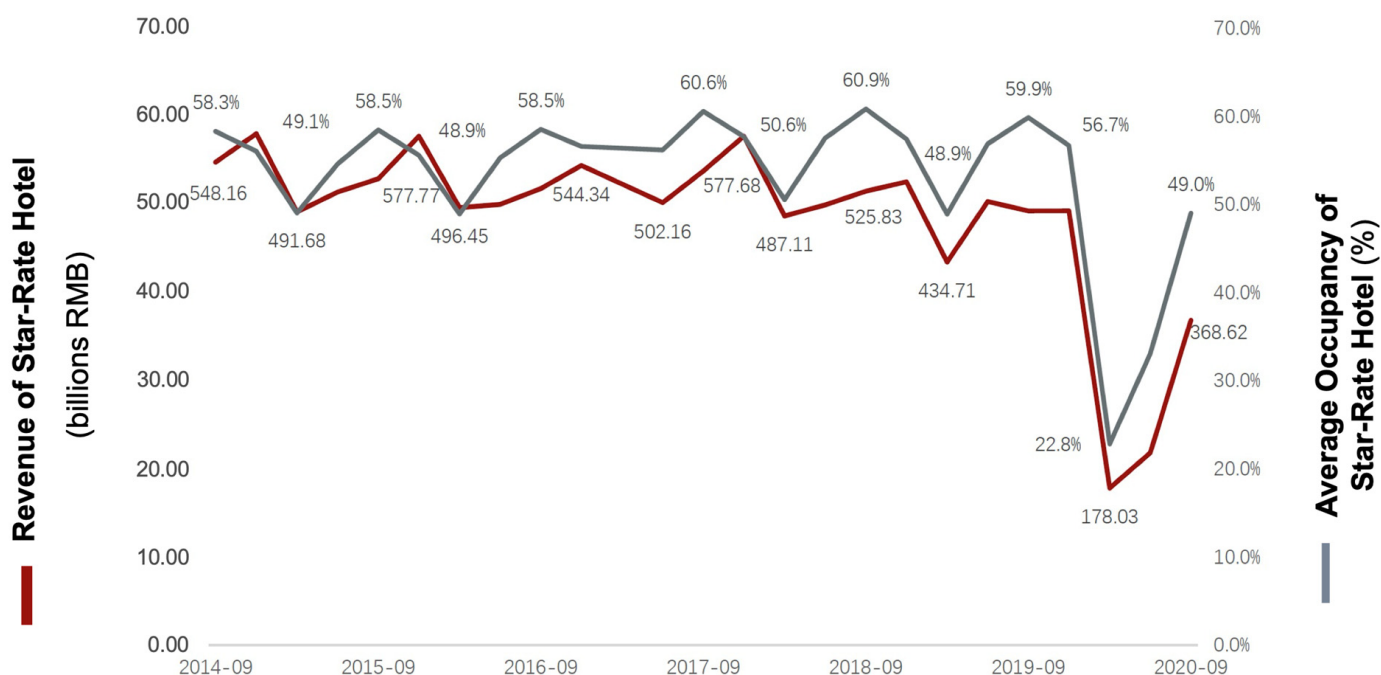


Figure 12. Revenue and average occupancy of star-rated hotels in China from 2014 Q3 to 2020 Q3.

The hospitality industry in China has been hit by the impact of the Newcastle Pneumonia outbreak. In March 2020, operations in the Chinese star-rated hospitality industry hit a low point, with an overall revenue of RMB 17.8 billion and occupancy rates reaching only 22.8%. However, as the epidemic gradually came under control in China and the economy recovered, the hospitality industry's operations quickly recovered and grew rapidly. In the aftermath of the epidemic, users became more demanding in terms of the level of epidemic prevention and the cleanliness of hotels, and demand for contactless services has increased [37,38].

7. Factors Limiting the Development of IoT in Hospitality Industry

7.1. Constraints to the Application of IoT in Hospitality Industry in China

The factors limiting the development of IoT in the hospitality industry can be divided into four points: a lack of intelligence, a lack of service, privacy issues, and a lack of financial follow-up [39]. As summarized in Table 3, the lack of intelligence limits the application of IoT in the hospitality industry, mainly because current algorithms limit the development and application of IoT smart devices, so artificial intelligence devices are in their infancy and the capabilities of service-oriented robots are not outstanding. The main reason for this is that some of the IoT devices lack a sense of service, and the lack of human service can create a bad user experience for the user; therefore, the hotel is irreplaceable in some positions [40].

Privacy is a hot topic in the hotel IoT and the IoT industry, as the IoT collects user data during use, and the legality of user data collection is questionable. Moreover, the cost is also another contradiction in the application of IoT in hotels, as current hotel IoT equipment is a new high-tech product with a high price tag. At the same time, hotels need to invest a lot of money in retrofitting IoT equipment, and if weak electrical renovations are required, they are costly.

Table 3. The constraints of IoT application development in hospitality industry in China.

Constraints	Specific Issues	Examples
Insufficient intelligence	Smart devices are only semi-intelligent and semi-manual, and cannot completely replace manual labor.	The layout of the hotel rooms and the positions of the furniture are different, and the machine cannot adapt to them independently, so manual intervention is required.
Lack of sense of service	IoT devices lack a sense of service and are more about problem solving.	Unable to recognize expressions and tone of voice; unable to provide accurate service.
Privacy issues	IoT enables customer personalization through big data collection, but also inadvertently invades customer privacy.	There is a large number of camera equipment, terminals, and sensors.
Inadequate financial follow-up	Smart hotels are larger and more costly in terms of investment and have certain capital requirements.	Requires large amounts of electrical energy, highly stable network environment, and high-quality system maintenance.

7.2. Investment Risks in the Application of IoT in Hospitality Industry in China

IoT in the hospitality industry has been widely discussed in the industry recently. As summarized in Table 4, with the development of China's communication industry and the Internet, hotel intelligence has become an inevitable trend. China's IoT application in the hotel industry chain level is relatively clear; the industry chain's upstream for IoT equipment entails the raw materials, midstream for the hotel IoT service providers, downstream for the hotel. In the upstream, China's chip market relies heavily on overseas imports, and China's chip industry requires independent development capacity to grow. China's independent research and development of chip enthusiasm and chip design industry is developing rapidly. The midstream comprehensive service providers and hardware equipment manufacturers are required to integrate with each other; thus, the IoT comprehensive service providers and software service providers are mainly for cooperation. Regarding hotels, the use of IoT in downstream hotels is beneficial to hotel cost control, and the IoT has an outstanding contribution to saving energy, labor cost, management cost, etc. From 2016 to 2020, the market size of the IoT applications in hotels in China grew from 51.74 billion RMB to 67.18 billion RMB, with a compound annual growth rate of 5.4%, and the three main reasons have also been summarised as below.

Table 4. The constraints of IoT application development in hospitality industry in China.

Risks	Main Content	Risk Index	Impact Index	Risk Control Response
Competition risk	Market homogenization is evident, and competition is becoming fierce.	70%	70%	<ol style="list-style-type: none"> 1. Improve product quality, expand market share, and stabilize existing market position; 2. Improve service quality and form brand reputation.
Construction or renovation cost risk	The high construction cost will bring some economic pressure and cash flow risk.	40%	70%	<ol style="list-style-type: none"> 1. Stable equipment and service prices; 2. Progressively realize hotel intelligence according to the ability.
Security risk	IoT hotel cyber security is a crucial aspect.	30%	60%	<ol style="list-style-type: none"> 1. Build a stable network security maintenance system; 2. Real-time monitoring of hotel network security; 3. Timely response to keep losses to a minimum.

Table 4. Cont.

Risks	Main Content	Risk Index	Impact Index	Risk Control Response
Market risk	A single intelligent hotel IoT transformation does not attract customers.	20%	30%	<ol style="list-style-type: none"> 1. Multi-channel publicity to accurately capture customer groups; 2. No reduction in the number of manual customer service.
Technical risk	The IoT industry is rapidly renewing and there is a risk of rapid obsolescence of the original IoT devices and service systems, etc.	10%	10%	<ol style="list-style-type: none"> 1. Construction and updating of important IoT application parts; 2. Advocate flexible applications.

1. The rapid development of mobile communication and Internet has built the foundation for the application of the IoT in hotels.

As the client access point of the IoT, the growth and popularity of smartphones is conducive to the application of IoT, making the use of IoT applications more widespread and the operating interface easier and faster, which also provides the foundation for the application of the IoT in hotels.

2. The demand for contactless services in hotels has increased, and the application of IoT in hotels has achieved new growth opportunities in the post-pandemic period.

After the epidemic, the hygiene requirements and health needs of the hotel industry have increased, and consumers are more concerned about the cleanliness of hotels and have a stronger demand for contactless services in hotels. The application of IoT in hotels mainly includes intelligent robots, intelligent guest control systems, etc. These hotel IoT devices will contribute to the realization of contactless services in hotels [41].

3. The development of the Internet of Things in hotels will move towards the humanization of equipment and services.

The development of the IoT in the hotel will progress towards equipment humanization, service through the role of human–machine linkage, and reasonable IoT equipment and manual management, so that the IoT reasonably promotes the efficiency of manual work, while injecting “warmth” and “quality” for IoT equipment [42].

8. Trends in the IoT Application in Hospitality Industry—The Integration of Technology and Services

The hospitality industry is mainly service-oriented, so a heap of advanced IoT equipment is not conducive to the operation of the hotel. The development of the IoT in the hotel will progress towards the humanization of equipment and service, and the integration of technology, data, and services will promote the development of the hotel. The hospitality industry is primarily service-oriented, providing users with a good and comfortable stay experience, and the piling up of advanced IoT devices will result in negative impacts such as poor user adaptation and reduced comfort, which is not conducive to the hotel business [43].

The development of IoT in the hotel will progress towards the humanization of equipment and services, through the role of human–machine linkage alongside the reasonable management of IoT equipment and human labor, so that the IoT can reasonably promote the work efficiency of human labor, while injecting “warmth” and “quality” into the IoT equipment (Figure 13). The main role of the IoT is not only to provide a better sensory experience for users, but also to assist hotels to operate more effectively. However, the big data obtained from the IoT devices cannot accurately paint a picture of the users [44].

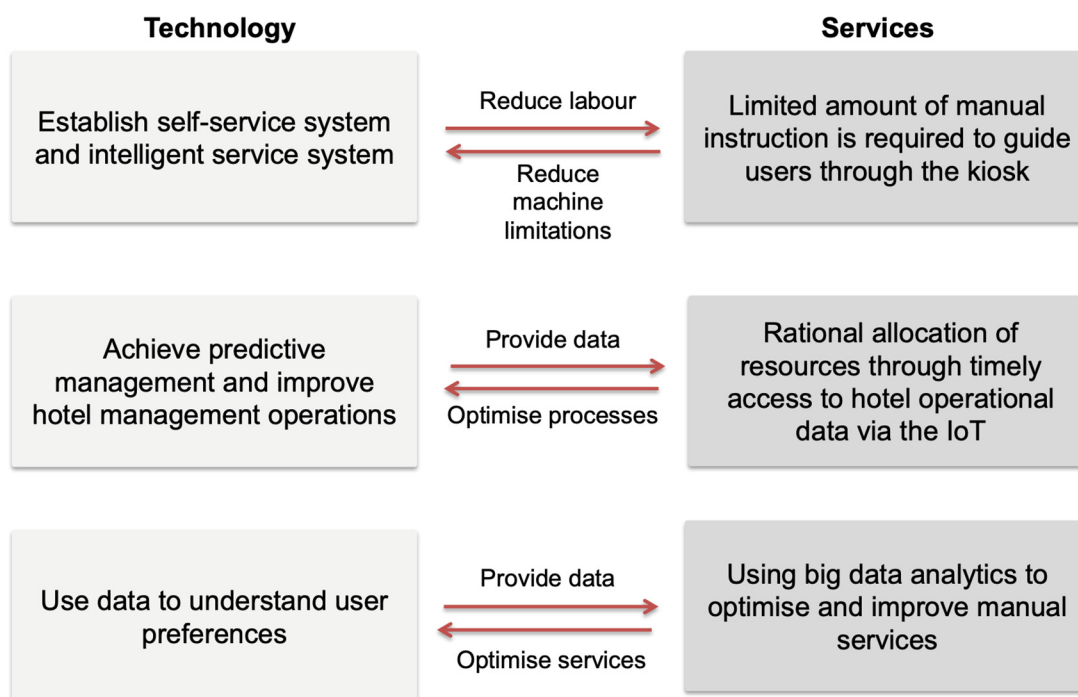


Figure 13. The integration of the Internet of Things in hotels with services.

9. Conclusions

In the past five years, the hospitality industry in China has been working hard towards achieving intelligent hospitalization management. It can be foreseen that the strategic use of the Internet and the future development of tourism in the Internet of Things and other high-tech areas will also provide the ultimate integration of the hospitality industry, digital tourism resources, and travel management, gradually constructing a functional trinity. In addition, the application of the IoT will promote the improvement of guest satisfaction, staff productivity, environmental sustainability, while at same time reducing costs and increasing profits in the hospitality industry.

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