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Tourism on a Budget: Retrofitting IoT Solutions in Existing Apartment Accommodation

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Abstract

Background: The concept of applying smart devices known as the Internet of Things (IoT) is widespread in many industries, including tourism. However, a gap has been observed regarding retrofitting possibilities in existing facilities. **Objectives:** This paper explores feasible scenarios for implementing contemporary technological innovations in existing tourist capacities at an affordable price. **Methods/Approach:** To achieve the objectives, a conceptual model is first developed that provides an overview of the possible solutions for retrofitting IoT into an existing apartment. Then, a case study analyses several practical procedures suitable for smaller private renters to accomplish the optimal effects of the selected implementation measures. **Results:** The results show that even with small investments, consumers of tourist accommodation services will recognise the advantages of the comfort of a smart home. In contrast, service providers have the potential to reduce costs. The benefits for owners of multiple facilities at dispersed locations are particularly highlighted. **Conclusions:** Based on the advantages that the proposed change could bring to the providers of tourist services, various options are available for achieving the optimal combination of solutions - the maximisation of modernisation effects while minimising costs.

Keywords: Energy saving; Internet of things; technology; tourism; smart objects

JEL classification: Z32 Tourism and Development
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Introduction

Today, due to constant striving for better housing comfort, the automation of buildings and residential environments is increasingly coming to the fore, i.e. the concept of a smart home is becoming more and more of interest (Chataut et al., 2023), especially within a context of industrial informatics (Pejić Bach et al., 2023b). In order to remotely monitor (and manage) specific parameters and change characteristics, implementing the smart home concept requires system components known as the Internet of Things (IoT). IoT refers to physical devices connected to the Internet, with embedded software technologies that can connect and exchange data over the Internet, in real time without human interaction.

In addition to smart homes, IoT has a wide application in many economic sectors and contributes to the green and digital transition (Sarker et al., 2024). Tourism is considered an economic sector when analysing the filling of the state budget. However, tourists who travel outside their residence and use hotels or apartments evaluate the quality of accommodation and provide feedback on their experience. Privately owned apartments and rooms cover about 50% of the tourist offer in Croatia and therefore play a significant role in the experience of Croatian hospitality. Significant portions of these existing and outdated properties are still run by small family owners, who are unable or unsure how to renovate their facilities thoroughly. Guests are then disappointed by the lack of modern features already common today. Customised IoT solutions would make the facility smart and allow guests to use it according to pre-set parameters, while the owner can remotely monitor and subsequently manage the main characteristics of the residence. Therefore, two research questions emerged:

- RQ1: What measures can be implemented in existing facilities with as little investment as possible for as much impact as possible?
- RQ2: What are the advantages of implementing IoT in tourism for small private service providers?

The article is organised as follows: after the introduction, the background section gives an overview of the relevant literature, and the research methodology is described afterwards. The following sections present a conceptual model for implementing IoT solutions in tourist accommodation facilities and the case study on which the proposed model was tested. After analysing and discussing the proposed solution, appropriate conclusions are drawn.

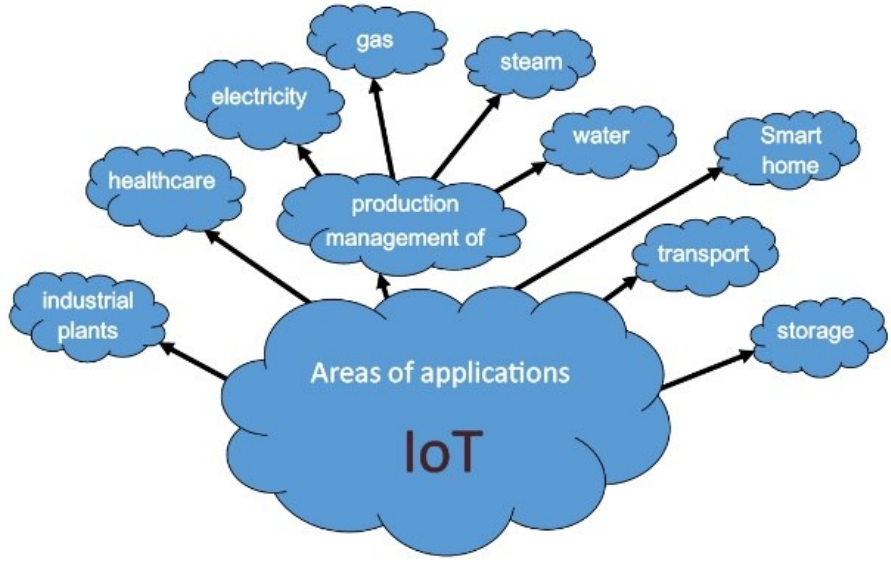
Background

Two directions related to the application of IoT systems are most often considered today (Srpak et. al., 2024a). The first direction is the automation of buildings and their surroundings, because more and more people want to monitor the state of basic parameters remotely, when they are not at the location. The second direction is the Industrial Internet of Things (IIoT), i.e., its application in industry (Nguyen et al., 2019), whereby companies improve their production, increase efficiency, and facilitate maintenance (Pejić Bach et al., 2023a). Internet of Things (IoT), apart from very popular smart houses, has found wide application in industrial plants, management of production of electricity, gas, steam, water, sales, transport and storage of products, healthcare (Nižetić et al., 2020). Thus, IoT allows companies and individuals to monitor the operation of their systems in real time, collecting data from the performance of individual devices to supply chains and logistics operations (Jurić et al., 2024). Because of this, companies achieve better control of automated processes and reduction of labour costs, waste generation and improvement of service, thereby reducing the

price of the final product (Aboltins et al., 2020). Another improvement method in the industrial environment is retrofitting industrial equipment to comply with Industry 4.0, as shown in (Torres et al., 2022). This approach reveals how to renew and adapt the existing production facilities to new market trends, improve productivity and reduce maintenance costs by adding IoT devices.

Tourism as an industrial branch includes production, transport, storage and services related to sports and health. However, the application of IoT in accommodation facilities such as hotels and apartments is often considered in the context of the smart home concept. Figure 1 illustrates some application areas of IoT devices and technology.

Figure 1
IoT Applications Areas



Source: Author's illustration

Tourism is a vital economic sector for Croatia. The final output in the tourism industry is satisfied guests with experiences that exceed expectations. The number of guests, the number of overnight stays, the non-boarding consumption of guests, etc., comprise the official measures of the success of the tourist season in Croatia. However, significant differences in the quality of accommodation are noticeable, especially in the niche of private providers of accommodation facilities. Smart tourism was introduced several years ago (Gretzel et al., 2015) and is constantly developing. So, the question arises, how can the collection and exchange of data (IoT implementation) help improve tourism services? Modern technological solutions are implemented in new facilities, such as hotels, restaurants, and recreational or amusement parks, mostly immediately during construction. Smart and sustainable equipment is systematically installed, and it is possible to personalise specific IoT solutions according to the user's specifications. In hotel rooms and apartments, small interventions such as turning on the lights via a motion sensor, controlling home appliances remotely, and providing guests with a sense of contemporary services and comfort (Hu et al., 2023), while simultaneously saving energy for the accommodation providers (Machorro-Cano et al., 2019). Due to awareness of environmental impact, as well as high competition in tourism, increasing orientation on sustainability and implementing ESG policies by saving energy is a priority for many hotels, so in (Eskerod

et al., 2019) recommendations are given to encourage the use of IoT in luxury hotels to achieve their sustainability goals.

The connection between IoT and tourism is the subject of research in many papers, such as (Liu & Wei, 2023), where the authors examine the application of IoT technologies in constructing smart scenic spots to promote tourist attractions. In the study (Belka et al., 2021), the authors show the IoT solution for a Bluetooth Low Energy (BLE)-based indoor tracking system for human traffic analysis, applied in indoor tourist facilities. The paper (Kamiyama et al., 2019) shows the behaviour monitoring of ten people in their 20s, in a real house set up as an IoT house concept for tourists, to create a new application of the developed sensor system for recognising behaviour patterns. To achieve the goal of a customised cruise experience, the paper (Nolich et al., 2019) presents a new IoT-based architecture (E-Cabin) to create a reasoning system adapted to data collected from the environment and each specific passenger and their activities. The privacy and security issues of data collected from Smart Home Systems (SHS), i.e. managing access control policies, data storage, and data flow management, are addressed in (Aung & Tantidham, 2017). The advantages of IoT implementations in tourism are also discussed in (Srpak et al., 2024b).

A lack of research was noticed in applying IoT in already existing facilities, operating for a more extended period, often as a family business, struggling to catch up with new players in the market. Moreover, they face increasingly demanding customers whose priorities in choosing accommodation locations also seem to transform. Therefore, the main objective of this research is to contribute to exploring opportunities for this specific segment of tourism services.

Methodology

A search of the Web of Science platform and the Scopus database provided insight into the research area and gaps in the field of research on integrating modern technologies into existing tourist facilities, as presented in the Background section.

To encourage implementation in existing facilities, IoT technologies need to be brought closer to the owners of existing facilities. This means primarily introducing them to the available equipment and presenting them with the advantages of applying IoT in tourism (Srpak et al., 2024b). Then, it is valuable to demonstrate the possibilities of such implementations through concrete and feasible scenarios.

Therefore, a conceptual model of an IoT system containing sensors and actuators for integration into existing tourist accommodation facilities was created, sending data to the owner. The case study verifies the proposed solutions from the conceptual model on the specific example of a two-room apartment, with a flowchart for searching for the optimal combination of measures for the profitability of the investment.

Conceptual model for applying IoT in a small apartment

This conceptual model will describe the most commonly used modules to present the available IoT technology equipment and demonstrate its advantages, providing an outlook to RQ1. A smart home as an intelligent object implies the integration of various electrical devices and systems for automatic control of the object, and mainly includes:

- Increasing the safety of using the facility,
- Automated lighting and heating/cooling,
- Energy-saving environment,
- Central or remote control of the main features in the residence.

To increase the security of use in modern buildings, smart locks are installed as standard today. Cards have been used for years to open room doors in hotels, and then they need to be inserted into the card reader to provide electricity to most consumers only while the guest is in the room. However, smart locks can be installed on the existing door of the facility, and activation can be via a card, fingerprint, code or physical key, and even remotely via a mobile phone application supplied by the door lock manufacturer. Monitoring the presence of unknown/unexpected persons, dangerous gases or fires in a facility can also increase the safety of those staying in the accommodation.

The feelings of modern features utilisation and comfort of living can be achieved by installing smart home appliances (refrigerator, oven, coffee maker, dishwasher, microwave, water heater, washing machine) or simply by controllable lighting. Automatic lighting control (via motion sensors) is often implemented in areas where people occasionally pass, such as hallways, terraces, garages, in front of the entrance door, etc. In areas where people stay longer, especially living rooms and bedrooms, installing lighting with adjustable intensity is desirable, depending on the user's preferences. Installing smart room thermostats and sensors on windows and balcony doors (open/closed) enables automatic heating/cooling management and can contribute to energy savings.

Usually, at the centre of a smart home (in the living room) is a control panel where all parameters can be monitored, and depending on the authorisation level, specific settings can be changed. The full potential of a smart home is achieved if the system sends data to a server via the Internet to enable remote monitoring of critical parameters and their subsequent analysis.

Figure 2 shows the floor plan of an apartment with indicated positions of typically used sensors, a smart lock, a roller shade driver as an executive element, and a control panel for local monitoring and control of the most common parameters in smart homes.

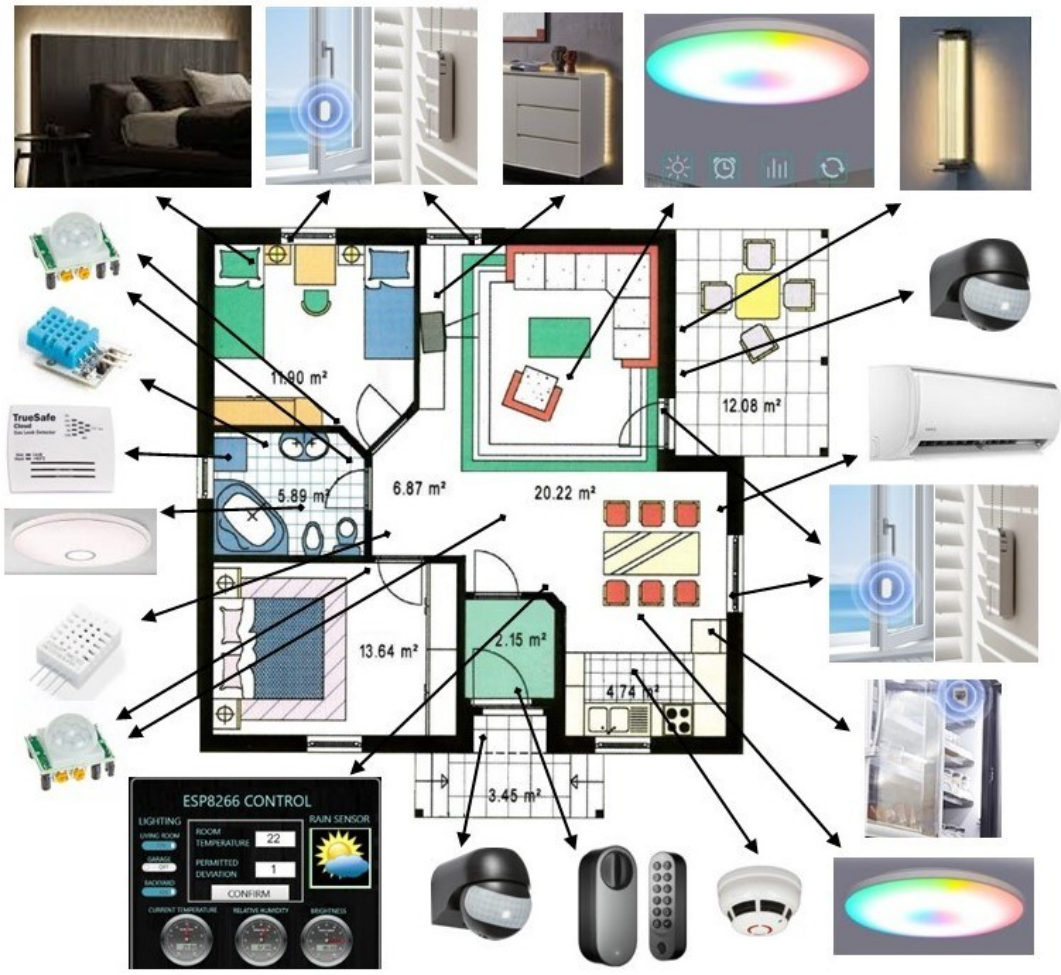
The elements required to assemble a functional IoT system are:

- Sensors—devices that measure pressure, temperature, humidity, movements, etc. The selection of parameters depends on the desired level of automation of the smart home.
- Control unit: microcontrollers with Internet access that store, process, and send the collected data to the server.
- Executive elements – devices for automatically turning on and off the lighting, heating/cooling, refrigerator or hot water preparation, controlling blinds, etc.
- Communication protocol—the "language of communication" usually between IoT elements in the system and/or between an IoT system and a person monitoring and controlling the system.
- Web server and data processing: Publicly available brokers (web services) can be used, but a web application must be created for administrative monitoring, database management, and system monitoring and control.

To control the lighting and detect the presence of someone when the apartment is not rented, it is recommended that motion sensors be installed in all rooms. The temperature should also be measured in all rooms, while it would be advisable to measure the humidity at least in the living room, kitchen, and bathroom. If a gas water heater is placed in the bathroom, or a gas stove in the kitchen, a carbon monoxide detector should be installed, and a smoke detector for a fire alarm should be installed at least in the kitchen. Installing an openness sensor in all windows and balcony doors, as well as a motion sensor outside on the terrace and in front of the main door, is advisable. If automated blinds are installed on the windows and balcony doors, the

guest can raise and lower them using a remote control or a control panel. In addition, it is helpful to program lowering in the evening and raising in the morning when the apartment is not rented (in winter), which deters potential burglars who will not be sure if the apartment is empty.

Figure 2
Illustration of IoT equipment positions in a Smart Home



Source: Author's illustration

All built-in sensors and executive elements must be connected to a control unit that enables local management. It also processes selected relevant data and sends it to the server. The typical communication protocol used in IoT systems is a protocol designed for M2M (machine-to-machine) communication between IoT elements, called Message Queuing Telemetry Transport (MQTT), composed of two main parts:

- MQTT broker (central server) - receives and processes messages, filters (by topics) and forwards messages to clients on demand
- MQTT client - any device that can connect to the broker, via a wired or wireless network connection - (publishers or subscribers).

After that, it is necessary to create a software application adapted to the chosen and installed combination of solutions, so that the owner can receive relevant notifications in real time and analyse the data subsequently.

Case study of retrofitting IoT in existing facilities

The application of modern IoT solutions in tourist apartments in a coastal area built 20 to 30 years ago is suitable for retrofitting analysis. Such apartments are not too old to need a complete renovation, but they were completed before the widespread application of the smart home concept.

In small family businesses, the owner often has only one or two accommodation units, lives in the same or nearby facility, and can be at the guest's service daily. In this case, he takes care of the maintenance of the apartment himself, notices, and eliminates any problems in time. Their guests are mostly older adults who value a personal approach, and there will probably be no need to install IoT technologies. However, consumer habits also change nowadays, so the need for more independence and privacy during vacation might impact their decision not to rent such facilities.

The case selected here to present the advantages of implementing modern IoT solutions is frequent on the Adriatic coast, providing evidence and demonstration for RQ2. One provider of accommodation services has facilities at two or more locations, for example, three locations with between two and four accommodation units each. A detailed inspection, cleaning of the facility and any repairs will be carried out before the start of the summer season, from June to September. During the summer season, contracted cleaning service providers clean the apartments between check-ins and check-outs of guests, change towels and bedding, and replenish necessities (soap, shampoo, coffee, tea, possibly chocolate or welcome fruit, etc.). Without automation, the owner will only discover any problems if a guest complains (the fridge or water heater does not work) or the cleaning staff notices and reports a problem.

We discuss the most commonly applied measures that can be added to existing apartments. From these measures, each owner can choose those that he considers important, that is, those that will bring him the most effect for the least investment.

First, installing smart locks at the entrance to the building and in each apartment saves the owner a significant amount of time for check-ins and check-outs. The owner can electronically give the guest a code (via email or phone) after paying the agreed fee, instead of waiting for the guest at the facility. Since it is easy to program a time limit for each code, there is no need to come and collect the key at checkout to give it to another guest. The next guest receives a new code.

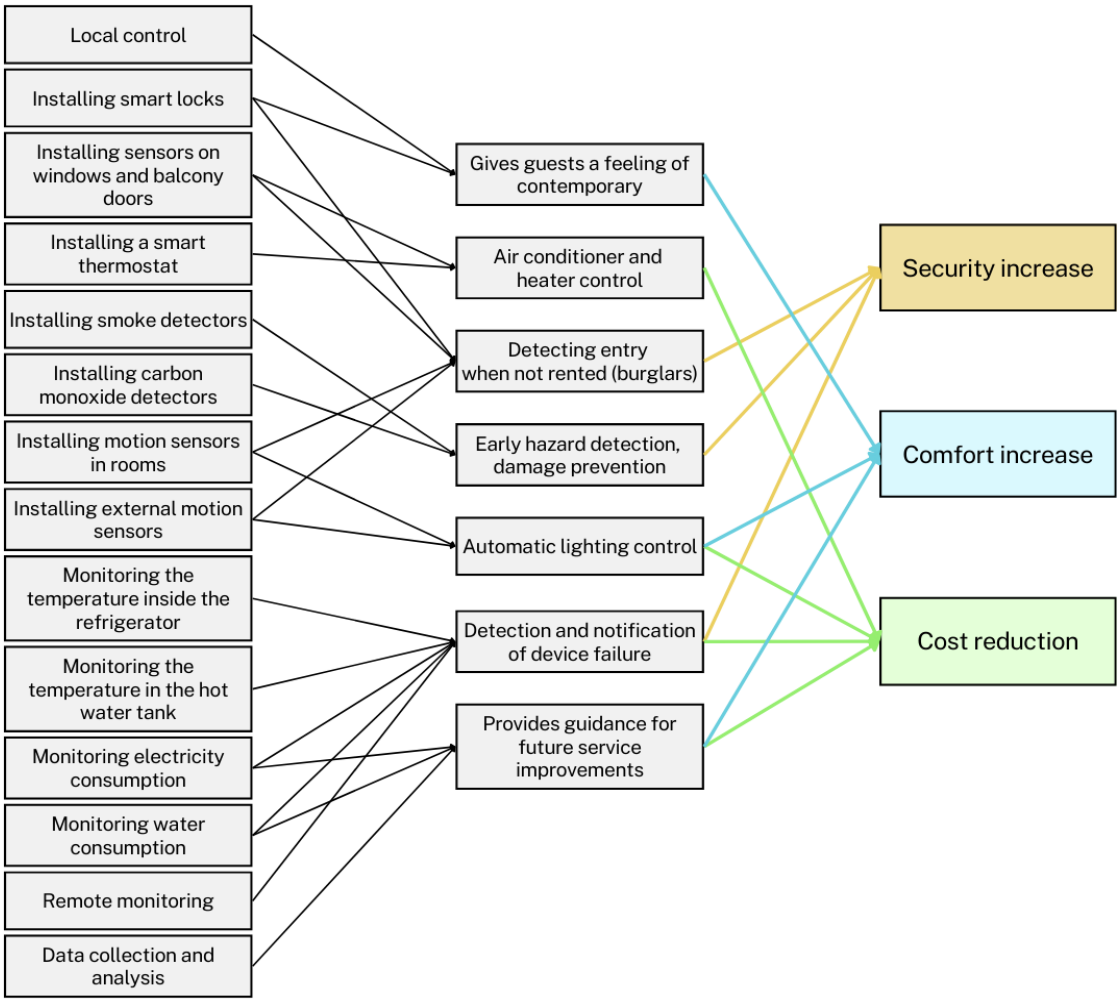
Furthermore, to create a modern ambience for the guest and significantly save time and money for the owner, the following can be implemented in each apartment:

- Lighting automation - switching on the lighting with a motion sensor in front of the entrance, on the staircase, in the hallway or bathroom, the possibility of dimming the lighting in the living room and bedroom;
- Smart thermostat installation at the heating device (if the facility is also used outside the summer season) - the maximum temperature for selection can be limited, and the temperature can be automatically reduced when the facility is unoccupied (between guests);
- Monitoring the temperature inside the refrigerator and information on power will indicate a malfunction or that the guest went out and left the refrigerator door open.
- Monitoring the temperature in the hot water tank, again along with information on power, will indicate a possible device malfunction;
- Installing sensors on windows and balcony doors with connection to the air conditioning power supply (to switch it off when windows/doors are open) will significantly save electricity;

- Monitoring electricity consumption, as well as water consumption, by hour and day, can indicate a malfunction by sudden or significant deviation from the usual amount;
- Monitor smoke detectors (primarily in the kitchen) and carbon monoxide (in the boiler room, utility room, or living room, if there is a fireplace) for early detection of fire risk or suffocation.
- Motion sensor monitoring can indicate the presence of someone while the object is not rented, i.e. burglary, intruder.

With such automation, it is a smart home, but if these sensors have an IoT module and a connection to a system for sending data to a server, then the full potential of modernisation is achieved. In this way, the owner can immediately receive a warning when something is wrong, e.g., a fire hazard, the refrigerator is on, the temperature is too high, the water is running while no one is in the apartment, or there is a facility intrusion. It is even possible to program a warning if a device (oven, iron, microwave, coffee maker) is turned on without interruption for an unusually long time. Figure 3 presents a block diagram showing the flow chart of which measures would achieve which effects and contribute to which results.

Figure 3
Flow chart for selecting the optimal combination of IoT retrofitting measures



Source: Author's illustration

Since these are existing buildings, this means adapting electrical and plumbing installations, doors and windows, and installing smart appliances. Likewise, software solutions must be adapted to each facility and owner, i.e., applying standard solutions to new buildings is difficult. Still, significant benefits are visible for owners who have multiple similar apartments. First, applying the same concept in all apartments reduces the cost of product development per unit. Then, it is easier to monitor the functionality of installations and devices and spot problems by comparing data from different, but similar, apartments. Finally, significant savings can be achieved even with small interventions (replacing ordinary devices with smart ones, adding sensors to existing installations or wirelessly). The cost can be recovered from the rent within two to three months, depending on the facility's rent price (location) versus chosen options and the prices (quality) of the installed equipment.

Conclusion

This paper focused on analysing solutions that can be implemented in existing facilities with a small financial investment and less time required to install them. Furthermore, it described ideas and methods for retrofitting IoT solutions, aiming to break the prejudice that home automation is expensive, complicated, and unprofitable for small private service providers, providing an outlook to RQ1.

The analysis of implementing modern technologies in existing facilities in the case study described here shows significant benefits for owners of multiple facilities, thus referring to RQ2. The most important result is the monitoring and/or remote management of many facilities in real time. By retrofitting IoT sensors, connecting them to a system for collecting and sending data, providers of accommodation services who are at the same time owners and maintenance staff, can analyse the data in a customised application, and gain insight into guests' habits after the season. Data collected using IoT applications connected to the main devices in the facilities (air conditioners or heaters, stoves, cookers, boilers, showers) can indicate how to improve their services in the future to increase guest satisfaction and contribute to sustainable tourism services.

By analysing the available solutions and the advantages of their application, each facility owner can choose the optimal combination of solutions for their facilities. Implementing modern IoT technologies can maximise modernisation effects while minimising costs.

The advantages of IoT in tourist accommodation facilities can be summarised in two groups. Advantages for consumers, i.e., guests, are as follows. Even little improvements, such as turning on the lights via motion sensors, controlling appliances using a remote control, or turning off air conditioning upon opening doors, give them a sense of a modern, safe, comfortable environment. Moreover, entering and exiting the facility during use, independently of the building owners, provides them more privacy. Advantages for service providers, i.e. apartment hosts, are as follows: saving energy and water when the facility is occupied, detecting unauthorised entry when it is not occupied, early detection of fire hazards, etc. Comparing usage data from similar apartments of the same owner can indicate possible problems or malfunctions. It is better to prepare the facility for the next rental season to improve the services by analysing data afterwards.

A real example of an IoT system built into tourist facilities could be analysed. Furthermore, a survey on the experiences of owners of facilities modernised in this way can be conducted in the field.

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