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INTEGRATING BIG DATA, THE INTERNET OF THINGS AND MACHINE LEARNING TO OPTIMISE OPERATIONAL ACTIVITIES IN THE HOSPITALITY AND CATERING SECTORS

The modern hospitality and catering industry faces numerous challenges: increasing competition, changing customer expectations, the need to reduce costs and ensure sustainable development. The integration of Big Data, the Internet of Things (IoT) and machine learning (ML) technologies forms a powerful toolkit for optimising operational processes, improving efficiency and personalising services. These technologies enable the collection, processing and analysis of vast amounts of data in real time, transforming traditional establishments into ‘smart’ venues capable of adapting to dynamic market conditions [1; 2]. The Internet of Things plays a key role in collecting data from sensors installed in hotel rooms, restaurant kitchen equipment, lighting systems, HVAC and inventory. IoT sensors record parameters such as energy consumption, temperature, humidity, food stock levels and guest movement. This

data is transmitted to cloud platforms, where Big Data ensures its storage, integration and pre-processing. Machine learning, in turn, analyses the resulting datasets, identifies hidden patterns and generates forecasts. For example, algorithms such as XGBoost, Random Forest or Deep Neural Networks enable highly accurate forecasting of demand for rooms, meal types or peak occupancy, achieving classification accuracy of up to 85% [3; 4].

One of the most important areas of application is the optimisation of energy consumption. IoT sensors monitor electricity usage, heating, ventilation and air conditioning in real time. Machine learning models analyse data on room occupancy, weather conditions and guest behaviour, automatically adjusting systems to minimise wastage. In hotels, such solutions enable energy consumption to be reduced by 20-40%, lowering operating costs and environmental impact. In restaurants, IoT helps optimise the operation of kitchen equipment, preventing energy wastage during downtime [1; 5].

The integration of technology significantly improves inventory and supply chain management. In catering establishments, IoT sensors track product expiry dates, stock levels and storage temperatures in real time, ensuring constant monitoring of refrigeration and freezer equipment, storage areas and display cabinets. This data is automatically transmitted to centralised platforms, where big data combines it with historical sales figures, seasonal trends, external factors (weather, local events, holidays) and even customer behaviour data. Machine learning analyses these multi-layered datasets, forecasts demand for individual menu items with high accuracy, automatically generates recommendations for orders from suppliers and optimises restocking schedules. As a result, food waste is reduced by 30-35%, as the system alerts staff in good time about products nearing their use-by date, suggests using them in special offers, or redirects them to other dishes. This not only reduces operational costs and environmental impact but also improves service quality by minimising the risk of running out of popular items and ensuring a steady supply of fresh ingredients [2; 6].

Personalisation of services is made possible by analysing big data on guest behaviour, reviews and preferences. Machine learning processes text reviews, booking data and interactions with IoT devices (smart lighting, room temperature, meal recommendations). Systems offer individualised services: automatic room configuration to suit the guest's preferences, chatbots for quick service, or personalised

menus in restaurants. Research shows that such personalisation increases customer satisfaction by 15% and encourages repeat visits [3; 7].

Predictive maintenance is another effective application of technology integration. IoT sensors installed on key equipment (refrigerators, hobs, convection ovens, dishwashers, lifts, HVAC systems and laundry facilities) continuously record operating parameters: vibration, temperature, energy consumption, pressure and humidity. Machine learning models analyse this data in conjunction with historical breakdown records and operational schedules, identifying hidden anomalies and predicting potential failures several days or weeks in advance. This allows maintenance to be scheduled at convenient times (for example, during periods of low occupancy), significantly reducing equipment downtime and the risk of emergencies that could affect guest comfort or food safety. Combined with Big Data, such systems optimise not only repairs but also room cleaning schedules, staff allocation and even the energy consumption of the entire establishment, depending on actual occupancy and forecast demand. As a result, maintenance costs are reduced (sometimes by 20-40%), operational safety and the overall reliability of the infrastructure are improved, which directly impacts the quality of service and the establishment's reputation [1; 5].

In the catering sector, technology helps to optimise food preparation processes and ensure food safety. The Internet of Things (IoT) enables continuous monitoring of temperature and hygiene, whilst machine learning analyses data to predict the quality of dishes and identify risks. Big data enables the development of food safety models, the optimisation of recipes and the reduction of waste during production [6; 7].

Despite significant benefits, the implementation of these technologies presents challenges. These include ensuring data cybersecurity, high initial investment costs, the need for skilled staff, and integration with legacy systems. Furthermore, the ethical use of guest data and compliance with privacy regulations (GDPR and similar) are crucial. Further research should focus on developing hybrid models, improving system interoperability, and adapting solutions for small businesses in the hospitality sector [2; 7].

Consequently, the integration of Big Data, the Internet of Things and machine learning is radically transforming operations in the hospitality and catering sectors.

These technologies enable businesses to simultaneously improve efficiency, reduce costs, enhance service quality and achieve sustainable development goals. In the future, their further adoption will enable the creation of fully autonomous ‘smart’ establishments, focused on delivering maximum value for both the customer and the business. These three areas-inventory management, personalisation and predictive maintenance-demonstrate the synergistic effect of integrating Big Data, the Internet of Things (IoT) and machine learning. They transform operational activities from reactive to proactive, enabling management in the hospitality and catering sectors to make decisions based on accurate data rather than intuition. Looking ahead, further refinement of algorithms and the expansion of sensor networks pave the way for fully automated ‘smart’ kitchens and hotels, where resources are utilised as efficiently as possible and guests enjoy an exceptional, personalised experience.

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