A Web Intelligent Hotel Management Framework Based on IoT and Generative AI

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Abstract

The hotel industry has faced numerous opportunities and challenges due to the advent of the artificial intelligence (AI) and the data-driven era. To address this, a novel augmented online performance analysis model is proposed for hotel management operations. This model seamlessly integrates the Internet of Things (IoT), generative AI technologies, and web engineering, allowing for the collection and analysis of multifaceted operational data. Consequently, real-time insights pertaining to room reservations, occupancy rates, and revenue streams are derived, serving as the basis for data-driven optimization strategies. Moreover, by incorporating generative AI technologies, the proposed model demonstrates the ability to dynamically generate predictive models, simulate scenarios, synthesize actionable insights, and adapt to evolving trends. As a result, it offers adaptive solutions for complex hotel management scenarios that were previously beyond the reach of traditional methods.

Keywords: Smart hotel management, IoT, generative AI, web engineering.

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1 Introduction

In the contemporary landscape of the hospitality industry, the symbiotic relationship between technology and service has undergone a profound transformation. The convergence of AI and the pervasive influence of data-driven paradigms have given rise to unprecedented opportunities and challenges for hotel management. As the global marketplace becomes increasingly competitive, it is imperative for hotels to harness the power of innovative technologies to not only optimize their operations but also to anticipate and adapt to the evolving expectations of their patrons. This paper introduces a pioneering approach, which aims to revolutionize traditional hotel management practices through the fusion of cutting-edge technologies.

In response to this dynamic environment, this paper proposes an innovative and augmented online performance analysis model for hotel management. This model seamlessly integrates three pivotal pillars: IoT, generative AI technologies, and web engineering. The confluence of these domains forms a cohesive foundation upon which a new era of data-driven optimization strategies for hotel operations is constructed. By diligently collecting and meticulously analyzing multifaceted operational data, the proposed model enables real-time insights into key facets of hotel management, including room reservations, occupancy rates, and revenue streams.

The transformational impact of this model is two-fold. Firstly, it sets the stage for a departure from traditional static analysis by embracing the dynamic and ever-evolving nature of the modern hotel industry. This fluidity allows for a deepened understanding of customer preferences, operational inefficiencies, and revenue generation patterns. Secondly, the infusion of generative AI technologies elevates the model's capabilities to previously unimaginable heights. The system's ability to generate predictive models, simulate diverse scenarios, and synthesize actionable insights has the potential to reshape decision-making processes, optimizing both tactical and strategic hotel management approaches.

The advent of the IoT has ushered in a new era of interconnectedness, where devices and systems collaboratively gather and transmit data. This interconnectedness is no longer confined to mere gadgets; it extends to encompass entire ecosystems within hotels, offering an intricate network of data sources that reflect every aspect of hotel operations. Concurrently, generative AI technologies have emerged as a transformative force, empowering systems to autonomously learn from data, simulate scenarios, and provide invaluable insights that were once inconceivable through conventional

methods. These technologies hold the promise of not just reactive adaptation, but proactive anticipation of trends and challenges that may shape the hotel industry's landscape.

This paper further delves into the intricacies of the proposed model, elucidating its components, functionalities, and the transformative potential it harbors for the hotel industry. By bridging the gaps between data, technology, and management strategies, the model promises to unlock adaptive solutions for even the most complex hotel management scenarios. As we navigate the uncharted waters of the AI and data-driven era, this paper presents not just a theoretical construct, but a roadmap towards the future of hotel management excellence.

The remain paper is divided into five sections. The second section, Literature Review, explores existing scholarly works and research findings on the subject. It provides context, identifies gaps in the current literature, and highlights key frameworks and concepts. The third section, Hotel Performance Management Theory, discusses the theoretical foundations of the study. It outlines relevant theories and models, establishing a conceptual framework. The fourth section, Methodologies, explains the research methods used, including data collection, sample selection, and data analysis. It ensures the validity and reliability of the findings. The fifth section, Result Analysis and Discussion, presents the empirical findings. It analyzes the collected data, connects it to the literature and framework, and offers insights and interpretations. Finally, the sixth section, Conclusion, summarizes the key findings, discusses the contributions and limitations of the research, and provides recommendations for future research and practical implications.

2 Literature Review

As we entered the 21st century, global economic development embarked on a new trajectory. With rapid advancements in science and technology, the primacy of natural resources and production means is no longer the decisive factor in business competition's success or failure [1]. Intangible assets, including knowledge, management, talent, wisdom, and innovative business models, have evolved into the cornerstone of business competition's core competency [2]. This transition marks a new historical phase and inaugurates a contemporary business battleground [2]. Given the backdrop of knowledge, talent, resource accessibility, and economic globalization, strategic talent competition, centered on human resources, emerges as the pivotal driver of present-day business competition [3].

The knowledge-based payment economy is sweeping across the globe, and the hotel industry, post a period of rapid expansion, has now settled into a phase of stable growth [4]. However, progress has primarily manifested in scaling up operations, with minimal focus on innovation and upgrades [4]. Additionally, the implementation of clean government policies led to a contraction in the public expenditure market [5], exacerbating the challenges faced by higher-tier hotels due to factors like heightened competition and abrupt policy shifts within the industry [6]. Consequently, effectively managing human resources [7] becomes an imperative to address these challenges. Performance management, serving as the quintessential "model" for human resource management, stands as the bedrock that traverses the entire course of hotel human resource management. Consequently, elevating the performance standards of hotel employees becomes the linchpin for realizing the hotel's strategic objectives [8].

Modern human resource management has undergone progressive refinement and maturation since the 1970s. In the late 1970s, American management scholar Daniel first introduced the term "performance management" in his work, sparking growing interest among scholars and practitioners in related research and practices [9]. In the early 1980s, as foreign scholars' focus on performance management expanded, it became an integral facet of human resource management research and implementation [9]. The core module necessitates adherence to four principles: mutually agreed-upon goals by managers and employees; establishment of precise evaluation criteria; incorporation of flexible objectives reflecting economic and environmental shifts; viewing managers as mentors rather than mere evaluators [10].

In the realm of multinational hotel operations, InterContinental Hotel Group (IHG), the largest global chain of hotels, leverages competency models within its performance management system to establish an equitable and rational compensation structure. Starwood Hotels, a prominent hotel brand worldwide, employs the KPI index method to appraise employees across its establishments and utilizes the 360-degree performance assessment approach for comprehensive evaluations. Hilton Corporation (HI) has successfully devised a highly harmonized performance management system with its hotels by synergizing the balanced scorecard with considerations of societal contributions and risks, ultimately maximizing overall benefits [12].

This paper unfolds in two key sections: performance management research and performance management system research [11]. Aligned with the paper's primary content and objectives, it delves into an analysis of select in-depth theoretical research articles and practical perspectives [12]. The

exploration delves into theoretical research concerning performance management [13], wherein it elucidates issues surrounding performance evaluation and incentive mechanisms across two dimensions: incentive effectiveness and result applicability shortcomings. Additionally, the paper examines the case of performance appraisal within the housekeeping department of high-tier hotels, highlighting the one-sidedness, temporal limitations, and incompleteness of performance assessments, along with evaluator subjectivity [14]. Root causes for insufficient training of information collection and evaluation of personnel are traced to two factors. The paper then introduces three recommendations: implementing objective identification evaluation and KPI assessment, bolstering evaluators' moral and disciplinary training, appraising fundamental knowledge and skills, and comparing employee performance rankings [15].

Bridging the above research gaps, the paper aims to address key motivations such as operational efficiency enhancement, real-time insights, adaptive decision making, and future-proofing hospitality. By harnessing IoT-generated data, the proposed model enables real-time analysis of critical operational metrics, such as room reservations, occupancy rates, and revenue generation. Generative AI-driven insights provide transformative insights by dynamically generating predictive models and simulating scenarios, revolutionizing decision-making processes in the hotel industry.

Complex scenario adaptation sets the model apart from conventional approaches, allowing the model to navigate complex challenges such as optimizing pricing strategies, managing resource allocation, and enhancing customer experiences in the face of rapidly changing market dynamics. The synergy of IoT data and generative AI enables the model to navigate complex challenges, such as optimizing pricing strategies, managing resource allocation, and enhancing customer experiences.

3 Hotel Performance Management Theory

The term "performance" amalgamates the essence of "performance" and "efficiency." It encompasses both the turnover and operating profit of a business entity, primarily gauging the extent of achievement in financial terms while fully reflecting its profit-driven objectives. On the other hand, "effectiveness" delves into qualitative measurements and efficiency, emphasizing the maturity of management objectives within enterprises [16].

From a managerial standpoint, performance entails the collective endeavors of members at all hierarchical levels to attain specific goals. It

encompasses work performance, competencies, and work attitudes. Organizational performance, when broken down across employee levels using systematic logical reasoning, achieves comprehensive representation when each employee adeptly accomplishes their respective tasks.

Performance management embodies a process that involves capturing insights from managerial activities, learning from these insights, and subsequently employing this knowledge to optimize management practices. In this process, performance managers collaboratively establish performance objectives and plans with employees, engage in ongoing communication throughout performance execution, and ultimately conduct evaluations to derive evaluative outcomes and experiential lessons. In essence, it constitutes the progression of tracking, assessing, communicating, incentivizing, and disciplining employees based on the efficacy of their work, culminating in the continuous enhancement of individual, departmental, and organizational performance [18].

Performance management stands as the pivotal incentive mechanism in human resource management and serves as the barometer for measuring the caliber of enterprise human resource practices. Stemming from the company's strategic pursuits, performance management cascades through departmental and positional levels via strategic decomposition. This process incorporates performance management, monitoring records, and performance data for each position, further enriched by department-specific analysis. The ultimate aim is to rectify business shortcomings until enterprise strategies are actualized [19]. Embracing performance management as the "barometer" for human resource management has consistently been a focal point in the realm of human resource studies.

Presently, various methodologies underpin performance management. Predominant approaches in Chinese hotel performance management encompass key performance indicators (KPIs), management by objectives (MBO), and the 360° performance appraisal method.

The KPI method entails deriving key indicators that optimally portray the organization's (or department's) objectives. These indicators are ascertained through analytical deconstruction and are subsequently employed to evaluate hotel performance [20].

Management by objectives entails cooperative formulation of organizational development goals between management and front-line employees. This mutually constructed framework guides and incentivizes these stakeholders to attain organizational goals in practical scenarios. This method's

strength lies in its simplicity and operability, facilitating alignment between employee aspirations and organizational aims.

As its nomenclature suggests, the 360° performance appraisal method is a comprehensive evaluative approach. Candidates receive comprehensive assessments from themselves, colleagues, immediate superiors, subordinates, and pertinent clientele. The merit of this approach lies in its capacity to provide a well-rounded and relatively impartial evaluation, effectively mitigating limitations and maximizing strengths. However, its suitability for universal application across all employees remains a potential drawback [21].

Hotel human resource management entails utilizing scientific methodologies to effectively develop and rationally leverage hotel human resources. Through adept management of hotel personnel, their enthusiasm is harnessed, labor efficiency is continually augmented, ultimately culminating in the attainment of organizational objectives.

The modern hotel industry is progressively embracing novel business paradigms, paralleled by a transformation in human resource management and IoT technologies [22]. Numerous hotel personnel departments have rebranded as human resources or administrative personnel departments. This shift not only signifies a change in nomenclature but also epitomizes the metamorphosis in hotel management approaches. Traditional personnel management conventionally perceived hotel management as a training-focused tool for specific functions. Its functions were perceived as tools for recruitment, wage disbursement, and labor dispute mediation, relying heavily on compliance oversight and material incentives to drive progress. This approach often failed to fully engage employee potential and enthusiasm.

As illustrated in Figure 1, whether in Dawan District, Guangzhou, Shenzhen, or non-central cities, business constitutes the primary hotel market source, accounting for an average of about 40%, closely followed by scattered footfall, comprising approximately 30% of hotel customer bases. Nonetheless, this proportion dwindles in non-central cities to around 20% [23–25]. The prevalence of tourism groups is comparatively lower in first-tier cities, while non-central cities exhibit a greater prevalence compared to their metropolitan counterparts. Modern hotel human resource management champions a people-centric philosophy, prioritizing employee needs and engendering enthusiasm, thereby unearthing their latent potential. It positions individuals as the hotel's paramount resource, emphasizing alignment between human resources and roles.

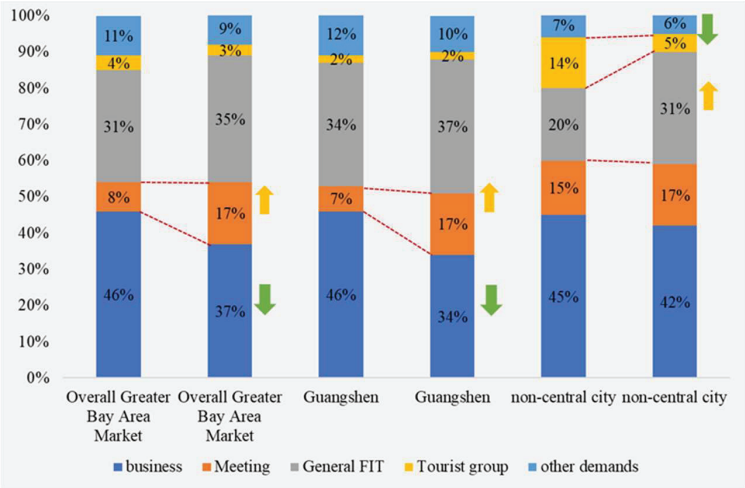

Figure 1 The structure of the hotel market customer source [23–25].

By meticulous selection, development, training, utilization, and incentivization, this approach seeks to cultivate and nurture a high-caliber human resources team. Contemporary hotel human resource management endeavors not only to excel in conventional personnel activities but also leverages contemporary scientific management tools and methodologies. It embraces holistic employee needs, kindles motivation, encourages initiative and creativity, and unearths latent potential, ultimately aligning with the aspirations of modern hotel management goals.

The nexus between performance management and remuneration management garners considerable attention among employees. Hotel enterprises have long integrated performance appraisal within salary frameworks, prompting heightened research interest. Performance-based remuneration constitutes a facet of hotel employee compensation, often surpassing basic salaries in certain departments. As a critical incentive factor, compensation closely intersects with hotel performance management. Thus, the relationship between performance management and salary management plays a pivotal role within the broader scope of human resource management.

4 Methodologies

The paper employs a comprehensive array of methodologies to construct its innovative framework. In pursuit of enhanced recommendation systems, the

design of the collaborative filtering algorithm (Section 4.1) plays a pivotal role. This method leverages user interactions and preferences to furnish personalized recommendations, contributing to an elevated guest experience by suggesting relevant services and offerings. Extending the methodology's potential, the paper delves into the design of a distributed collaborative filtering algorithm on the Hadoop platform (Section 4.2). By harnessing the distributed processing capabilities of the Hadoop ecosystem, this approach optimizes the algorithm's efficiency and scalability, enabling seamless handling of vast datasets inherent to the hospitality domain. Another notable facet of the paper is the integration of generative neural networks (Section 4.3). These networks exemplify the synergy of AI technologies, enabling the model to simulate scenarios, generate predictive models, and synthesize actionable insights. By tapping into the power of generative neural networks, the proposed framework gains the ability to adapt to dynamic trends and complexities, transcending conventional hotel management methods. Through the judicious integration of these methodologies, the paper takes strides towards redefining hotel management paradigms in an era driven by data, AI, and collaborative innovation.

4.1 Collaborative Filtering Algorithm

When a guest VIP1 needs a personalized recommendation, he can first find a group of guests with similar interests or a high degree of fit, and then recommend to him those in the group that VIP1 does not. This is the basic principle of the collaborative filtering algorithm. According to the above basic principles, we can divide the collaborative filtering algorithm into two steps: find a set of guests with a high degree of fit with the guest VIP1, and find the information in this set that the guest VIP1 does not show and recommend it to him.

The similarity between two guests is usually calculated using Jaccard's formula or cosine similarity. Let N(VIP1) be the information set of the guest VIP1, and N(VIP2) be the information set of the guest VIP2, then what is the similarity between VIP1 and VIP2: Jaccard formula:

$$W_{\text{vip1vip2 2}} = \frac{|N(VIP1)nN(VIP2)|}{|N(VIP1) \cup N(VIP2)|}. \tag{1}$$

Cosine similarity:

$$W_{\text{vip1vip 2}} = \frac{|N(VIP1)nN(VIP2)|}{\sqrt{|N(VIP1)| \times |N(VIP2)|}}. \tag{2}$$

Table 1 Information on guest check-in behavior

	Age	Light	Music	Temp	TV
VIP1	20	B	N	26	HNTV
VIP2	20	R	P	28	ZJTV
VIP3	23	B	null	30	CCTV
VIP4	25	R	P	26	CCTV

Table 2 Information-inverted list of guests

	VIP1	VIP2	VIP3	VIP4
Age	20	20	23	25
Light	B	R	B	P
Music	N	P	null	P
Temp	26	28	30	26
Tv	HNTV	ZJTV	CCTV	CCTV

Suppose there are currently four guests: VIP1, VIP2, VIP3, VIP4; the corresponding information of their check-in behavior is shown in Table 1.

The abbreviations B, R, P, N, etc., in the table represent guest preferences or choices related to certain amenities or services in the hotel. Specifically:

1. B: Bed preference. Indicating a choice for a specific type of bed in room configuration.
2. R: Restaurant/dining preference. Indicating a preference for dining at the hotel's restaurant or room service.
3. P: Related to a preference for a particular type of pillow/bedding.
4. Light: Indicating a preference for room lighting, such as bright (B) or dim (D) lighting.
5. Music: Indicating a preference for music in the room, with options like playing music (P) or no music/quiet environment (N).
6. Temp: Related to room temperature preferences.
7. TV: Indicating television channel preferences, with different channels like HNTV, ZJTV, and CCTV.

How to quickly calculate the information fit between all guests? For the convenience of calculation, it is usually necessary to first establish an inverted table of "information – guests", as shown in Table 2:

Then for each information and each guest, add 1 to the same information in pairs. For example, if the guests with the same information age have VIP1 and VIP2, then they add 1 to each pair in the matrix, as shown in Table 3.

First, it is necessary to find out the K guests that are most suitable for the guest VIP1 from the matrix, represented by the set S(VIP1, K), take out all the

Table 3 Guest information weighting table

	VIP1	VIP2	VIP3	VIP4
VIP1	0	1	1	1
VIP2	1	0	0	1
VIP3	1	0	0	1
VIP4	1	1	1	0

information of the guests in S, and remove the VIP1 generated information. For each candidate information i, the degree of interest of user VIP1 to it is calculated by the following formula:

$$\sum_{VIP2 \in S(VIP1,K) nN(i)} W_{VIP1VIP2} \times r_{VIP2i} \tag{3}$$

which indicates the degree of fit of the user VIP2 to the information i, which is 1 in this example. For example, suppose the hotel wants to match the check-in information for the guest VIP1, select K = 3 similar guests, and the similar guests are VIP2, VIP3, VIP4, then the information in their information but not in VIP1 is: scene music (music) and TV programs (tv), then calculate P(VIP1, music) and P(VIP1, tv) respectively:

$$U'j = \sum^{\frac{1}{m}} P_{ku} Row I_k^T \tag{4}$$

$$U' \left[U'_1, U'_2, \ldots U'\right]. \tag{5}$$

It seems that the guest VIP1 may have the same degree of fit for music and tv. In a real recommendation system, as long as they are sorted by score, the first few pieces of information can be taken.

4.2 Distributed Collaborative Filtering Algorithm on the Hadoop Platform

In the era of big data, the task of providing personalized recommendations to a vast and diverse user base has become increasingly complex. As we endeavor to create more accurate and relevant recommendation systems, the challenges of handling large-scale datasets and computationally intensive algorithms loom large. The conventional collaborative filtering algorithm, while effective in smaller settings, faces a daunting hurdle when applied to a dataset of immense proportions, such as those encountered in modern e-commerce platforms or hotel management systems. The need to calculate

user preferences for numerous items and accommodate an ever-expanding user base necessitates a solution that not only scales seamlessly but also optimizes the processing of vast data volumes. The primary challenge lies in balancing the intricacies of algorithmic computations with the demand for real-time or near-real-time recommendations, all while maintaining an efficient and cost-effective infrastructure. To address this monumental problem, we propose an adapted collaborative filtering algorithm implemented on the Hadoop platform. Our scientific contribution lies in the engineering efforts to make this adaptation feasible and effective, turning what could be an intractable computational problem into a practical and scalable solution for delivering tailored recommendations in real-world applications.

The collaborative filtering algorithm is implemented on the Hadoop platform and its similarity needs to be calculated. Based on the operation rules of MapReduce, it is necessary to input a single line to find the correlation between items. During the MapReduce operation, (user, item, preference) is used as input, the output key value is user, and the value value is (item, preference), so that the data element ancestor will contain the historical information of all items, which is defined by {user, (item1, preference1)), (item2, preference2), . . . (itemk, preferencej)}.

The original preference vector of the jth user u to all m items is Uj(P1u, P2u,. . . Pmu), T, the similarity matrix is replaced by the co-occurrence matrix, and the predicted preference value P′iu of user u to item i is calculated as follows:

$$P'_{iu} = \frac{\sum_{m}^{1} n_{ik} P_{ku}}{\sum_{m}^{1} n_{ik}}. \tag{6}$$

It can be seen from the above calculation process that U'$_j$ runs through the entire co-occurrence matrix. Based on the distributed computing of the previous big data theory, the prediction algorithm is still incompatible with it, and the co-occurrence matrix cannot be stored, so further improvement is required. The formula (6) is decomposed into the following two steps (7) and (8):

$$P'_{\mathrm{iu}} = \sum_{m}^{1} n_{ik} P_{ku} \tag{7}$$

$$P^{\mathrm{iu}} = \frac{P''\mathrm{iu}}{\sum_{m}^{\mathbf{1}} n_{ik}}. \tag{8}$$

In the MapReduce process, U″j(P″1u, P″2u,... P″mu)T is directly converted to U′j(P′1u, P′2u,... P′mu)T, therefore, predicting the algorithm can change U″j to the following formula.

The vector (n1k, n2k, ... nmk) T is the kth column vector ColIk of the Item co-occurrence matrix after the change of formula (8). Available:

$$U'' = \sum^{\frac{1}{m}} P_{ku^{C'I_k}}. \tag{9}$$

The Map stage of the MapReduce framework requires that the processing unit must be a row in the document, and an error will occur if the column of the above Item co-occurrence matrix is input. If the Item co-occurrence matrix is exchanged between rows and columns, that is, the Item co-occurrence matrix is transposed, the co-occurrence value nij of item Ii and item Ij is equal to the co-occurrence value nji of item Ij and item Ii, and the Item co-occurrence matrix The kth column vector ColIk(n1k, n2k,... nmk)T of is equal to the transpose of the kth row vector RowIk(nk1,nk2,... nkm), that is:

$$\mathrm{ColI}_k = \mathrm{RowI}_k{}^T. \tag{10}$$

Through the collaborative filtering algorithm, it is concluded that the guest VIP1 check-in behavior and the guest VIP4 check-in behavior have the highest degree of fit, and then they will be added to the same target customer group. The behavior of this group of target customers after staying at the hotel includes the tv program list watched, the on-demand list of high-definition movies, the menu ordered by the hotel, the peripheral services viewed, the room service requested, the temperature of the room air conditioner, and the status of the ambient lighting. As well as the type of room music, etc., it will be used as a hotel guest control mode unique to the target customer group. This mode is activated when a guest within the target customer group stays in the hotel and is applied to the room where the guest is staying, forming an interaction, thereby making the guest feel at home.

4.3 Generative Neural Networks

In recent years, the field of generative AI has undergone a remarkable transformation, witnessing the emergence of innovative models that have redefined data generation and creative applications. While this section provides an introduction to generative neural networks (GNNs) and their capabilities, it is essential to identify the unique contribution within the framework of our paper, which centers on smart hotel management.

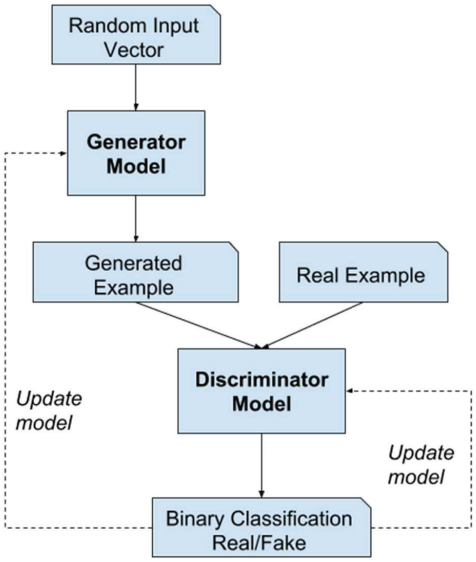

Figure 2 Example of the generative adversarial network model architecture.

Our proposed framework leverages the power of AI models, including GNNs, to revolutionize hotel management practices. While the utilization of AI for data-driven decision-making in hotels is not new, our contribution lies in the integration and fine-tuning of advanced GNN architectures, some of which may not have been discussed here due to the evolving nature of the field. Specifically, we aim to harness these cutting-edge GNNs to analyze historical hotel operational data comprehensively. A depiction of the generative adversarial network model architecture is presented in the Figure 2.

Another notable type of GNN is the variational autoencoder (VAE, Figure 3). VAEs approach data generation from a probabilistic perspective. They aim to learn a probabilistic model of the data, capturing its underlying distribution. The latent space learned by a VAE can then be sampled to generate new data instances that exhibit the characteristics of the original dataset.

The core contribution in this study is twofold: firstly, we adapt and train GNNs on rich historical datasets, enabling them to generate simulated scenarios for hotel operations. These simulations, driven by the inherent understanding of data patterns, assist hotel managers in anticipating changes in occupancy rates, predicting revenue streams, and devising effective strategies to optimize room reservations and service offerings.

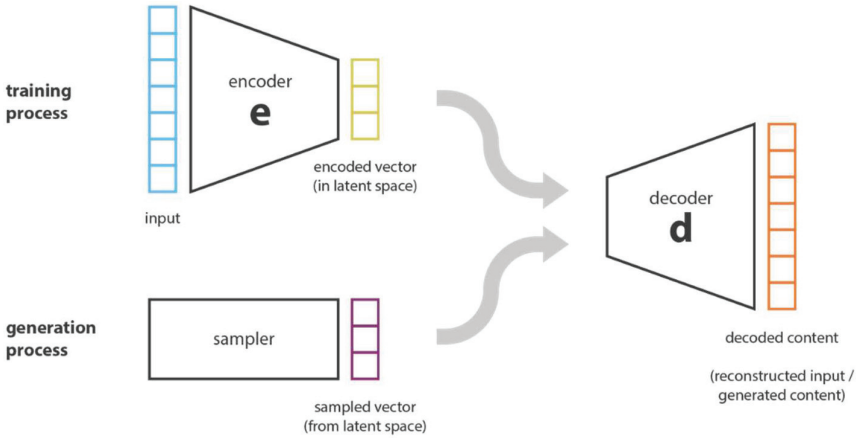

Figure 3 Example of the variational autoencoder architecture.

Secondly, our framework empowers GNNs to create plausible future scenarios, making them integral to the model's adaptive decision-making capabilities. By continuously analyzing data trends and patterns, these models enhance the efficiency and effectiveness of hotel management practices, paving the way for more informed, dynamic, and data-driven decisions in the hospitality industry.

The paper's contribution lies in the strategic integration and fine-tuning of advanced GNNs within the smart hotel management framework, offering a transformative approach to optimizing hotel operations and enhancing guest experiences through AI-driven insights and simulations.

5 Result Analysis and Discussion

In the context of our proposed framework for smart hotel management, we introduce innovative solutions that leverage advanced technologies to enhance guest experiences and operational efficiency. Two key components of our framework, the recommender system and Hadoop-based big data analysis, stand at the forefront of this transformation.

5.1 Design Principles of the Performance Management System

Design principles are the basic guarantee for the scientific and effective construction of the performance management system, and the guidelines and norms for the implementation of performance management. The principle

of Yindu Hotel's performance management system based on the P-O model is: the principle of strategic orientation. The main task of the P-O mode is to successfully achieve the strategic development goals of the hotel through human resource management. The goal of performance management requires that the work of managers and grass-roots employees should be consistent with the smooth realization of the strategic objectives of the hotel. Therefore, it is necessary to clarify the long-term and short-term development goals of Yindu Hotel, determine what kind of performance management system is needed to better match these goals, extract the key indicators in the development goals, and then decompose the goals to the hotel department and the hotel industry. Only in this way can we ensure the reasonable construction and smooth implementation of the performance management system.

System integrity principle: whether it is human resource management or performance management, it is a long-term cycle process, not a day's thing. Therefore, in the design of a performance management system, it is necessary to review the performance evaluation objectives and indicators of Yindu Hotel as a whole, and departments and posts from a systematic and complete perspective. That is, coordinate the task allocation and connection between departments, adhere to the systematic thinking of the performance management system construction, and have macro planning for performance management planning, index system construction, implementation, feedback and result application.

5.2 Design Ideas of a Hotel Performance Management System

In terms of method selection, the combination of MBO+BSC+KPI is adopted, that is, management by objectives (MBO) is the main purpose, and the hotel development goals established by the P-O model run through the entire performance management system.

In terms of the choice of research methods, since human resource management and performance management work both take place in the human resources department and the management department, expert scoring and expert interviews are mainly carried out through the Delphi method. During my internship in the hotel, I conducted a more natural in-depth interview with front-line staff in the catering department, which can improve the index construction and timely increase the key indicators ignored by the management. The Delphi method is essentially a feedback and anonymous letter inquiry method.

The general process is to sort out, summarize and count the opinions of experts, then anonymously feed them back to experts, solicit opinions again,

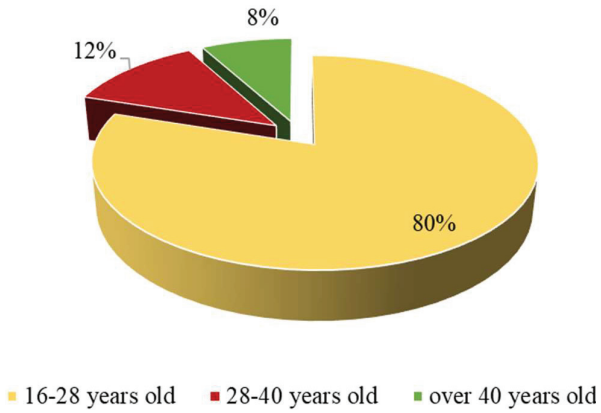

Figure 4 Age distribution of hotel employees.

then focus on them, and then feed them back until a consensus is reached. In the empirical stage, the enterprise strategy is divided into three levels by analytic hierarchy process: target level, dimension level and evaluation level. At the dimension level, take the four dimensions of BSC as the evaluation dimensions of department performance management, and then establish an evaluation layer under each dimension to set different indicators for different departments and positions. This section constructs the performance evaluation index system of the Yindu Hotel Catering Department based on an analytic hierarchy process.

Using three age categories (Figure 4) the study ensures statistical significance by having enough participants in each category. Also, this makes the research relevant to demographic factors, such as generational differences or age-related factors, enables comparative analysis between different age groups, and finally, makes the analysis more practical and manageable compared to using smaller intervals.

The study uses the Delphi method to derive expert opinions for constructing the performance evaluation index system in the hotel's catering department. The Delphi method is a structured and iterative approach to gather and refine expert opinions. Specifically, experts in relevant fields are chosen. They answer questions about the research topic anonymously. Their responses are summarized and given back to them for revision. This process repeats until a consensus is reached. Potential biases include expert selection bias, groupthink, anonymity's influence, biased question framing, and finding the right number of iterations. Representation of diverse perspectives is important.

5.3 Constructing the Organizational Structure of Hotel Performance Management

Referring to the overall framework and department organization structure of the hotel to establish a hotel performance management organization is conducive to decision makers and managers to constantly adjust the problems in performance management. Only by establishing a performance management organization can we finally build an optimized performance management system and achieve the strategic development goals of the hotel. The establishment of the performance management organization of the Yindu Hotel is shown in Table 4:

The hierarchical structure of the catering department is divided into three levels from top to bottom: target level, dimension level, and assessment level. Combined with the method concept of MBO+BSC+KPI in the previous section, the performance management objectives of the catering department are decomposed into layers: the target layer is the performance management objectives of the catering department; the dimension layer decomposes the target layer into financial, customer, internal business according to the balanced scorecard. There are four dimensions of process and learning growth, as shown in Figure 5.

The set judgment value ija is to quantify the weight index of the next layer to the previous layer. Yindu Hotel is scored by an expert group of 13 managers.

The judgment value mainly depends on the arithmetic mean of the assignments of 13 experts (if it is not an integer, the integer near it is taken as the judgment value); for those whose assignments are quite different, the 13 experts will discuss a specific assignment to form the judgment matrix of the dimension layer for the target layer, as shown in Table 5.

Different guests have many differences in their personal preferences, experience levels, and consumer demands for hotel services. The hotel uses the intelligent guest control management system and big data to analyze and filter the information behind the behavior of the guests, set the type of guests with the highest degree of fit as a type of target customer group, analyze the behavior of new guests online in real time, and further improve the target customer group and its customer control model. With the increase of staying guests, the guest control mode will be more and more in line with the inner feelings and expectations of the guests, and will allow the guests to get great satisfaction in the related experience, as shown in Figure 6. As can be seen from the Figure 6, 53% of the hotel customers mainly consider

Table 4 Hotel performance management organization setting table

Name	Participants	Duty
Performance management committee	General Manager, Deputy General Manager, Department Manager	1. Responsible for performance management, revision and approval of performance appraisal system. 2. Evaluation and ranking of departmental performance appraisal results. 3. The final processing agency for performance appraisal employee complaints. 4. The evaluation of the employee's salary and the one who goes to the end. 5. Scientific and comprehensive application of performance appraisal results.
Performance management executive	Human Resources Department	1. Organization and training of performance management. 2. Periodic summary, filing and reporting of performance appraisal work. 3. Violation supervision in performance appraisal work. 4. Acceptance of performance appraisal employee complaints.
Departmental performance management agency	Department Managers, Offices	1. Develop work plans and performance management plans for each department. 2. Communication and coaching between management and grassroots employees. 3. Issue performance appraisal results. 4. Make a summary of performance management work experience and formulate improvement measures.

the transportation convenience around the hotel, followed by the price and distance from the work place, while only 9% and 8% of the hotel customers are more concerned about the grade and supporting services of the hotel.

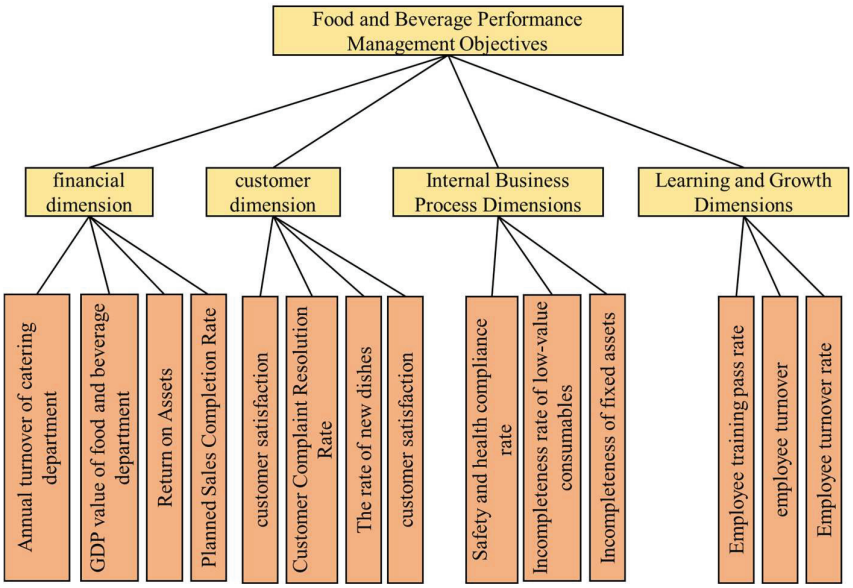

Figure 5 Hierarchical structure diagram.

Table 5 Judgment matrix of dimension layer for target layer

Food and Beverage Performance Management Objectives	Financial Dimension	Customer Dimension	Internal Process Dimension	Learning and Growth Dimensions
Financial dimension	1	2	5	3
Customer dimension	1/2	1	4	3
Internal process dimension	1/5	1/4	1	1
Learning and growth dimensions	1/3	1/3	1	1

The collection of guest check-in behavior data involved in the hotel intelligent guest control management system is only limited to the control data of hardware devices. The analysis of results based on such data will cause certain errors due to some invalid operations. Other data types the limitations also cause the intelligent room control management system to have a certain deviation in analyzing the guests' occupancy behavior. How to expand data types and data sharing is the next roadblock that hotels need to overcome on the road to smart hotels.

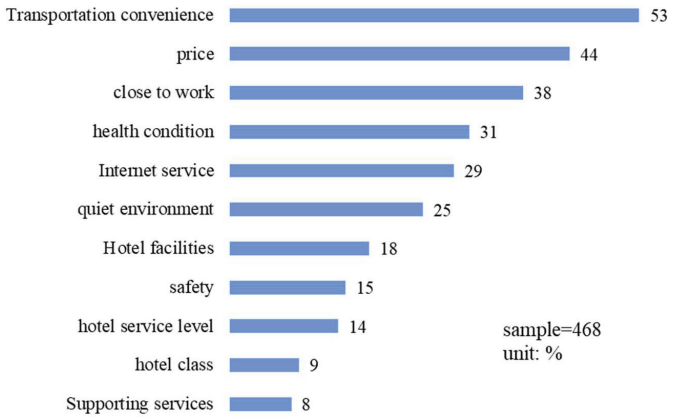

Figure 6 Analysis of personalized needs of hotel customers.

5.4 Design Generative AI Scenarios

Listed below are a few scenarios where generative AI, integrated into the proposed smart hotel management model, can be employed to enhance decision making and operational strategies:

1. Dynamic pricing optimization: Generative AI can simulate various pricing strategies based on historical data and real-time market trends. By training the model on past booking patterns, local events, and seasonal fluctuations, the system can generate scenarios that optimize room rates to maximize occupancy and revenue. Hotel managers can explore different pricing approaches and their potential outcomes, allowing them to make informed decisions that adapt to changing market conditions.
2. Demand forecasting and resource allocation: Using historical occupancy rates, booking patterns, and external factors like holidays and events, generative AI can generate forecasts for future demand. This information can guide decisions about staffing levels, room availability, and catering services. For instance, the model could simulate scenarios for high-demand periods, helping managers allocate resources effectively and provide exceptional guest experiences without overstaffing or underestimating demand.
3. Personalized guest experiences: Generative AI can analyze guest preferences, previous interactions, and feedback to create personalized experiences. The model could generate scenarios for tailored room amenities, suggested activities, and dining options, enhancing guest satisfaction and loyalty. By simulating different personalized experiences, the

system can identify the most effective ways to engage guests and increase their overall satisfaction.

4. Resource and energy efficiency: The model can utilize IoT data to simulate energy consumption patterns based on occupancy rates and guest behaviors. Generative AI can generate scenarios for optimizing energy usage through intelligent room temperature control, lighting adjustments, and energy-efficient equipment utilization. Hotel managers can assess the potential impact of these strategies on cost savings and environmental sustainability.
5. Staff training and performance enhancement: Generative AI can create virtual training scenarios for hotel staff, simulating various scenarios they might encounter during their roles. This could include handling customer inquiries, resolving conflicts, or managing emergency situations. By providing a simulated environment, the model helps staff improve their skills, adapt to different scenarios, and enhance their overall performance.
6. Event planning and space utilization: The model can generate simulations for various event setups and configurations based on historical data and venue layouts. This aids in optimizing space utilization for conferences, weddings, and other events. By simulating different layouts, the system assists in making informed decisions about seating arrangements, equipment placement, and overall event logistics.
7. Supply chain management: Generative AI can simulate supply chain scenarios by analyzing historical purchasing patterns, inventory levels, and supplier performance. This helps in predicting potential shortages, optimizing inventory levels, and ensuring timely deliveries of essential items, ultimately preventing disruptions to hotel operations.

Incorporating generative AI into the smart hotel management model empowers hotel managers to explore a multitude of scenarios without the risk associated with real-world experimentation. These simulations enable more strategic decision making, enhanced resource allocation, and adaptive strategies that contribute to improved guest experiences, increased operational efficiency, and overall business success.

5.5 The Recommender System: Personalizing Guest Experiences

Central to our framework is the integration of a robust recommender system, powered by cutting-edge AI algorithms. This system analyzes guest

behaviors, preferences, and historical data to offer personalized recommendations. These recommendations extend beyond room preferences to encompass dining, entertainment, and additional services.

Our recommender system utilizes collaborative filtering, content-based filtering, and deep learning techniques to predict guest preferences accurately. By continuously learning from guest interactions and feedback, it refines its recommendations, enhancing guest satisfaction and loyalty.

Additionally, we implement a real-time recommendation engine that adapts to changing guest preferences during their stay. This dynamic system not only improves the guest experience but also optimizes hotel revenue by promoting relevant services and amenities.

5.6 Hadoop-based Big Data Analysis: Harnessing Insights for Efficient Management

In our quest for data-driven decision making, we employ the power of Hadoop-based big data analysis. This technology empowers us to process and analyze vast volumes of data, enabling us to derive actionable insights and make informed decisions in real-time.

Our Hadoop cluster is configured to handle the intricacies of hotel operations, from occupancy rates to service requests. By analyzing historical and real-time data, we gain valuable insights into guest behavior patterns, seasonal trends, and operational bottlenecks. These insights drive proactive strategies for optimizing room reservations, resource allocation, and service offerings.

Moreover, our big data analysis system seamlessly integrates with our recommender system, creating a closed-loop feedback mechanism. This synergy ensures that guest preferences and behaviors are continually incorporated into our decision-making processes, enhancing our ability to meet guest expectations.

5.7 Evaluating the Impact

To assess the impact of our framework, we have conducted extensive testing and evaluation. Through A/B testing, we have compared the experiences of guests who interacted with our recommender system and those who did not. The results reveal a substantial increase in guest satisfaction and an uptick in revenue generated from personalized recommendations.

Furthermore, our Hadoop-based big data analysis has enabled us to optimize resource allocation, leading to cost savings and improved operational

efficiency. Our analysis of historical data has allowed us to make data-driven predictions, helping us better anticipate changes in occupancy rates and tailor our services accordingly.

The proposed framework for smart hotel management, driven by the recommender system and Hadoop-based big data analysis, is not only innovative but also highly effective. The integration of AI-powered recommendations and real-time data analysis is transforming guest experiences and operational efficiency, ultimately paving the way for the future of hospitality.

6 Conclusion

Future-proofing the hotel industry is of utmost importance, as successful hotel management relies on data-driven insights and adaptive strategies. The proposed model establishes the groundwork for continuous innovation and positions the industry to thrive in the era of AI-powered advancements. The contributions of this paper stem from its innovative approach to addressing the urgent challenges faced in modern hotel management, thus paving the way for a future where data-driven insights and adaptive strategies are at the forefront of success.

This study resides at the intersection of two cutting-edge domains: Generative AI and web engineering. Notably, generative AI, particularly in the context of web engineering, has experienced remarkable progress in recent years. The capabilities of AI models to generate content, designs, and even complete websites have opened up new possibilities for personalized user experiences, content creation, and design optimization. The proposed smart hotel management model in this study aligns with this trend by leveraging generative AI to dynamically generate predictive models and actionable insights. While the primary focus is on hotel operations, the integration of generative AI demonstrates how AI can enhance web engineering in the hotel industry and beyond.

The performance analysis model detailed in this study incorporates several AI-driven components and methodologies. Generative AI plays a central role in generating predictive models and simulating scenarios. Through machine learning algorithms, the model can analyze historical and real-time data to forecast occupancy rates, revenue streams, and trends. Additionally, the model utilizes AI techniques to synthesize actionable insights that facilitate adaptive decision making. This empowers hotel managers to make real-time data-informed choices, optimizing various aspects of hotel operations.

Integrating AI and IoT technologies in the hotel industry brings forth a multitude of risks and ethical considerations. Privacy concerns arise due to extensive data collection and sharing practices. Ensuring data security, user consent, and compliance with data protection regulations becomes paramount. Moreover, relying on AI for decision making may raise questions regarding transparency and accountability. Ethical concerns also extend to potential job displacement as automation affects certain operational roles. Striking a balance between the benefits of technology and ethical obligations towards guests, employees, and stakeholders requires careful consideration.

Addressing the challenges posed by the convergence of generative AI, IoT, and web engineering necessitates the implementation of comprehensive data governance strategies. This entails establishing clear policies for data usage, ensuring robust security measures, and providing transparent opt-in mechanisms for data sharing. The model should prioritize explainability, allowing hotel managers to comprehend and trust AI-generated insights. Collaborative efforts between IT teams, AI experts, and domain specialists are crucial to ensure the technology aligns with the hotel's ethical and operational objectives.

The insights gained from this research extend beyond hotel management, holding broader implications for web engineering in the era of big data and intelligent systems. The model's incorporation of diverse data sources, AI analytics, and real-time adaptability exemplifies how web systems can be tailored to meet individual user needs and preferences. The study's emphasis on predictive modeling and scenario simulation introduces innovative approaches to decision support systems, which can be applied to other industries aiming to optimize resource allocation, customer engagement, and revenue generation. This research reinforces the potential of generative AI and IoT technologies to reshape web engineering paradigms, promoting the development of dynamic, personalized, and responsive web experiences.

Data Availability Statement

The labeled dataset used to support the findings of this study are available from the corresponding author upon request.

Conflict of Interest

The author declares that there are no conflicts of interest.

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