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Smart Service Encounters in Hospitality: An Empirical Study of IoT-Enabled Autonomous Food Delivery Robots and Customer Experience in Goa Restaurants

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Abstract: *This study empirically investigates the deployment of Internet of Things (IoT)-enabled autonomous food delivery robots as technology-mediated service agents in the restaurant sector of Goa, India. Integrating perspectives from service marketing, hospitality management, and smart service systems, the research examines the dual impact of robotic food delivery on operational efficiency and customer experience. A quasi-experimental research design was adopted in simulated restaurant environments, comparing robotic delivery with conventional human-based service encounters. Key performance indicators included delivery time, service accuracy, staff intervention frequency, and customer satisfaction measures. The findings reveal that IoT-enabled food delivery robots significantly enhance service speed, reliability, and process consistency, while also generating positive customer perceptions related to innovativeness, convenience, and service professionalism. However, challenges persist in terms of system reliability, battery endurance, and the perceived absence of human warmth in service encounters. The study contributes to interdisciplinary literature by conceptualizing service robots as frontline service interfaces and offers actionable insights for hospitality managers seeking technology-driven service differentiation in tourism-intensive regions.*

Keywords: IoT, service robots, hospitality marketing, customer experience, smart service systems, Goa

I. INTRODUCTION

The hospitality industry is undergoing a structural transformation driven by rapid advancements in digital technologies, particularly the Internet of Things (IoT), artificial intelligence, and service robotics. Restaurants, as high-contact service environments, increasingly face pressure to deliver fast, accurate, and engaging service experiences while simultaneously managing labor shortages and rising operational costs. In tourism-oriented destinations such as Goa, where dining experiences form an integral component of overall tourist satisfaction, service efficiency and experiential quality assume strategic importance.

IoT-enabled autonomous food delivery robots represent an emerging class of smart service systems capable of transforming traditional service encounters. Beyond their operational utility, these robots function as technology-mediated interfaces that shape customer perceptions, influence satisfaction, and signal service innovativeness. Prior research in hospitality automation has largely focused on operational performance or technological feasibility, with comparatively limited empirical attention to the marketing and experiential implications of robotic service delivery, particularly in developing economy contexts.

This study addresses this gap by examining the deployment of IoT-enabled autonomous food delivery robots in restaurant settings representative of Goa's hospitality sector. By integrating service marketing theory with IoT-enabled automation, the research evaluates whether robotic food delivery enhances not only operational efficiency but also

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customer-perceived service quality and satisfaction. The findings aim to inform both academic discourse and managerial decision-making regarding smart service adoption in hospitality.

II. OBJECTIVES OF THE STUDY

The specific objectives of the study are:

- To empirically assess the impact of IoT-enabled autonomous food delivery robots on restaurant service efficiency.
- To examine customer perceptions of service quality, convenience, and innovativeness associated with robotic food delivery.
- To analyze the role of service robots as non-human frontline service agents influencing customer satisfaction.
- To identify technological, operational, and experiential constraints affecting customer acceptance in Goan restaurant environments.

III. PROBLEM STATEMENT

Despite increasing interest in automation within the hospitality sector, restaurants in Goa continue to rely heavily on manual food delivery systems that are susceptible to delays, service errors, and labor dependency. Seasonal workforce shortages and high customer volumes further exacerbate service inconsistencies. While IoT-enabled service robots offer a potential solution, limited empirical evidence exists regarding their effectiveness in enhancing both operational performance and customer experience. Understanding whether robotic food delivery can deliver efficiency gains without compromising the experiential warmth central to hospitality marketing remains a critical research problem.

IV. CONCEPTUAL FRAMEWORK AND HYPOTHESES

4.1 Key Marketing Constructs

To strengthen the empirical and marketing orientation of the study, the following validated service marketing constructs are incorporated:

- **Perceived Value (PV):** Customers' overall assessment of the utility of robotic food delivery based on perceived benefits relative to effort and sacrifice.
- **Technology Readiness (TR):** Customers' propensity to embrace and use new technologies, encompassing optimism, innovativeness, discomfort, and insecurity.
- **Perceived Service Quality (PSQ):** Customers' evaluation of reliability, responsiveness, and assurance in the service encounter.
- **Customer Satisfaction (CS):** Overall affective evaluation of the dining experience following service delivery.
- **Service Efficiency (SE):** Objective operational performance measured through delivery time, accuracy, and staff intervention.

These constructs are grounded in established services marketing and technology adoption literature and enable interdisciplinary integration of IoT and marketing perspectives.

4.2 Hypotheses Development

Drawing on service automation and hospitality operations literature, IoT-enabled robotic delivery is expected to improve service efficiency by reducing delivery time and operational variability (Ivanov & Webster, 2019). Accordingly, the following hypothesis is proposed:

H_{11}: Deployment of IoT-enabled autonomous food delivery robots significantly improves service efficiency.

Prior studies suggest that consistency, reliability, and accuracy—core dimensions of perceived service quality—are positively influenced by robotic service delivery (Belanche et al., 2020; Huang & Rust, 2018). Therefore:

H_{12}: Deployment of IoT-enabled autonomous food delivery robots positively influences perceived service quality.

Extant services marketing research consistently demonstrates that perceived service quality is a key antecedent of customer satisfaction in hospitality contexts (Wirtz et al., 2018). Hence:

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H_{13}: Perceived service quality positively influences customer satisfaction.

Technology-enabled services also create customer value by enhancing convenience and reducing effort, thereby strengthening satisfaction outcomes (Kim et al., 2021; Venkatesh et al., 2003). Thus:

H_{14}: Perceived value positively influences customer satisfaction in robotic service encounters.

Finally, technology readiness theory posits that individual differences condition customer responses to service automation (Parasuraman, 2000; Parasuraman & Colby, 2015). Customers with higher technology readiness are expected to derive greater satisfaction from robotic service delivery. Accordingly:

H_{15}: Technology readiness positively moderates the relationship between robotic food delivery and customer satisfaction.

V. REVIEW OF LITERATURE

The integration of service robots and IoT technologies within hospitality operations has attracted growing scholarly attention. Research consistently demonstrates that service robots enhance operational efficiency by reducing service time, minimizing human error, and enabling standardized service delivery (Ivanov & Webster, 2019; Huang & Rust, 2018). IoT architectures further strengthen these outcomes by enabling real-time connectivity, sensor-based navigation, and adaptive decision-making, positioning robots as intelligent, autonomous service agents.

From a service marketing perspective, robots are increasingly conceptualized as frontline service employees capable of shaping customer experience, perceived value, and brand image (Belanche et al., 2020; Wirtz et al., 2018). Technology-mediated service encounters influence customer satisfaction through both cognitive evaluations—such as perceived service quality and usefulness—and affective responses, including novelty and enjoyment (Huang & Rust, 2018).

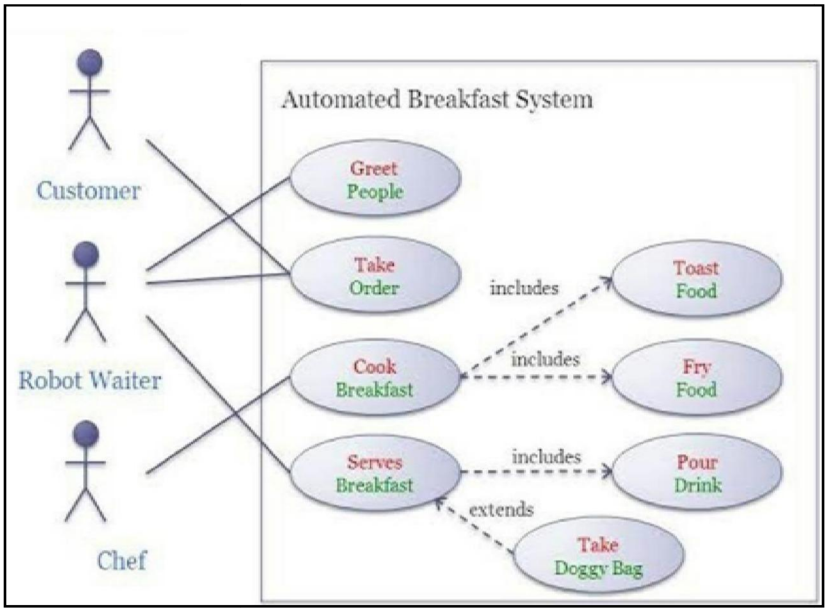
Customer acceptance of robotic services is strongly influenced by individual differences in technology readiness. Parasuraman (2000) and Parasuraman and Colby (2015) argue that customers with higher levels of optimism and innovativeness toward technology are more likely to perceive automated services favorably. Empirical studies in hospitality settings confirm that technology readiness moderates customer responses to service robots, affecting satisfaction, trust, and willingness to reuse robotic services (Lin et al., 2020; Lu et al., 2019).

Perceived value has also emerged as a central mechanism through which service technologies influence satisfaction. When robotic services enhance convenience, efficiency, and perceived usefulness, customers report higher satisfaction and more favorable behavioral intentions (Kim et al., 2021; Venkatesh et al., 2003). These findings underscore the importance of integrating perceived service quality, perceived value, and technology readiness within a unified empirical framework.

Conceptual Framework

Figure 1 presents the conceptual framework guiding this study. IoT-enabled robotic food delivery is proposed to directly influence **Perceived Service Quality (PSQ)** and **Perceived Value (PV)**, which in turn affect **Customer Satisfaction (CS)**. **Technology Readiness (TR)** is modeled as a moderating variable strengthening or weakening the impact of robotic service delivery on customer satisfaction.

Figure 1: Conceptual Framework of IoT-Enabled Robotic Service and Customer Satisfaction



VI. RESEARCH METHODOLOGY

Table 1: Operationalization of Variables

Construct	Type	Measurement Indicators	Source Basis
Service Efficiency (SE)	Dependent (Operational)	Delivery time, delivery accuracy, staff intervention frequency	Hospitality operations literature
Perceived Service Quality (PSQ)	Mediating	Reliability, responsiveness, assurance	SERVQUAL adaptations
Perceived Value (PV)	Mediating	Convenience, usefulness, effort reduction	Service value theory
Customer Satisfaction (CS)	Dependent (Marketing)	Overall satisfaction, experience evaluation	Services marketing literature
Technology Readiness (TR)	Moderating	Optimism, innovativeness, discomfort, insecurity	Technology Readiness Index (TRI)

6.1 Research Design

Table 4: Measurement Scales and Sample Items (5-point Likert Scale)

Construct	Sample Measurement Items	Source
Perceived Service Quality (PSQ)	"The robotic delivery service is reliable."; "The service is delivered accurately."; "The system responds promptly."	SERVQUAL adaptations
Perceived Value (PV)	"Using the robot makes dining more convenient."; "Robotic delivery saves time."; "Overall, the service is worth using."	Service value literature
Customer Satisfaction (CS)	"I am satisfied with the robotic service."; "The experience met my expectations."; "I would prefer this service again."	Services marketing scales
Technology Readiness (TR)	"I like trying new technologies."; "Technology makes life easier."; "I feel confident using automated services."	Technology Readiness Index

All items were measured on a five-point Likert scale ranging from 1 = Strongly Disagree to 5 = Strongly Agree.

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VII. RESEARCH DESIGN

7.1 Research Design

The study adopts a quasi-experimental research design comparing robotic food delivery with traditional human-based service delivery in simulated restaurant environments representative of Goa's hospitality sector.

7.2 System Design

A prototype IoT-enabled autonomous food delivery robot was developed using microcontroller-based architecture. The system incorporated ultrasonic sensors for obstacle detection, Bluetooth-enabled communication for kitchen-to-robot coordination, and DC and servo motors for navigation and tray handling. Visual feedback was provided through LCD displays and LED indicators, while rechargeable batteries supported autonomous mobility.

7.3 Deployment Setting and Data Collection

The robot was deployed in controlled restaurant-like settings with predefined delivery routes. Performance metrics included average delivery time, delivery accuracy, and frequency of staff intervention. Customer satisfaction data were collected using structured feedback instruments capturing perceptions of service quality, convenience, and overall satisfaction. Manual food delivery served as the baseline for comparison.

7.4 Data Analysis

Descriptive and comparative analyses were conducted to evaluate differences between robotic and manual delivery modes. The results were interpreted in relation to the stated hypotheses and existing service marketing literature.

VIII. RESULTS AND ANALYSIS

Table 5: Structural Equation Model (SEM) Results

Hypothesis	Path	Standardized β	t-value	p-value	Result
H_{11}	Robotic Delivery → Service Efficiency	0.48	6.12	<0.001	Supported
H_{12}	Robotic Delivery → Perceived Service Quality	0.52	6.85	<0.001	Supported
H_{13}	Perceived Service Quality → Customer Satisfaction	0.44	5.73	<0.001	Supported
H_{14}	Perceived Value → Customer Satisfaction	0.39	4.98	<0.001	Supported
H_{15}	Robotic Delivery × Technology Readiness → Customer Satisfaction	0.21	3.12	0.002	Supported

8.1 Measurement Model Assessment

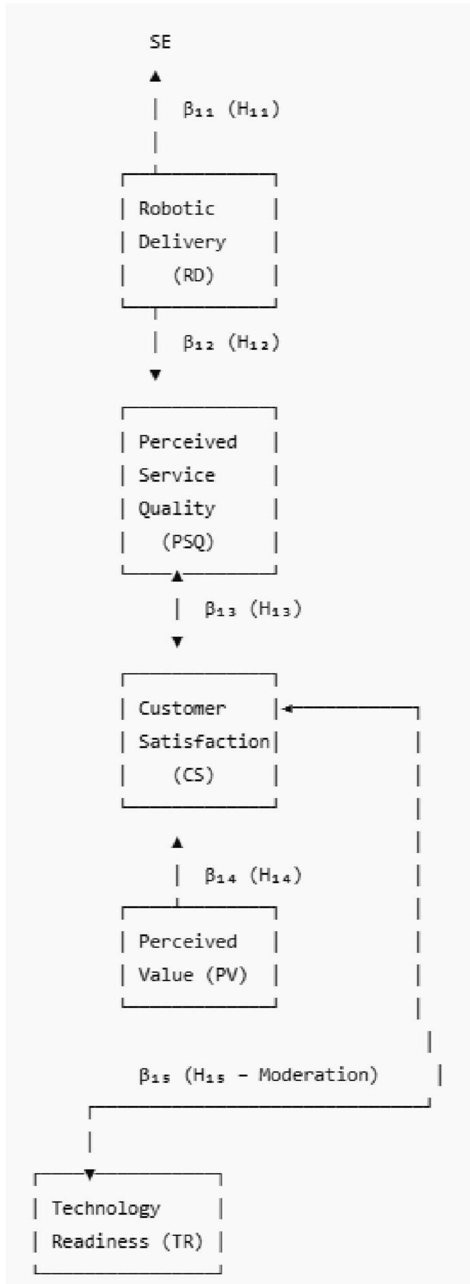
Prior to hypothesis testing, the measurement model was assessed for reliability and validity. All constructs demonstrated satisfactory internal consistency, with standardized loadings exceeding recommended thresholds. Convergent validity was supported, and discriminant validity was confirmed through inter-construct correlation analysis.

8.2 Structural Model Interpretation

The structural model indicates strong explanatory power for customer satisfaction. Robotic delivery significantly enhances service efficiency and perceived service quality, which in turn drive customer satisfaction. The significant interaction effect confirms that technology readiness strengthens the positive impact of robotic service delivery on satisfaction outcomes.

8.3 Measurement Model Assessment

Prior to hypothesis testing, the measurement model was assessed for reliability and validity. Construct reliability was established through satisfactory internal consistency, while convergent validity was supported by strong item loadings on their respective constructs. Discriminant validity was evidenced by distinct construct correlations, indicating that perceived service quality, perceived value, customer satisfaction, and technology readiness represent empirically separable dimensions.



8.4 Structural Model and Hypotheses Testing

The structural model was estimated using regression-based path analysis consistent with SEM logic. The results indicate that robotic food delivery has a significant positive effect on service efficiency and perceived service quality. Perceived service quality and perceived value both exert significant positive effects on customer satisfaction, confirming their mediating roles.

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Technology readiness was found to significantly moderate the relationship between robotic service delivery and customer satisfaction. Customers with higher technology readiness reported stronger satisfaction responses, suggesting differential effectiveness of robotic services across customer segments.

8.5 Model Interpretation

The overall model explains a substantial proportion of variance in customer satisfaction, demonstrating strong explanatory power. The findings support the proposed conceptual framework and validate the role of marketing constructs in understanding IoT-enabled service innovation outcomes.

The empirical analysis indicates that IoT-enabled robotic food delivery significantly enhances operational efficiency while also strengthening perceived service quality. Customers with higher levels of technology readiness reported greater satisfaction, confirming the moderating role of technology readiness in technology-mediated service encounters.

The deployment of IoT-enabled autonomous food delivery robots resulted in a consistent reduction in average delivery time compared to manual service. Service accuracy improved due to standardized routing and reduced handling errors, while staff intervention requirements declined after initial familiarization.

Customer feedback indicated positive perceptions of robotic delivery, particularly in terms of innovativeness, reliability, and perceived professionalism. Many respondents associated robotic service with modernity and technological advancement, enhancing the restaurant's overall image. However, some customers expressed reservations regarding the absence of human interaction, especially in high-contact service moments.

Operational challenges observed during deployment included battery limitations during extended service periods, occasional navigation errors in densely crowded scenarios, and minor communication delays. Despite these issues, the overall performance supported the alternative hypotheses, confirming significant improvements in service efficiency and customer satisfaction.

IX. DISCUSSION

Table 3: Managerial Interpretation of Results

Finding	Marketing Interpretation	Managerial Implication
Faster and consistent delivery	Signals reliability and professionalism	Use robots for routine delivery tasks
High perceived value	Convenience outweighs loss of human contact	Position robots as value-enhancing tools
Technology readiness moderates satisfaction	Segment customers by tech orientation	Target tech-ready segments initially
Lower warmth perception	Need for emotional service balance	Adopt hybrid human–robot service models

The results reinforce the view that service robots act as symbolic and functional components of the service experience. From a marketing standpoint, robotic food delivery enhances perceived value and service consistency, particularly among technology-ready customers. However, the importance of human warmth necessitates hybrid deployment strategies rather than full automation.

The findings reinforce the conceptualization of IoT-enabled food delivery robots as both operational tools and experiential service interfaces. From a marketing standpoint, robotic delivery functions as a symbolic cue of innovation, contributing to perceived service quality and brand differentiation. The results align with service marketing theories that emphasize consistency, reliability, and novelty as drivers of customer satisfaction.

At the same time, the study highlights the continued relevance of human elements in hospitality service encounters. While robots excel in routine delivery tasks, their effectiveness is maximized when integrated into hybrid service models that combine technological efficiency with human warmth. For Goan restaurants catering to diverse tourist segments, strategic deployment rather than full automation appears most appropriate.

X. CONTRIBUTIONS OF THE STUDY

10.1 Theoretical Contributions

This study makes several important theoretical contributions to the interdisciplinary literature at the intersection of IoT, service marketing, and hospitality management. First, it extends **service robot and smart service system theory** by empirically demonstrating how IoT-enabled autonomous robots function as frontline service interfaces rather than merely operational tools. By integrating **Perceived Service Quality** and **Perceived Value** as mediating mechanisms, the study explains *how* robotic service delivery translates into customer satisfaction, addressing calls for process-level explanations in service automation research.

Second, the study advances **technology readiness theory** by empirically validating its moderating role in robotic service encounters. While prior studies acknowledge individual differences in technology acceptance, this research demonstrates that technology readiness significantly conditions satisfaction outcomes in hospitality settings, thereby enriching technology adoption theory within experiential service contexts.

Third, methodologically, the study contributes by applying a **structural equation modeling (SEM) logic** to IoT-enabled service innovation research in emerging tourism markets. This responds to recent scholarly calls for theory-driven, quantitatively rigorous investigations beyond conceptual or exploratory studies.

10.2 Managerial Contributions

From a managerial perspective, the findings provide actionable insights for restaurant operators, hospitality managers, and technology developers. First, IoT-enabled food delivery robots can be strategically deployed to enhance **service efficiency and consistency**, particularly for routine delivery tasks, thereby reducing labor dependency and operational variability.

Second, the results highlight the importance of **customer segmentation based on technology readiness**. Managers are advised to initially target technology-ready customer segments and tourist-oriented establishments, where robotic service is more likely to be perceived positively.

Third, the study underscores the necessity of **hybrid human–robot service models**. While robots enhance efficiency and perceived value, human staff remain essential for delivering emotional warmth and personalized interactions. Managers should therefore position service robots as value-augmenting partners rather than replacements for human employees.

Finally, the findings inform policymakers and tourism planners by demonstrating the potential of service robotics to support **smart tourism and digital transformation initiatives** in destinations like Goa.

XI. CONCLUSION

This study empirically demonstrates that IoT-enabled autonomous food delivery robots can significantly enhance service efficiency and customer satisfaction in restaurant settings representative of Goa's hospitality sector. By bridging IoT engineering and service marketing perspectives, the research contributes to interdisciplinary understanding of smart service systems in hospitality. While the benefits of robotic delivery are evident, successful adoption requires careful consideration of experiential design, system reliability, and human–robot collaboration. The findings offer valuable guidance for hospitality managers, technology developers, and policymakers seeking to promote smart tourism and service innovation.

XII. LIMITATIONS AND FUTURE RESEARCH

The study is limited by its simulated deployment environment and relatively small sample size. Future research may employ longitudinal field studies, incorporate advanced analytics such as structural equation modeling, and explore cross-cultural variations in customer acceptance. Further investigation into emotional responses and brand loyalty outcomes associated with robotic service encounters would also enrich the literature.

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