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SmartQ-Bill: AI-Driven Voice Billing with Quantum

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ABSTRACT:

Traditional billing systems in supermarkets, grocery stores and other retail environments often rely on manual product entry and conventional billing methods. This can lead to time-consuming processes and billing errors, especially in crowded and noisy environments. This paper presents SmartQ-Bill, an AI-driven voice-based billing system that enables cashiers to generate bills using voice commands. The system captures cashier speech through a directional microphone, applies noise reduction using the noisereduce library, and performs speaker authentication before processing commands. OpenAI Whisper converts speech into text, while a Retrieval-Augmented Generation (RAG) framework integrated with ChromaDB retrieves relevant product information, including product names and prices. An AI-based confirmation mechanism allows cashiers to verify recognized items and quantities before finalizing the bill. To introduce a quantum computing component, IBM Qiskit is used to generate a unique Quantum-Generated Bill Identifier (QGBI) for each invoice, supporting bill identification and traceability. The system uses ReportLab for digital invoice generation and PyPDF for PDF management, with a user-friendly web interface for accessing generated bills. The paper describes the system architecture, voice-processing workflow, RAG-based product retrieval, bill validation and quantum identifier generation. The proposed approach aims to reduce manual effort, improve billing accuracy, support secure invoice management and provide an efficient voice-based billing solution for modern retail environments.

Keywords: *AI-Driven Voice Billing, Speaker Authentication, Noise Reduction, Quantum Computing, Quantum Random Number Generation (QRNG).*

1.INTRODUCTION:

Supermarkets, grocery stores and other retail environments handle a continuous flow of customer transactions, where cashiers must enter product names, quantities and prices accurately to generate bills. In many retail environments, traditional billing systems depend on manual product selection and keyboard-based entry. This process can become time-consuming and may lead to billing errors, particularly during peak hours and in crowded, noisy surroundings. Background conversations and environmental sounds can also affect voice-based interactions, while incorrect product entries and quantity mismatches can reduce billing accuracy. In addition, conventional billing methods may not provide an integrated approach to voice processing, user authentication, intelligent product retrieval and reliable digital invoice identification.

Recent developments in Artificial Intelligence (AI), Automatic Speech Recognition (ASR) and quantum computing provide opportunities to improve the billing process. However, as the literature survey in Section 2 shows, existing approaches generally focus on individual areas such as speech recognition, speaker authentication, noise reduction, product retrieval or quantum-based applications. Integrating these technologies into a single voice-driven billing workflow, particularly for noisy retail environments, remains an important challenge.

This work proposes SmartQ-Bill: AI-Driven Voice Billing with Quantum, an intelligent voice-based billing system designed to reduce manual effort and improve billing accuracy in retail environments. The main contributions are:

- Voice-based billing: A hands-free billing interface in which cashiers can add products and specify quantities through voice commands, reducing the need for manual product entry.
- Noise reduction and speaker authentication: A directional microphone captures cashier speech, while the noisereduce library helps reduce background noise. Speaker authentication verifies the cashier before processing voice commands.
- AI-based speech recognition and product retrieval: OpenAI Whisper converts spoken commands into text, while a Retrieval-Augmented Generation (RAG) framework integrated with ChromaDB retrieves relevant product information, such as product names and prices.
- AI-based bill confirmation: A confirmation mechanism allows cashiers to review recognized products and quantities before finalizing the bill, helping identify and correct possible recognition errors.

- Quantum-based bill identification and digital invoice generation: IBM Qiskit is used for the quantum component associated with generating a unique Quantum-Generated Bill Identifier (QGBI) for each invoice. ReportLab generates PDF invoices, while PyPDF supports PDF management through the user-friendly web interface.

The rest of the paper is organized as follows. Section 2 reviews related work and identifies the research gap. Section 3 describes the proposed system architecture. Section 4 explains the methodology, including voice capture, noise reduction, speaker authentication, speech recognition, RAG-based product retrieval, bill confirmation and QGBI generation. Section 5 presents the system implementation, testing and evaluation. Section 6 discusses the expected outcomes, advantages and limitations. Finally, Section 7 concludes the paper and presents future scope.

2. RELATED WORK:

Fifteen studies related to voice-based billing, speech recognition, speaker authentication, noise reduction and quantum computing were reviewed. They can be broadly classified into four groups.

Speech recognition and voice processing systems. Hannun et al. [2] develop an end-to-end speech recognition system using Deep Neural Networks and Recurrent Neural Networks, demonstrating the potential of deep learning for large-scale speech processing. Transformer-based ASR approaches [3] improve speech transcription and support real-time voice commands, while Wav2Vec 2.0-based methods [11] use self-supervised learning for scalable speech recognition. These approaches provide a foundation for converting cashier voice commands into text. However, their computational requirements and performance under challenging retail noise conditions remain important considerations.

Speaker authentication and noise-robust speech systems. Studies combining Whisper with speaker embeddings [4][15] explore the integration of speech recognition and speaker identity information to improve voice-processing robustness. Speaker recognition approaches using VoxCeleb [5] and Reshape Dimensions Networks [6] focus on reliable speaker representation and authentication. CNN, RNN, MLP and Voice Activity Detection (VAD)-based approaches [7][10] investigate speech processing in noisy environments. Although these methods improve speech and speaker recognition, strong background noise, low signal-to-noise ratio and variations in real-world speech can still affect performance. These studies motivate the use of noise reduction and speaker authentication in SmartQ-Bill.

Voice-based billing and intelligent transaction systems. Conversational speech recognition with deep learning [8][14] directly addresses voice-based billing and hands-free transactions using spoken commands. These approaches demonstrate the usefulness of speech technology in automating retail billing, but limited speech datasets and dialect variations remain challenges. The Quantum Digital Payment Framework [9] explores quantum computing for transaction security, authentication and traceability, while blockchain-based biometric authentication and encryption [13] focus on improving transaction trust and security. However, these studies do not combine the complete workflow of voice capture, cashier authentication, product retrieval, bill confirmation and digital invoice generation.

Quantum machine learning and quantum-based approaches. QSVM with Quantum Feature Maps [1] investigates quantum machine learning for keyword spotting using the Google Speech Commands dataset. Quantum Neural Networks and QSVM-based approaches [12] further explore the use of quantum computing for speech and audio analysis. These studies provide a foundation for exploring quantum techniques in AI applications, but practical implementation is affected by quantum hardware limitations, scalability and computational constraints. They motivate the exploration of a quantum component in SmartQ-Bill through IBM Qiskit for generating a unique Quantum-Generated Bill Identifier (QGBI) for each invoice.

Based on the reviewed studies, SmartQ-Bill aims to integrate noise reduction, speaker authentication, Whisper-based speech recognition, RAG with ChromaDB for product retrieval, AI-based bill confirmation and Qiskit-based bill identification into a unified voice-driven billing system. Unlike approaches that focus mainly on individual speech-processing, authentication, billing or quantum techniques, the proposed system brings these components together in a single workflow designed for noisy retail environments.

Table 1. Summary of the reviewed literature

Ref.	Year	System / Focus	Key Strength	Limitation
[1]	2026	QSVM + Quantum Feature Maps	Quantum-based keyword spotting	Hardware scalability
[2]	2026	Blockchain + Biometric Authentication	Improves transaction security	Implementation complexity
[3]	2025	Transformer-based ASR	Real-time speech recognition	High computational cost
[4]	2025	Whisper + Speaker Embeddings	Improves noisy speech recognition	Affected by strong noise
[5]	2025	Speaker Recognition + Certification	Robust voice authentication	Limited to speaker recognition
[6]	2025	Reshape Dimensions Network	Efficient speaker representation	Limited real-world evaluation
[7]	2025	CNN + RNN + MLP + VAD	Noisy speech recognition	Low-SNR limitations

[8]	2025	Quantum Digital Payment Framework	Improves transaction security	Quantum scalability
[9]	2025	CNN + RNN + MLP + VAD	Evaluates noisy speech processing	Performance drops in noise
[10]	2025	Wav2Vec 2.0 + Transformer	Scalable speech recognition	High computational requirements
Ref.	**Year**	**System / Focus**	**Key Strength**	**Limitation**
[11]	2025	QNN + QSVM	Quantum-based audio analysis	Hardware limitations
[12]	2025	Whisper + Speaker Embedding	Combines speech and speaker identity	Adversarial noise
[13]	2023	Conversational Speech Recognition	Voice-based billing	Limited speech data
[14]	2023	Deep Learning for Voice Billing	Hands-free billing	Dialect variations
[15]	2020	Deep Speech (DNN + RNN)	End-to-end speech recognition	Requires large datasets

2.1 Research gap

The survey shows five recurring gaps, which the proposed system targets directly (Table 2).

Table 2. Identified gaps and the corresponding design response

Finding in literature	**Research gap**	**Proposed response**
Speech recognition is affected by background noise.	Difficulty recognizing voice commands in noisy retail environments.	Directional microphone and noisereduce for noise reduction.
Existing systems focus mainly on speech-to-text conversion.	Lack of integrated cashier verification.	Speaker authentication before processing commands.
Speech recognition systems convert voice into text.	Accurate product identification and price retrieval remain challenging.	Whisper with RAG and ChromaDB for product retrieval.
Voice-based billing can reduce manual entry.	Recognition errors may cause incorrect billing.	AI-based confirmation of products and quantities.
Quantum computing is explored in speech and payment applications.	Limited integration of quantum techniques into billing workflows.	Qiskit-based Quantum-Generated Bill Identifier (QGBI).
Traditional billing systems rely on manual invoice preparation.	Time-consuming invoice generation and management.	Automated PDF generation using ReportLab and PyPDF.

3. PROPOSED SYSTEM ARCHITECTURE

3.1 Overall Architecture

The proposed SmartQ-Bill system follows a modular architecture designed for voice-based billing in noisy retail environments. The cashier interacts with the system through a user-friendly web interface and a directional microphone. The captured voice is processed using the noisereduce library to reduce background noise and speaker authentication to verify the cashier's identity. The authenticated audio is converted into text using OpenAI Whisper. The recognized product details are processed through a Retrieval-Augmented Generation (RAG) framework, which uses ChromaDB to retrieve product information from the database. An AI-based confirmation mechanism allows the cashier to verify the products and quantities before bill generation. The billing module calculates the total amount and generates a unique Quantum-Generated Bill Identifier (QGBI) using IBM Qiskit. Finally, ReportLab generates the invoice in PDF format, while PyPDF supports PDF management. The generated bill is displayed through the web interface.

3.2 User roles

Role	Responsibilities
Cashier	Logs in to the system, provides voice commands through the microphone, adds products and quantities, verifies recognized items, confirms the bill and generates invoices.
Administrator	Manages product details, prices, inventory information, user accounts and system configurations; maintains the product database.
Customer	Provides product requirements to the cashier, checks the generated bill and receives the final invoice.
System / AI Module	Performs noise reduction, speaker authentication, speech-to-text conversion using Whisper, and product retrieval through RAG and ChromaDB.
Billing and Invoice Module	Calculates the total bill, generates a unique QGBI using Qiskit, creates PDF invoices using ReportLab and manages PDF documents using PyPDF.

3.3 Technology Stack

Layer	Technology	Purpose
Front End	Web-based User Interface	Provides an interface for cashier interaction, voice input, bill confirmation and invoice viewing.
Programming Language	Python	Implements backend logic, voice processing, product retrieval and billing operations.
Noise Reduction	noisereduce	Reduces background noise from the cashier's voice in noisy retail environments.
Speaker Authentication	Speaker Authentication Module	Verifies the cashier's voice identity before processing commands.
Speech Recognition	OpenAI Whisper	Converts spoken billing commands into text.
Product Retrieval	RAG Framework	Retrieves relevant product information based on recognized voice commands.
Vector Database	ChromaDB	Stores and retrieves product information for efficient product matching.
Quantum Computing	IBM Qiskit	Generates the Quantum-Generated Bill Identifier (QGBI) for each bill.
Invoice Generation	ReportLab	Creates PDF invoices containing product details and billing information.
PDF Management	PyPDF	Supports reading, merging, splitting and managing generated PDF documents.
Database	Product Database	Maintains product names, prices and related product information used during billing.

4. METHODOLOGY

4.1 Voice-Based Billing Lifecycle

Fig. 2 illustrates the end-to-end workflow of the proposed SmartQ-Bill system. The major steps are as follows:

1. Voice Input: The cashier provides product names and quantities through a directional microphone using voice commands.

2. Noise Reduction: The captured audio is processed using the noisereduce library to reduce background noise and improve speech clarity in noisy retail environments.

3. Speaker Authentication: The system verifies the cashier's voice identity before processing the billing commands, ensuring that only an authenticated speaker can proceed.

4. Speech Recognition: The authenticated audio is passed to OpenAI Whisper, which converts the spoken commands into text containing product names and quantities.

5. Product Retrieval: The recognized text is processed using the Retrieval-Augmented Generation (RAG) framework. ChromaDB retrieves the relevant product information, including product names and prices, from the product database.

6. AI-Based Confirmation: The system presents the recognized products and quantities to the cashier for verification. If any details are incorrect, the cashier can correct them before finalizing the bill.

7. Bill Generation: After confirmation, the billing module calculates the total amount using the retrieved product prices and generates a unique Quantum-Generated Bill Identifier (QGBI) using IBM Qiskit.

8. Invoice Generation: ReportLab generates the final invoice in PDF format, while PyPDF supports PDF document management. The generated invoice is displayed through the user-friendly web interface.

9. Bill Completion: The cashier can review the final invoice and provide it to the customer, completing the voice-based billing process.

4.2 Role-Based Access Control (RBAC) and Voice Authentication

SmartQ-Bill uses speaker authentication and controlled access to ensure that billing commands are processed only after verifying the cashier's voice identity. Unlike a general voice-processing system, the proposed approach includes an authentication step before speech recognition and bill generation. The system verifies the speaker, processes the authenticated voice input and allows the cashier to review and confirm the recognized billing details before finalizing the invoice.

If authentication fails, the system does not proceed with the billing command. The proposed design follows these principles:

- **Speaker Verification:** The system verifies the cashier's voice identity before accepting billing commands.
- **Noise Handling:** The noisereduce library reduces background noise to improve the quality of captured voice input.
- **Authenticated Processing:** Only successfully authenticated voice input proceeds to the Whisper speech recognition module.
- **Command Confirmation:** Recognized product names and quantities are presented to the cashier for verification before bill finalization.
- **Accurate Billing:** Product prices are retrieved from the ChromaDB-supported product retrieval process, and the billing module calculates the total amount using the confirmed details.
- **Invoice Identification:** A unique Quantum-Generated Bill Identifier (QGBI) is generated using IBM Qiskit for each bill.
- **Accountability and Verification:** The generated invoice contains billing details and its unique identifier, helping distinguish individual bills.

Table 3. Role–permission matrix

Role / Component	Provide voice input	View billing details	Authenticate speaker	Process voice commands	Confirm bill	Generate invoice	Manage products
Cashier	Yes	Yes	Yes (voice verification)	Yes	Yes	Yes	No
Customer	No (through cashier)	Yes (final bill)	No	No	No	No	No
Administrator	No	Yes	No	No	No	No	Yes
Noise Reduction Module	No	No	No	Yes (noise reduction)	No	No	No
Speaker Authentication Module	No	No	Yes	No	No	No	No
Whisper Speech Recognition	No	No	No	Yes (speech-to-text)	No	No	No

Role / Component	Provide voice input	View billing details	Authenticate speaker	Process voice commands	Confirm bill	Generate invoice	Manage products
RAG + ChromaDB Module	No	Yes (product details)	No	Yes (product retrieval)	No	No	No
Billing and QGBI Module	No	Yes	No	No	No	Yes (QGBI and bill processing)	No
Invoice Generation Module	No	Yes	No	No	No	Yes (PDF invoice)	No

4.3 Voice-Based Billing Workflow

The voice-based billing process is the core functionality of the proposed SmartQ-Bill system and is illustrated. Initially, the cashier provides voice commands through a directional microphone to specify product names and quantities. The captured audio is processed using the noisereduce library to reduce background noise. The system then performs speaker authentication to verify the cashier's identity before accepting the voice command. After successful authentication, OpenAI Whisper converts the speech into text. The recognized product names and quantities are passed to the RAG framework, which uses ChromaDB to retrieve the corresponding product details and prices from the product database. The system displays the retrieved information for cashier verification. If any product or quantity is incorrect, the cashier can correct the details before proceeding. Once the cashier confirms the bill, the billing module calculates the total amount and generates a unique Quantum-Generated Bill Identifier (QGBI) using IBM Qiskit. Finally, ReportLab generates the invoice in PDF format, and PyPDF supports PDF management. The completed invoice is displayed through the web interface for the cashier to review and provide to the customer.

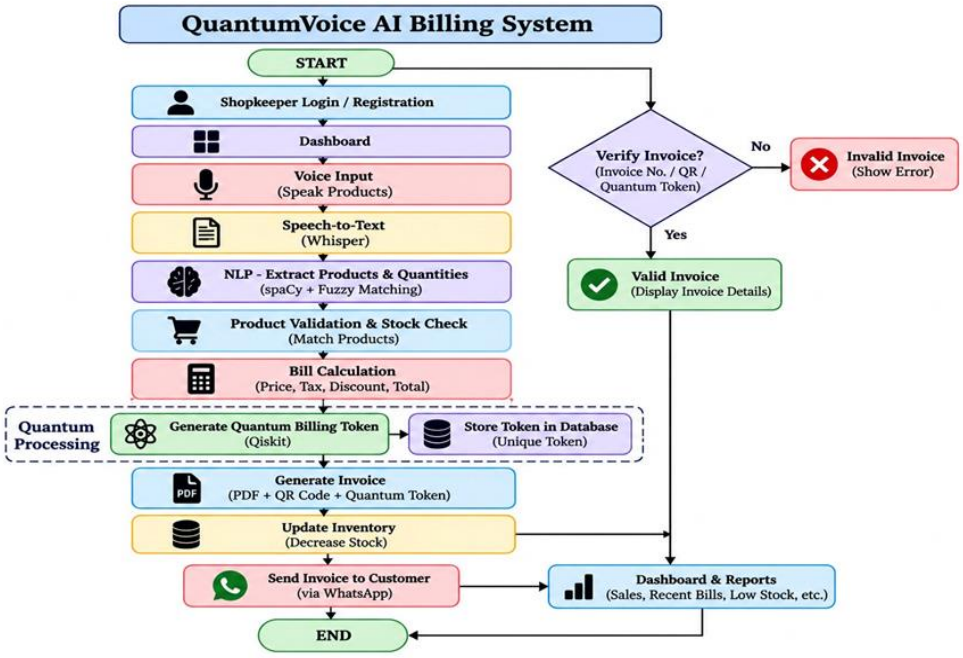


FIG.1. VOICE BASED BILLING WORKFLOW OF SMARTQ-BILL

Table 4. Billing Operations and Processing Conditions

Operation	Processing Chain	Condition
Voice Input	Cashier → Directional Microphone	Product names and quantities are provided through voice commands.
Noise Reduction	Microphone → noisereduce	Background noise is reduced from the captured audio.

Operation	Processing Chain	Condition
Speaker Authentication	Voice Input → Speaker Authentication	Cashier's voice identity must be verified.
Speech Recognition	Whisper → Text Conversion	Authenticated voice commands are converted into text.
Product Retrieval	RAG → ChromaDB → Product Database	Matching product details and prices must be retrieved.
Bill Confirmation	Retrieved Products → Cashier Verification	Product names and quantities must be checked and confirmed.
Bill Generation	Billing Module → Qiskit (QGBI)	Confirmed billing details are used to generate the bill with a unique identifier.
PDF Invoice	ReportLab → PyPDF	Final invoice is generated and managed in PDF format.

The voice processing, product retrieval and invoice generation modules of SmartQ-Bill work together as a single integrated billing workflow. The initial process follows the chain Directional Microphone → Noise Reduction → Speaker Authentication → Whisper Speech Recognition, whereas the product identification and billing process follows Whisper → RAG → ChromaDB → Cashier Confirmation → Bill Generation. After confirmation, the system generates a unique Quantum-Generated Bill Identifier (QGBI) using IBM Qiskit and creates the final PDF invoice using ReportLab and PyPDF. Each module performs a specific function, and its output is passed to the next stage, allowing the system to automate the complete billing process through voice commands.

4.4 Digital Document Management and Verification

- Automated PDF invoice generation: ReportLab is used to generate digital invoices containing product details, quantities, prices and the total bill amount.
- Unique bill identification: IBM Qiskit is used to generate a unique Quantum-Generated Bill Identifier (QGBI) for every generated invoice.
- PDF document management: PyPDF is used to support PDF operations and manage the generated invoice documents.
- Invoice access: The generated PDF invoice is displayed through the web-based interface, allowing the cashier to view and provide the invoice to the customer.
- Future verification enhancement: Digital signatures and cryptographic hashing can be incorporated to verify invoice integrity and detect unauthorized modifications.

4.5 Digital Invoice Management and Verification

The proposed SmartQ-Bill system supports digital invoice generation and management through the following functionalities:

- Automated PDF Generation: ReportLab generates digital invoices containing product names, quantities, prices and total billing amounts.
- Unique Bill Identification: IBM Qiskit is used to generate a unique Quantum-Generated Bill Identifier (QGBI) for every generated invoice.
- PDF Document Management: PyPDF supports reading, merging, splitting and managing generated PDF invoices.
- Invoice Display: The generated invoice is displayed through the user-friendly web interface for review and customer access.
- Invoice Verification: The QGBI serves as a unique reference for identifying individual bills. Cryptographic hashing and digital signatures can be integrated to support additional invoice integrity verification.

4.6 Security

Security in SmartQ-Bill is supported through speaker authentication, voice verification and controlled bill generation. The proposed system follows these security measures:

- Speaker Authentication: The cashier's voice identity is verified before processing billing commands.
- Noise Reduction: The noisereduce library reduces background noise to improve the quality of captured voice input.
- Confirmation Mechanism: Recognized product names and quantities are verified by the cashier before final bill generation.

- Product Data Validation: Product details and prices are retrieved from the product database through RAG and ChromaDB.
- Unique Bill Identification: QGBI provides a unique identifier for each generated invoice.
- Invoice Integrity: Digital signatures and cryptographic hashing can be incorporated to detect unauthorized invoice modifications **and improve document authenticity.**

5. IMPLEMENTATION AND EVALUATION PLAN

5.1 Implementation Status

The SmartQ-Bill project is carried out in stages, including literature survey, requirement analysis, planning and system design. The implementation involves developing the voice processing module using noise reduction and speaker authentication, integrating OpenAI Whisper for speech recognition, and implementing RAG with ChromaDB for product retrieval. The billing module integrates IBM Qiskit for generating the Quantum-Generated Bill Identifier (QGBI), while ReportLab and PyPDF support invoice generation and management. The web-based interface provides access to the billing operations and generated invoices. System integration, testing, evaluation, deployment and documentation are carried out as subsequent stages of the project.

5.2 Evaluation Protocol

The SmartQ-Bill system will be evaluated using sample retail product data and voice commands under different background noise conditions. Its performance will be assessed based on speech recognition, speaker authentication, product retrieval, billing accuracy and invoice generation. The system's performance can also be compared with the conventional manual billing process. No performance figures are claimed in this paper; the following metrics will be reported after testing.

Table 5. Evaluation Metrics

Metric	Definition	Baseline for Comparison
Speech Recognition Accuracy	Percentage of spoken product commands correctly converted into text by Whisper.	Manually transcribed voice commands
Word Error Rate (WER)	Measures errors in recognized text, including substitutions, deletions and insertions.	Actual spoken transcript
Noise Reduction Performance	Evaluates the reduction of background noise in captured audio.	Original audio without noise reduction
Speaker Authentication Accuracy	Measures the percentage of authorized and unauthorized speakers correctly identified.	Actual speaker identity
Product Retrieval Accuracy	Percentage of correct product details retrieved using RAG and ChromaDB.	Product database records
Billing Accuracy	Measures whether product quantities, prices and final bill amounts are calculated correctly.	Manually calculated bills
Invoice Generation Time	Time taken to generate the final PDF invoice after bill confirmation.	Conventional manual invoice generation
QGBI Uniqueness	Checks whether each generated bill receives a unique Quantum-Generated Bill Identifier.	Previously generated bill identifiers
System Response Time	Measures the time taken by the system to process voice commands and retrieve product information.	Conventional manual billing process
Usability	Evaluates the ease of use of the web interface and voice-based billing system through user feedback.	User feedback on the existing billing process

5.3 Results

The SmartQ-Bill application interface was developed to support voice-based billing, product management, payment selection and invoice management. The implemented interface screens are presented . These screenshots illustrate the major functions and user interactions available in the application. The results presented in this section focus on the functional interface and workflow rather than quantitative performance, as system evaluation metrics will be reported after testing.

Voice billing module: the Voice Billing interface, where the cashier can select a language and provide product names and quantities through the microphone. The interface also provides sample voice commands to guide the user. A captured voice or manually entered text area is available to display or enter billing details before further processing.

Product management module: Products interface, which allows the store administrator or authorized user to view the available product catalogue. Each product entry displays its name, price and barcode information. The interface also provides options to add, edit and delete product records, supporting the maintenance of product information required for billing and retrieval.

Payment selection module: Payment selection interface, where the cashier can choose between cash and UPI/QR payment methods. The selected payment mode determines the next step in the payment process. For cash payments, the interface allows the cashier to enter the received amount, view the change to be returned and confirm the payment.

UPI QR payment module: UPI payment screen generated for a walk-in customer. It displays the payment amount and a QR code that the customer can scan using supported UPI applications. The interface also provides a payment confirmation option for the cashier. The displayed screen represents the payment interface; successful payment should be confirmed through the actual payment process.

Bills management module: Bills interface, which displays generated invoices along with customer details, invoice numbers, amounts and payment status. The cashier can view invoice records and identify whether a bill is paid or pending. The interface also displays the associated payment mode and provides options to view or share invoice information.

Additional billing interfaces: Barcode Scanner and Photo Billing interfaces. The Barcode Scanner screen provides options to scan a product barcode using the camera, upload an image or enter a barcode manually. The Photo Billing screen provides options to capture or upload product-related images. These screens should be included only if the corresponding features are implemented and tested as part of the current system.

6. DISCUSSION

Expected Benefits. SmartQ-Bill is designed to reduce manual effort and improve billing efficiency in noisy retail environments. Voice-based product entry helps cashiers add products and quantities without repeatedly entering details manually. Noise reduction and speaker authentication support reliable voice input, while OpenAI Whisper converts speech into text. RAG with ChromaDB helps retrieve relevant product information, and the AI-based confirmation mechanism allows cashiers to correct errors before finalizing bills. The integration of IBM Qiskit for generating a unique Quantum-Generated Bill Identifier (QGBI), along with automated PDF invoice generation, provides a structured approach to digital retail billing. The actual improvements in accuracy and processing time will be determined through the evaluation described in Table 5.

Limitations. The performance of voice recognition may be affected by high background noise, different accents, pronunciation and speaking speed. Speaker authentication also depends on the quality of the captured voice input. Product retrieval accuracy depends on the completeness and correctness of the product database. The confirmation step requires cashier involvement before finalizing the bill. Additionally, the QGBI generation process requires further testing to evaluate its reliability and practical implementation on quantum hardware. A unique QGBI identifies a bill but does not independently guarantee document integrity or prevent unauthorized modifications. Digital signatures and cryptographic hashing can be incorporated to strengthen invoice verification. The system's performance and scalability in real retail environments must also be evaluated through practical deployment.

7. CONCLUSION AND FUTURE SCOPE

This paper presented SmartQ-Bill, an AI-driven voice-based billing system integrated with quantum computing techniques for retail environments. The proposed system combines noise reduction, speaker authentication, OpenAI Whisper speech recognition, RAG-based product retrieval using ChromaDB and an AI-based confirmation mechanism to support accurate voice-based billing. IBM Qiskit is incorporated to generate a unique Quantum-Generated Bill Identifier (QGBI) for each bill, while ReportLab and PyPDF support digital invoice generation and management. By integrating these technologies, SmartQ-Bill aims to reduce manual billing effort, improve convenience and support efficient invoice generation in noisy retail environments.

Future Scope

Future enhancements to SmartQ-Bill will focus on improving voice recognition, billing accuracy, security, scalability and practical deployment. The following developments can be considered:

- **Improved Voice Recognition:** Enhance speech recognition in noisy retail environments by using additional speaker samples and testing with real-world retail audio recordings.

- **Multilingual Voice Billing:** Extend the system to support multiple languages to make voice-based billing more accessible to cashiers in different regions.
- **Quantum Hardware Integration:** Test the QGBI generation component on real quantum computers and evaluate its reliability, execution time and practical feasibility.
- **Enhanced Product Retrieval:** Expand the product database and improve RAG-based retrieval to provide more accurate product identification and reduce billing errors.
- **Secure Invoice Verification:** Incorporate digital signatures and cryptographic hashing to verify invoice integrity and detect unauthorized modifications.
- **Real-World Deployment:** Deploy and evaluate the system in supermarkets, grocery stores and shopping malls to assess its usability, performance and scalability under practical retail conditions.

REFERENCES

1. Caleb, R., & Pushparaj, J. (2026). *Empirical Evidence of Quantum Kernel Concentration in Few-Shot Keyword Spotting*. IEEE Access,
2. *Voice Memory for Agentic Speech Recognition*. (2026).
3. Abey, J. (2026). *Improving Security and Customer Trust in E-Commerce Using Modern Digital Technologies*. Journal of Internet Services and Information Security, 16(1), 689–700.
4. Rymer, & Roorda. (2026). *Cryptographic Custody Primitives as the Missing Assurance Layer in Agentic Infrastructure for Physical Goods*.
5. Bagul, P., Prajapati, S., Kakade, S., Lahane, T., & Shrivastav, R. (2025). *Voice Based Billing System*. International Journal of Advanced Research in Science, Communication and Technology, 5(4).
6. Liu, S., Zhang, Y., Ren, S., Qiu, S., Lu, Z., Wang, X., & Li, Y. (2025). *Experimental Demonstration of Complete Quantum E-Commerce Based on an Efficient Quantum Digital Payment*. Photonics Research.
7. Medetov, B., Zhetpisbayeva, A., Akhmediyarova, A., Nurlankyzy, A., Namazbayev, T., Kulakayeva, A., Albanbay, N., Turdalyuly, M., Yskak, A., & Uristimbek, G. (2025). *Evaluating the Effectiveness of a Voice Activity Detector Based on Various Neural Networks*. Eastern-European Journal of Enterprise Technologies.
8. Elakkiya, D., Buvaneswari, T., Sivaguru, R., Saranya, K., Monisha, S., & Kalaiselvi, S. (2025). *Advancements in Speech Recognition Using Artificial Intelligence: A Comprehensive Review and Future Directions*. International Research Journal on Advanced Engineering Hub, 3(7), 3160–3165.
9. Korzh, D., Karimov, E., Pautov, M., Rogov, O. Y., & Oseledets, I. (2025). *Certification of Speaker Recognition Models to Additive Perturbations*. Proceedings of the AAAI Conference on Artificial Intelligence.
10. Norval, M., & Wang, Z. (2024). *Quantum AI in Speech Emotion Recognition*. Research Article.
11. Alavilli, S., Banerjee, A., Elbanna, G., & Magaro, A. (2024). *Incorporating Talker Identity Aids With Improving Speech Recognition in Adversarial Environments*.
12. Yakovlev, I., Makarov, R., Balykin, A., Malov, P., Okhotnikov, A., & Torgashov, N. (2024). *Reshape Dimensions Network for Speaker Recognition*.
13. Jeffries, N., King, E., Kudlur, M., Nicholson, G., Wang, J., & Warden, P. (2024). *Moonshine: Speech Recognition for Live Transcription and Voice Commands*.
14. Parabattina, B. (2024). *Automated Billing System from Conversational Spoken Telugu Language*. SERB SURE Project Proposal, Government of India.
15. Hannun, A., Case, C., Casper, J., Catanzaro, B., Diamos, G., Elsen, E., Prenger, R., Satheesh, S., Sengupta, S., Coates, A., & Ng, A. Y. (2014). *Deep Speech: Scaling up end-to-end speech recognition*.