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Quick response code generation for e-invoicing in Saudi Arabia

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ABSTRACT

In the digital era, the emergence of quick response (QR) code technology has become a vital tool for enhancing the efficiency of electronic invoice management and promoting security and transparency in financial transactions, while reducing costs and ensuring compliance with regulations. This study focuses on QR code technology and electronic invoice requirements in the Kingdom of Saudi Arabia, by exploring the generation of QR codes for electronic invoices. The study begins by analyzing QR code technology and its role in encoding and decoding information. Subsequently, the electronic invoice requirements in Saudi Arabia are reviewed, with a focus on the applicable systems and regulations. The research also includes details on generating QR codes for electronic invoices, considering factors such as data encoding, security protocols, and compatibility standards using the Python programming language. Various steps of this process are explained. The study aims to provide a comprehensive understanding of the technology and requirements related to electronic invoices in Saudi Arabia and to develop a program for creating QR codes for electronic invoices to improve and develop the financial and technological infrastructure in the Kingdom of Saudi Arabia, thereby contributing to supporting the digital economy and promoting sustainable development.

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1. INTRODUCTION

In the context of rapid technological advancement in the modern world, transitioning to electronic invoicing plays a vital role in improving invoicing processes and delivering more efficient services. This transition aims to leverage computing and information technology to streamline financial operations, reducing waste and errors associated with traditional manual procedures. The significance of electronic invoicing revolves around achieving multiple operational and economic objectives. It contributes to cost savings associated with printing, distribution, and management of traditional invoices. Additionally, it works to prevent human errors during the invoicing process, thereby reducing the chances of mistakes and enhancing the accuracy of financial information [1].

Furthermore, electronic invoices contribute to transparency and security. They provide accurate and instantly updated information to the consumer, increasing trust and transparency levels among the involved parties. By recording each step of the invoicing process, an accurate and transparent account of financial transactions can be provided. Moreover, electronic invoices contribute to combating the shadow economy and reducing commercial concealment, making it difficult to hide business operations and manipulate

financial data. Finally, electronic invoices increase compliance with tax obligations, as all transactions are accurately recorded, thus reducing potential legal and tax risks [2].

Creating a two-dimensional barcode [3] for electronic invoices is considered an innovative and effective solution to enhance the efficiency of financial operations and facilitate tracking and monitoring processes. This initiative comes in the context of transitioning traditional processes to advanced electronic operations, surpassing its role as a technological tool to become a comprehensive solution for improving financial operations performance and achieving overarching goals. The importance of creating two-dimensional barcode [4] lies in several aspects. Using barcodes facilitates the reading and tracking of electronic invoices, enabling the extraction of invoice data efficiently and facilitating data monitoring and management, considering the variation in invoice formats among institutions. Instead of printing full data on the invoice, multiple pieces of information can be stored in the barcode. This reduces printing and distribution costs, conserves space, and facilitates sharing information with government entities such as tax authorities.

In many countries, tax legislation mandates the use of two-dimensional barcodes in electronic invoices as part of tax compliance, increasing the importance of including them in these invoices. In the context of Saudi Arabia, the General Authority of Zakat and Tax [2] requires the presence of a barcode in electronic invoices, reflecting the importance of this technology in facilitating tax operations and achieving legal compliance. The presence of barcodes is considered a vital step towards improving and developing the financial and technological infrastructure in Saudi Arabia, facilitating invoice tracking and quickly identifying necessary information. It also contributes to supporting the digital economy and promoting sustainable development.

The importance of prior research in the field of financial technology is evident in its focus on the need for accuracy and transparency in financial transactions. However, challenges such as human errors, printing and distribution costs, and issues related to combating the shadow economy and ensuring tax compliance persist. This study aims to address these challenges by focusing on the implementation of quick response (QR) codes in electronic invoices. The significance of using QR codes lies in their ability to ensure invoice accuracy by including essential data such as the company name, seller's value added tax (VAT) number, date and time, and total price. These QR codes can be read using the designated program from the General Authority of Zakat and Tax in Saudi Arabia, thereby enhancing the accuracy and transparency of invoicing processes.

Research on digital invoicing highlights its transformative impact on financial operations. Ahmad *et al.*, [5] study reveals that electronic invoicing significantly reduces costs related to processing, disputes, and duplicate payments, while improving cash flow and working capital through early-payment discounts. Garba *et al.*, [6] explores the integration of blockchain technology into electronic invoicing, showing how it can enhance transparency and efficiency. Her analysis highlights blockchain’s potential to improve the reliability of invoicing systems, though adoption challenges remain. Bellon *et al.*, [7] investigates the effects of electronic invoicing on tax compliance and business performance in Peru, finding increased reported sales and VAT obligations. His research indicates that electronic invoicing improves compliance and reduces costs, although additional reforms may be necessary.

Lee *et al.*, [8] research assesses South Korea's mandatory electronic tax invoices, demonstrating their success in reducing compliance costs and increasing transaction transparency. Adoption rates soared from 15% before the mandate to 99.9% by 2013, with significant improvements in taxpayer services and reduced tax evasion. Marques and Reis [9] discusses Portugal’s legislative changes introducing QR codes on invoices. His study underscores the benefits of QR codes in verifying and streamlining the invoicing process, enhancing accuracy and efficiency.

Collectively, these studies highlight the significant benefits of electronic invoicing and QR codes in improving financial operations, transparency, and compliance. Due to advancements in electronic invoicing, many countries, including Saudi Arabia, have moved towards adopting electronic invoices to reduce printing and distribution costs and achieve more effective tax compliance. The objective of this research is to develop a QR code specifically for electronic invoices that complies with the requirements of the zakat and tax authority in Saudi Arabia.

The structure of this paper is organized as follows: section 2 provides a comprehensive background on QR code technology, focusing on aspects such as encryption and encoding. Section 3 outlines the specific requirements for electronic invoicing in Saudi Arabia, detailing both regulatory and practical considerations. Section 4 presents the research methods employed, including the approaches and techniques used for developing and testing the proposed system. Finally, section 5 concludes the paper by summarizing the findings and discussing their significance and implications for enhancing financial operations and supporting digital transformation.

2. BACKGROUND

2.1. QR code technology

The QR code is considered an efficient type of two-dimensional barcode, originally developed in Japan in 1994 by Denso Wave Company. The QR code is characterized by its ability to store data in a two-dimensional format, meaning it can store large amounts of information compared to traditional linear barcodes. The QR code consists of black and white squares arranged in a grid-connected to each other. Additionally, the code contains finder patterns, which help locate the code and guide the reader to extract the information [4].

The QR code is an effective means of transferring information, as it is easy to generate and quickly readable by smartphones. It can encode large amounts of information, up to more than 4,000 characters [10], making it popular in many applications in daily life. QR codes can be used in various fields, including embedding web addresses inside QR codes, allowing users to quickly access websites through their smartphones, storing contact information such as names, phone numbers, and email addresses inside QR codes, providing product information for companies such as prices, inventory availability, and technical details, as well as converting short texts such as emails and text messages.

QR codes can be read by most mobile phones and webcams in web browsers. Additionally, QR codes are defined in 40 different versions and 4 selectable error correction levels: L, M, Q, and H, where these levels can correct different error rates resulting from distortion, making it a robust and reliable system for information transfer [11]. Computing can be effectively and accurately used to generate QR codes by relying on programming languages and the available libraries. There are several methods through which QR codes can be generated using computing, including:

a) Utilizing specialized libraries: there are numerous libraries available in popular programming languages such as Python, Java, C#, and others, which enable you to generate QR codes easily and efficiently. Libraries like ZXing [12] for Java and Python, and QR code [13] for Python, provide programming interfaces for generating and analyzing QR codes. The QR code library is lightweight and user-friendly, allowing you to generate QR codes quickly while providing great flexibility in customization. These libraries rely on advanced algorithms to ensure accuracy and efficiency in generating QR codes, offering a wide range of options for customizing the code according to your needs. You can specify properties such as size, colors, alternative text, error correction level, and more, to include your information in a precise and efficient manner that meets the requirements of your application.
b) Using web services: there are online services that allow you to generate QR codes without the need to write the code yourself. You can use application programming interfaces (APIs) for these services to incorporate QR code generation into your application or website. Many web services provide APIs for easily generating QR codes. Among these services, Google Charts [14] and QR code generator API [15] are famous examples. These services rely on the cloud to generate the codes, meaning you don't need to install or manage any infrastructure. Simply put, you can access these services online and use them to generate QR codes easily without needing to write the code yourself. This saves time and effort and allows you to integrate QR codes into your applications quickly and efficiently.
c) Using mobile applications software: there are many mobile applications available on smartphones that allow you to easily and accurately generate QR codes. You can use these applications to generate codes and share them directly or incorporate them into your promotional materials. Among these applications, the barcode scanner is a famous example. It provides a simple and user-friendly interface for inputting data and generating QR codes based on it. Users simply input the data they want to include in the QR code, and the code is generated instantly. This application is an easy and efficient way to generate QR codes instantly, making it useful for individuals and companies alike to include various information in QR codes and share them easily [16].
d) Using cloud computing: cloud computing services can be used to perform QR code generation at the server level instead of doing it on your device. This can be useful if you manage a large-scale application that requires generating large quantities of QR codes frequently. Cloud computing services such as Amazon web services (AWS) [17] or Microsoft Azure [18] can be used to execute QR code generation at the server level. This means that the codes can be generated directly on the cloud without the need to install or manage any infrastructure. This approach provides flexibility and ease in generating QR codes, allowing you to efficiently and reliably meet the needs of your application. Cloud computing is an ideal option for applications that require frequent and intensive processing to generate QR codes in large quantities or in real time.

When using any of these methods, it's crucial to ensure the accuracy and security of your QR code generation. There is significant importance in encoding and encrypting data before creating the QR code.

Encryption is utilized to secure the data and protect it from tampering, and unauthorized access, and to ensure its integrity during transportation and storage. Encoding, on the other hand, facilitates the

transformation of data into a format that can be easily read and used in QR code symbols. By implementing encryption techniques, you add layers of security to your data, making it more resistant to unauthorized access or tampering [19]. Additionally, encoding ensures that the data is represented in a format that is compatible with QR code standards and can be accurately interpreted by scanning devices. Ultimately, both encryption and encoding play essential roles in safeguarding the integrity and security of your QR codes, ensuring that they effectively serve their purpose of transmitting information securely and reliably.

2.2. Encryption

Encryption is the process of converting data from its original form into another form that is unreadable or unintelligible except by authorized individuals or devices, achieved through the use of complex algorithms. The purpose of encryption is to protect data from unauthorized access and ensure information confidentiality, and it is utilized in a variety of scenarios including electronic communications, data storage, online financial transactions, and cyber-security in general. Encryption is performed by using a key (or a set of keys) to transform the data into an encrypted form [20].

There are several types of encryption algorithms, varying in security level, strength, and usage:

a) Symmetric encryption: in this type of encryption, the same key is used for both encryption and decryption operations. Some important symmetric encryption algorithms include triple DES (data encryption standard), Blowfish, Twofish, Camellia, RC4 (Rivest Cipher 4), ChaCha20, and AES (advanced encryption standard) [21].
b) Asymmetric encryption: also known as public-key encryption, this method utilizes two different keys: a public key for encryption and a private key for decryption. Well-known asymmetric encryption algorithms include RSA (Rivest-Shamir-Adleman) and ECC (elliptic curve cryptography) [22].
c) One-time pad encryption [23]: this encryption method relies on using a key that is used only once, and it must be the same length as the original text. One of the significant algorithms in this category is the Vernam Cipher or the one-time pad encryption.
d) Hashing: in this process, data is transformed into a fixed-length string called a hash, which is used to verify the integrity of data and detect any changes. Common hashing algorithms include SHA (secure hash algorithm) [24].

These various encryption techniques are used to encode and protect data from unauthorized access before embedding them into QR codes, ensuring their integrity and confidentiality during transportation and storage.

2.3. Encoding

Encoding refers to the process of transforming data from one format to another in a manner that facilitates its storage or transmission without losing its original meaning. Its purpose is to represent data in a structured format that can be easily interpreted or utilized, often tailored to specific requirements such as network communication or database storage [25]. Encoding methods play a critical role in data representation across various technological domains. Base2 encoding, relying on binary digits 0 and 1, serves as the foundation for digital computing, while Base16 encoding employs hexadecimal digits to represent data, widely used in computer science and digital electronics. Base64 encoding converts binary data into a text format using alphanumeric characters and symbols, facilitating secure data transmission over the internet [26].

Base58 encoding, similar to Base64 but excluding certain characters, finds application in cryptocurrency systems like Bitcoin, ensuring clarity and efficiency in data representation [27]. Additionally, Base32 encoding offers a more compact representation compared to Base64, suitable for scenarios where efficient data transmission is paramount. Base85 encoding further enhances data compression and transmission efficiency, making it a preferred choice in various data-intensive applications [28].

Uniform resource locator (URL) encoding, essential for web applications, ensures data compatibility with URLs by replacing unsafe characters with percept-encoded representations. American standard code for information interchange (ASCII) encoding represents data using the standard American character set, crucial for legacy systems and communication protocols. Multipurpose internet mail extensions (MIME) encoding enables the representation of non-ASCII characters in email messages, ensuring interoperability across different email clients. JSON web tokens (JWT) [29] provide a secure means of representing and transmitting information in web and application contexts, commonly utilized for authentication and authorization. Unicode encoding supports a wide range of characters and symbols from different languages and cultures worldwide, ensuring interoperability and standardization. Finally, UTF-8 and UTF-16 encodings efficiently represent Unicode characters, catering to diverse text encoding requirements in web development and internationalization [30].

3. E-INVOICING REQUIREMENTS IN SAUDI ARABIA

Modern business and financial operations in the Kingdom of Saudi Arabia require the use of electronic invoicing, which must comply with the electronic invoicing regulations set by the general authority of zakat and income tax in Saudi Arabia [31]. These regulations specify the legal, technical, and procedural requirements that must be followed to use electronic invoices legally. The electronic invoicing system aims to transform the process of issuing paper invoices and notifications into an electronic process that allows for their exchange between the seller and the buyer in an integrated electronic format. The implementation of electronic invoicing in Saudi Arabia occurs in two stages [32]:

a) Phase one - issuance stage: in this stage, individuals subject to electronic invoicing regulations must create electronic invoices and notes according to specified conditions. This stage was effectively implemented on December 4, 2021.
b) Phase two - integration and linking stage: this stage requires the integration of individual systems with the authority's system according to specified conditions. The implementation of this stage begins on January 1, 2023.

There are several steps and requirements aimed at facilitating the electronic invoicing process and ensuring compliance with legal and technical standards in the Kingdom of Saudi Arabia:

a) The technical regulations for electronic invoicing specify the requirements and procedures for using electronic invoices legally.
b) Electronic invoices must be archived, and electronic tax reports must be submitted.
c) Electronic invoices are updated to ensure compliance with the specified technical and legal requirements.
d) Technical solutions must be able to communicate with the API provided by the authority.
e) QR codes are added to simplified tax invoices.
f) Legal companies and institutions must maintain electronic copies of invoices for a specified period according to local legislation.
g) Electronic invoices must comply with the technical regulations specified by the general authority of zakat and income tax in Saudi Arabia.
h) Invoices must comply with the tax model required by the authority.

Every resident in the Kingdom and every permanent establishment for a non-resident individual must withhold tax from amounts paid to non-residents for their income derived from a source in the Kingdom by the rates specified in the income tax law and it's executive regulations [33]. An individual can tamper with the invoice and QR code and use another company's name to imply that they made the purchase, resulting in reduced profits and tax paid. Therefore, in recognition of the importance of the trade name, the Saudi system [34] has decided to protect it and requires competent authorities to prohibit its use or delete it if used in violation of regulations, with the right to compensation if justified. The system also imposes a financial penalty for the misuse of the trade name, with the penalty doubling for repeat offenses, without prejudice to any stricter penalties stipulated in another system. The protection of the trade name is limited to specific time and place.

To ensure the integrity of electronic invoices and prevent tampering, technological solutions must include mechanisms to detect any attempts to manipulate invoices and prevent any alteration or forgery of the information contained therein. These solutions should also prevent the alteration of time or date in electronic invoices in a way that could mislead or input false information into resulting documents. These additions enhance the security and reliability of electronic invoicing, ensuring data integrity and compliance with legal and technical requirements.

3.1. Electronic invoicing

There are numerous steps and requirements aimed at facilitating the electronic invoicing process and ensuring compliance with legal and technical standards in the Kingdom of Saudi Arabia. As depicted in Figure 1, simplified tax invoice for Institutions must contain the following elements [35]:

a) Invoice number and date.
b) Details of the issuing company including its name, address, and 15-digit tax identification number.
c) Additionally, product details such as total price, tax value, unit price, quantity, and product name must be included.
d) The invoice should also calculate the total amount without tax, the value of the tax, and the total price including tax.

The name of a company in the Kingdom of Saudi Arabia [34] can adopt trade names derived from the person's name or by choosing an innovative designation, with the possibility of adding commercial data, provided that the name is appropriate, clear, and does not violate public order and morals. As for joint-stock companies or simple recommendation companies, they must choose names related to the purpose for which

they were established, without using the names of natural persons. The trade name is considered a means of distinguishing the trader and the company in the field of business, and it is a symbol in economic competition.

The seller's VAT number, it consists of 15 digit number obtained by the establishment after registration in the VAT or excise tax [33]. Furthermore, the invoice must include a QR code containing specific information that facilitates its readability and comprehension for customers and relevant authorities. It should contain five essential elements in the following order: i) company name, ii) seller's VAT number, iii) date (including day, month, and year), time (including hour, minute, and second), iv) total price (including VAT), and v) VAT.

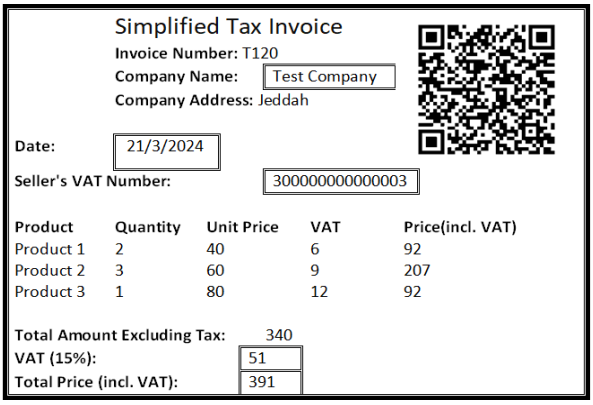

Figure 1. Simplified tax invoice

4. METHOD

The program is designed to create QR codes for electronic invoices compliant with the zakat and tax authority in the Kingdom of Saudi Arabia using Python. The process, as shown in Figure 2, involves several key steps outlined.

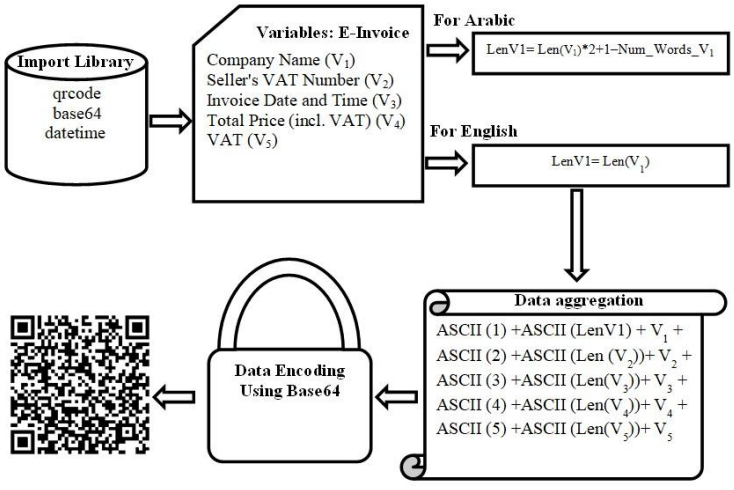

Figure 2. The steps required to build a QR code

4.1. Implementing QR code using Python

To generate barcodes using Python, several key libraries are typically imported, as shown in Table 1. These libraries are imported at the beginning of the Python script to ensure that all necessary functionalities are available for creating and manipulating barcodes effectively. These libraries collectively equip Python scripts with the capabilities needed to handle barcode generation, image processing, data encoding, and

date/time manipulation seamlessly. By importing these libraries initially, developers ensure that the script has access to all essential functionalities required for effective barcode implementation.

Table 1. Key libraries for barcode generation in Python

Library	Function
QRcode	Allows for the creation of QR codes directly within Python. Provides functions to generate QR codes from textual data.
Base64	Used for encoding binary data into ASCII text. Ensures that the encoded data is represented in a readable format, crucial for embedding information within the QR code.
Datetime	Represents a specific date and time, including both the date (year, month, day) and the time (hour, minute, second, microsecond).

4.2. Data aggregation

After importing the required libraries, the process involves aggregating data in a specific format suitable for generating a barcode that complies with the requirements set by the general authority of zakat and income in Saudi Arabia. Data must be formatted into a single string. This string includes:

a) Five special symbols are used to delineate the five different elements within the string. These symbols correspond to the ASCII numbers from 1 to 5, representing the sequence of each element.
b) For each element, the length of the string is calculated; this length is then converted into a hexadecimal format; finally, the ASCII code of the hexadecimal number is determined.
c) Actual element.

Each element is represented in the string sequence by appending its respective ASCII character, followed by the hexadecimal length representation, and concluding with the actual element data itself. To calculate the length of the first element, which is typically the company name in Arabic, the process considers the complexity of Arabic characters compared to English ones. Arabic characters occupy 2 bytes each, while spaces occupy 1 byte. The length of the first element is multiplied by 2, and then the number of spaces (number of words-1) is subtracted. Therefore, the formula for determining the length of the first element is as follows:

$$LenV1 = len_{V1} * 2 - \left(Num_{Words_{V1}} - 1\right)$$

then,

$$LenV1 = len_{V1} * 2 + 1 - Num_{Words_{V1}} \quad (1)$$

where:

- Len_{V1} is the calculated length of the first element.
- Len_{V1} represents the number of characters in the company name string V1V1V1.
- $Num_{Words_{V1}}$ denotes the number of words in V1.

This formula adjusts for the multi-byte nature of Arabic characters and ensures accurate representation of the company name's length in bytes, crucial for generating compliant electronic invoices. Date and time information is formatted as ("%Y-%m-%d %H:%M:%S"), ensuring uniformity and compatibility with electronic systems for invoice tracking and management. VAT calculation involves a straightforward formula based on the total price inclusive of VAT, ensuring accurate representation of financial data within the barcode. The VAT amount is calculated as:

$$VAT = total\ price\ include\ VAT * \frac{15}{115} \quad (2)$$

4.3. Encoding information for QR code

In this step, the information prepared in the earlier stages is encoded into a textual string using Base64 encoding. Base64 encoding converts binary data into a format that is suitable for transmission over systems that are designed to handle text data. This ensures that the encoded data is represented in a readable format, facilitating smooth processing and avoiding potential issues related to encoding discrepancies.

4.4. Generating the QR code

The QR code library in Python is utilized to generate the QR code. First, a QR code object is instantiated. Then, the encoded data (from the previous step) is added to this object. The QR code library

provides flexibility to customize various properties of the QR code, such as the cell size, background color, and foreground color. These customizations can help ensure that the generated QR code meets specific visual and technical requirements.

4.5. Saving the QR code

Once generated, the barcode can be saved in various formats suitable for printing on electronic or paper invoices. It can also be integrated into electronic applications such as the E-invoice QR reader program or the Saudi Arabia General Authority of Zakat and Tax (GAZT) application. This functionality enables efficient tracking of invoices by customers and facilitates quick access to essential invoice details, enhancing overall invoice management processes.

5. CONCLUSION

In this study, we successfully implemented a Python-based solution for generating QR codes compliant with the electronic invoicing standards of the General Authority of Zakat and Tax in Saudi Arabia. The process involved several key steps: importing necessary libraries for barcode creation, aggregating data in a specific format, encoding the information using Base64, generating the QR code using the QR code library, and finally saving the barcode for use in electronic and paper invoices. The encoding and formatting of data into a structured string ensured compatibility with required specifications, facilitating seamless integration into electronic invoicing systems. Utilizing ASCII characters and hexadecimal representations allowed for efficient handling of diverse data elements such as company names, dates, and VAT amounts, crucial for accurate financial reporting. Our results demonstrate that the developed solution meets the technical requirements for electronic invoice QR codes in Saudi Arabia. Comparisons with existing methodologies highlight the efficiency and accuracy of our approach in handling Arabic text and complex data formats.

Future research should prioritize enhancing the scalability of the solution to efficiently manage larger datasets and exploring additional customization options for QR code properties. This focus will facilitate seamless integration and operational efficiency, crucial for handling phase two of electronic invoicing in Saudi Arabia. Phase two involves integrating individual systems with the authority's system under specified conditions. This research direction aims to ensure robust performance and compliance with evolving regulatory requirements, thereby supporting sustainable digital transformation within governmental and commercial environments. In conclusion, this study not only provides a practical solution for electronic invoicing compliance but also lays the foundation for future advancements in QR code technology within financial and administrative domains.

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AUTHOR CONTRIBUTIONS STATEMENT

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Abdelrazek Wahba Sayed				✓		✓	✓	✓		✓	✓		✓	
Zeinab Rabea	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓		✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

No conflict of interest.

DATA AVAILABILITY

- Data availability is not applicable to this paper as no new data were created or analyzed in this study.
- Code availability https://github.com/ZeinabRabea/QRcode_KSA_v1-

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