



REVIEW OF SECURITY FEATURES IN INDIAN AND FOREIGN BANKNOTES: COMPARATIVE PERSPECTIVES ON FRAUD PREVENTION AND COUNTERFEITING

Amisha Baggan*, Mayuri

India.



***Corresponding Author: Amisha Baggan**

India.

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ABSTRACT

Currency is the foundation of any state economy, enabling trade, commerce, and financial transactions. With the increasing sophistication of counterfeit currency production due to advanced digital printing and imaging technologies, central banks worldwide have been constantly enhancing the security features of their banknotes to protect their currency and ensure confidence in their value.^{[1],[16],[20]} Contemporary banknotes possess an array of protection tools, both overt and forensic, which can be used by the general public and experts to identify forgeries.^{[1],[10],[16]} Among the first countries to adopt polymers as the primary material for their banknotes were Canada, Australia, the United Kingdom, and Singapore, which implemented transparent windows and introduced even more advanced holographic security devices on their banknotes.^{[10],[11],[13]-[15],[19]} In turn, the Reserve Bank of India employs a variety of global security measures for its banknotes, including those made of polymer, such as watermark, windowed security thread, latent image, see-through register, and tactile feature for the visually impaired.^{[12],[33]} This article compares the security features of Indian currency notes with those of foreign counterparts, as well as an overview of recent innovations in the field of banknote examination, image processing, and artificial intelligence applied to detect counterfeit notes. The study identifies current trends and potential areas of innovation in the field of currency security.^{[1],[10],[16],[17],[19]}

KEYWORDS: Currency, Banknote Security, Counterfeit Detection, Indian Currency, Polymer Banknotes, Forensic Examination, Currency Authentication.

1. INTRODUCTION

Currency is one of the most fundamental pillars of any economy since it not only acts as a medium of exchange but also as a store of value and unit of account. A credible currency not only enhances economic growth but also aids in building public confidence.^{[20],[29],[30]} However, the rising complexity and availability of high-resolution graphics and scanners have created a major threat to the integrity of global currencies.^{[1],[16],[26],[27]}

Thus, the design of any banknote requires incorporation of multiple distinctive security features to prevent forgery and increase the overall level of trust in a currency.^[12] Overt security features include watermarks, security threads, micro-printing, latent images, intaglio printing, optically variable ink, and tactile features, among others.^{[1],[10],[12],[16]}

On the other hand, covert security features comprise UV fluorescence, IR features, magnetic inks, and machine readable elements among others.^{[1],[10],[12],[16]}

In this respect, the Reserve Bank of India has introduced multiple security features in the Mahatma Gandhi (New) Series currency notes to prevent counterfeiting and facilitate easy identification of the banknotes by common people. Some of the key security features include multi-toned watermark, windowed security thread, colour-shifting ink, see through register, micro-printing, and tactile mark for visually impaired.^{[12],[33]} Apart from Indian currency, other major global currencies such as US Dollar, Euro, British Pound, Canadian Dollar, Australian Dollar, Japanese Yen, Chinese Yuan, and Singapore Dollar, among others also comprise several security features to prevent counterfeiting and facilitate

easy identification by common people.^{[3],[4],[8],[9],[10],[11],[13]-[15],[19],[31],[32]} However, some countries are beginning to use alternate materials in currency production to improve security and facilitate easy identification of banknotes by common people. For instance, several foreign currencies have embraced the use of polymer substrates and transparent windows for production of high-quality currency notes.^{[3],[4],[8],[9],[10],[11],[13]-[15],[19],[31],[32]}

Besides the use of traditional techniques and equipment to identify counterfeit banknotes, recent studies have highlighted the potential of using forensic science methods and emerging digital technologies and techniques to detect forgeries. The use of UV, IR, microscopes, spectroscopy, computer vision algorithms, machine learning, and polymer screening have enhanced detection of counterfeit banknotes.^{[1],[10],[16],[17],[19]}

This review article aims to compare the security features of Indian and foreign banknotes, present recent innovations and technologies used in detecting counterfeit banknotes, and conclude with research trends and implications for future research in this field^{[1],[10],[12],[16],[19]}. Indeed, this review will benefit researchers, forensic scientists, policy makers, and banking officials in enhancing the security of currencies and promoting sustainable economic growth.

2. LITERATURE REVIEW

A bibliographic analysis of the documents published between 2010 and 2023 revealed that researchers explored various ways of improving the security of banknotes, given the increased risk of counterfeiting. Studies emphasize the importance of introducing advanced materials, new technologies, forensic examination, and automatization of the detection process.

Berenguel Centeno et al. (2019)^[1] have conducted a study on the security of banknotes and identity documents with the use of a forensic and computer vision approach. The researchers demonstrated that there are three main aspects of banknote security, including security-related substrates, inks, and printing techniques. Besides, the article mentions the image processing and machine learning opportunities for improving the security of banknotes and highlights the significance of incorporating forensic examination techniques.

Spencer (2011)^[13] discussed the advantages of using polymer banknotes, introducing the case of Canada, which became the first country to adopt this technology. According to the author, polymer material enhances the protection of banknotes and enables their circulation for an extended period. In addition, the use of polymers facilitates the introduction of new security features, such as transparent windows and holographic elements, which are difficult to counterfeit.

Van der Horst, Snell, and Theeuwes (2021)^[17] analysed

the effectiveness of public banknote authentication. According to the study, drawing the attention of the public to specific features allows them to identify counterfeit banknotes with ease. The researchers concluded that it is critical to raise awareness of the general population about the security features of banknotes to ensure their effective authentication.

Wang, Toreini, and Hao (2021)^[19] introduced a new approach to preventing counterfeiting by incorporating polymer fingerprint technology. According to the article, the unique characteristics of polymer materials can be used to introduce inherent security features, which do not require additional treatment of the banknotes. The study shows that such features as micro patterns can be used to ensure the authenticity of the notes with ease.

Rafiei, Karimi, and Bodaghi (2023)^[10] have conducted a comparison of the materials used for polymer banknotes and traditional ones. The researchers explored the production process of the currency and analysed the security features introduced with the use of new materials. According to the article, polymer money has various advantages over cotton paper, including high durability, sustainability, and enhanced optical characteristics. Moreover, the study highlights the increasing popularity of polymer banknotes among different countries.

Tomar et al. (2024)^[16] have performed a comprehensive bibliographic analysis of the materials used in the production of banknotes and the methods of forensic analysis applied to detect counterfeit notes. The researchers identified a wide range of security measures that can be utilised in different areas, namely spectroscopy, XRF, LIBS, hyperspectral imaging, and chemometric analysis. Besides, the article underlines the potential of new technologies, such as artificial intelligence, machine learning, and biometric sensors, which are considered to be the future of currency security.

The Reserve Bank of India (2023)^[12] has developed a series of banknotes, highlighting the new security features, such as watermark, windowed security thread, latent image, shifting ink, micro-lettering, see-through register, and tactile mark. The report revealed the security measures designed for the Mahatma Gandhi (New) Series, which have been introduced to help the public and experts identify the genuine paper currency.

The European Central Bank (2021; 2022)^[3,32] has incorporated a wide range of security features into the new series of Euro banknotes. According to the report, the coins and paper money benefit from the portrait hologram, emerald number, security thread, watermark, and satellite hologram. Moreover, the document explains the choice of specific designs and colours and highlights how various elements of the currency can help prevent counterfeiting with ease.

The Federal Reserve Board (2023)^[4], the Bank of England (2023)^[15], Bank of Canada (2023)^[14], and others have implemented different approaches to enhance the safety of the paper money in their countries. The articles emphasize the importance of adopting a comprehensive strategy, which introduces a wide range of protective elements, including visible and invisible ones and those detectable by machines. The documents show that the use of multiple security measures, including such machine-readable features as magnetic inks, ensures the reliability of the currency.

The Reserve Bank of Australia (2023)^[11] has introduced the public to the Next Generation Banknote, which utilizes the transparent window, rolling colour effects, tactile features, and microprinting. According to the report, these elements allow for the enhancement of durability and protect the currency from counterfeiting. In addition, the design ensures the ability of the public to identify the banknotes easily.

The Monetary Authority of Singapore (2023)^[8] and People's Bank of China (2020)^[9] highlight the importance of incorporating optical security devices and elements of advanced materials into the new series of banknotes. The documents demonstrate that there are various options for enhancing the security of the currency and ensuring the possibility of its easy authentication by the general public and machines. The technologies include colour-changing inks, microprinting, tactile elements, and machine-readable features. Furthermore, the study showed that the use of such elements reduces the possibility of counterfeiting.

In general, the reviewed documents show that the current level of security of banknotes has increased significantly with the use of new materials and technologies. Some countries have taken specific measures to ensure the authenticity of their currency and facilitate the detection of forgeries. In particular, although the majority of the explored sources mention the use of standard security features in Indian banknotes, a number of countries have taken advantage of the opportunities offered by transparent windows, holographic elements, and polymer material.

Therefore, future studies should explore the possibilities of artificial intelligence, nanotechnology, hyperspectral imaging, and sensors to further enhance the security of money and ensure an easy and fast detection process.

3. Methodology

The research uses a systematic review method that will compare the security features of the currencies of different countries. This study will include all the secondary data gathered from the papers published previously or published by the Reserve Bank of India, international institutions, and other central banks, etc. The research has been conducted by considering the papers published in journals, books, and other research

publications. The search was conducted through Google search, Scopus, Science Direct, Springer link, IEEE, and other sources like the Reserve Bank of India, European Central Bank, US federal Reserve, Bank of Canada, Reserve Bank of Australia, Bank of England, Monetary authority of Singapore, and the People's Bank of China.^{[3],[4],[8]–[12],[14],[15],[32],[33]}

The following search terms were used: banknote security features, counterfeit currency detection methods, currency authentication, polymer banknote, Indian currency, forensic examination of currency notes, image processing, machine learning, authentication using image processing, and artificial intelligence. The inclusion criteria for selecting the relevant articles from the search results included articles published between 2010 and 2023. The study includes research articles that address the issues related to banknote security features, examine the features used to differentiate the genuine from the counterfeit, discuss the application of artificial intelligence, and discuss new innovations in the field of currency authentication.^{[1],[10],[16]}

The following 12 documents were selected from the search results that included research articles and papers discussing the various aspects of banknote security features, techniques used for the authentication of currency notes, and recent advances in the field of counterfeit detection.^{[1], [10], [16], [19]} The information present in the selected documents was analyzed and compiled according to the themes present in the documents. The themes included the features of security paper, techniques used for examining the currency notes. The examined literature highlighted the following approaches used for the examination of currency notes: ultraviolet examination, infrared examination, examination using a magnifying lens, binocular examination, spectroscopy, digital image processing, computer vision, application of machine learning, and fingerprinting of polymer banknotes for authentication.^{[1],[10],[16],[17],[19]}

The study aims to identify the differences and similarities between Indian and other foreign currencies in terms of features, examination techniques and recent advances in the field. The findings were synthesized to highlight the differences and similarities detected in the reviewed literature. Similarities and differences were identified according to the themes present in the selected documents.^{[10], [16], [19].}

4. RESULTS

The literature analyzed for this research indicates that both Indian and foreign currencies contain numerous elements created to increase the security of banknotes and reduce counterfeiting. At the same time, the reviewed articles suggest that the latest banknotes are equipped with a variety of security features that can be detected by ordinary banknote holders, corporations, and expert committees. The literature implies that other countries

utilized a combination of protective elements and distinctive characteristics that can be seen on products such as Canadian, Australian, British, Singaporean, and Euro banknotes, which also contain various cutting-edge security technologies. Such foreign currencies have been produced using polymers, resulting in enhanced protection levels and additional properties compared to traditional cotton paper currency.

5. DISCUSSION

The present review underlines that the security of the banknote has increased significantly over the past decade due to the development and implementation of more complex and advanced counterfeiting methods. The read articles suggest that the majority of central banks around the globe tend to apply various overt, covert, and machine-readable security features to improve the quality and reliability of the issued currencies.^{[1],[10],[16]} Such security elements help reduce the risk of forgery and ensure the efficient detection of counterfeit notes by the banknote holders.

The findings of several articles reveal that the Indian currency banknotes are provided with multiple integrated anti-counterfeiting security features, including watermarks, security threads, micro-lettering, latent images, see-through registers, intaglio printing, colour-shifting inks, fluorescence, and tactile marks.^{[12],[33]}

Those security features allow banknote holders to determine genuine paper money with the help of visual inspections, special micro-printed or raised tactile elements, and specific reactions to ultraviolet light.^{[12],[33]} In addition, the Reserve Bank of India implemented significant security improvements for the Mahatma Gandhi (New) Series to prevent counterfeiting and support the trust in legal tender.^{[12],[33]}

One unexpected finding of the present review is that the majority of the analyzed articles underline the critical role of forensic examinations in banknote authentication, with traditional forms of analysis being applied to reveal the complex security features of modern banknotes.^{[1],[16]}

For instance, the inspection of banknotes can be conducted with the help of ultraviolet light, infrared photography, magnifying glasses, binocular microscopy, and spectroscopy.^{[1],[16]} In doing so, those analytical techniques are now considered a routine practice in central banks, forensic laboratories, law enforcement, and even private institutions to identify counterfeit notes by exploring their security features.^{[1],[16]}

At the same time, a number of the reviewed articles underline that computer scientists and engineers are now developing innovative imaging and computer algorithms to enhance the detection of counterfeit banknotes. Those algorithms can be applied in ATMs, automated teller machines (ATMs), and other automated systems to improve the security and efficiency of transactions.^{[1],[16],[17],[19]} The integration of artificial intelligence can play a vital role in supporting the daily

operations of businesses and individuals by detecting fake banknotes automatically and eliminating the possibility of human error.^{[16],[19]} In addition, artificial intelligence and machine learning can be applied to examine the colour, micro-printed elements, and other unique aspects of banknotes with greater precision and efficiency in comparison with visual inspections.^{[1],[16],[17],[19]}

Finally, several reviewed studies suggest that the integration of public awareness and education in the fight against counterfeiting can significantly improve the detection of counterfeit notes by the general society.^{[4],[12],[17]} The findings of multiple articles demonstrate that the educational role of the central banks has enhanced significantly in recent years, with multiple public campaigns being launched to help people identify the most common signs of counterfeit banknotes.^{[4],[12],[17]} However, despite the efforts of central banks to educate the public, there is still a necessity to increase the public awareness and understanding of counterfeit notes' characteristics and harmful effects on individuals, businesses, and global economic stability. The general recognition and support of the central banks' initiatives and strategies to prevent counterfeiting can become a major step towards the enhancement of global financial security.

The results of the present review suggest that the modern banknotes have multiple security elements to ensure their reliable detection by the public and prevent their forgery. The central banks of different countries are making great efforts to prevent counterfeiting by implementing significant security improvements and launching public awareness campaigns. However, despite the rapid progress in terms of banknote security, government entities, scientists, and researchers should remain vigilant and up-to-date in terms of counterfeit detection and prevention. In addition, the central banks of various countries, including India, should consider the opportunity to apply more advanced technologies to further improve the security of their banknotes and ensure the reliability of paper money in terms of its appearance, quality, and origin. The wide adoption of new technologies, including polymers, transparent windows and sheets, optical variable devices, and artificial intelligence, can be instrumental in the fight against counterfeiting.^{[10],[13],[16],[19]}

6. CONCLUSION

The present review compares the security features of Indian and foreign currencies and demonstrates improvements in banknote authentication technologies and security measures over the past decade. The reviewed articles show that current banknotes have been endowed with more sophisticated overt, covert, and machine-readable security features to ensure protection against counterfeiting.^{[1],[10],[16]}

The present review found that Indian currency notes

issued by the Reserve Bank of India had standard international security features, including watermark, security thread, micro-printing, latent image, see-through register, intaglio printing, colour-shifting ink, fluoroscopic, and tactile features. This allows for their multilevel authentication by the general public, banks, and experts, which ensures the reliability of Indian currency.^{[12],[33]}

At the same time, the review highlighted that the Canadian, Australian, UK, Singapore, and Euro currencies, among others, have implemented additional security technologies, such as polymer material, transparent windows, holographic elements, and other advanced security measures. These technologies enable producing longer-lasting banknotes, improving citizens' welfare.^{[3],[8],[10],[11],[13]–[15],[19],[32]}

One of the review's significant conclusions is that forensic science and related emerging technologies, including ultraviolet light, microscopes, IR scanning, spectroscopy, computer vision, machine learning, and artificial intelligence, can improve counterfeit detection capabilities.^{[1],[16],[17],[19]} These technologies are already being used in practice to detect forgeries and have proven their effectiveness.

Thus, although Indian currency notes possess adequate protection mechanisms, their current level is still insufficient, and the implementation of new technologies is necessary to resist counterfeiting. Currency note redesign, continuous innovation, and education are critical to protecting the economy from fake money by increasing the complexity of forgery and ensuring society's trust in legal tender.^{[10],[12],[16],[19]}

In summary, the banknote security concept comprises advanced materials, technologies, and methods to protect against counterfeiting. Thus, future research should be focused on developing next-generation security features based on new materials and technologies, including nanotechnology, hyperspectral imaging, blockchain technology, and artificial intelligence.^{[16],[19],[21],[22],[24],[29]}

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