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The Role of Artificial Intelligence in the Post-Election Phase with an Emphasis on Iran's Legal and Electoral System

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ABSTRACT

As a decisive stage in the electoral process, the post-election phase includes final vote counting and aggregation, reviewing and handling protests and complaints, auditing the election process, and having competent authorities confirm or invalidate the results. The accuracy, speed, transparency, and monitoring of this stage play an important role in ensuring accurate election results and maintaining public trust. In this context, artificial intelligence, with capabilities such as rapid data processing, machine vision, and pattern recognition, provides the capacity to improve post-election processes, especially in counting and aggregation of votes, reducing human errors, identifying potential contradictions, facilitating the audit of results, and supporting the handling of protests and complaints. However, this technology faces challenges such as algorithmic error and bias, lack of transparency in how intelligent systems operate, the security and integrity of electoral data, determining legal liability for system errors, the legal validity of AI outputs, and the need to maintain human oversight. This study examines the opportunities and challenges of using artificial intelligence in the post-election phase, focusing on the status of Iran's legal and electoral system, using a descriptive-analytical method and library resources. The findings of the study show that the use of artificial intelligence can help improve the health and efficiency of the post-election process by increasing the speed and accuracy of vote counting and aggregation, reducing human errors, and strengthening audit capabilities; however, the lack of a clear legal framework, ambiguity in the status and legal value of the output of intelligent systems, and the need to ensure transparency, accountability, and human oversight are among the most important challenges facing the use of this technology in Iran's electoral system. Accordingly, using artificial intelligence in Iran's post-election phase requires formulating and completing legal and institutional requirements, ensuring effective audit and oversight capabilities, and establishing clear mechanisms to address electoral errors and protests.

Keywords: *Algorithmic Transparency, Artificial Intelligence, Electoral Auditing, Human Oversight, Iranian Electoral System, Legal Accountability, Post-Election Phase, Vote Counting.*

Introduction

The post-election phase is one of the most important stages of the electoral process, and the validity and accuracy of the final results largely depend on how it is conducted and monitored. This phase begins after voting ends and the initial results are announced. It includes processes such as the final count and accurate aggregation of votes, the review and handling of protests and complaints, the audit of the electoral process, and, finally, the approval or invalidation of the results by the competent authorities. In the Iranian electoral system, this phase is



also particularly important because vote-counting results and the processes for reviewing protests and complaints play a fundamental role in determining the outcome of the election and confirming its validity. From this perspective, any error, ambiguity, or deficiency in post-election processes can affect the accuracy of the results, the ability to exercise electoral rights, and, ultimately, public trust in the electoral process.

In recent years, the proliferation of new technologies and digital transformation has brought artificial intelligence into various areas of governance and public management. With its ability to process large volumes of data, identify complex patterns, and support decision-making, artificial intelligence has gradually gained an important place in governance processes, and governments and public institutions in many countries are seeking to utilize its capabilities to increase efficiency, transparency, and accountability (1, 2). Given the sensitivity of electoral processes and the need to ensure integrity, transparency, impartiality, security, equality, and public trust, artificial intelligence in the post-election phase can transform processes related to counting, aggregation, auditing, and reviewing election results.

One of the most important opportunities for using artificial intelligence at this stage is machine vision-based technology capable of counting and recognizing votes recorded on ballots. In systems that still use paper ballots as a record of the voter's will, manually counting a large volume of votes is time-consuming and prone to human error. Counting mistakes, digit transposition, and errors in summing results can affect the accuracy of vote aggregation. In the Iranian electoral system, given the continued use of paper ballots, smart tools can be examined as a means of increasing accuracy and reducing human error in counting and aggregating results (3, 4). In addition, artificial intelligence can analyze data from official minutes and polling-station results to identify possible discrepancies and cases requiring human review or reassessment, which can help reduce errors caused by data entry, transfer, and aggregation (3).

Despite these opportunities, using artificial intelligence in the post-election phase also raises important legal issues and challenges. The most important issue is how to ensure transparency and the ability to evaluate the performance of intelligent systems because, in electoral processes, merely presenting the final result is insufficient; there must also be a possibility of examining and evaluating how the result was reached so that, in the event of a dispute, effective objection, review, and adjudication are possible. In this regard, the digital governance literature considers algorithmic transparency and institutional accountability to be basic requirements for using intelligent systems in public decision-making (5-7). This necessity becomes even more important in the post-election phase because the output of an intelligent system can directly affect the determination of election results and the electoral rights of individuals.

On the other hand, using artificial intelligence to count, aggregate, and audit votes also raises issues of privacy, liability for system errors, and human oversight. Any error in an algorithm's performance or incorrect processing of electoral data may lead to an incorrect election result; in such circumstances, determining legal liability and the possibility of compensating for the consequences of system errors is fundamental. In the legal literature, processing personal data and the possibility of privacy violations can create legal liability (8). Regarding liability arising from the operation of AI-based systems, determining liability in the event of error and damage remains a key legal challenge (9). Moreover, in smart electoral applications, the need for transparency, accountability, and the ability to control and challenge the system's output makes human oversight a basic requirement (10).

In the Iranian legal and electoral system, these issues are doubly important because the use of AI in the post-election phase must fall within the laws and jurisdictions of the competent legal authorities. Therefore, the

fundamental question is whether the capacities available in the Iranian legal system permit the use of AI in processes such as counting and aggregating votes, auditing results, and handling complaints and, if so, what legal and institutional requirements are necessary to ensure the validity and legitimacy of the use of this technology. In this context, any use of intelligent systems must be designed to realize the benefits of technology while upholding transparency, auditability, accountability, human oversight, and the possibility of effective objection and redress. Legal and policy experiences in AI regulation also emphasize respect for fundamental rights, impact assessment, and the assurance of human oversight and accountability in the general applications of this technology (11). Despite numerous studies on the use of AI in elections, a significant portion of the existing research has focused on technological applications and different stages of the electoral process, while a coherent examination of the legal opportunities and challenges of using AI in the post-election phase, especially with a focus on the Iranian legal and electoral system, still requires further study and analysis. This research gap matters because the post-election phase directly affects how election results are determined and stabilized. Any use of AI technology in this phase must therefore be evaluated from the perspective of public law, the legitimacy of electoral decisions, the capacity for monitoring and auditing, legal liability, and the protection of citizens' electoral rights.

Accordingly, this study, using a descriptive-analytical approach, examines the opportunities and challenges of using artificial intelligence in the post-election phase, with a focus on Iran's legal and electoral system. In this regard, it examines the capacities of artificial intelligence to count and aggregate votes, reduce human error, audit results, and support the handling of protests and complaints. It also analyzes the legal and technical challenges arising from this technology, including algorithmic transparency, liability for errors, data security and integrity, the legal value of intelligent systems' outputs, and the need for human supervision. The study aims to explain artificial intelligence's capacity to improve the accuracy, speed, and auditability of post-election processes and to examine the legal and institutional requirements for the legitimate, transparent, and accountable use of this technology in the Iranian electoral system.

The History of Artificial Intelligence and Its Use in Elections

Explaining the "theoretical and legal foundations" of using artificial intelligence in elections would be incomplete without understanding the formation and evolution of this technology, as well as its gradual entry into governance mechanisms. On the one hand, the history of artificial intelligence shows how this technology has evolved from theoretical ideas and limited experiments into data-driven systems that affect public decisions and government services. On the other hand, it shows that its entry into sensitive processes, including elections, has occurred gradually and often in parallel with the shift from e-government to digital governance and the growing role of data-driven decision-making. Therefore, this paper first traces the emergence and evolution of artificial intelligence at the conceptual and institutional levels. It then frames the path of its "applicability in elections" as a transition from electronic elections to intelligent applications for managing, monitoring, and protecting the electoral process (12).

History of the Emergence and Evolution of Artificial Intelligence

The Emergence of the Idea of Artificial Intelligence and the Issue of Ethics in Smart Technologies

The earliest stage in the history of artificial intelligence was primarily conceptual, characterized by efforts to formulate the possibility of machines performing certain cognitive functions traditionally associated with human

intelligence. At this stage, the issue of “ethics” was raised from the outset as a serious companion to AI development, since any technology capable of influencing decision-making or shaping social processes inevitably raises fundamental questions about accountability, justice, and the permissible limits of technological intervention. Classic literature on the ethics of artificial intelligence emphasizes that AI ethics is not merely an ornamental consideration but a condition for its social acceptance and legal regulation (13). In relation to public law, this point has also become the basis for emerging discussions of “accountability, transparency, and controllability of technological decisions,” especially when AI is used in governance and comes into contact with the fundamental rights of citizens (14-16).

Transition from Limited Systems to Data-Driven Artificial Intelligence and Digital Governance

The second stage can be characterized as a phase of “data-centricity and integration with public administration,” in which AI moves beyond limited laboratory applications and, alongside the transformation of e-government infrastructure, emerges as a tool for big-data analysis, administrative decision support, and process optimization. In the Iranian literature on “governance transformation,” the transition from e-government to digital governance is described as a shift in focus from “delivering electronic services” to “reinventing processes and data-driven decision-making” (17). In this context, domestic studies on AI’s role in enhancing the quality of public services highlight its potential for data analysis, error reduction, and increased efficiency, while also emphasizing legal challenges related to legitimacy, privacy, and oversight (18).

Deployment of Artificial Intelligence in the Public Sector and the Rise of “Algorithmic Transparency”

The third stage examines how the expansion of artificial intelligence applications in the public sector has brought algorithmic transparency and institutional accountability to the forefront, emphasizing the growing importance of legally assessing the underlying logic of data-driven administrative decisions and ensuring citizens’ ability to challenge such decisions. In the comparative literature on digital governance, transparency and evaluability of algorithmic systems are identified as fundamental conditions for good governance and the legitimacy of public decisions (5-7). Domestically, research on the implementation of AI in Iran’s public administration indicates that the primary challenge is not merely technical feasibility but rather the absence of clear frameworks for liability, oversight standards, and guarantees regarding citizens’ rights (19, 20).

History of Artificial Intelligence Applications in Election Administration

Historical Background: The Transition from Traditional Elections to Electronic Elections

It is impossible to understand the history of AI applications in elections without considering the context of “electronic voting.” This is because many requirements and concerns now prominent in AI applications, such as security, verification, auditability, public trust, and grievance mechanisms, were previously articulated in the legal and technical literature on electronic voting. In Khosravi’s thesis on the “legal dimensions of electronic voting,” these very issues are presented as the central axes for the legal assessment of digital elections (3). Similarly, Takhtaei’s thesis on end-to-end electronic voting, which emphasizes verifiable and reliable designs to enhance trust and auditability, shows that the foundations for “controllability” were established before the widespread adoption of AI (4). Furthermore, from the perspective of information technology law, every stage of the digitization of the electoral

process increases reliance on cybersecurity and heightens exposure to cybercrime risks; consequently, classic sources on cyberspace law and the criminal law of information technology serve as essential prerequisites for a historical analysis of the evolution of digital elections (21, 22).

The Gradual Introduction of Artificial Intelligence into Election Management and Administration within the Framework of Digital Governance

The next phase emerges when elections are understood within the context of “digital governance,” meaning that election management is viewed not merely as an operational task but as part of data-driven public administration. In this framework, artificial intelligence can analyze participation data, optimize resource allocation, forecast congestion and operational needs, and monitor performance. Domestic literature has explicitly addressed this connection between artificial intelligence and public administration (17). Similarly, in comparative literature, international experiences with AI in public administration focus primarily on “data analysis” and “evidence-based decision-making,” albeit with the caveat that, as public decisions become increasingly dependent on AI, the need for accountability and transparency grows (1, 14, 15). Consequently, the history of AI application in elections should be viewed as part of this broader trend: the expansion of data-driven administrative systems and the shift toward intelligent decision-support tools in election management.

A Focus on Legal Risks: Privacy, Liability, and Oversight in Smart Electoral Applications

As data and intelligent analytics play a larger role in electoral processes, “legal risks” are moving from the periphery to the forefront. The first risk concerns data privacy, as verification, monitoring, or predictive analytics may require processing voters’ and candidates’ personal data. In both Imami jurisprudence and statutory law, a data privacy breach can give rise to civil liability, a principle that plays a decisive role in any data-driven electoral application (8). The second risk involves liability arising from errors in automated systems. Domestic literature on civil liability for AI-based autonomous robots supports extending these principles to other decision-support systems, particularly when a system’s output affects individuals’ rights or status (9). The third risk concerns legal oversight and controllability; in intelligent applications, the “result” alone is insufficient, and the logic of the process must be evaluable to enable challenges and legal review. The literature on administrative law and AI has addressed this issue, focusing on transparency, accountability, and legal gaps (23).

Transition to Rights-Based Regulation: From Fragmented Experiences to Legal Frameworks

The recent phase in the history of AI applications within the public sector and, by extension, in elections is characterized by efforts to “regulate” the use of AI. From a comparative perspective, European reports and documents emphasize that AI applications in the public sector must be constrained by a “fundamental rights” and “impact assessment” approach, incorporating mechanisms for human oversight, transparency, and accountability (11). Similarly, domestic literature on legal frameworks governing AI use in the administrative system, alongside discussions of the legal implications of its implementation, shows that the historical trajectory of AI adoption runs parallel to processes of “regulation” and “legal institution-building.” In other words, as technology advances, the legal system must facilitate legitimate, trust-building use by establishing appropriate safeguards and liability frameworks (24).

Application of Artificial Intelligence in the Post-Election Phase

The electoral process does not conclude with the official announcement of results. The post-election phase includes final vote counting and aggregation, handling objections and complaints, auditing the process, and ultimately validating or annulling the election by the competent authorities, which, in Iran, include the Guardian Council. Artificial intelligence can also play a role at this stage, particularly in two areas: automated vote counting using computer vision and solutions designed to improve counting accuracy and minimize human error.

AI-Assisted Vote-Counting Process

In many countries, including Iran, ballots are retained as the primary tangible record of the voter's intent, as fully electronic voting systems without a paper trail pose serious cybersecurity risks, such as hacking, undetectable tampering, and denial-of-service attacks, and can erode public trust. However, the manual counting of millions of ballots across tens of thousands of polling stations is a time-consuming process, sometimes spanning days or even weeks, that is both tedious and prone to human error, such as miscounting, misplaced ballots, or arithmetic mistakes (3, 4). By leveraging machine vision and deep neural networks, artificial intelligence can execute the automated counting process with exceptional speed, accuracy, and auditability. This discussion outlines the technical stages, opportunities and benefits, challenges and legal-technical risks, and regulatory requirements associated with implementing smart vote counting within Iran's electoral system.

Main Stages of Smart Vote Counting Using Machine Vision

The AI-driven automated vote-counting process typically comprises the following six stages, which must be executed with precision and strict adherence to the chain of integrity:

1. **High-quality scanning:** Ballot papers, which in Iran are typically designed with a horizontal or vertical layout featuring candidate names alongside "blank" or "invalid" options, are scanned using high-speed industrial scanners at a minimum resolution of 300 dpi (dots per inch). The scanners must be capable of duplex scanning for double-sided ballots and detecting various ink colors, such as blue fountain-pen ink or black ballpoint ink. To prevent errors, staff must check ballots and, where possible, clear them of creases, tears, or stains before scanning.
2. **Image preprocessing:** Scanned images undergo a preprocessing stage that includes brightness and contrast normalization to compensate for insufficient or excessive lighting during scanning; noise removal to eliminate stray ink spots, dust, or distracting lines; image alignment to rotate the image into a perfectly horizontal position if the ballot was fed into the scanner at an angle; and border detection and cropping to remove unused margins and reduce processing load (2).
3. **Detection of candidate positions and marks:** At this stage, the computer vision algorithm must identify the precise location of the box or circle corresponding to each candidate on the ballot and detect the location of voting marks, such as an "X," a circle, an underline, or any other authorized mark. Iranian election regulations typically define the valid mark as either "circling the candidate's name" or "writing the word 'Yes.'" The algorithm must be trained on thousands of actual ballot samples featuring diverse handwriting, ink types, and lighting conditions to recognize the mark even if it is incomplete or extends outside the designated box (25).

4. **Mark classification:** After identifying the location of the mark, the algorithm must determine whether the mark is valid, such as a complete circle drawn around a candidate; invalid, such as a mark outside the designated box, multiple candidates marked, or a mark erased and redrawn; or ambiguous, requiring human review, such as where half of the circle lies inside the box and half outside or where a line connects two candidates. Advanced classification models can achieve very high accuracy rates; however, ambiguous cases require an “uncertainty state” that sets those ballots aside for manual review (22).
5. **Data extraction and storage:** A data record is created for each ballot, containing the ballot’s unique identifier, such as a printed serial number or QR code, the selected candidate or a status of “blank” or “spoiled,” and a digital signature or system verification indicating that the algorithm generated the output. These records are stored in a secure, encrypted database. The system also retains the original ballot image in encrypted form to allow review in the event of a challenge (2).
6. **Aggregation and reporting:** Once all ballots from a polling station or district have been counted, the system automatically calculates the vote totals and generates an electronic official record or minutes. Polling-station officials can finalize this record with digital signatures after verifying it against a manual sample count.

A key point regarding Iranian law is that Article 33 of the Presidential Election Law, and similar provisions in other election laws, stipulates: “The vote count shall be conducted, the result recorded in the official minutes, and the minutes signed by the polling station officials.” This article does not specify the counting method; therefore, from a legal standpoint, it does not explicitly prohibit the use of electronic aids, including artificial intelligence, to assist polling-station officials with the count. However, to avoid disputes over interpretation and strengthen public confidence, it would be advisable to add an explicit note to this article authorizing the use of approved intelligent systems as a supplementary or verification method. It should also state that, if the manual count and the intelligent system’s count differ, the manual count conducted in the presence of candidates’ representatives shall be final unless the discrepancy is systemic and the Guardian Council decides otherwise.

Potential Opportunities, Benefits, and Achievements

First: exceptionally high counting speed. An industrial scanner can process tens of thousands of ballots per hour, and an intelligent system can report the count within seconds after scanning. This represents a major transformation compared with manual counting, which, for a single polling station handling 10,000 ballots, could take several hours or, at the national level, days or weeks. For instance, in Estonia’s parliamentary elections, which use electronic voting alongside physical voting mechanisms, automated procedures facilitate rapid reporting of preliminary results. In Iran, given the country’s vast geography and the sheer volume of ballots, this speed could help prevent rumors and instability during the “interim period between voting and the announcement of results” (18).

Second: extremely high accuracy under ideal conditions. Advanced computer vision models, when trained on diverse data, including various handwriting styles, ink types, paper creases, and lighting conditions, can achieve accuracy levels significantly higher than manual counting, particularly as human fatigue increases. In a constituency with 200,000 votes, even a 0.1% error rate would amount to a 200-vote difference, a margin that could prove decisive in a close election (22).

Third: the ability to audit and review each ballot individually. Unlike manual counting, where ballots are packed and sealed after results are announced and reopening them requires specific formalities, smart counting scans

each ballot and stores its image. If a candidate or observer objects, the system can display the ballot image on a screen and allow the vote to be reviewed without physically handling the ballot, even by multiple independent observers simultaneously. This feature can enhance transparency and facilitate the rapid and cost-effective resolution of objections (2).

Fourth: detection of physical fraud and hidden invalidities. Computer vision systems can automatically identify and flag the following for human review: multiple marks rendering the vote invalid; marks outside the designated area, unless the voter's intent is clearly discernible; erasures and re-marking indicating possible alteration; marks made with different inks; and possible ballot forgery through verification of security print patterns, watermarks, fonts, and paper dimensions against the genuine sample. Consequently, the system can filter the large volume of apparently valid ballots and present suspicious cases to human observers (2).

Fifth: reducing the mental and physical strain on polling-station staff. In Iran, staff members may be required to manually count thousands of ballots late at night after a long working day. This can lead to extreme fatigue, reduced concentration, and an increased risk of error. By scanning ballots and transmitting images to a central hub for intelligent counting, or by using semi-automated counting through local scanners, staff can focus on verification and secure ballot management, significantly reducing mental stress. This may also improve their performance in other duties, such as voter authentication and supervision.

Sixth: integration with authentication systems. If ballots contain unique barcodes or QR codes designed in a manner that does not compromise voter anonymity, the system can automatically verify that the number of counted ballots matches the number of voters who cast their votes, thereby helping prevent duplicate voting or inconsistencies in ballot totals.

Legal-Technical Challenges, Risks, and Hazards

First: misclassification of ambiguous ballots. The greatest technical-legal challenge in smart counting involves ballots on which the voting mark is unclear; for instance, a circle drawn around a candidate where half of it falls outside the designated box, an "X" marked for Candidate A alongside a small dot, possibly accidental, near Candidate B, or a line connecting two candidates' names, making the voter's intent ambiguous. The smart system must make a determination in such cases. If the decision is incorrect, such as declaring a vote invalid when the voter's intent is clear or, conversely, counting a vote for Candidate A despite an ambiguous mark, the citizen's right to vote may be infringed. Iranian legal provisions establish criteria for invalidating votes, such as where a mark fails to identify a specific candidate or where more than one candidate is selected. Translating such legal criteria, which may be open to interpretation, into definitive algorithmic code is extremely difficult. For example, defining "more than one person marked" may be relatively straightforward, whereas determining whether a mark "does not identify a specific candidate" is highly interpretive (26). The optimal solution is to define an "ambiguous state" and automatically refer such ballots for human review.

Second: physical security and the chain of integrity during ballot transfer to the scanner. Scanning ballots entails physically moving them from ballot boxes to scanning devices. This transfer occurs either at the polling station using an on-site scanner or at a county-level aggregation center after sealed packages are transported. In either case, the chain of integrity, meaning the preservation and documentation of the ballot's authenticity from the moment it leaves the box until it is scanned, must be guaranteed in the presence of candidate representatives and observers.

Any disruption to this chain, such as displacement, substitution, addition, or removal of ballots, could undermine the validity of the counting process.

Furthermore, if the scanner connects to a network, whether the Internet or an internal network, the system becomes vulnerable to cyberattacks, such as tampering with images during transmission to the server. Therefore, it is recommended that scanners operate offline and save images in encrypted form onto removable storage media, such as an encrypted hard drive or secure flash drive. The storage medium, together with the signed official record, should then be transported to the aggregation center in a secure envelope. At the aggregation center, observers should oversee the extraction and processing of the images (4).

Third: the lack of algorithmic transparency for public observers. If the smart counting system is designed by a state-owned or private company and its source code or model is not publicly accessible, effectively functioning as a “black box,” candidates and public observers may question the accuracy of the count. They may argue that they cannot determine whether the system improperly invalidated ballots cast in their favor or counted them for an opponent. Therefore, open-source code or, at minimum, auditability by independent experts approved by all parties is vital to the legitimacy of smart counting. In Iran, security considerations may preclude making source code fully public. A middle-ground solution would be for the Guardian Council to appoint a team of professors from reputable universities specializing in computer science and law as “independent auditors.” This team would have full access to the code and data and prepare a report confirming the absence of intentional bias or systematic error. Such a report could be made available to candidates and key observers under appropriate confidentiality arrangements (6, 7).

Fourth: costs associated with infrastructure, maintenance, and extensive training. Implementing smart counting across Iran would require substantial investment, including purchasing or leasing tens of thousands of high-quality industrial scanners; procuring powerful central servers for image processing; developing and maintaining specialized software and deep-learning models; training tens of thousands of polling-station staff, observers, and aggregation-center operators; and establishing support lines and rapid-response teams for system failures. Given Iran’s budgetary constraints, a more practical approach might be to conduct scanning at county-level aggregation centers rather than at individual polling stations; however, this method lengthens the chain of integrity and may make it more vulnerable (18).

Fifth: low social and psychological acceptance. Iranian voters and candidates are accustomed to the traditional, tangible process of manual counting, in which polling-station staff count and sign ballots in the presence of candidates’ representatives. Introducing a smart counting system, regardless of its technical superiority, may therefore encounter considerable skepticism: “How can a machine make decisions instead of a human?” “What if it is hacked?” “Who can guarantee there has been no collusion?” “Who approved this method?” Overcoming such mistrust requires an extensive information campaign, complete transparency, pilot implementation, media access, participation by representatives of all candidates, and a gradual rollout in which intelligent counting is initially used as a parallel method rather than a complete replacement. Otherwise, even a technically sound system may face public rejection (2).

Legal and Institutional Requirements and Recommendations for Iran

In the Iranian legal system, the Presidential Election Law, and similar provisions in other election laws, does not specify the counting method; consequently, there is no explicit legal prohibition against using auxiliary electronic

tools, including artificial intelligence. However, to prevent widespread disputes and mistrust, the following measures should be taken before any practical implementation:

1. **Explicit legislative amendment through the addition of a note:** The Islamic Consultative Assembly or the competent legal authorities should add a note to the provisions concerning vote counting, explicitly stating: "The use of intelligent vote-counting systems approved by the Guardian Council is permitted as an auxiliary or alternative method, subject to transparency and auditability safeguards. In the event of a discrepancy between the system's output and the manual count, the manual count shall be the final criterion unless the Guardian Council rules otherwise due to a systemic error."
2. **Development of a technical-legal regulation:** The Ministry of Interior, in collaboration with the Guardian Council and the Passive Defense Organization, should draft comprehensive regulations covering, at a minimum, technical standards for scanners, including resolution, speed, and quality; cybersecurity standards, including encryption, offline storage, and chain-of-integrity requirements; accuracy standards and permissible error rates; the algorithm-audit process by independent experts, including the composition of the audit panel, access protocols, and confidentiality requirements; and the process for handling objections arising from automated counting, such as allowing candidates to request manual review of a specified number of ballots from selected polling stations.
3. **Mandatory pilot implementation:** The smart counting system should not be deployed nationwide all at once. The following gradual approach is recommended: Year 1: implementation in two or three small electoral districts using a parallel, purely experimental approach in which manual counting continues and the smart system's output is used only for accuracy assessment and data collection, not for announcing official results. Year 2: if successful, with acceptable accuracy confirmed and identified issues resolved, implementation in a larger number of districts as a primary auxiliary method, subject to random manual verification. Year 3: if successful and publicly accepted, gradual nationwide rollout (4).
4. **Issuance of a "trust certificate" by an independent authority:** Before any election, an appropriate body should oversee AI ethics and issue a trust certificate for the system, confirming its technical and ethical suitability for use in the election. This certificate should be based on an independent audit report and made publicly available.
5. **Establishing a "crisis committee" for suspicious cases:** During the vote-counting phase, a committee comprising representatives of the Guardian Council, the Ministry of Interior, and the candidates should be formed. This committee would be responsible for making final decisions, such as ordering a full manual recount or annulling the results of a specific polling station, where a significant discrepancy arises between the system's output and a manual review.

Overall, AI-driven smart vote counting is one of the most valuable potential applications of this technology in elections, as it could transform one of the longest and most tedious stages into a faster and more accurate process. However, the risks are commensurate with the opportunities. A minor software defect or security vulnerability could undermine the integrity of the entire election. Therefore, a gradual and transparent approach with independent oversight is the most appropriate path for Iran's electoral system. Iranian lawmakers should adopt this technology cautiously, with electoral integrity taking precedence over the acceleration of result announcements.

Strategies for Improving Vote-Counting Accuracy and Reducing Human Error in the Electoral Process

This section complements the previous discussion on automated counting through machine vision by focusing on improving the accuracy of manual counting and minimizing human error during data entry, transmission, and result aggregation, even when humans perform the final ballot count. A crucial point is that, within Iran's current electoral system, errors likely to trigger objections and recounts may occur not only during the physical counting of ballots but also in subsequent stages, including misreading figures from handwritten tally sheets, typographical errors during system entry, digit transposition during summation, and data-transmission problems (3). Artificial intelligence offers smart and potentially cost-effective alternatives to fully automated counting that can address these specific vulnerabilities. This section examines five key solutions in detail, along with their associated opportunities, challenges, and legal requirements.

Key AI Strategies for Improving Counting Accuracy and Reducing Human Errors

1. **Optical Character Recognition (OCR) for reading handwritten tally sheets:** In Iran's current system, each polling station records its manual count results on a paper tally sheet, often featuring hurried and sometimes illegible handwriting. This sheet is then transmitted to the county center, either physically or through available communication channels. At the county center, a human operator reads the figures and enters them into the central system. This stage can become a significant source of error, including misreading a number due to poor handwriting, typographical mistakes, omitted digits, or transposed digits. By employing intelligent OCR trained through deep-learning models to recognize different styles of Persian handwriting and numerals, the system can process an image of the tally sheet captured through a mobile device or scanner and directly extract the figures. Modern OCR technology can achieve high recognition accuracy under suitable conditions. The system can then automatically compare the extracted figures with manual entries, if both methods are used, and flag any discrepancies for human review (12). If the data match, the risk of human error is reduced; if a discrepancy exists, the operator must re-examine the tally sheet.
2. **Reconciliation and consistency algorithms:** A simple yet vital rule at each polling station is that the total number of votes cast, including the sum of candidates' votes, blank votes, and invalid votes, must correspond to the relevant number of voters or ballots recorded at the station. This constitutes a robust error-detection constraint. An intelligent system can automatically verify this balance and, in the event of a discrepancy, issue an immediate alert, preventing polling-station staff from finalizing the official record until the inconsistency is examined and resolved. This process can be executed in real time through a simple mobile or tablet application into which staff enter the results (27). In a purely manual system, such discrepancies may be discovered only later, making them substantially more difficult to trace and rectify.
3. **Detecting human error in numerical summation:** In traditional tallying procedures, polling-station officials may make mistakes when summing figures, such as the total votes for different candidates together with blank and invalid ballots, even where the recorded number of voters is correct. An intelligent system can automatically calculate the sum from the individual figures entered for each candidate and compare it with the "total declared by the polling station," issuing an alert if there is a discrepancy. In such cases, the

officials should be required either to correct the error or to formally confirm an override where they determine that the initially entered figures are accurate.

4. **Multi-layered integration with risk-based random auditing:** This approach can provide an efficient method for strengthening election integrity. The process may unfold as follows: Step 1: officials conduct a manual count at each polling station and record the result on the official tally sheet. Step 2: an image of the tally sheet or relevant election document is transmitted to a central facility. Step 3: intelligent OCR extracts the numerical data and enters them into the system. Step 4: an intelligent algorithm based on sampling principles selects a random sample of polling stations, with sample size increasing if discrepancies are identified. Selection can be risk-based, meaning that stations presenting anomalous results, such as unusually narrow margins or unexpected turnout patterns, have a higher probability of being selected. Step 5: a full manual recount or verification against OCR-extracted data is performed for sampled stations. Step 6: if the error rate within the sample exceeds a predetermined threshold, the audit expands to a larger sample and, if necessary, to broader recount procedures. Such a method seeks to balance speed, accuracy, time, and cost (22).
5. **Identifying common human error patterns through the analysis of historical data:** By collecting and analyzing data from election records across multiple cycles while ensuring privacy, common error patterns can be identified. For instance, in some polling stations, operators may frequently transpose digits, omit zeros, or make recurring errors when reading large numbers. An intelligent system could generate an alert during data entry when a value appears statistically anomalous, prompting the operator to verify the figure before final submission. Such rule-based alerts can correct many unintentional errors before the data are finalized.

Potential Opportunities, Benefits, and Achievements

First: a significant reduction in recording and aggregation errors. Such errors may occur when data are transferred from official tally sheets to central systems. Implementing Optical Character Recognition and automated reconciliation can substantially reduce these risks (3).

Second: acceleration of the announcement of official results, reducing delays and limiting the period during which rumors and unsubstantiated predictions may circulate. Under the current system, once vote counting at polling stations concludes, tally sheets must be transmitted to aggregation centers, where data are processed and consolidated. By using OCR and direct digital data entry at the polling station through secure electronic devices, aggregation can be performed significantly more rapidly (17). Such speed can reduce uncertainty during the period between the close of polls and the announcement of official results.

Third: easier and lower-cost auditability for candidates and observers. Images of official tally sheets and extracted data can be stored in a central database with differentiated access levels. Through a secure portal, authorized candidates or observers could review the tally sheet from a specific polling station and compare it with the reported data. This would enhance transparency and make it possible, in the event of a dispute, to consult the relevant image directly rather than immediately requiring physical transfer of the original document (14, 15).

Fourth: increasing public confidence in the accuracy of results. When citizens know that the counting and aggregation process involves multiple layers of verification and both automated and manual auditing, including manual counting, optical character recognition, automated reconciliation, and random audits, they may be more

likely to accept the final results even if their preferred candidate does not win. Public trust is one of the most valuable assets of an electoral system.

Fifth: mitigation of potential fraud by operational staff. In a manual system, an insider at an aggregation center could potentially alter figures before data entry, and establishing such misconduct may be difficult without a preserved original image. However, if every tally sheet is scanned and stored in a central system with access logs recording who accessed which image and when, any subsequent alteration can leave a digital trace and can be cross-checked against the preserved image. This can create a strong deterrent effect (28).

Sixth: enabling post-election analysis to refine the process. By collecting structured data from tally sheets, researchers can analyze error patterns to improve staff training and redesign official record forms for future elections. Furthermore, access to appropriately anonymized data can facilitate more detailed research on election integrity.

Legal-Technical Challenges, Risks, and Hazards

First: low image quality and illegible handwriting, which can lead to Optical Character Recognition errors. In many polling stations, particularly in rural areas, official records may be prepared hurriedly and with illegible handwriting on low-quality paper that may be stained, crumpled, or otherwise difficult to process. Furthermore, some transmission methods can significantly degrade image quality by reducing resolution or introducing artifacts. Under these conditions, OCR error rates can increase considerably, potentially creating confusion rather than reducing it. One solution is to replace low-quality transmission methods with direct photography using a suitable mobile device or tablet and secure digital transmission. This requires basic training for polling-station staff and the provision of appropriate equipment (2). In addition, official record forms could be redesigned with separate boxes for each digit to facilitate OCR processing.

Second: the non-acceptance of Optical Character Recognition output as an “official document” from a legal standpoint. In the Iranian legal system, an “official document” is defined under Article 1287 of the Civil Code as a document drawn up at the Registration Office for Deeds and Properties, at notarial offices, or before other public officials acting within the scope of their authority and in accordance with legal regulations. The output of an intelligent OCR system is not itself the original document; rather, it may function as technological evidence or an evidentiary aid. Therefore, if a discrepancy arises between OCR output and the figures declared by a polling station as recorded in signed paper minutes, the legal status of each source must be clearly determined. A practical solution would be for polling-station members to enter the figures into a direct digital-input device, such as a secure tablet or laptop, in addition to recording them manually. This would create two independent sources, manual and digital, allowing automated cross-checking to identify inconsistencies. If a discrepancy arises, the polling station should resolve it before finalizing the record. Upon final confirmation, the digital output, appropriately authenticated through digital signatures, could be treated in accordance with the relevant rules governing valid electronic documents (4).

Third: the cost and time required to train tens of thousands of polling-station staff across Iran. Training personnel who may be appointed for short periods to operate mobile applications, tablets, basic scanners, or OCR-assisted systems constitutes a substantial national undertaking. A practical solution would be to develop self-learning applications containing short instructional videos and step-by-step guidance, supplemented by a support line on election day. A tiered training approach could also be adopted, initially training polling-station heads, who would

then instruct other members. Backup personnel should be designated for remote locations or areas lacking network coverage, and alternative procedures, such as encrypted physical transmission, should also be established (18).

Fourth: cybersecurity risks during image transmission. If images of official records are transmitted through public networks or wireless connections, they may be intercepted or tampered with in transit. Therefore, communications must be end-to-end encrypted, and image authenticity should be verified through appropriate digital-signature mechanisms based on secure cryptographic keys. Secure communication protocols should also be employed. For polling stations lacking Internet access, a recommended alternative is to store data on encrypted removable media and arrange secure physical delivery (29).

Fifth: dependence on electricity and the Internet, or the digital divide. In Iran, some rural polling stations and even certain urban areas may still face power outages or weak or unavailable Internet connectivity, particularly in mountainous, nomadic, or border regions. Smart solutions such as OCR and image transmission are ineffective without adequate electricity and connectivity. Therefore, such polling stations must have alternative procedures, including reliable mobile connectivity where available or encrypted physical storage and transport of data to the nearest connected center. Smart systems should first be implemented in urban and well-served areas, while traditional methods remain available in hard-to-reach areas until the necessary infrastructure is developed (18).

Legal and Institutional Requirements and Recommendations for Iran

To capitalize on the aforementioned opportunities and manage the associated challenges, the following measures are essential:

1. **Revising election bylaws or adopting new technical guidelines:** The Ministry of Interior, in collaboration with the Guardian Council, should draft bylaws or guidelines that explicitly recognize Optical Character Recognition and direct digital entry as valid supplementary methods. These regulations should establish the evidentiary value of OCR output in adjudicating complaints, for example, by classifying it as technological evidence or a rebuttable presumption. They should also define technical specifications, such as minimum image resolution, ink quality, and paper characteristics, to ensure images are suitable for OCR processing, and mandate an appropriate random-audit process while specifying relevant statistical criteria.
2. **Clear division of responsibility for errors:** Since these solutions involve a combination of humans and machines, the law must clearly delineate responsibilities. Polling-station officials should be responsible for the accuracy of the manual count and the correctness of initial data entry; aggregation-center operators and automated systems should be responsible for preserving input data and ensuring proper processing; and system designers should be responsible for technical defects, such as software bugs that cause systematic errors (26).
3. **Mandatory training courses:** The Ministry of Interior should conduct practical, rather than merely theoretical, training courses for polling-station staff or at least presiding officers, covering proper photography of official result records, the use of relevant applications, and the identification of common errors. Training materials should also be available through short instructional videos and manuals.
4. **Establishment of integrated data infrastructure:** The Information Technology Organization of Iran should develop a secure central system to receive, store, and process images of official result records. This system should hold appropriate security certification and include comprehensive logging and tiered access rights for competent observers, candidates, and judicial or supervisory authorities.

5. **Phased and pilot implementation:** Under no circumstances should all polling stations nationwide be connected to the system simultaneously. During the first year, a limited pilot should be implemented in parallel across selected provinces or districts without affecting official results; this phase should be used to gather data and evaluate the OCR error rate and the extent of human-error reduction. In the second year, if the pilot is successful, the system could be deployed as the primary auxiliary method in areas with adequate connectivity. In the third year, alternative solutions, such as encrypted physical storage, could be implemented in areas lacking reliable network access.
6. **Public information campaign:** To mitigate skepticism and foster public acceptance, a broad media campaign spanning television, radio, and social media should explain the benefits and limitations of these methods in accessible language, emphasizing that human oversight remains central to the counting process while machines function as assistive tools.

Overall, strategies to enhance counting accuracy and minimize human error, particularly OCR, automated reconciliation, and risk-based auditing, may be more cost-effective, lower-risk, and quicker to implement than fully automated ballot counting, which requires expensive scanners and more fundamental procedural changes. These measures offer a pragmatic first step for Iran's electoral system to enter the era of artificial intelligence without compromising established legal principles or public trust. With a combination of innovation and institutional caution, Iranian lawmakers can capitalize on these opportunities to steer elections toward greater accuracy and transparency.

Conclusion

The findings of this study demonstrate that artificial intelligence can improve the post-election phase in Iran through AI-assisted vote counting based on computer vision, the identification of ambiguous and suspicious ballots, automated reconciliation of polling-station data, Optical Character Recognition for extracting information from official tally sheets, detection of numerical errors, and risk-based random auditing. These applications can reduce errors arising from counting, recording, transmission, and aggregation while strengthening the auditability of electoral results. Nevertheless, the use of AI in Iran's electoral system is not merely a technical issue; it also involves significant legal and institutional challenges, including algorithmic transparency and auditability, the security and integrity of electoral data, liability for errors in intelligent systems, the legal status and evidentiary value of AI-generated outputs, and the preservation of effective human oversight. Accordingly, the legitimate and trustworthy use of AI in the post-election phase should follow a gradual and pilot-based approach within a human-machine framework in which AI functions primarily as an assistive and auditing tool. At the same time, human oversight and legally competent authorities should retain final decision-making authority. Therefore, establishing clear technical-legal regulations, independent auditing and complaint-handling mechanisms, defined liability frameworks, and secure data infrastructures is essential for using AI to improve electoral integrity, transparency, accuracy, and public trust in Iran's electoral system.

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Authors' Contributions

All authors equally contributed to this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

All ethical principles were adhered in conducting and writing this article.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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