


**DEVELOPING A SECURE AND TRUSTED E-VOTING SYSTEM FOR LIBYAN ELECTIONS**

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ARTICLE INFO	<b>ABSTRACT</b>
<p><b>Article history:</b></p> <p>Received 04 July 2022</p> <p>Accepted 11 October 2022</p>	<p><b>Purpose:</b> The aim of this study is to identify the issues and problems in the current Libyan voting system, and to develop a secure e-voting prototype system associated with the Libyan electoral system and the laws and legislation governing.</p>
<p><b>Keywords:</b></p> <p>Secure; E-Voting; System; Libyan Elections; Voters Trust.</p>	<p><b>Theoretical framework:</b> E-voting systems allow greater participation of eligible voters to cast their vote remotely or any location that the voter could be during election.</p>
	<p><b>Design/methodology/approach:</b> This study used mixed methodology. A qualitative method via interview would be used to collect qualitative data from citizens and election staff to determine functionalities and features of the proposed system. Using Semi-structured interviews with ten eligible voters, election officials. While a quantitative study conducted to evaluate users and elections of officials to determine how the systems fulfils the requirements and their expectations, to determine if the prototype proposed system offers practical solution to the Libyan voters and if the functionalities of the system fulfil the requirement gathered at the problem definition stage. The second prototype was regarded as meeting the key functional and non-functional requirement and ease of use criteria by users. After fixing the concerns found during the first prototype's evaluation in terms of the requirement criteria. The criterion for ease of use were met.</p>
	<p><b>Findings:</b> As a result, 87% of the evaluators indicated that they would adopt the system if it was introduced. Whereas 87% of the evaluators suggested that they would recommend the E-Voting system to their friends, colleagues, and Libyan Election Council.</p>
	<p><b>Research, Practical &amp; Social implications:</b> Following the trial of the second prototype, the evaluators proposed that the Libyan E-Voting System (L-EVS) would assist them enable them to exercise their election rights.</p>
	<p><b>Originality/value:</b> Concerns and issues from previous political elections have spawned over numerous studies regarding voter confidentiality, voting security, and voting accuracy.</p>
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## DESENVOLVIMENTO DE UM SISTEMA DE VOTAÇÃO ELETRÔNICA SEGURO E CONFIÁVEL PARA AS ELEIÇÕES LÍBIAS

### RESUMO

**Objetivo:** O objetivo deste estudo é identificar as questões e problemas no atual sistema eleitoral líbio e desenvolver um sistema protótipo seguro de voto eletrônico associado ao sistema eleitoral líbio e às leis e legislação que o regem.

**Estrutura teórica:** Os sistemas de votação eletrônica permitem uma maior participação dos eleitores elegíveis para votar remotamente ou em qualquer local que o eleitor possa estar durante a eleição.

**Desenho/método/abordagem:** Este estudo utilizou uma metodologia mista. Um método qualitativo através de entrevista seria usado para coletar dados qualitativos dos cidadãos e do pessoal eleitoral para determinar as funcionalidades e características do sistema proposto. Usando entrevistas semi-estruturadas com dez eleitores elegíveis, funcionários eleitorais. Enquanto um estudo quantitativo realizado para avaliar os usuários e as eleições dos funcionários para determinar como os sistemas cumprem os requisitos e suas expectativas, para determinar se o protótipo do sistema proposto oferece solução prática para os eleitores líbios e se as funcionalidades do sistema cumprem os requisitos reunidos na fase de definição do problema. O segundo protótipo foi considerado como satisfazendo os principais requisitos funcionais e não-funcionais e critérios de facilidade de uso pelos usuários. Após corrigir as preocupações encontradas durante a avaliação do primeiro protótipo em termos dos critérios de exigência. O critério de facilidade de uso foi atendido.

**Conclusões:** Como resultado, 87% dos avaliadores indicaram que adotariam o sistema se ele fosse introduzido. Enquanto 87% dos avaliadores sugeriram que recomendariam o sistema de votação eletrônica a seus amigos, colegas e ao Conselho Eleitoral Líbio.

**Pesquisa, implicações práticas e sociais:** Após o julgamento do segundo protótipo, os avaliadores propuseram que o sistema de votação eletrônica líbio (L-EVS) os ajudaria a exercer seus direitos eleitorais.

**Originalidade/valor:** As preocupações e questões das eleições políticas anteriores geraram numerosos estudos sobre a confidencialidade dos eleitores, a segurança do voto e a exatidão do voto.

**Palavras-chave:** Segurança, Votação eletrônica, Sistema, Eleições Líbias, Confiança dos Eleitores.

## DESARROLLO DE UN SISTEMA DE VOTO ELECTRÓNICO SEGURO Y FIABLE PARA LAS ELECCIONES LIBIAS

### RESUMEN

**Objetivo:** El objetivo de este estudio es identificar las cuestiones y los problemas del actual sistema de votación libio y desarrollar un prototipo de sistema de voto electrónico seguro asociado al sistema electoral libio y a las leyes y la legislación que lo rigen.

**Marco teórico:** Los sistemas de voto electrónico permiten una mayor participación de los votantes elegibles para emitir su voto a distancia o en cualquier lugar en el que el votante pueda estar durante las elecciones.

**Diseño/metodología/enfoque:** En este estudio se utilizó una metodología mixta. Se utilizará un método cualitativo a través de entrevistas para recoger datos cualitativos de los ciudadanos y del personal electoral para determinar las funcionalidades y características del sistema propuesto. Se utilizaron entrevistas semiestructuradas con diez votantes y funcionarios electorales. Mientras que se realizó un estudio cuantitativo para evaluar a los usuarios y las elecciones de los funcionarios para determinar cómo los sistemas cumplen los requisitos y sus expectativas, para determinar si el prototipo de sistema propuesto ofrece una solución práctica a los votantes libios y si las funcionalidades del sistema cumplen los requisitos recogidos en la etapa de definición del problema. Se consideró que el segundo prototipo cumplía los requisitos funcionales y no funcionales clave y los criterios de facilidad de uso por parte de los usuarios. Tras solucionar los problemas detectados durante la evaluación del primer prototipo en cuanto a los criterios de requisitos. El criterio de facilidad de uso se cumplió.

**Resultados:** El 87% de los evaluadores indicaron que adoptarían el sistema si se introdujera. El 87% de los evaluadores sugirió que recomendaría el sistema de voto electrónico a sus amigos, colegas y al Consejo Electoral de Libia.

**Investigación, implicaciones prácticas y sociales:** Tras la prueba del segundo prototipo, los evaluadores propusieron que el Sistema de Voto Electrónico Libio (L-EVS) les ayudaría a ejercer sus derechos electorales.

**Originalidad/valor:** Las preocupaciones y los problemas de las elecciones políticas anteriores han dado lugar a numerosos estudios sobre la confidencialidad de los votantes, la seguridad de las votaciones y la precisión de las mismas.

**Palabras clave:** Seguridad, Voto Electrónico, Sistema, Elecciones Libias, Confianza de los Votantes.

## INTRODUCTION

E-voting systems allow greater participation of eligible voters to cast their vote remotely or any location that the voter could be during election (Bakon & Ward, 2015). Voter participation during an election, is a cornerstone of a good democracy and e-voting systems can facilitate higher participation. E-voting combines the use of information technology with the election, where during the elections held, the voting and vote counting process is done manually, so the potential for fraud in the vote count is very large when the vote recapitulation of the village, sub-district, district / city, province, to center. In addition, e-voting can create quick vote count so that people can directly know the election results and also able to cut the budget, especially the budget for the ballot, etc. The application of e-voting does require sophisticated and modern hardware, software, and software requirements. And a very secured e-voting system is required to maintain and increase voter's trust. The e-voting system will improve transparent and accountable election quality (Subagyo, 2012).

In new democratic Libya, ability to vote has become the most valuable tool in a democratic decision making. After the toppling of Muammar Qadhafi in 2011. The National Transitional Council (NTC) was formed in Benghazi and given the responsibility to provide a roadmap that could pave the way to the General National Congress (GNC) election. The GNC drafted a constitution that facilitated the foundation for a democratic transition based on the principles of fundamental rights and Sharia Law (EU, 2012). The legal and constitutional framework has overall provided for an election process that is democratic and inclusive, in line with international standards and best practices. The election-related legislation ensures the defence of civil and political rights without discrimination and guarantee genuine elections through the respect of freedoms of association, movement and freedom of expression and assembly. The right to vote and to be elected through universal and equal suffrage by secret vote is entrenched in the Election Law, while the right to access to justice and legal remedies is guaranteed by the Draft Constitutional Declaration (EU, 2012).

According to Trauthig, (2018) endemic insecurity in the country jeopardises national participation in the elections and potential spoilers will continue to target the elections. Overbearing logistical difficulties in executing the elections and an unclear response to the dire economic situation further impede the potential positive influence the elections are supposed to have on the Libyan people. A finding by IFES (2018) emphasised that security is a concern among many Libyans which has to be addressed before they will take part in any future elections. In other words, they are more willing to vote if security of the process was guaranteed. Despite the fact that women participation of the first elections for over four decades is most

certainly an important and positive step towards the realisation of the importance of women's political participation in new Libya, the number of women who participated in the votes are less compared to their male counter parts. As women face restriction of easy and free movement and transportation. Women especially are less encouraged to participate because of logistics and safety issues.

Concerns and issues from previous political elections have spawned over numerous studies regarding voter confidentiality, voting security, and voting accuracy. Although various voting schemes have been proposed to improve the security and accuracy of electronic voting (e-voting) system, many disputes that happened in the past still have not been resolved, and new challenges keep emerging continuously. As we know, the paper ballot-based voting system inevitably yields a certain rate of physical device failures and human errors. Moreover, the tally result may suffer from unavoidable delays and ballot feeding errors when election committee counts votes on paper or machine-readable ballots (Pan, Hou and Ansari, 2014). Privacy of votes was the subject of major debates during the 19th century, at the time of the progressive introduction of universal suffrage. Since then, it has become a standard in all major democracies. The introduction of electronic technologies as part of the voting process however raises new challenges and privacy concerns (Bernhard et al., 2015).

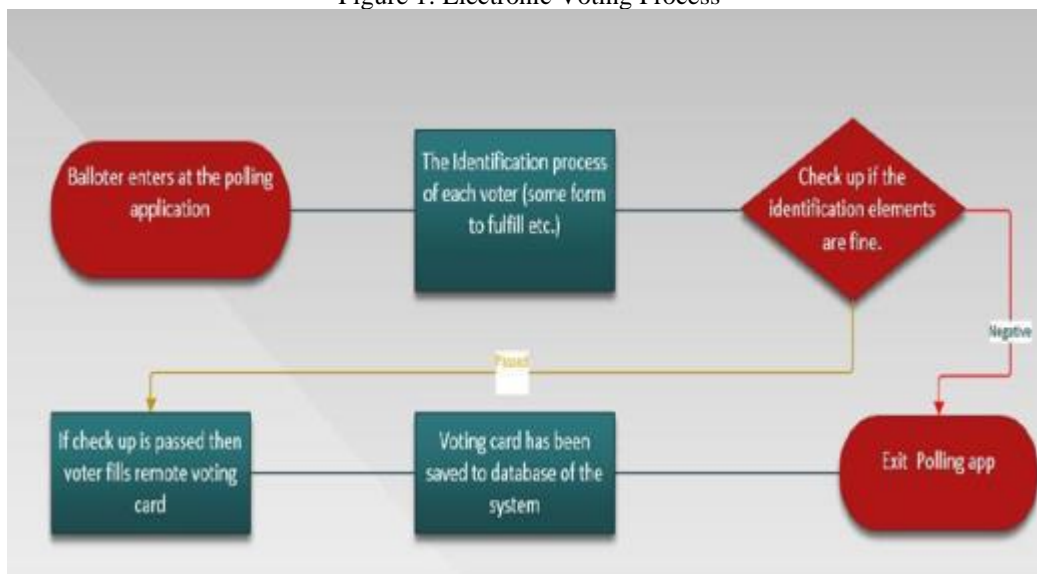
The political division that has now occurred in Libya since 2014 has led to the reluctance of some regions to participate in elections, and the low turnout of voters leading to collapse and conquer in Libya. Some of the reasons of weak participation in elections are the manipulation of votes and privacy issues of the participants personal data. The ongoing conflict across many parts of the country, as well as the masses of internally displaced people, make this questionable. Libyans are most likely to vote only if they see that the risks have been considered and planned for. Currently, neither regional, national, or international powers can guarantee this. This study is an attempt to improve the current voting system in Libya to make it more robust and trusted by Libyan citizens to increase voters' participation of Libyan elections using a secure a secure e-voting system. Thus, enhancing and strengthening Libyan Democracy. The aim of this study is to identify the issues and problems in the current Libyan voting system, and to develop a secure e-voting prototype system associated with the Libyan electoral system and the laws and legislation governing.

## **LITERATURE REVIEW**

The qualities and characteristics of E-voting and paper voting systems are similar. In traditional paper voting process, voters entering the polling station have to be identified. If the

identity is verified, voters are allowed to vote. The two main categories of e-voting systems are local or location-based e-voting system and remote e-voting. Local e-voting systems are used within polling stations only. This term generalizes all kind of electronic voting machines and terminals which are used in polling stations as a replacement for paper ballots. Thus, local e-voting systems are only used in environments that are under the control of an election commission. In remote e-vote voters have the opportunity to vote by using computers systems at remote locations or at polling stations inside. Also, remote e-voting systems are not limited to being used in a polling station only. Remote e-voting systems have to be further categorised into remote e-voting systems that are used within an attended (controlled) environment, and remote e-voting system that can be used anywhere. The former category of remote e-voting systems means that e-voting need not only take place in a polling station but can be in any controlled environment, e.g., having remote e-voting clients in police stations or in banks. In these scenarios, the e-voter does not visit an election commission, but she votes in a controlled, attended environment. ManySo citizens use computers and networks for electronic voting process. Voters can vote from any location of their choice. The process is described in Figure 1.

Figure 1: Electronic Voting Process



Currently, very little research could be found regarding the state of Libyan elections. Pack and Cook (2015) asserted that the outcome of the 2012 Libyan election raises a doubt about the ability of post-conflict elections to function as tools of democratization or as mechanisms to unify social fissures, especially in societies lacking in formal institutions. The

growing concern for the next election in Libya, lead IFES to conduct this resent survey to determine if the citizens of Libya still consider democracy and election. Voting of the citizens into the GNC were done manually. Libya is yet to adopt e-voting systems into its elections. Libya is a young nation in terms of democracy and elections. The first ever free and fair election was conducted in 2012. The voting was done manually where the voters had to go to the polling stations and to cast their votes. A remote e-voting system which this study is proposing was not used during the election of 2012. Besides, to the best of the researcher's knowledge, no studies of e-voting implementation or adoption in Libya could be found.

## **RESEARCH METHODOLOGY**

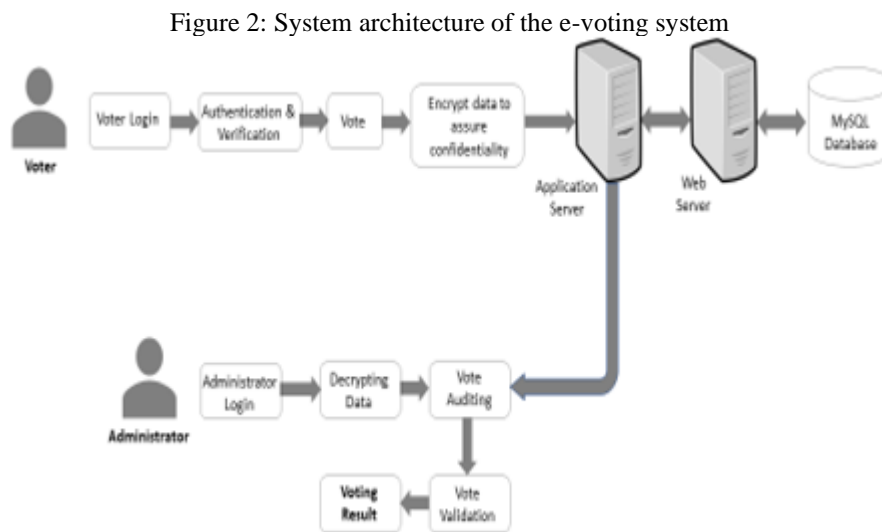
This study used Science and Engineering research approach. The approach of Nunamaker et al. (1991) methodology of conducting Information System Research is used for this study. This study used mixed methodology. A qualitative method via interview would be used to collect qualitative data from citizens and election staff to determine functionalities and features of the proposed system. Semi-structured interview questions will be asked from informants. A total of ten eligible voters, election officials and other stakeholders will be interviewed to in Libya to collect data in the first phase to specify the system requirement for the proposed e-voting system and questionnaire would be created to be used as an instrument. While a quantitative study conducted to evaluate users and elections of officials to determine how the systems fulfils the requirements and their expectations. To determine if the prototype proposed system offers practical solution to the Libyan voters and if the functionalities of the system fulfil the requirement gathered at the problem definition stage, up to twenty users and election officials would be approached to use the systems and provide their feedback through a questionnaire.

## **PROPOSED SYSTEM**

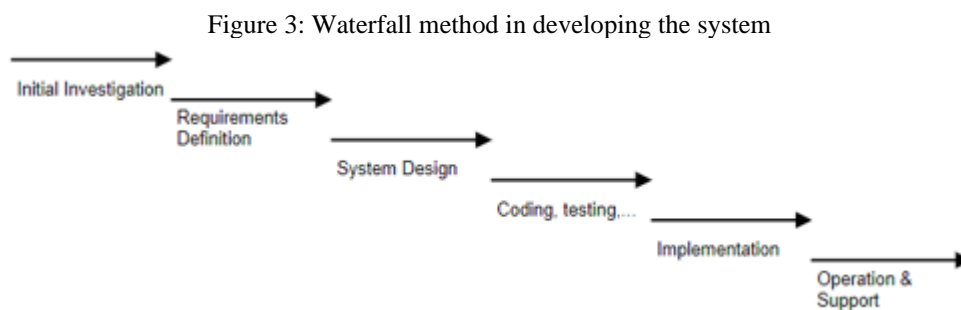
This research proposes a remote Internet e-voting concept that suits the needs of Libyan elections. The proposed e-voting system would be built based on these two main principles in order to enhance security: (1) the proposed e-voting system would consist of strong end-to- end encryption between the vote casting period and the electronic device to be used for counting. This means that the voter would quickly encrypt the vote after he/ she has made her choice and would only be decrypted during the only main moment of counting. (2) the proposed e-voting system would use a strong domain separation model that ensures that voters are uniquely



identified during voting yet ensuring that votes are cast anonymously and is still possible to verify if a citizen has already voted or not, see Figure 2.



The chosen methodology for the system development is the Waterfall Method where steps can be defined as in Figure 3.



## RESULTS AND DISCUSSION

The quantitative method was one of the approaches used to collect information from Libyans so as to draft the system requirement specification for proposed Libyan E-Voting Systems. To gather the requirement specification of the proposed system, 200 questionnaires were submitted by hand to 220 Libyans in Tripoli from 1st April 2020 30th June 2020. The respondent was picked at random in other words convenient sampling were carried out. The respondents were mostly from Tripoli region. The selection of the respondent from Tripoli region was due to the fact that the civil war was going, and the most peaceful region is found within the Tripoli area only. They were free to answer it or no. Out of the 220 questionnaires, 163 (75%) Libyans have answered and returned their questionnaires by 30th June 2020.

However, 20 (9.1%) of the returned questionnaire were partially filled up and the remaining 37 (16.8%) of the questionnaire were not returned. The 163 fully answered questionnaires were analysed with SPSS software using a simple descriptive technique. Further analysis of all questions is fully given below.

## SOCIO DEMOGRAPHICS

All of the 163 (100%) Libyans who responded the questionnaires are between the ages of 18-55 years old. Similarly, the Libyan constitution dictates that all Libyans over the age of 18 years are eligible to vote as mentioned in Table 1.

Table 1: Demographic Profile

Item	Description			
Age/years	18-25 39	26-35 72	36-45 39	46-66 20
Gender	Male 83%	Female 17%		
Education	Postgraduate 51%	Degree 31%	Vocational 14%	
Profession	Students 42%	Wage earners 33%	Self-employed 24%	Unemployed 1%
Monthly Income \$	Below 2000 31%	Over 2000 69%		

Total 39 of the respondents were between the age of 18-25 ,72 of the respondents is between the age 26-35 years whereas 39 of the respondents are between the age of 36-45 years. The remaining to respondents were between the age of 45 and above. The gender of the participants is illustrated. 83% of the respondents are male whereas the rest of the 17% are female. This wide disparity is the result of the fact that as a Muslim country with a very conservative culture, contacting any female other one's relative or colleague in a workplace or university, remains a huge challenge. The level of education 51% of respondent possess postgraduate level of education, the 31% of the respondent with a university degree level of education and the 14% of the respondent with vocational/technical level of education. The use of internet is positively correlated to the level of education. This means that they are more inclined to have IT skills and access to the Internet.

The profession of the respondents 42% of the respondent mentioned students as their profession. These are the Libyans that researcher could come into contact with through the network of students that the researcher knows. The 33% of the respondents are wage earners from public and private sectors. 24% of the respondents indicated that they are self-employed while about 1% indicated that are unemployed. The Monthly income of the respondents when



they were asked about their Monthly income, 31% of the respondent indicated that their monthly income is below \$2000.00. The remaining 69% of the respondents indicated that their monthly income falls between \$2000.00 - \$10,000.00 and above \$10,000.00. This question was asked so as to ascertain the economic situation of the respondents as computers and Internet access are required before voters could vote electronically. Good economic condition could enable Libyans to have access to computers and Internet needed to cast vote online.

### CHALLENGES AND SYSTEM FUNCTIONALITIES

These questions were asked with the aim of understanding the current nature of the challenges faced by Libyans with regards to the traditional voting systems. They respondents were also asked if they would favour the introduction of Internet Voting as an alternative to the traditional method of voting to securely cast their votes during elections, thus increasing voter turnout as their votes too would be counted. Evaluating and analyzing if they have the basic IT knowledge and access to the Internet and understanding their security concerns. See Table 2.

Table 2: Challenges and System Functionalities

Item	Description			
Frequency of Voting	Never 75%	Regularly 25%		
Willing to Vote	Willing to vote 84%	Will never 9%	Not sure 7%	
Computer Literacy	Have Knowledge 86%	Don't have 14%		
Internet Access	Daily 71	More than once a week 49	Once a week 38	Once a month 25

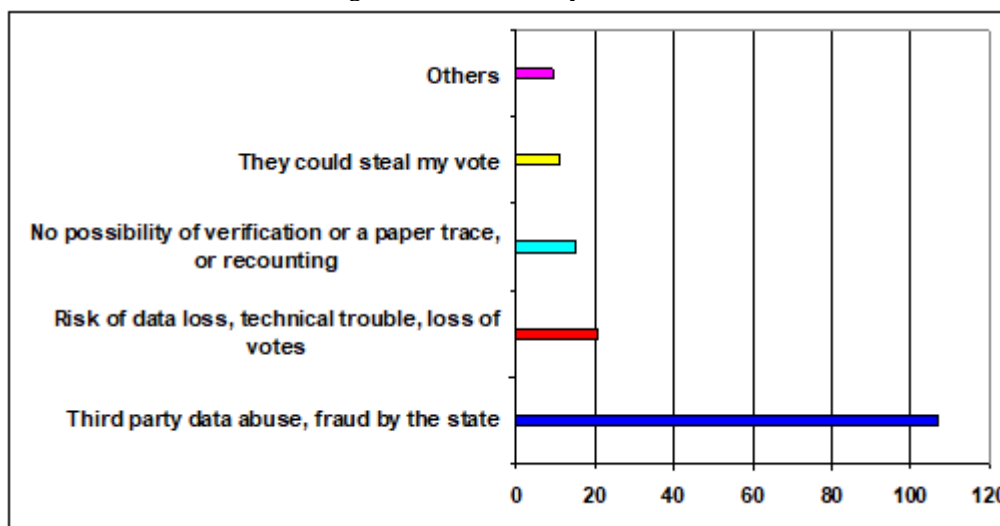
The frequency of voting participation of the respondents. 75% of the respondents indicated that, they have never voted since the introduction of democracy in Libya in 2012. The remaining 25% who responded that they regularly or sometimes since voting system was introduced in Libya. This clearly shows that they will be an increase in turn out of voters if they were allowed to vote online. Voters desire to cast votes regularly if Internet Voting is implemented in Libya. 84% of the respondents has indicated that, they would vote more regularly if Internet Voting was introduced. Just 9% of the respondents say that they still would not vote even if there was Internet voting and whereas the remaining 7% of the respondents are not sure. This an indication that the respondents found the Internet voting to be convenient and safe than the traditional system of voting in a country where war is rampant. The level of computer literacy of the respondents. To be able to vote online, basic level of computer efficacy

is important. 86% of the survey participants indicated that they are computer literate. 14% of the respondents indicated that they do not have knowledgeable in IT. This indicate that should Internet Voting be implemented in Libya; majority of the Libyan votes do have the basic IT skills and knowledge need to use it but there are many potential voters lacking computing efficacy and as such training and education are need so that no one is left behind. 71 respondents use the Internet every day, 49 of them use it more than once a week, 38 of them use it once a week whereas the remaining 25 of the respondents use the internet at least once a month. The proportion of respondents using this tool several times per week is thus higher than nine out of ten people.

### MAIN SECURITY CONCERN WHEN IT COMES TO INTERNET VOTING

The type of security threats that are of major concern to the respondents Internet voting of the total number of Libyans who responded to this question 65% mentioned data misuse or hacking and data abuse or fraud to be their main security concern. Another 13% of the respondents mentioned data loss, technical trouble, or vote loss to be the main security issues that concern them. 9% of the respondent said lack of control possibilities, the absence of a paper trail or the problems of recounting are their main concern while 7% of the respondents mentioned the risk of vote theft. The 6% of the respondent mentioned other reasons without specifying which reasons, as mentioned in Figure 4.

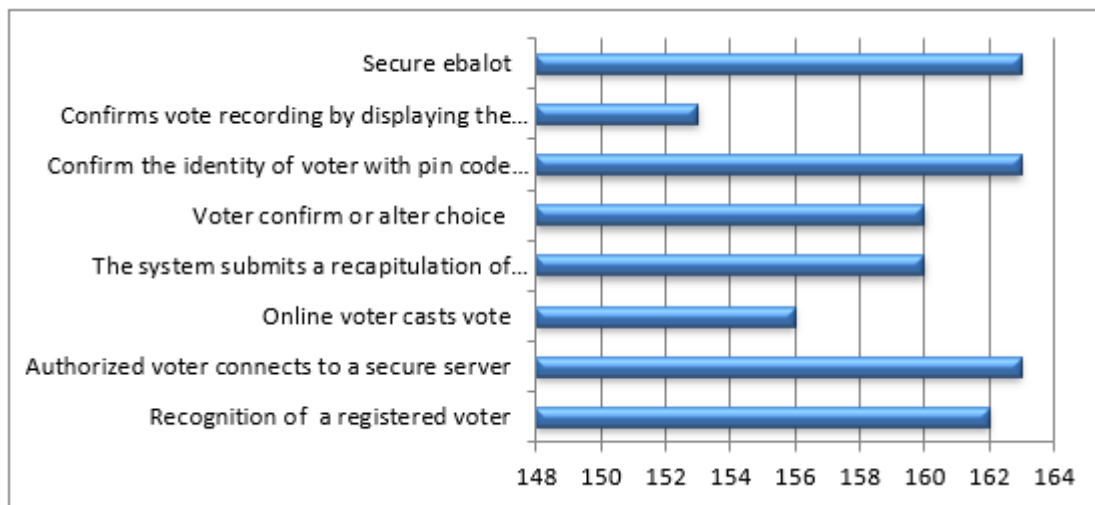
Figure 4: Main Security Concerns



## THE FUNCTIONS OF THE LIBYAN E-VOTING SYSTEM

The key functions and features that the respondents indicated that they would prefer to have in the system. 162 of the respondents indicated that they would want the system to be able to recognize a registered voter. All of the 163 respondents want the system to allow only the authorized voter to be connected to a secure server. 154 of the respondents indicated that only the online voter can cast his/her vote. Also, all the 163 respondents agreed that the system should submit a recapitulation of voter's choices after the voters have cast their votes. 163 of the respondents also indicated that voters should be able to confirm or alter their choices. All the 163 voters also want the confirmation of the voters' identities with pin code that matches their places of births. 153 of the respondents indicated that the system should confirm it has recorded the votes by displaying the date and time of the recording. The final preferred features and functions that the respondents want to have in the system is the ability to use the system to cast a secured ballot. All the 163 respondents agreed that the e-ballot should be secured. See Figure 5.

Figure 5: Proffered Features and Functions of the Proposed System

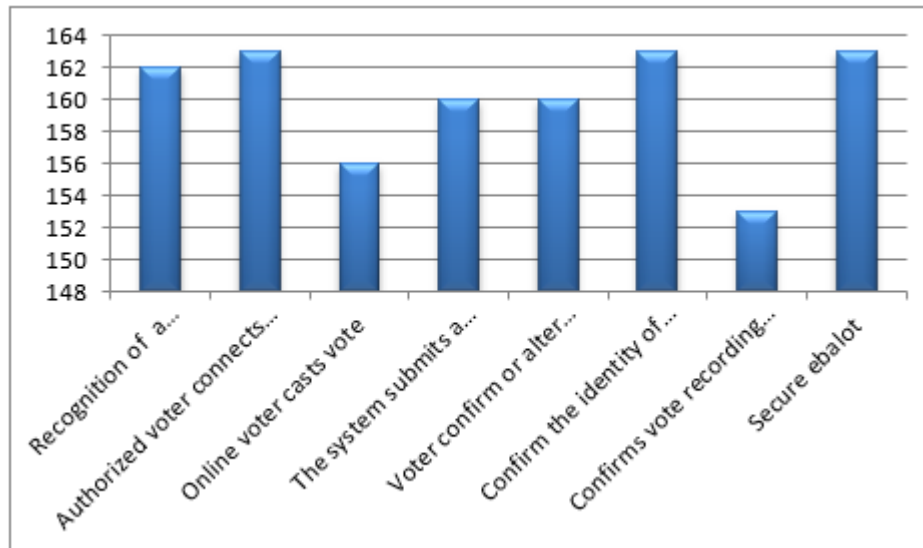


## THE IMPORTANT FEATURES OR FUNCTIONS OF LIBYAN E-VOTING SYSTEM

The important functions and features that the respondents said they that the system must have. According to 162 the system should be able to recognize registered voters. All of the 163 respondents want the system to allow only the authorized voter to be connected to a secure server. 156 of the respondents indicated that only the online voter can cast his/her vote. Also, all the 160 respondents agreed that the system should submit a recapitulation of voter's choices after the voters have cast their votes. 160 of the respondents also indicated that voters should be able to confirm or alter their choices. All the 163 voters also want the confirmation of the

voters' identities with pin code that matches their places of births. 153 of the respondents indicated that the system should confirm it has recorded the votes by displaying the date and all the 163 respondents agreed that the e-ballot should be secured, as mentioned in Figure 6.

Figure 6: Important Functions of the E-voting Systems Required



## PROPOSED SYSTEM REQUIREMENT CATALOGUE

To attain the objective the proposed e-voting system, a list of requirements gathered from the analysis of the questionnaire and the Switzerland and Estonia E-voting systems are illustrated in Tables below. A requirements catalogue is a list of requirements through which a desired project goal is to be achieved (T2informatik, 2019). It should ideally be a systematic and prioritized list of software or system needs. The requirements must be well-defined, comprehensive, and understandable, as well as atomic, recognizable, universally documented, verifiable, and consistent. The MoSCoW method of requirement catalogue invented by Dai Clegg was used for this catalogue. The MoSCoW method is a four-step prioritisation process used to categorize requirements. The minimum usable subset (MUS) or what the project must deliver is another way of defining the term MoSCoW. To put it another way, if the project is to stay on schedule, it must provide them before the deadline. See tables 3-6.

Table 3: Voter Identification Requirement Catalogue  
Requirements Catalogue Entry 1

Requirement Number	1
Requirement Name	Voter enters his/her Identification card number
Description	To be recognized as a registered voter, one must enter his/her card number. When an online voter is recognized as an authorized voter, he/she is connected to a secure server.
Priority	High
Source	MosCow requirements, Survey data, documentation review and Observation
Issues and outstanding questions	If one tries inserting random numbers, chances of finding an existing number is one in five billion
Comments/Suggested Solutions	This key requirement has to be developed to ensure the benefits are achieved
Benefits	The proposed solution is based on a voter's ID number printed given by the Libyan Election council. Together with a password that would be changed for each ballot. The password would be sent to voter's email.
Related Documents	Libyan Election Council documents, the constitution of Libya, the research project schedules
Resolution	A user interface that allows eligible voters to enter their voting identification numbers and the system can verify the ID numbers and their corresponding passwords. A fully functional system that meets the security requirements

Table 4: Casting Votes

Requirements Catalogue Entry Two	
Requirement Number	2
Requirement Name	Casting Vote
Description	Online voter cast his vote or make choices from the categories of the election and their respective list of candidates given. Each vote will be encrypted with a predefined asymmetric encryption key.
Priority	High
Source	MosCow requirements, Survey data, documentation review and Observation
Issues and outstanding questions	Cast ballots can be neither seen nor changed by anyone even by IT specialists in charge of the voting application
Comments/Suggested Solutions	Each vote will be encrypted with a predefined encryption key. This key will be at least a double one.
Benefits	Members of the political parties assigned to hold the keys. These would ensure that the e-ballots are secured
Related Documents	Libyan Election Council documents, the constitution of Libya, the research project schedules
Resolution	A user interface that allows eligible voters to cast their votes, the votes will be encrypted and decrypted. A fully functional system that meets the security requirements

Table 5: Authentication

Requirements Catalogue Entry Three	
Requirement Number	3
Requirement Name	Authentication
Description	The system submits a recapitulation of voter choices, voter confirms or alter his/her choice and confirm the identity by giving using a secret PIN.
Priority	High
Source	MosCow requirements, Survey data, documentation review and Observation

Issues and outstanding questions	Ineligible voters could try to vote. People with unauthorized access could try to access the system. If one tries inserting random numbers, chances of finding an existing number is one in five billion
Comments/Suggested Solutions	The voter is asked to identify himself /herself by stating his date of birth, place of origin (to be chosen from a scroll-down menu of the number of regions and districts) and the pin code sent to him/her via an email.
Benefits	This ensures that only an eligible person with a right to vote should be allowed to take part in the ballot. Also, each voter has only one vote and can only vote once.
Related Documents	Libyan Election Council documents, the constitution of Libya, the research project schedules
Resolution	A fully functional system that meets the key security requirements of an Online Voting System

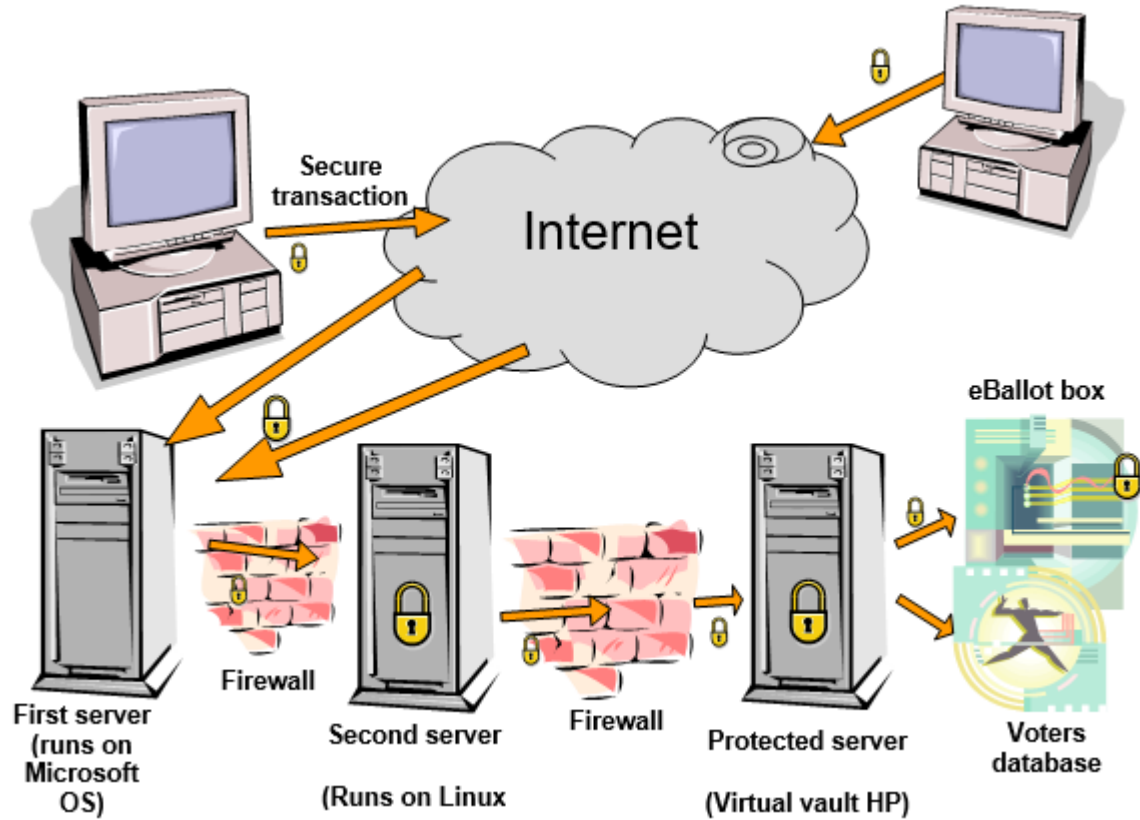
Table 6: Requirements Catalogue Entry Four

Requirements Catalogue Entry Four	
Requirement Number	4
Requirement Name	Confirmation
Description	The system confirms that it has registered the vote by stating the date and time of registration. This latter information can be verified at any time by re-entering the voting card number.
Priority	High
Source	Survey data, documentation review and Observation
Comments/Suggested Solutions	Through the secured socket layer (SSL), established between the voters PC and the state servers, the encrypted eBallot will be transmitted to database server securely locked in a tight security room
Related Documents	Libyan Election Council documents, the constitution of Libya, the research project schedules

To check the proper functioning of the system, the political parties' representatives should be provided with a 'test ballot box', test voting cards and blank ballot papers. They should then require proceeding with a double vote, in other words to cast test votes via the internet, while also completing the manual ballot papers including the number of the test voting card used. Once the ballot is over, the test ballot papers are to be counted and checked by the controllers themselves. The results of the test eBallot box counted by the system are compared with the manual test ballots count. Both counts must match, and it must be possible to identify each test ballot paper. Figure 7 illustrate if the test eBallot box is identical and equivalent to the decrypted eBallot in the database and the manual ballot test, then it shows that the process proves the system is valid functioning accurately and securely from the start to the finish.



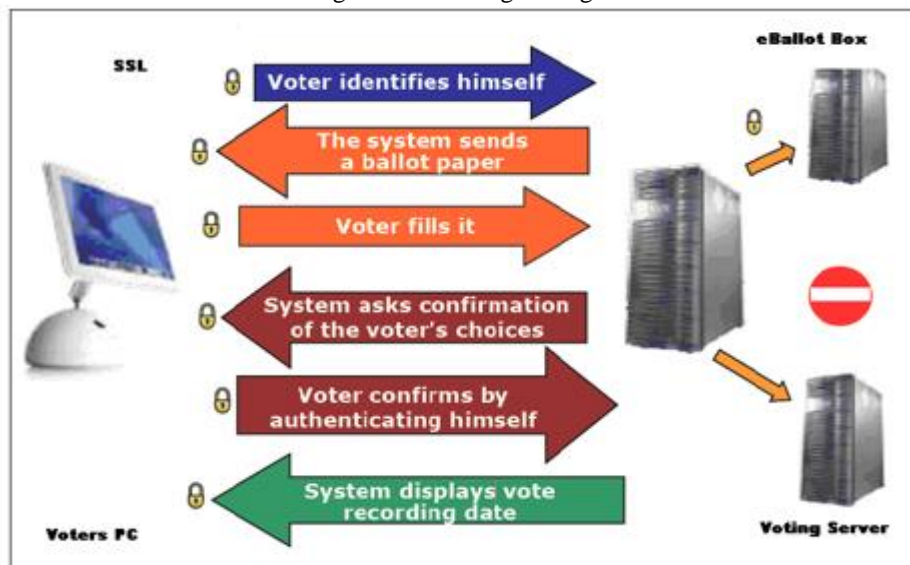
Figure 7: System Security architecture (Chevallier, 2007)



## DESIGN AND DEVELOPMENT OF THE PROPOSED SYSTEM

The voting procedure and process are summarized and illustrated in the Figure 7. The voter identifies himself/herself, the system sends a ballot paper, voter fills it, system asks confirmation of the voter's choices, voter confirms by authenticating himself, system displays vote recording date, as shows in Figure 8.

Figure 8: E-Voting Dialogue



## USE CASE MODEL OF LIBYAN E-VOTING SYSTEMS

A use case model shows a view of the system from the user perspective, thus describing what a system does without describing how the system does it. A use case provides developers with a view of what the users want. It is free of technical or implementation details. We can think of a use case as a sequence of transactions in a system. The use case model is based on the interactions and relationships of individual use cases. A use case always describes three things: an actor that initiates an event; the event that triggers a use case; and the use case that performs the actions triggered by the event. In a use case, an actor using the system initiates an event that begins a related series of interactions in the system. Use cases are used to document a single transaction or event. An event is an input to the system that happens at a specific time and place and causes the system to do something.

## SYSTEM DEVELOPMENT

Internet Information Services (IIS) is a flexible, general-purpose web server from Microsoft that runs on Windows systems to serve requested HTML pages or files. An IIS web server accepts requests from remote client computers and returns the appropriate response. This basic functionality allows web servers to share and deliver information across local area networks (LAN), such as corporate intranets, and wide area networks (WAN), such as the Internet. A web server can deliver information to users in several forms, such as static webpages coded in HTML; through file exchanges as downloads and uploads; and text documents, image files and more. The Election Council of Libya login page. The system administrators provide access to the election council members. The page where candidates' details are added, modified, and deleted by the Libyan Election Commission. The page for adding Candidate. The candidate's full name, the affiliated political party that he/she belongs to, the candidate's Identification Number, the province and district that the candidate is standing for, and photos can be added in this page. At the management voter page, eligible voters could be registered, the registration could be modified and deleted by the Libyan Election Commission. The voter registration page. In this page, eligible voters' details such as full names, email address, phone numbers and date of births, gender, province district and address could be added. The page where election information such as the type of election when the election starts and when the election ends are provided and activated by the election council of Libya.

The Internet Voting Home Page. This site would be activated and could be accessed only during an election period and eligible voters could browse from the following web address <https://.www.ecl.gov.ly/evote/html> with their browser. A voter can start casting his/her vote by

clicking on the Online Voting System. The eligible voters are reminded to check the authenticity of the digital certificate given to the website before they start the process of casting their votes. This is to alert the voter about phishing and other fraudulent websites from that could be targeting unsuspecting voters. Voter enters a valid 16 digit encoded voting card number: To be admitted to the vote server, the voter is required to enter a valid voting card number into the system. The sixteen-digit encoded number would be in the E-voting card number. Voter receives an on-screen reminder of the penalties applicable in the event of fraud (similar wording to that on the back of the voting card). Once the voter has read this reminder and decides to proceed, an electronic ballot paper appears on the screen. The voters are given the choice to select their state, district, and candidate before casting their votes for parliamentary elections. However, for municipal elections, voters are given the choice to select their p provinces, municipality before casting their votes and for a presidential election, voters can just choose their candidates.

The voter casts a vote by selecting their prefer candidates from the lists of candidates listed with their name's pictures and party affiliations. The voter can abstain by leaving both boxes empty. The voter confirms his/her vote choices. E-Voter enters the pin code number that is sent to voter via email. This pin code or 'control code' is used to enable voters to check that they are effectively voting on the official Libyan Election Council website. The voter is then asked to identify himself by stating his date of birth, place of origin (to be chosen from a scroll-down menu of the number of the constituencies). Before the votes are submitted. In Figure 8, the system confirms that it has registered the vote by stating the date and time of registration. This latter information can be verified at any time by re-entering the voting card number on the Election web site. Through the secured socket layer (SSL), established between the voters PC and the state servers, the encrypted eBallot will be transmitted to database server securely locked in the Election Commission Office, waiting for the political parties' representatives to decrypt it with their private keys during the counting stages. The voter can print a copy of the receipt after successful completion casting the votes. Voter who tries to vote again would be denied by the system and a prompt would appear to remind the voter that he or she has casted his/her votes with the previous, thus he wouldn't be able to vote for the second time.

The overall overview the E-Voting System security architecture needed to be implemented to provide robust prevention and protection against a system that requires maximum security. All the related Internet Voting equipment should be connected to a specific strand of the national network and separated from this latter by a 'firewall'. The firewall only lets through traffic to systems like the vote servers which are likely to be called up. The whole

system is linked to the electoral Commission of Libya Network by a single fibre optic connection. Moreover, the Electoral Commission of Libya network itself should be separated from the public and internet network by several firewalls, which will provide protection against intrusion. The machine structure is therefore camouflaged, making it impossible to obtain direct access to the database servers containing the eBallot box. At the entry to the system, a pair of machines distributes the load between the servers so that if one server suffers power outage, the entire load is transferred to the remaining server.

The voter application functions in the WWW-environment. In addition to HTML pages, a connection based on the secure communication protocol SSL128 ("Secure Socket Layer") would be established between the voter's PC and the server. This protocol encrypts the communications exchanged with internet servers working according to public key infrastructure (PKI). Inside the SSL connection duration for the voting session is built on a specific secure channel using the latest headways in applied cryptography and quantum numbers. The web navigation will depend on DNS or domain name servers. The system forces them to be refreshed far more frequently than usual (every few minutes instead of every few days). The Internet Voting system will have two types of servers: the internet/application servers and the data base servers. These servers should be installed in the safest computer room of Libya. Access to this room is to be regulated by the highest security and safety rules and policies of the land. Only a small number of technicians will have the authority to enter these premises, and they should not be allowed to enter there alone. Network access is to be limited to a single entry via a dedicated optical fibre. To maximize security of the servers and the related set ups the controlling and managing should be done by the State of Libya.

E-voting server should be protected by two-level web server system separated by two firewalls. The first level is the normal web server, which would give access to the second level only during the voting period (the rest of the time, the URL will point to an error web page). The second level asks the voter for his or her vote card number and rejects all invalid vote cards. As the card number changes in every operation, it is quite an efficient protection for the actual e-voting web server. These two servers should be based on different technologies which also contribute to make things more difficult for a hacker. The first server could be based on Microsoft technology, the "identification" and voting server could be based on a special operating system with a very high security level.

These servers will be cloned and will ensure the dialogue with voters by means of web pages and manage the voting process. These servers will have the software application that voters use to cast vote via internet and host a webpage on the Election Commission of Libya's

internet site. The operating system will be designed specifically for protected web-based applications. There will be two partitions: The external partition that will contain the Apache web server and the internal partition that will also contain the Tomcat application server. The link between the two will be controlled by the operating system. This principle will protect the application server and the underlying database. These servers too will be cloned. They store information relative to the electoral roll and the eBallot box. Both servers are set up in automatic replication mode, which guarantees that the information is always stored twice in table form and twice in log file form. Oracle's transactional engine makes it impossible for a vote to be partly registered. It guarantees that a vote is either fully registered (encrypted ballot paper and entry in the electoral roll), or not at all, in which case the voter may vote again. These servers are the database that will contain the votes, should contain the polling station number and the voter's choice, in an encrypted form.

Any specific equipment is placed under the control of a monitoring system. This latter is it cloned and self-checking. At the slightest sign of failure, a signal is transmitted to the network security administrators and specialists who will take the necessary measures. A crisis team can be alerted in case of major problems. The monitoring system also checks the internet voting homepage: the slightest attempt at modification will also trigger an alarm. The number of votes received is also to be compared with the number of entries on the electoral roll; any discrepancies therein will set off an alarm. This system is used to rapidly report the slightest incident and ensure that any attempts at fraud do not go unnoticed. Since E-Voting will be a new voting possibility, there should be a phone helpline for the voters. This free hotline should provide verbal assistance to voters who could be facing any kind of difficulties when they try to cast their votes. This assistance should be provided from 9 am to 10 pm during the two weeks leading to the ballot, included on weekends. Results generation requires the presence of the political parties' respective controllers, who are invited to enter their private keys into the system. They are required to provide the password that enables the registered votes to be doubly encrypted. The file of ballots is processed by a results management system, which also integrates the counting of ballot box votes (performed manually by district and province levels) and the decisions of the parties' controllers on void or suspect ballot papers.

## **THE EVALUATION METHOD**

The evaluation survey was divided into four sections. The Internet-voting requirement evaluation method developed by Vejačka, (2013), the Framework for web evaluation by Qi et al., (2010) and Davies (1989) Technology Acceptance Model (TAM) were the theoretical

underpinnings used for this survey. The aim of this prototype is to primarily focus on ease-of-use heuristics. The objective of this evaluation is to further examine the applicability of these principles and to ascertain the perceptions of usefulness that could provide information regarding improvement and addition of more development of added design principles. The initial prototype was evaluated by thirty people from Tripoli, Bengazi, Ziten, Mistrata, and Bayda. An additional twenty people in the total of sixty participants, mostly from Tripoli, took part in the second prototype evaluation. Male and female eligible voters between the ages of 20 and 60 are among the participants. The participants included citizens in both private and public sectors as well as students and retirees. The participation of respondents for the evaluation of the L-EVG was purely voluntary.

Participants were encouraged to use and interact with the prototype. Upon the completion of casting votes, the evaluation questionnaire was given to the participants and are asked to give their feedback after interactions with the system. Analysis of the feedback will be used to determine if the prototype meets requirement and the design principles of the system. Should participants conclude that the prototype meets all requirements and design principles, then the evaluation ends. However, If the prototype fails to meet requirement and the design principles, based on the feedback from the participants, the proposed system will be enhanced, and the participants would be asked to try the enhanced prototype and give their second feedback.

## **PROTOTYPE EVALUATION**

The shortcoming of the prototype identified by the users in the first evaluation were addressed and enhanced. The requirement features (Robustness of Internet voting system, Eligibility, Availability, reliability and operability of voting, Auditability, User-friendly usability, Transparency of voting Enfranchisement and uniformity of voting) and system features (Ease of navigation, Logical flow Design. Look & feel of User Interface, Ease of casting vote, Ease of system learning, Accessibility, Verifiability, repeatability, and controllability of vote counting Clarity of the privacy and security components) were not satisfactory to the evaluators were improved. The intuitiveness and ease of use requirements too were enhanced to meet the expectation of the users in the second prototype. The enhanced prototype was again evaluated by 60 participants who tried the system and gave feedback. The sections and content of the questionnaire are identical to those used for the initial prototype evaluation. The goal was to see if the second prototype met the requirements and followed the



expected design principles for simplicity of use. The findings from the second prototype are discussed below.

### GENERAL COMMENTS AFTER THE EVALUATION

Table 7 highlighted the evaluators were asked to describe their experiences after participating in various activities with L-EVS. The following are some of the general comments made by the system's evaluators:

Table 7: Evaluators General Comments

No	Comment	Evaluator Number
1	<i>"This system could help me to vote no matter where I am in Libya"</i>	Evaluator 25
2	<i>"As a woman, I feel that this Online Voting System would be convenient for me during an election period"</i>	Evaluator 30
3	<i>"I found the security aspects of the Voting system to be adequate"</i>	Evaluator 13
4	<i>"The system is easy to navigate and understand"</i>	Evaluator 10
5	<i>"I could cast a vote a secured vote with the system just like a traditional voting system"</i>	Evaluator 42
6	<i>"I like the fact the that my votes would be encrypted, and members of Electoral Commission of Libya and party representatives would decrypt"</i>	Evaluator 20
7	<i>"The system logical flow and functionalities are smooth"</i>	Evaluator 7
8	<i>"I enjoy my experience with the entire E-Voting system"</i>	Evaluator 45
9	<i>"My main security concerns were addressed"</i>	Evaluator 11
10	<i>"The system could be used to cast vote just like traditional method of voting"</i>	Evaluator 3
11	<i>"I had no issue with using the system to cast vote"</i>	Evaluator 2
12	<i>"The ability of the system to be used for voting is great"</i>	Evaluator 36
13	<i>"I enjoy a positive experience with the system was positive"</i>	Evaluator 1
14	<i>"I am pleased with voter verification and authentication"</i>	Evaluator 40
15	<i>"I would like the candidate selection option screen to be bigger"</i>	Evaluator 15
16	<i>"Vote protection and privacy controls are added"</i>	Evaluator 32
17	<i>"I feel good about using this innovation. It can bring convenience and allow many Libyans to take part of the elections"</i>	Evaluator 27
18	<i>"For Libyans living in the remote regions, this Online Voting System could really help"</i>	Evaluator 25
19	<i>"The features and functions are designed well with security as the main focus of development. If all the security measures are followed, then this system would be a great success"</i>	Evaluator 35
20	<i>"Though I am pleased with the functionalities with the system, efforts should be made to constantly maintain security"</i>	Evaluator 50

### CLOSING COMMENTS

Users were given the option to provide final comments on the second prototype once the evaluation was completed. Some of the users who took part in the second prototype's evaluation gave their closing comments on L-EVS. The vast majority feedback was positive, and the evaluators believe that the improved L-EVS would be beneficial to them and that such

a system should be implemented. The evaluators' detailed final comments can be found in Table 8.

Table 8: Closing Comments

No	Comment	Evaluator Number
1	<i>"If this voting system is implemented, it would definitely increase voter participation of Libyan Elections"</i>	Evaluator 6
2	<i>"This would be a good system if implemented if all the security threats risks are well addressed"</i>	Evaluator 14
3	<i>"This type of E-voting system would really be useful in Libya"</i>	Evaluator 3
4	<i>"This system can be improved still. And it will be an excellent system if an improvement is made"</i>	Evaluator 17
5	<i>"I am eager to see such a system introduced in Libya Elections"</i>	Evaluator 22
6	<i>"Such a system can improve Libyan Election Process"</i>	Evaluator 25
7	<i>"For voters in remote part of Libya, it would be very useful to them"</i>	Evaluator 28
8	<i>"I think this Online Voting should be implemented in minor elections first not a major one"</i>	Evaluator 31
9	<i>"This is a positive and useful innovation"</i>	Evaluator 33
10	<i>"This is an excellent system. I hope that one day it will be fully implemented in Libya"</i>	Evaluator 36
11	<i>"I have nothing to say. The system as a whole is positive."</i>	Evaluator 38
12	<i>"Everything is OK." It will be beneficial to voters."</i>	Evaluator 40
13	<i>"All is good. It will benefit voters"</i>	Evaluator 42
14	<i>"Overall, a good system. Such a system is required."</i>	Evaluator 45
15	<i>"A system such as this should be implemented"</i>	Evaluator 49
16	<i>"Such a system is welcome for Voters in Libya due to the size of Libya"</i>	Evaluator 51
17	<i>"My main concern is privacy and security of the E-Voting"</i>	Evaluator 52
18	<i>"This system would give convenience during Elections"</i>	Evaluator 53
19	<i>"This system could save us from the issues of travelling for a long distance to cast voted during elections"</i>	Evaluator 1
20	<i>"If this system security measures are handled well, it will be an important system for Libyan democracy"</i>	Evaluator 5

Table 9: Expected Versus Actual Unsatisfactory Rate System Requirement

System Requirement	Expected Satisfactory Rate < 20	Status
Safety and secrecy of voting	1.9%	Achieved
Robustness of Internet voting system	1%	Achieved
Authorisation and authentication of voters	1.9%	Achieved
Eligibility	1.9%	Achieved
Availability, reliability, and operability of voting	1.9%	Achieved
Auditability	0%	Achieved
User-friendly usability	3.7%	Achieved
Transparency of voting	1.9%	Achieved
Enfranchisement and uniformity of voting	1.9%	Achieved
Verifiability, repeatability, and controllability of vote counting	0%	Achieved
Unprovability of voting	0%	Achieved
No possibility re-vote	0%	Achieved

As shown in Table 9 all the system requirement functionalities are rated well and have received the expected satisfactory level of 80% and the above. This result was achieved after enhancing the prototype based on the feedback from the initial prototype.

Table 10: Aspects of the System Evaluation Finding

System Feature	Unsatisfactory Rate ≤ 20%	Status
Ease of navigation	13%	Achieved
Logical flow	1.9%	Achieved
Look & feel of User Interface	5.6%	Achieved
Ease of casting vote	5.8%	Achieved
Ease of system learning	3.7%	Achieved
Accessibility	1.9%	Achieved
Number of clicks	1.9%	Achieved
Clarity of the privacy and security components	1.9%	Achieved

Table 10 shows the findings regarding the key aspects of the system. It indicates that all of the features in the items have received the expected satisfactory level of 80%. This improvement too was achieved as a result of the improvement of the initial prototype based on the findings from the feedbacks given by the evaluators.

### COMPARISON OF RESULTS AGAINST TAM 2 CONSTRUCTS

Table 11 shows a comparison of “perceived usefulness” to the TAM2 model's antecedents (Venkatesh & Davis, 2000). The following is a summary of the findings, along with particular references from the second evaluation's findings.

Table 11: Summary of Results Against Ease-of-Use Constructs

Constructs	Definitions	Result Analysis
Subjective Norm	“The degree to which an individual perceives that people important to him/her think that he/she should or should not use the system”. (Venkatesh & Davis, 2000).	Most of the evaluators confirmed that they would adopt the L—EVS if it was full completely implemented, they will accept and use it. They found the system to be very useful in helping them to take part of elections. And greater number of the respondents also agreed that they would recommend L-EVS to their friends and Libyan Election Commission.
Image	“The degree to which an individual perceives that use will enhance status”. (Venkatesh & Davis, 2000)	Some of the participants noted that increase in voters’ participations during an election period and can improve the election process of Libya.
Job-relevance	“The degree to which the system is applicable to the job”. (Venkatesh & Davis, 2000).	Most of the evaluators agreed that a secured E-voting System would is a plus to Libyan Election process.

Output Quality	<i>“The degree to which the individual believes that the system performs his/her tasks well”</i> . (Venkatesh & Davis, 2000).	The L-EVG requirements criteria and the features and functions of the system were evaluated and given a good score by the evaluators.
Result Demonstrability	<i>“The degree to which the individual believes that the results of using the system are tangible, observable and communicable”</i> . (Venkatesh & Davis, 2000).	From verification and authentication to the selection of districts and candidates, the casting of votes, confirmation of votes and the acknowledgment that voter receives are well demonstrated by the system and can be observed by the eligible voters. Most of the evaluators gave a good score for the result demonstrability.

From verification and authentication to the selection of districts and candidates, the casting of votes, confirmation of votes and the acknowledgment that voter receives are well demonstrated by the system and can be observed by the eligible voters. Most of the evaluators gave a good score for the result demonstrability.

## CONCLUSION

The Technology Acceptance Model (TAM) served as a valuable framework for designing and evaluating prototypes for Libyan E-voting. Evaluators were not willing to adopt or suggest the system to their friends and Libyan Election Commission until the ease-of-use criteria are met, according to findings from the first prototype. The second prototype was regarded as meeting the key functional and non-functional requirement and ease of use criteria by users. After fixing the concerns found during the first prototype's evaluation in terms of the requirement criteria (Eligibility, Availability, reliability and operability of voting, Auditability, User-friendly usability, Transparency of voting, Enfranchisement and uniformity of voting) Clarity of the privacy and security components, Verifiability, repeatability and controllability of vote counting and aspects of the system (Ease of navigation, Logical flow, Look & feel of User Interface, Ease of casting vote, Ease of system learning, Number of clicks). The criterion for ease of use were met. As a result, 87% of the evaluators indicated that they would adopt the system if it was introduced. Whereas 87% of the evaluators suggested that they would recommend the E-Voting system to their friends, colleagues, and Libyan Election Council. Following the trial of the second prototype, the evaluators proposed that the L-EVG would assist them enable them to exercise their election rights.

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