

# **The Development of Remote E-Voting around the World: A Review of Roads and Directions**

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**Abstract.** Democracy and elections have more than 2,500 years of tradition. Technology has always influenced and shaped the ways elections are held. Since the emergence of the Internet there has been the idea of conducting remote electronic elections. In this paper we reviewed 104 elections with a remote e-voting possibility based on research articles, working papers and also on press releases. We analyzed the cases with respect to the level where they take place, technology, using multiple channels, the size of the election and the provider of the system. Our findings show that while remote e-voting has arrived on the regional level and in organizations for binding elections, on the national level it is a very rare phenomenon. Further paper based elections are here to stay; most binding elections used remote e-voting in addition to the paper channel. Interestingly, providers of e-voting systems are usually only operating in their own territory, as out-of-country operations are very rare. In the long run, for remote e-voting to become a reality of the masses, a lot has to be done. The high number of excluded cases shows that not only documentation is scarce but also the knowledge of the effects of e-voting is rare as most cases are not following simple experimental designs used elsewhere.

**Keywords:** Remote Electronic Voting, State-of-the-Art

## **1 Introduction**

“While democracy must be more than [...]elections, it is also true [...] that it cannot be less,”[1] former Secretary General Kofi Annan once said. Elections are the core element of democracy as a society’s way to make decisions. Elections are the way to express how societies use technology and as new technologies have emerged and evolved, elections have changed accordingly. While there have been democratic structures in societies like India, the birthplace of democracy is attributed to old Athens in 507 BC [2]. From then on similar structures of direct democracy, bound by

face-to-face societies, also developed in several places around the world like in ancient Rome [3], with the Vikings [4] or in the Cantons of Switzerland [5, 6]. The next level of democracy developed with the creation of nation-states in the late 18<sup>th</sup> century with the need for representatives. This form of indirect democracy spread in three waves [7] from the United States and France around the globe to today's predominant role of democracy as a rule of government.

The political scientist Robert Dahl classifies these developments as the first and the second transformation of democracy [8]. With it, democracy moved away from the old ideal of identity of the ruler and the ruled. Thus, the worldwide decrease in voter turnout and the rapid development of information and communication technologies like the Internet have led him and others to think about a third transformation – the development of the electronic democracy.

Positive visionaries like Grossman [9], Fuller [10] and Fromm [11] conceived the electronic republic with a new, more direct and pervasive form of democracy. Fuller anticipated even “electrified voting, [...] a mechanical mean[s] for nation-wide voting, daily and secretly, by each adult citizen.” The more pessimistic view is taken by Golding [12] and Haywood [13], who foresaw a negative effect of new technologies for democracy, due to inequalities in information access. The experience with the transformational effect of the Internet on private (e-commerce) and public (e-government) sectors has strengthened the position of neutral researchers that foresee a similar transformational change for democracy (Bimber [14] and Leggewie & Bieber [15]), which will in the end develop a direct representation where representatives can be held more accountable by the electorate.

Either way, the development of an electronic democracy with transnational character [16] needs the further development of e-enabled instruments of democracy [17], i.e., e-initiatives, e-referenda and of course also e-voting instruments. Amongst them remote e-voting has received the largest attention, and it reached the national level in Estonia first. On March 3<sup>rd</sup>, 2007 the Estonian national election offered the world's first legally binding remote electronic voting (e-voting) possibility [18]. With that event remote e-voting has finally reached the stage of international attention even though experts warned three years earlier in the SERVE report that the Internet is not ready for elections yet [19]. Most other nations are still in the phase of experimentation. To date most trials do not follow classical experimental setups [20] and are embedded in their national context [21] which makes it hard for comparison and learning from others.

This paper is the first attempt to conduct a state-of-the-art analysis [22] of 104 remote e-voting uses in the past twelve years to build knowledge on the future of voting. We analyzed the documentation in research articles, working papers and press releases of 104 e-elections conducted around the world. While we aimed for a representative sample, it is clear that the current cases cannot serve this purpose. Rather it gives an indication how remote e-voting has developed so far. In the following we will first give a theoretical background on remote e-voting, and then present the results of our review. Finally, we will discuss the findings and give our conclusions.

## 2 Theoretical Background

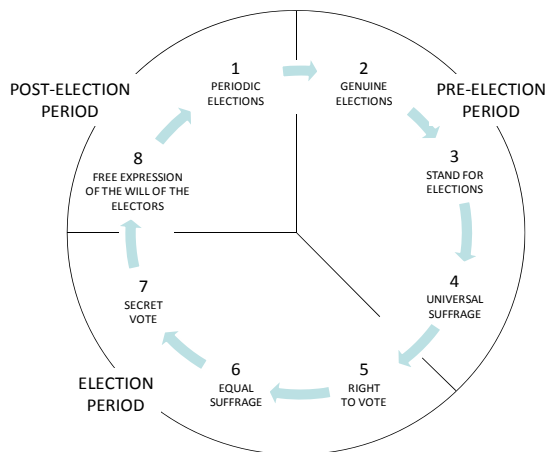
In this chapter we will explain what we mean by remote electronic voting and which methodology we used.

### 2.1 The terminus technicus remote electronic voting and its variants

**Definition.** When talking about e-voting it is necessary to define the subject. The Council of Europe recommendations define electronic voting as “the use of electronic means in at least the casting of the vote” [23]. We first have to look at elections in a broad sense (for our purposes this includes e-referendums) and then concentrate on the implications of ICT usage therein.

**The Electoral Process.** The United Nations facilitated the agreement on the International Covenant on Civil and Political Rights [24]. Article 25 defines eight principles for elections that depict the whole electoral process: (i) periodic elections, (ii) genuine elections, (iii) stand for election, (iv) universal suffrage, (v) voting in elections on the basis of the right to vote, (vi) equal suffrage, (vii) secret vote, and (viii) free expression of the will of the voters. Suksi [25] groups these principles into a cycle consisting of three periods:

1. Pre-Election Period: This is the time from calling an election until the actual start of the polling.
2. Election Period: This is the actual Election Day where the vote casting takes place.
3. Post-Election Period: This is the time during which the results are announced and a new election is called.



**Fig. 1:** The Electoral cycle [25]

**Local/Remote.** The electoral process usually takes place at the polling station and is supervised. This can be referred to as voting at presence. But there is also the possibility of remote voting. The criterion to differentiate those two is if an election commission supervises the act of voting or not [26]. At current elections the voter comes to the polling station where the election commission checks the identity and eligibility and ensures the voter's anonymity when casting the ballot. When the election has finished the election commission counts the votes. With remote elections the identity and the right to vote is checked beforehand or remotely and the voter has to make sure that his anonymity is not compromised. This raises questions of voter coercion and vote buying [27].

**Forms.** According to the dimensions of medium and place of voting the systems can be assigned to six basic groups. The medium hand is characterized by its inherent need of presence and is limited to a certain number of people and does not allow for voting in an uncontrolled environment. In modern institutionalized elections this medium is very seldom used. Most modern day elections use paper as a medium of choice. Polling station voting using paper ballots is characterized by the controlled environment and the usage of paper as a medium. Postal voting also uses the medium paper, but provides no controlled environment. If the ballot is cast electronically one can differentiate between voting machines that are placed in the controlled environment of a voting station and remote electronic voting that also uses an electronic channel as a medium, but provides no controlled environment. Table 1 gives an overview [28]:

**Tab. 1:** Forms of electronic voting

	Environment	Controlled	Uncontrolled
<b>Medium</b>			
<b>Hand</b>		In-Person	-
<b>Paper</b>		Polling Place	Postal Voting
<b>Electronic</b>		Voting Machine	Remote Electronic Voting

**Multi-Channel.** It is possible that one election uses more than one form of voting. Critical from the operational viewpoint is if more than one channel is allowed and if paper and electronic channels have to be combined. When counting the votes the system must ensure that multiple voting in different channels is not possible. One has to make sure that the individual results of the channels are combined in such a way that the end result is correct. For the time being, democracy theory and constitutional law (requirement of universality) require additional paper channels as long as not everyone has the skill and access to the Internet, thus remote e-voting can only be an optional channel in legally binding elections for the time being.

**Levels.** Remote e-voting can take place at elections of diverse levels of attention. We differentiate five different levels determined by political importance, legal commitment, and parallel testing. The political importance is defined by Lijphart {Lijphart, 1998 #757} as such that the first and the second level elections are

politically binding which means they are regulated by law and the results of the elections have consequences. The most rigid legal framework is found with first level elections like presidential or parliamentary. On the second level less important political elections can be found. Typical elections for that level would be local elections. Elections of lesser importance, because of their lesser political impact like (student) union elections or elections in corporations, can be considered as the third level. These tend to have fewer rules on how the election has to be conducted. Still some kind of outcome is dependent on the result of the election. Critical for all of them is that they have to fulfill certain rules so the outcome of the election can be binding and some kind of action can be derived. This leads to another classification of elections. A test is an election that's sole purpose is to test the system. Such tests are often conducted in an early stage of the development of a system and their sole purpose is to test the system. A logical next step is to simulate an election and test the system parallel to a binding one. The aim of such a test is to trial the system under realistic conditions and the results of which are not legally binding. These five categories build the five levels of elections:

**Tab. 2:** Levels of elections

Levels	Leg. Binding	Org. Binding	Non-Binding
1 <sup>st</sup> Level: national	<input checked="" type="checkbox"/>		
2 <sup>nd</sup> Level: regional, local	<input checked="" type="checkbox"/>		
3 <sup>rd</sup> Level: org., assoc., companies	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	
4 <sup>th</sup> Level: shadow, parallel			<input checked="" type="checkbox"/>
5 <sup>th</sup> Level: technical test			<input checked="" type="checkbox"/>

**Identification and Anonymity.** The basic problem of electronic voting is how to solve of the unequivocal identification of a voter and at same time being able to guarantee anonymity with a secret ballot casting [29].

**Identification.** For identifying a voter three basic criteria can be used to differentiate the technologies: (i) knowledge, (ii) possession, and (iii) properties. A fourth possibility is a combination thereof. These identification technologies are used in remote e-voting:

1. *Username and Password:* The identification relies on the voter knowing a secret.
2. *Transaction Number (TAN):* The voter possesses something that identifies him/herself.
3. *Biometrics:* The voter him/herself with his/her individual biometric properties identifies him/herself. A reader for the biometric feature is needed.
4. *Smart Cards:* The voter knows a secret that in combination with the possession of the card identifies him. Or a property pattern of the voter is stored on the smart card that is checked against the voter's property when casting a ballot - either way, a reader for the smart card is needed.

**Anonymity.** Critical for a voting system is the question of guaranteeing anonymity. There have been many articles written to categorize and cluster protocols guaranteeing anonymity [30-33]. While the criteria used in these papers are very sophisticated, in practice a simpler and more distinctive criterion is time [34]: At which point in the electoral cycle is secrecy (anonymity) established?

1. In the Pre-election Period: Anonymity is established in the pre-election period by the organizing institution. The most common implementation of such a system uses transaction numbers (TAN). These numbers are generated centrally and a scratch-field is applied. Then in a second step the voter's address is applied and sent to the voter who can use the number anonymously for exactly one vote.
2. During the electoral period: With this method the anonymity is established during the vote casting procedure. It can either be done by separating the servers in an identification and ballot box server or by blind signatures; the most common implementation of Chaum's blind signature [35] is in the Fujioka et al. algorithm [36]. The process can be explained as follows: the voter fills out his/her ballot sheet, then puts it in a carbon-copy envelope. The voter then signs another envelope with his/her personal signature and inserts the carbon-copy envelope and sends the package to his/her register. They check the voting eligibility based on the voter's signature, then sign the carbon copy envelope and return it to the voter. The voter opens the cc-envelope and has a signed ballot sheet (due to the carbon copy) without the voter's register ever having seen the ballot sheet. Finally she returns the ballot sheet to the ballot box and has thereby cast a valid vote anonymously.
3. In the post-electoral period: In this case the anonymity is established after the end of the election day, when the votes can still be identified but the count can only be conducted together meaning the content of a single vote is never released. The most common implementations use homomorphic encryption like the Schoenmakers algorithm [37] or hardware security modules like the Estonian system [38].

**Provider.** To conduct an electronic election is a complex undertaking and is usually operated by a consortium. We identified the provider that was critical or characteristic for the whole system. Of special interest was in which country the provider operated and how much experience the company had.

**Size.** One important criterion for assessing e-voting use is how many votes are cast. Looking at the sample we found it useful to group the elections into three size groups. The first group (A) contains all elections with more than 30,000 votes. The middle group (B) contains elections with a number of e-votes between 3,000 and 30,000. The last group (C) consists of small elections with a number of e-votes smaller than 3,000.

**Tab. 3:** Criteria to categorize remote e-voting

<b>Criterion</b>	<b>Category</b>				
<b>Level</b>	National	Regional	Association	Shadow	Test
<b>Channels</b>	Electronic		Paper and Electronic		
<b>Identification</b>	Username/PW	TAN	Signature	Biometric	
<b>Anonymity</b>	Pre-election period		Election period	Post-election period	
<b># Votes</b>	A # >30,000		B 30,000 > # > 3,000		C # < 3,000

## 2.2 Research Methodology

Conducting a review can be organised in many ways; the approach we selected follows the handbook of review synthesis [39] which proposes five phases: (i) problem description, (ii) literature research, (iii) literature analysis, (iv) analysis, and (v) presentation.

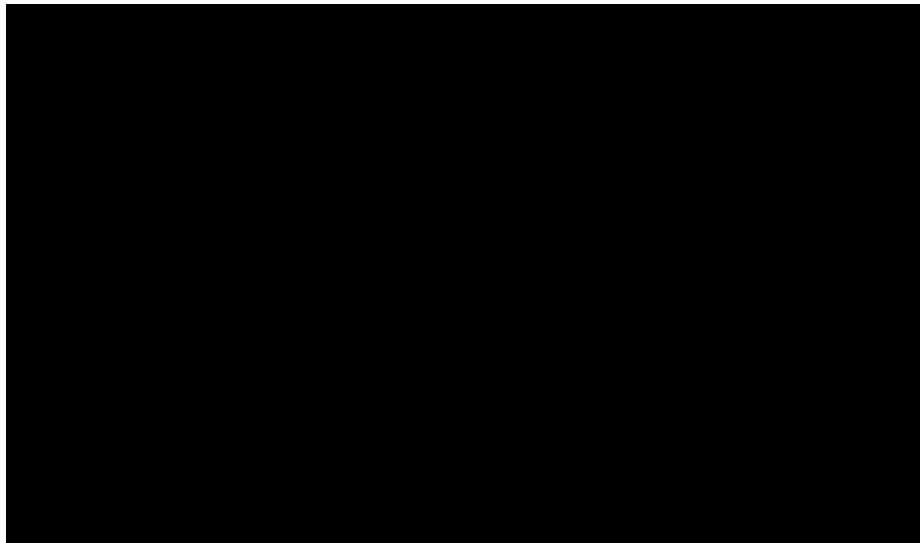
(i) The goal of this review was to conduct a review on the progress of remote electronic voting. (ii) To use as sources we consulted research articles, system documentation, whitepapers, technical reports, and even press releases if necessary. As remote electronic voting is a very new topic for the general public, often more than one source had to be consulted to gain a complete picture. Not surprisingly research articles usually gave a better insight on the project setup and system description while lacking actual election related data. This was where we consulted press releases. To find the appropriated sources we used a network of experts around the world that were invited to provide data or point to relevant documents. We provided them an online questionnaire on a public website to identify relevant elections. Because of the multitude of sources the data had to be consolidated. That makes it difficult to find common ground, so we needed to add an extensive array of integration work. (iii) The criteria that were developed in the previous chapter were used to characterize the elections. (iv) The collected data was then entered it into a database for analysis, and (v) then presented and discussed in the following chapters.

## 3 Results

In total we identified 139 elections in 16 countries within the time period of 1996 to the 30<sup>th</sup> of April 2007 where remote e-voting occurred. For the analysis we needed a minimum amount of information about every election. We had to eliminate 35 (!) elections in total. Three elections were excluded from analysis because of missing data about voters and turnout. The largest exclusion reason was for not having system documentation available, which applied to thirty elections. Without the documents we could not assess which forms of identification or anonymity were used. Finally, two could not be included at all because we lacked information on the voter data and on

the used system. In total we had 104 fully documented elections which we could include in the following analysis. These elections were held in 13 different countries on three continents; two elections were held trans-nationally. The first election was held in 1996 in Finland and the last in 2007 in Estonia. The following table shows the distribution of all elections over time and by country. From the analysis, excluded elections are put in brackets.

**Tab. 4:** Number of elections per year and country included (excluded) in review



The countries with the most elections were Germany (30), Switzerland (24) and the United Kingdom (19). Surprisingly the United States has just 2 publicly documented elections.

**Example.** As an example we will walk you through the process of classifying elections with the example of the 2007 parliamentary elections in Estonia. The election was on the national level and was legally binding. This places the election into *level 1* of the 5 levels. It was also a *multi-channel election* that offered both paper and remote e-voting channels. Voters could cast their vote electronically over the internet before Election Day or at local polling stations on or before Election Day on paper. The voters could use the remote e-voting system with their national ID card, a *smart card* which bears a digital signature. The vote is first encrypted using the public key of the ballot box, and then signed by the voter with her private key. To count the votes Estonia uses a hardware security module for hidden result calculation which means anonymity is established in the *post-electoral period*. The *provider* of the system was Cybernetica AS, which is of *Estonian* origin. Approximately 940,000 people were eligible registered voters and 30,275 cast their votes electronically. This places the election in *group A* of large elections.

The other elections were categorized in the same way. The result of the systematization is depicted in table five and is described below.

**Tab.5:** Overview of the results

Criterion	Category				
<b>Level</b>	National (4; 3.8%)	<b>Regional</b> <b>(38; 36.5%)</b>	Association (30; 28.9%)	Shadow (27; 26%)	Test (5; 4.8%)
<b>Channels</b>	Electronic (39; 37.5%)		<b>Paper and Electronic</b> <b>(65; 62.5%)</b>		
<b>Identification</b>	Username/PW (4; 3.9%)	<b>TAN</b> <b>(84; 81.5%)</b>	Signature (15; 14.6%)	Biometric (0; 0%)	
<b>Anonymity</b>	<b>Pre-election period</b> <b>(53; 50.9%)</b>		Election period (29; 28.2%)	Post-election period (21; 20.4%)	
<b># Votes</b>	A, # >30,000 (9; 8.7%)	B, 30,000 > # > 3,000 (30; 28.9%)	<b>C, # &lt; 3,000</b> <b>(65; 62.4%)</b>		

**Level.** With 38 cases the group of 2<sup>nd</sup> level elections is the biggest. The 3<sup>rd</sup> level is the second-largest with 30 elections. Of all binding elections the group of national elections is with four instances the smallest (once each in Estonia and Switzerland, twice in the Netherlands). The group with shadow elections has 27 elections and only five elections had a sole test purpose. Interestingly the legally binding elections attribute for over 40% of the cases.

**Multi-channel.** In one third of the cases the remote voting channel was the only method to cast votes. For the majority (65 cases) of the elections, e-voting was just an additional channel to the traditional paper way.

**Identification.** With 84 elections the most favourite way of identifying voters, by far, was the TAN-system. 15 elections used signature cards and just 4 elections used a relatively insecure username and password system. Biometric systems were not used at all.

**Anonymity.** In two-thirds of the investigated remote e-voting elections the anonymity was established before Election Day using organizational pre-registration. The second most common way is to establish it during the electoral period, which was used in 28.2% of the cases. The use of establishing anonymity after the election was used in 20.4% of the cases.

One election did not fit the categorization in the field of identification and anonymity because the identification was done based on IP-address and anonymity could therefore just be guaranteed organizationally.

**Size.** The elections with remote e-voting have a large span width between the largest (130,000) and smallest (54) number of voters. Most elections were rather small, as 65 elections had fewer than 3,000 votes cast. 28.9% of the elections had between 3,000 and 30,000 voters. In the largest group with over 30,000 votes only 9 elections could be found.

**Provider.** In total 25 different providers organized the analysed elections. Four of them account for 54.8% of all conducted elections, while the other 45.2% were distributed amongst 21 providers. Most providers (76%) have experience only in their home country; the six who have operated elections outside their home country have done so in a maximum of three foreign destinations. Only one provider has operated solely abroad which is due to the fact that it is homed in the US but also has a strong base in European countries.

#### 4. Discussion

Starting with the reported findings in the previous chapter we will discuss the results here more closely. The “idea” of collecting all elections was very ambitious. 1<sup>st</sup> level and most 2<sup>nd</sup> level documentation is publicly available. Most of the time it is not in one place but with enough work the information can be gathered. For elections on the third level most of the time public information is hard to get. We know that there are a lot of elections in the US in the private sector but simply could not get public documentation for them.

Everybody wants to sell a success story. This is especially noticeable when looking at turnout data. The most inconvenient low numbers simply get left out. The problem of selective information is not just a problem with result numbers but with information about elections in general. A language and regional bias is noticeable and also inherent in the method of experts referring to experts and resources. Nearly all papers and documentation just deal with single cases. There are very few comparative sources. Some initiatives can be found, but nothing comprehensive.

Generally it is hard to maintain data quality. The problems result from combining multiple sources that use different wording, are incomplete, and even contradicting.

A broader constant process would be needed. The US and Asia can surely contribute to the process. Experts are asked to leave their box and overcome their bias. A start would be the 30 elections that had to be excluded because of missing technical system documentation.

**Elections.** The number of elections using remote e-voting has risen during the time span in our review. Interestingly most of the cases took place in the new millennium with a heap in 2003, and have maintained at that level since then. Further, the number of countries acting on e-voting is rising as well. Still it has to be mentioned that the average cycle for political elections is 4-5 years, which also limits the number of possible legally binding e-voting uses. We also noticed a strong bias of remote e-voting in Europe, where 100 of the 104 cases are located. This is of course due to the fact that Europe with its large number of countries also inherently has the largest number of elections to conduct. Furthermore the biggest potential of remote e-voting - to conduct trans-national elections - has not yet really been taken advantage of. Only two elections in that area have been noticed so far. This probably also deals with the fact that these elections could only happen on a 3<sup>rd</sup> level as the potential candidate for this – the European Union – has no mandate for elections yet and cannot make legislation for this as of now.

**Level.** We were surprised that 40% of the conducted elections were legally binding (1<sup>st</sup> and 2<sup>nd</sup> level). A large stake can be attributed to the pilot series at the local level in 2002 & 2003 in the United Kingdom. On the national level the number is much smaller and has happened only in three countries (Estonia, Netherlands and Switzerland). In most countries to use remote e-voting channels, laws or even the constitution have to be changed, which makes remote e-voting very unlikely to happen on the go. It needs a strategic intention of the government for this. On the third level with (not legally) binding elections we expected more cases, but instead they make up only 29% of the total number. This could relate to a lack of interest in publishing the experiences with remote e-voting. Reasons could be only a small interest of the public, or that it has been conducted more than once already. In the field of non-binding elections, i.e., the area of testing a system, it is clear that most cases took place in parallel to a real election and only few are pure functionality tests or fictional elections. The reason for this is the problem of motivating the voters – why should they participate?

**Identification.** A lot of attention should be placed on the results in the field of identification. The numbers showed very clearly that the ID of choice for electronic voting is a TAN. It is easy to handle as voters know it from lottery tickets. In addition it is also cost effective as no reader is needed. Further the TAN is a good way for the election organizers to make project marketing. The most secure way - signature cards – obviously has a problem with usability and is too costly.

**Anonymity.** Similar to the case with the identification we found that most election organizers (71.3%) choose algorithms that keep the establishment of anonymity in their premises, i.e., either before or after Election Day. This has to do with the fact that in these algorithms the least number of calculations is necessary on the side of the voter which means in consequence that the voting procedure requires less additional software like java programs or applets and can run in an ordinary browser. Establishment during the electoral period was used in 28.2% of the cases.

**Multi-channel.** If we check the use of multiple channels in combination with the five levels a clear pattern emerges. 99% of all legally binding elections at the national and regional levels have at least one paper channel parallel to the electronic channel. In the 3rd level 58% use only electronic channels and 42% also use paper and electronic channels at the same time. The 4th level excludes per definition paper-based channels and the 5th level just uses electronic channels.

**Size.** When looking at numbers for votes cast one can clearly see that electronic elections are still an emerging field. Systems are gradually tested starting with smaller numbers. But in absolute figures all of these elections are not comparable to traditional elections. The biggest legally binding election to date - the Arizona State Democratic Preference Primary in March 2000 - had around 40 thousand votes cast.

**Provider.** Only four providers organized the majority of elections. These are also the providers which organized elections in different countries. The rest is distributed among 21 providers which in most cases just operate in their home country. This is most probably explained by the lack of trust in foreign companies and fear of them controlling such a core element of democracy.

## 5. Conclusions

With a field being around for 12 years, a review of the collected experience was long needed. A review of the conducted e-elections on a structured basis was a challenge due to the fragmented characteristic of the available information. Our sample of 104 cases covers 12 year, 3 continents and 14 countries. In general data quality is the biggest obstacle to overcome.

Our research shows that although there have been four legally binding top-level remote e-voting elections the field is not mature yet. The best indicator is the relatively small size of the cases. 62% of the elections have less than 3,000 voters and only 8.7% have more than 30,000. These numbers are far from any traditional election.

The obvious target area foreseen by the visionaries – citizens living abroad and transnational elections – was the focus of only seven elections.

Conducting e-elections needs a technical provider who usually is an IT-company. Interestingly they operate only in their home country. There seems to be resistance in engaging companies from abroad.

For the implementation selecting the right identification and anonymity schema is crucial for success. Here most cases selected a combination of TAN and pre-electoral establishment of anonymity. The information of a theoretically more secure signature and establishment during vote casting falls back in adoption most probably because of additionally needed infrastructure. However the Estonian example shows that legally binding remote e-voting with signature smart cards is possible.

Handling multi channels involving paper and electronic vote casting does not seem to be a problem. On the contrary, 99% of all legally binding elections offered remote e-voting only in addition to paper-based vote casting.

In the future research has to focus on its role in understanding and learning from what has been done so far. In this way, any academic involved in remote e-voting should follow basic academic styles. Not only does that mean the experiments should follow basic experimental designs but also documentation should be comprehensive, analytic and comparable. Based on existing approaches [40, 41] academics should develop a guideline on how to properly document e-voting uses, similar to election observation reports [42, 43].

To make this research more valuable it should be accessible by third parties in a public database. This would help readers learn from the results and also gain further insights in projects not included in this review.

It would also be interesting to deepen the analysis of this material available especially in the field of technology following a longitudinal approach. Here the development could deliver interesting insight into the adoption of identification and anonymity technologies.

Overall remote electronic voting has not reached the maturity to be applied in large-scale elections of major importance. More research needs to be put into the effects, outcomes and security of remote e-voting. Documenting the experience, as has been done here, is a first step to build up a research strategy.

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