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Evaluation of the I-Voting System for Remote Primary Elections of the Czech Pirate Party

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Abstract

The integration of digital technologies into political processes represents a pivotal shift in the operational dynamics of political parties, highlighting an evolution from traditional to digital platforms. This transformation offers greater member engagement and decision-making transparency while also introducing new challenges in terms of security and control. This study presents an analytical overview of the Helios voting system as implemented by the Czech Pirate Party, used not only for primary elections, offering a critical examination of its operational framework, security measures, verification processes, and implications for intra-party democracy and member engagement. The Czech Pirate Party's engagement with Helios exemplifies a broader trend toward digitalization within political organizations, reflecting both the potential benefits and inherent challenges of such technological adoption. Drawing on theoretical insights from the literature on political party transformation in the digital age, this article assesses how i-voting systems like Helios can potentially enhance or detract from internal democracy. The discourse around digital platforms is nuanced, revealing opportunities for increased democratic engagement alongside risks of enhanced centralization and control. Empirical data from a survey of the Czech Pirate Party's membership base provides insights into perceptions of the Helios system's usability, security, and its impact on democratic processes within the party. The study further investigates Helios's technical aspects, focusing on its security protocols, verification mechanisms, and governance structures related to data and platform ownership, to understand its implications for electoral integrity and party governance. The research aims to contribute to the dialogue on e-voting platforms, highlighting the need for a careful balance between embracing technological advancements and upholding democratic principles.

Keywords

E-voting; Remote voting; Internet voting; Czech Republic; Primary election; System evaluation; Helios; Open-Source; Standards; Digital Party.

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1 Introduction

Since the 1990s, political parties around the world have been experiencing an organizational crisis, the biggest symptoms of which are the decline of the membership base and intra-party mobilization (Gerbaudo, 2019). Digital participatory technologies offer a way to easily and cheaply draw citizens' attention to and engage with intra-party events. One such trend is the use of internet-based voting systems for political party personnel elections that include primaries. This trend has been amplified by the COVID-19 pandemic due to the increased need for remote communication.

In the Czech Republic, the Czech Pirate Party uses the Helios system combined with in-house developed systems and other open-source software to organize personnel elections via the Internet for its members (Martínek & Forýtek, 2022). Other Czech political parties, including the Greens and the Mayors and Independents, have also used Internet voting for their primaries. The Public Affairs party used online voting to approve their positions and actions by registered members (Cirhan & Stauber, 2018). The Czech legal system does not exclude the possibility of conducting personnel elections remotely using online tools. Under the Act on Association in Political Parties and Political Movements (Czech Republic, 2024), it is necessary to comply with Section 4, which requires democratic statutes and democratically constituted bodies. Each political party and other entities can adapt their statutes and bylaws to make use of remote electronic voting. The Act (Czech Republic, 1995) regulates elections to the Chamber of Deputies and other public authorities, which exclude the use of remote electronic voting. Within primaries, the primary regulation is the political party's electoral code.

This article aims to analyze the i-voting system of the Czech Pirate Party through the lens of democratic and technical norms using mixed methods. The article is structured as follows: after the introduction, we present a literature review on i-voting systems in political parties, followed by a review on the security analysis of i-voting systems. Subsequent sections outline the research objectives, data, and methods. The results and analysis are then discussed, leading to the discussion and conclusion. This article seeks to enhance the debate on the use of i-voting systems within political parties.

Our primary objective is to evaluate the Helios Voting system in combination with other party systems through analysis and primary research, addressing its benefits, risks, and security issues in the context of Internet voting systems used by the Czech Pirate Party, not only for its personal elections. We aim to evaluate the complex system according to a defined framework and verify the parameters and the entire i-voting system based on user experience. This paper contributes to the ongoing debate on voting systems in political digital parties (Deseriis & Vittori, 2019; Gerbaudo, 2019; Vittori, 2019).

The specific objectives of this study include describing the use of electronic voting systems by Czech parliamentary parties, with a detailed description of the system used by the Czech Pirate Party; evaluating voters' perceptions of remote electronic voting and its impact on intra-party democracy within the Czech Pirate Party; and contributing to the academic and practical discussion on the advantages and disadvantages of i-voting systems.

1.1 Theoretical background on the use of voting systems in intra-party democracy of political parties around the world

The first use of Internet voting in a primary election is considered to be the 2000 US Democratic Party presidential primary in Arizona (Solop, 2001). In Spain, at least 12 political groups, including Citizens, Comuns, CUP, Democrates, TEAM, ERC, ICV, JxCAT, Podemos, PSOE/PSC, SI and UPyD, have used the internet for their staff elections. Spain's intra-party democracy is regulated only very generally, with no minimum requirements for electronic voting systems. Article 6 of the Constitution recalls that political parties 'express political pluralism, participate in the formation and expression of the will of the people and are an essential instrument of political participation'. As a counterpart to such activities, the

Constitution emphasizes that "its internal structure and functioning must be democratic" (Barrat i Esteve, 2022).

The parties Podemos (Mikola, 2017) and Compromís used the nVotes voting system, as did the Norwegian political party Sosialistisk Venstreparti (Agora Voting, 2023). France makes a strong distinction between state-organized voting (referendums and elections) using only paper and other types of voting-related to internal representation in private companies, trade unions, political parties, or institutions, which can also take place remotely electronically. As of 2017, at least 245 companies and institutions have used the Neovote system in France for internal elections. In the primary party election of the French presidential candidate, 3 of the 5 main political parties used the Neovote system. Those are the primary for Les Républicains, the Primaire de l'Ecologie, and the Primaire Populaire (Blanchard et al., 2022). In France, Neovote clients also include the Mouvement démocrate, En Marche! and the Parti radical valoisien (Neovote, 2024).

The implementation of i-voting systems within political parties can be categorized into two groups. The first group consists of parties that have adopted i-voting systems in response to a crisis, typically poor electoral outcomes. These are generally traditional social democratic and socialist parties (Musella, 2023; Raniolo & Tarditi, 2020). The second group consists of so-called digital parties, which have utilized i-voting systems since their inception (Gerbaudo, 2019). Digital parties are characterized by replacing traditional organizational structures with online participatory platforms and communication. They aim to replace traditional local branches with online meetings, simplify party membership through online registration, and enable all registered members to vote on internal party matters. The digital infrastructure aims to reduce the costs of party organization and attract new members. Examples of these parties include the aforementioned Podemos and the Movimento 5 Stelle.

However, current research shows that although Podemos initially presented itself as an inclusive protest party, the ability of members to propose any initiatives for intra-party voting was severely limited due to the high threshold (support from 10% of the membership base) (Deseriis & Vittori, 2019). In Italy, the Movimento 5 Stelle (Von Nostitz & Sandri, 2021) is a political party known for its use of online voting, but it has faced criticism due to its lack of transparency and the complex architecture of the system that precludes horizontal interaction between users (Mosca, 2020). Furthermore, the platform is managed by an external company, and the party has no control over it (Deseriis, 2017).

1.2 Theoretical background on the use of voting systems in the intra-party democracy of Czech political parties

In the Czech Republic, the Czech Pirate Party has been using the PhpBB forum since its inception, which since 2016 has gradually been replaced by the Helios Voting system linked to other party information systems (Martínek & Forýtek, 2022). The Greens used the Belenios system (Jebavá & Masare, 2020), thus building on the European Green Party standard (Lanzone & Rombi, 2018). Mayors and Independents for the 2021 primary election used the electronic voting system Polls built on NextCloud, which would hardly meet the basic requirements for vote secrecy because it stores votes in an unencrypted form in the database.

Historically, among the parliamentary parties, we can also mention Věci veřejné, which used a system managed by NetServis for Internet voting (Kopecký, 2010). In the context of the personal election of the party chairman, approximately 800 supporters out of approximately 6,000 voted in 2012 (Husarová & Hromádka, 2012). In 2011, the TOP 09 party allowed delegates to vote for the party chairmanship via an electronic system with a tablet-based voting system (TOP 09, 2024) in order to eliminate errors when filling out the ballot (TOP 09, 2011).

During the COVID-19 pandemic, the Green Party used an official installation of the Belenios system for the staff elections, using members' e-mail addresses to prepare the voter list (Jebavá & Masare, 2020). Belenios (Cortier et al, 2019), which is based on the Helios Voting source code, also has some shortcomings (Baloglu et al., 2021a), which the active development and academic community is trying to address (Baloglu et al., 2021b).

1.3 Theoretical background on security analysis of i-voting system

Although the COVID-19 pandemic necessitated much greater use of remote communications, the development of remote electronic voting has taken place in lower-profile elections rather than in nationwide, politically binding elections. Currently, secret remote electronic voting is being used in elections for academic institutions, associations, commercial companies, cooperatives or political parties. Electronic voting is constantly addressing various cryptographic challenges (U.S. Vote Foundation, 2015), security threats (Beurdouche et al., 2017), or balancing conflicting demands such as the requirement for election integrity while ensuring voter privacy. Verifiability schemes for i-voting systems are examined in terms of usability and user experience by Marky et al. (2021). The procedural components of i-voting systems in Estonia, with an emphasis on controls related to procedural security mechanisms and measures to ensure system transparency, are examined in Nurse et al. (2017). The importance of transparency of i-voting systems is examined in a study by Agbesi et al. (2023).

In the context of secret electronic voting over the Internet, there are many parts of the entire voting system that need to be trusted and secured - from the voter's device, to the network infrastructure, to the voting system itself, including the actors involved. If a breach of integrity through an attack on the system is not discovered until after the results have been announced, it is very difficult to remedy the situation. Remote voting takes place in an uncontrolled environment where voter influence can more easily occur. Historical experience with attempts to influence the results of traditional (Transparency International, 2014) and electronic elections (Wolchok, 2012) is a constant reminder of the importance of the need to continuously improve security measures throughout the system (Bernhard et al., 2012), where a breach of integrity could have significant impacts on the whole society.

In order to increase voter confidence, it is important to evaluate the voting systems themselves and the procedures by which the election is conducted. Even so, only a few papers have addressed the evaluation of voting systems. In 2015, the IEEE did reactivate the 1622 Committee on Voting System Standards (Wack, 2014), but the result was only a set of recommendations. The Council of Europe produced Recommendation CM/Rec(2017)5 on e-voting standards (Council of Europe, 2017), which is non-binding for members, including the Czech Republic. To date, the Council of Europe e-voting standards remain the most important intergovernmental resource in this area. While these recommendations are not binding, several Council of Europe member states, such as Norway and Switzerland, have voluntarily adopted them. In Estonia, these standards have been referred to by the Supreme Court, while in Belgium they have been used as a benchmark in the evaluation of e-voting. The Committee of Ministers of the Council of Europe adopted the updated standards on 14 June 2017 under CM/Rec(2017)5 (Rodríguez-Pérez, 2022).

The Helios Voting system (Adida, 2008), which is also used by the Czech Pirate Party, has been evaluated from a cryptographic point of view by academics (Marcos del Blanco & Gascó, 2019; Panizo Alonso et al., 2018), who, however, focused only on a general evaluation of the software without evaluating the specific deployment of the system, which may be additionally modified for individual implementations.

In addition to the cybersecurity of the software itself, i-voting systems should be evaluated comprehensively in terms of ensuring the integrity of the entire election as stated by Garnett & James (2020) who define three basic principles for evaluating electoral integrity: opportunities for deliberation, equality of participation, robust electoral management quality. This paper focuses on a comprehensive evaluation of the actual implementation of the system including technical standards, regulations, and

fulfillment of democratic norms, which greatly expands the evaluation of the software alone to include an evaluation of electoral integrity not only from a technological perspective. The evaluation of a specific use case involving the whole selection process is described by von Nostitz and Sandri (2021).

2 Data and Methodology

The paper uses both qualitative and quantitative approaches for its analysis. Within the qualitative approach, the Helios application in the version used by the Czech Pirate Party will be analysed on the basis of materials from developers, professional articles, party statutes, internal party regulations, testing the system by organising its own voting and examining the source code of the application. The quantitative analysis will be based on data from a questionnaire survey conducted on a sample of 213 members and data from 207 intra-party votes.

The paper will use the analytical framework of von Nostitz and Sandri (2021) for its analysis. In their analysis of Podemos and the Movement of 5 Starts, they divide the analysis of voting platforms into two parts: democratic norms and technical standards. Democratic norms contains 5 indicators that, according to the authors, allow understanding the limits and possibilities of participation in the decision-making process. These are specifically participation, representation, competitiveness, transparency and responsiveness. Technical standards contain 4 indicators, namely: security, verification process and secrecy, data ownership and control. For each indicator, the results of both quantitative and qualitative analysis will be used. Using this methodology, it will be possible to comprehensively understand the digital democratic affordance of the i-voting system (Deseriis 2023).

2.1 Case description

The Czech Pirate Party, founded in 2009, has established itself as a notable political entity in the Czech Republic, emphasizing transparency, direct democracy, and digital rights. The party employs digital tools and online voting systems to enhance internal democracy and member participation.

Research highlights the party's strategic adjustments following its entry into the Chamber of Deputies in 2017. These adjustments involved refining their digital participatory practices to better engage voters and streamline internal decision-making processes (Šárovec, 2019). The party's use of online platforms for congresses and internal deliberation is noted for broadening participation, although it presents challenges in maintaining effective deliberative processes (Šárovec, 2022).

An analysis of the party's deliberative practices during the coalition formation in Brno in 2018 reveals both strengths and limitations. The study indicates that while the Czech Pirate Party promotes inclusive dialogue and collective decision-making, it faces challenges in ensuring all voices are effectively heard within its digital framework (Vodová & Voda, 2020).

Additionally, the party's rise in popularity and its impact on Czech politics can be attributed to its innovative practices and commitment to transparency. This commitment includes enabling broader member participation in decision-making through digital tools, which has helped maintain a tech-savvy and engaged electorate (Mortkowitz, 2019). In 2019, the party entered the European Parliament (Pink & Folvarčný, 2020). Currently, the party is represented in the government, Senate, House of Commons, European Parliament, as well as at the regional and municipal level.

Overall, the Czech Pirate Party represents a significant case of integrating digital tools into political processes, enhancing internal democracy, and engaging with a digitally-oriented voter base, making it an important subject of study in the context of political science and digital democracy (Šárovec, 2019; Vodová & Voda, 2020; Mortkowitz, 2019).

2.2 Data collection

A quantitative approach was used in this study across several datasets. In order to evaluate the impact of the digitization of decision-making processes on intra-party perceptions, an anonymous questionnaire survey was conducted among members of the Czech Pirate Party with the approval of the Bureau of the Czech Pirate Party. The draft questionnaire was tested with a group of respondents before it was finalized and, based on the findings, was modified into its final form. For the survey, the *ankety.pirati.cz* platform was used, based on the LimeSurvey application, where only Pirate Party members had access to the survey via a unique URL sent in an e-mail invitation that allowed members to fill out the questionnaire once. Responses to the survey were voluntary and anonymous, as stated on the survey homepage and in the email invitation. The poll ran from 22 February to 14 March 2024. 213 members out of a total of 1,179 party members completed the 19-question poll in full, a response rate of 18.6%. 16 research questions were Yes or No answers, 3 questions were socio-demographic questions focusing on gender, age and educational attainment.

Table 1. *Data on respondents.*

Data	Category	Number	Percentage
Gender	Women (F)	47	22,07 %
	Man (M)	146	68,54 %
	No answer	20	9,39 %
Age group	18-30 years old	27	12,68 %
	31-50 years old	93	43,68 %
	41-50 years old	56	26,29 %
	51-60 years old	24	11,27 %
	61-70 years old	11	5,16 %
	71 years and over	2	0,94 %
Highest completed education	High School	60	28,17 %
	Bachelor's	27	12,68 %
	Master's	97	45,54 %
	Doctoral	13	6,1 %
	Other	6	2,82 %
	No answer	10	4,69 %

All members of the Czech Pirate Party were invited to participate in the questionnaire; given the low number of members, the representativeness of respondents to the entire population is not addressed. Detailed survey results by question are in Appendix A. For further findings, the aggregated groups of answers for the given questions were analysed in relation to the answers to other questions. The research

method of descriptive statistics with numbers is used for the results. The data are aggregated and then interpreted verbally. Survey results are presented as percentages rounded to one decimal place.

In order to identify specific concerns and complaints about the system, on 2 June 2024 Pirates were asked to fill out an anonymous questionnaire on the *ankety.pirati.cz* platform with 4 open-ended questions on the Pirate Forum and in the Pirate communication application Zulip. Specifically, it was to elaborate on the reasons for questions 12, 15, 16 from Appendix A and one question to freely define possible concerns. By 12 June 2024, 22 critical responses were submitted, the main findings of which are paraphrased in the overall evaluation subsection.

Furthermore, an analysis of the voting history of the national Pirate Forum via the Helios system in the years 2017-2023, since the Czech Pirate Party entered the Chamber of Deputies, is used. The analysis follows both types of voting, i.e. personal elections and referendums. Personal elections include elections for party bodies, expert unions and candidates for elections. Referendums then include areas such as changes to the statutes, programmatic positions or joining a coalition. The analysis focuses on turnout in intra-party voting. Due to the large number of votes (n = 207), the data will be averaged for each year. The aim is to see if the quality of the vote (Deseriis, 2021) is sufficient to keep the average turnout stable over time.

2.3 Methodology for evaluating election turnout

Turnout (T) for each voting event is calculated using the following formula:

$$T = \left(\frac{V}{M}\right) \times 100 \quad (1)$$

Where:

- T is the turnout in percentage,
- V is the number of voting members,
- M is the total number of eligible voters (members).

To calculate the average turnout (T_{avg}) for the entire year:

$$T_{avg} = \frac{\Sigma_{i=1}^{n} T_i}{n} \quad (2)$$

Where:

- T_i is the turnout for the i-th voting event in the given year.
- n is the total number of voting events in the given year.

Turnout is calculated as the percentage of voting members out of the total number of eligible voters for each individual voting event. For each year, turnout is averaged separately for personal (denoted in Figure 1 primary) elections and referendums (denoted in Figure 1 consultations). Average turnout is a key indicator of party members' participation in voting. Higher turnout may indicate higher member engagement and higher adoption of the electronic voting system. Conversely, low turnout may indicate the need for adjustments in the system or in the approach to member mobilization.

The trend in turnout determines whether the participation of Czech Pirate Party members in intra-party voting shows an increasing, decreasing or stable tendency during the analysed period. A linear regression (Montgomery & Runger, 2010) is used to calculate the turnout trend, where the independent variable (x) is the years and the dependent variable (y) is the average turnout (T_{avg}) for each year. The linear regression equation has the form:

$$y = a + bx \tag{3}$$

Where:

- y is the average turnout,
- x is the year,
- a there's an intercept,
- b is the slope, which represents the change of the tour per unit time (year).

The regression coefficients a and b are calculated by the following formulae:

$$b = \frac{n\Sigma_{i=1}^{n}(x_i y_i) - \Sigma_{i=1}^{n} x_i \Sigma_{i=2}^{n} y_i}{n\Sigma_{i=1}^{n} x_i^2 - \left(\Sigma_{i=1}^{n} x_i\right)^2} \tag{4}$$

Where b tells whether turnout is increasing or decreasing on average each year and a:

$$a = \frac{\Sigma y_i - b\Sigma x_i}{n} \tag{5}$$

Where:

- n is the number of years,
- x_i is the *i-th* year,
- y_i is the average turnout in the *i-th* year.

2.4 Methodology for assessing the correlation between questions

Correlation analysis (Lee Rodgers & Nicewander, 1988) was used to analyse the dependencies between the questions in the dataset (Martínek & Malý, 2024). Yes responses were converted to a value of 1 and No responses to a value of 0. The correlation matrix was calculated using Pearson's correlation coefficient (Pearson, 1895). This coefficient measures the strength of the linear relationship between two variables. The resulting coefficient can take values from -1 to 1, where:

- 1 means perfectly positive linear dependence,
- 0 means no linear dependence,
- -1 means perfectly negative linear dependence.

The formula for the Pearson correlation coefficient r is:

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}} \tag{6}$$

Where:

- n is the number of pairs of values,
- x and y are the individual values of the two variables.

To interpret the results, a heatmap of the correlation matrix for the 16 research questions from the dataset is used to provide an overview of the interdependencies between the responses, which are numbered in order from Appendix A. The Pandas 1.4.0 library for the Python programming language was used for data analysis, and the heatmap was generated using the Python library Matplotlib 3.4.3 using the Seaborn 0.11.2 library.

3 Results and Analysis

3.1 Evaluation of the election process by the Helios Voting system of the Czech Pirate Party

Prior to the implementation of the Helios Voting system, the Czech Pirate Party used a polling system integrated into the phpBB discussion system, where the votes cast are not encrypted in any way and anyone with access to the database could see how each member voted. Currently, this polling system is only used to get nomination support and other less important votes. All major votes involving the election of the Bureau and members of other party organs, primary elections to fill nomination lists, recalls from Pirate Party elected positions, or referenda to change the constitution and the like are already conducted on the Helios Voting system, which uses homomorphic encryption to ensure the secrecy of the vote (Adida et al., 2009). The National Forum elects its candidates for the Euro elections, candidates for the post of Euro Commissioner, President or for the Pirate Party International organs in the primaries. Regional forums elect candidates for regional elections, parliamentary elections, senate, or nominees for national party bodies, or they can use Helios for local association primaries.

3.1.1 Regulations

Most party regulations, from the statutes to the election rules, are written without regard to the method of election, whereby an online election must be accommodated in the same way as a traditional paper-based election. The bylaws only briefly mention that voting shall be done electronically, by correspondence if possible, and with an extended voting period. The Rules of Procedure issued by the Republic Committee mention the basic requirements for Internet voting. The regulation that specifically establishes Helios as the system for secret ballot elections is the Decree on the Proceedings of the National Forum issued by the Party's Administrative Department. The Helios system is set out in the Principles for Secret Ballot Voting, including other basic requirements for the voting procedure. These are not detailed security requirements, as the policy originally regulated only unencrypted voting through a poll at the forum. All party regulations are available on the Pirate Wiki (Martínek & Forýtek, 2022).

3.1.2 Democratic norms for i-voting

Participation: The largest number of voters participated in the second round of the 2021 Helios election for party chairman in the personnel elections, with 948 members voting out of 1,232 voters and a 76.9% turnout. The largest number of voters in any election was in the 2021 Cabinet approval process, where 1,082 voters out of 1,193 participated with a 90.7% turnout.

Between 2017 and 2023 (since the Czech Pirate Party entered Parliament), 207 national votes have been launched. Of these, 118 were referendum-type votes and 89 were personnel-type votes. The overall average turnout was 34.22%, 30.66% in referendum-type votes and 38.95% in personal elections. Average turnout in both types of votes has been increasing over time. Thus, participation is stable or not declining over time, which was a problem for Podemos and Movement of 5 Stars, which experienced an initial boom and then participation declined (Deseriis and Vittori, 2019).

Party members are admitted by local associations after a public vote of the respective Bureau. The identity of party members is verified by regional coordinators and other authorized persons during physical meetings by checking ID cards or other identification. In view of the establishment of both the eDocuments digital ID card and the NIA (National Identification Authority) in the Czech Republic, there are demands among members to digitise the identity verification process.

Helios is compliant with Web Content Accessibility Guidelines 2.0 A (Marcos del Blanco & Gascó, 2019), which should allow visually impaired voters to vote independently. However, Recommendation CM/Rec(2017)5 (Council of Europe, 2017) requires WCAG 2.0 AA level of usability (W3C Web

Accessibility Initiative, 2023), which could be improved by modifying the design of the actual installation. In the questionnaire survey, 86.9% of members found the Helios voting system intuitive. The Pirates provide additional documentation to members on the website, including voting instructions, and the Pirate Party's system is translated into the official - Czech language. In terms of election typology, Helios only allows for elections based on vote counting, which excludes some alternative voting methods, as offered by the Belenios system.

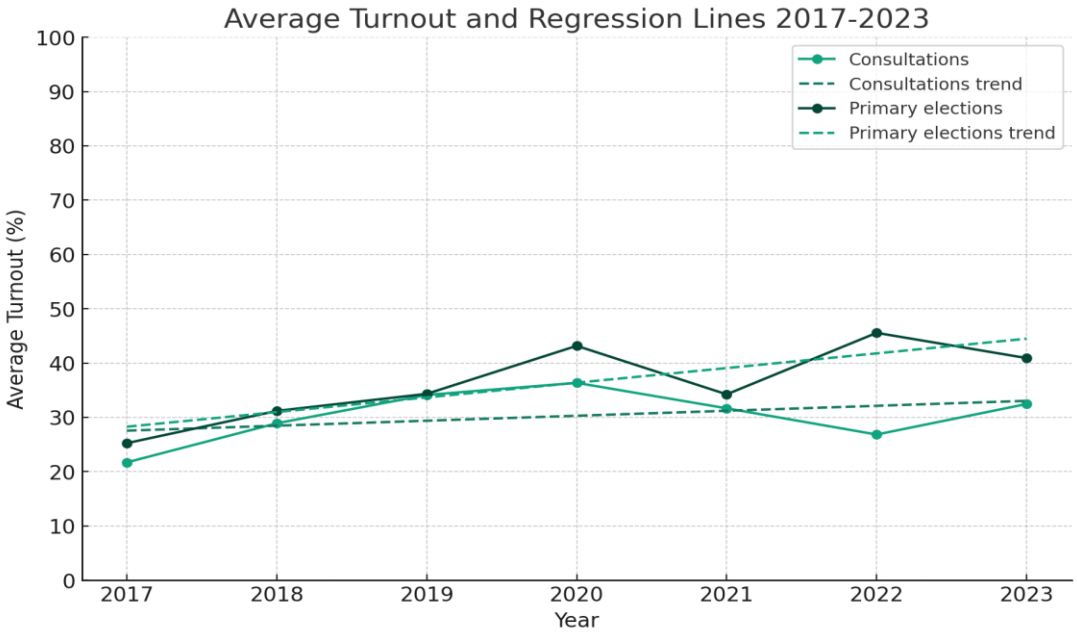

Figure 1. *Average voting participation of Czech Pirate Party members by year and type.*

Representation: All party members have the right to vote in national votes. Direct democracy thus allows the opinion of every member to be recorded, regardless of socio-demographic data. Any member can stand for election, just as any member can nominate a non-member for the primary. Although the party is male-dominated, with over 68.5% of men participating in the questionnaire survey, four women were elected in the most recent election of the five-member presidency, indicating that the electoral process does not impose barriers on the underrepresented gender. In the 2021 parliamentary elections, the average age of the candidates of the Czech Pirate Party was the lowest of all parliamentary political parties, remaining below 40 years, which was more than 9 years lower than the overall average of all parliamentary political parties and movements (Boček et al., 2021). The low average age of party members is also demonstrated by the questionnaire survey, where 56.3% of respondents are in the under 40 age category. The Czech Pirate Party does not use a quota system in voting. The average age of the survey participants is also mainly among the young and middle generation. University graduates are also over-represented among Pirate Party members compared to the average Czech population, with over 64.3% of respondents having completed a university degree. Visually impaired or otherwise disabled voters should be able to vote independently in online voting. In order to receive a nomination, candidates must by default receive the support of a group of members, the size of which is calculated according to the following formula:

$$a = 2 * \sqrt{x} \tag{7}$$

Where:

- a represents a required number of the group of members who supports the proposal,
- x represents a total number of members of the district (Martínek & Forýtek, 2022).

Competiveness: Each candidate must supply a publicly available candidate speech along with the acceptance of the nomination, as well as have basic information about themselves completed. No funds are provided to candidates in intra-party primaries. Candidates may present themselves at public candidate introductions or on their own. During the election, a list of all candidates is displayed on the Helios home page with links to their candidate speech and a personal medallion including a photo. The list of candidates in the election part of Helios is sorted randomly for each voter.

In order to mitigate the risk of pressure and corruption, the Pirates allow the ballot to be cast repeatedly until the election is over. Only the last vote cast is counted in the final results. However, according to the evaluation with recommendation CM/Rec(2017)5 (Council of Europe, 2017), the system is not resistant to coercion. As of February 2024, Pirates has deployed its own modification of the Helios system, which, while still displaying the voter list during voting, only displays the voting hash for the registered voter during the ongoing voting. As a result, information about the participation of individual members is not displayed until after the voting has ended, which is intended to reduce pressure on non-voting members.

In the questionnaire survey, 63.9% of Pirates consider it appropriate in terms of credibility that a list of voters with information about their participation be publicly available. 91.1% of respondents said they were aware of the possibility of re-voting, 81.2% of respondents used re-voting. 24.4% of respondents voted in the presence of a third person who could see the selected choice, only 2.4% of respondents voted according to the preference of the third person in their presence. 21.6% of respondents allowed themselves to be influenced by a third person when voting.

Transparency (and accountability): The foundation of open-source Helios systems is verifiability, where secrecy is ensured by homomorphic encryption. Currently, there is no formal, universal definition for E2Ev: End-to-End Verifiability because the associative and commutative operators are inaccessible to symbolic analysis tools, which for example makes it impossible to analyze the following homomorphic property as stated in (Cortier, 2015):

$$enc\ (pk;v_1) * enc\ (pk;v_2) = enc\ (pk;v_1+v_2) \tag{8}$$

where $*$ and + are associative and commutative operators. Thanks to them it is possible to sum the contents of votes (v_1 and v_2) encrypted (enc) with public key (pk) without further decrypting them individually.

Voting on the Helios platform normally runs from 10:00 am on Friday to 8:00 pm on Monday, except during the physical meetings of the national forum, when voting normally runs for an hour. Election administrators may cancel and re-announce the poll based on a discovered error or other concerns before the polls close. In the questionnaire survey, 61.5% of respondents said that the transparency of the electoral system, including access to the source code, was important to them in terms of trust.

Responsiveness: The Pirates practice direct democracy, the results are accepted by the party leadership and valid. The party's administrative department is responsible for the implementation of the results and verifies that the elections are carried out in accordance with the regulations. The standard option is the process of objecting to the presiding officer's procedure, whereby the immediate objection is decided by consensus or by a counted vote. If the objection is rejected, or if, on the other hand, the inaction of the responsible authorities appears arbitrary to some, they can appeal to the party's arbitration committee to rule on the validity of the legal act. If someone suspects manipulation of the voting system or other electoral fraud, he or she may take the complaint to the Party's Audit Committee, which should gather evidence and refer the matter to the Party's Arbitration Committee for a decision. In the context of a primary election, one can also approach the party's Republican Committee, which is in charge of electoral supervision and can make a political decision to modify the candidate list. All decisions are then subject to possible extraordinary review by the national forum. In addition to the primary elections, the Pirates also allow other votes, including the possibility of recalling elected candidates or voting on the invalidity of an election.

3.1.3 Technical standards for i-voting

Security: The servers where the *helios.pirati.cz* installation runs are under the control of the party, the TLS certificate from Let's Encrypt is used for encrypted connections, the source code of the system is transparently published on the pirate Gitlab (Martínek & Forýtek, 2022). For higher credibility, the voter list is publicly accessible - after the election is over and with information about the voter turnout, which is contrary to the recommendation CM/Rec(2017)5 (Council of Europe, 2017). The system is vulnerable to attacks on the voter client, network infrastructure and phishing etc. (Bernhard et al., 2012). On the other hand, it is a low-volume and lower-impact voting system; voting can also be postponed, which, for example, in the framework of the CNIL recommendation (La Commission nationale de l'informatique et des libertés, 2019), sets a medium level 2 risk level and thus less minimum security requirements for an Internet voting system. The academic origin of Helios has subjected the system to independent audits by the public and academic experts (Marcos del Blanco & Gascó, 2019).

According to the author of the system (Adida, 2008), Helios Voting is applicable for elections with low risk of corruption or other manipulation and low number of voters, specifically, a limit of around 1000 voters is given, although after adding additional resources the Helios system managed to process over 4000 votes during the 2009 University of Leuven elections (Panizo Alonso et al, 2018). The Czech Pirate Party has almost 1 200 members with the right to vote, and only one vote exceeded 1 000 voters, specifically the party's system managed to process the results for 1 082 votes cast to approve participation in the government. As part of the design of the election process, there is the possibility of dividing voters into smaller groups, for example by region, thus allowing more voters to vote according to designated districts, where the results can then be published simultaneously so that the groups are not influenced by each other.

Helios does not allow you to submit a wrongly filled in ticket. On the other hand, the Pirates retain the option to cast a blank ballot, which is considered a legitimate expression of the voter's will. In the questionnaire survey, 53.1% of respondents said they understand the way votes are encrypted and privacy is ensured in the Helios system, with only 13.2% concerned about breaking the secrecy of the vote. Interestingly, 47.4% of voters would not mind if someone revealed how they voted.

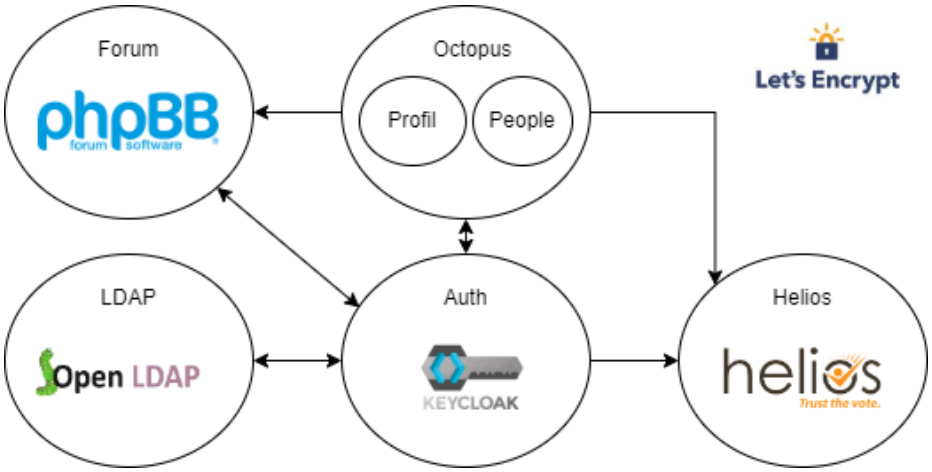

Figure 2. *Simplified scheme of the i-voting system of the Czech Pirate Party. Source: (Martínek & Forýtek, 2022).*

Verification process and secrecy: As part of eligibility, the Czech Pirate Party allows members to vote on the Helios system, which it uploads to the voter lists via an API connection from its own Octopus system, where an up-to-date register of members - eligible voters - is maintained. For authentication, members log in via the Single-Sign On system Keycloak (Martínek & Forýtek, 2022), where they can also enable two-factor authentication. Voting information is sent to the party email alias name@pirati.cz, which forwards the mail to the member's private email.

Helios has a cast-or-audit approach for casting as intended, i.e., the voter can check his vote as many times as he wants until he is convinced that Helios is trustworthy. For being recorded as cast, the voter receives a hash of his encrypted vote, which he can later check in the electronic ballot box. The party uses the current version of Helios version 3 with custom modifications (Bernhard et al., 2011). Since Helios version 2 (Adida et al., 2009), exponential El Gamal with homomorphic property is used for encryption. Finally, for the recorded state, ElGamal along with the Sako-Kilian mixnet (Sako & Kilian, 1995) are implemented Zero Knowledge Proof (ZKP). As a result, Adida concludes that Helios is E2Ev (Adida, 2008) if the ballot box and the voting authorities are honest. Otherwise, either party could irregularly add votes (Marcos del Blanco & Gascó, 2019).

An example of a website with published election results is shown in Figure B1 of Appendix B. In the survey, only 31% of party members actually verify the presence of the displayed tracking code in the publicly accessible electronic ballot box.

Data ownership: the Helios system is provided free of charge without any guarantees based on the Apache 2.0 license, so the party has only the costs of implementation, operation and maintenance of the system on its servers. The party manages the personal data of its members through a self-developed Octopus application. The party states that it handles personal data in accordance with the GDPR, with the head of the administrative department (Pirates, 2022) as the proxy. After decryption, the aggregated election results are displayed to all voters.

Control: Votes are encrypted by default with the Helios Voting system, which then uses ElGamal homomorphic encryption (Pereira, 2016) to keep the vote secret, allowing the overall result to be calculated without having to decrypt individual votes.

As part of the shared responsibility, the Pirates always use at least 3 party members as trustees for the national vote, who together with the election server generate their own keys needed for the final decryption and verification of the overall result. For county forum elections, the multiple trustees rule is not always followed, which increases the risk of privacy breaches as well as reducing credibility.

The system runs on a server controlled by the party, which is located in the Czech Republic. Access to the server is restricted to system administrators who have been authorised by the head of the Party's technical department. The server is backed up. In the questionnaire survey, 89.2% of members are satisfied that the Helios system is managed directly by the party.

3.2 Overall evaluation of the Czech Pirate Party's i-voting system

Overall, the Pirates rate the Helios system for their online voting positively, specifically 96.2% of respondents believe that the Pirates should continue to allow electronic voting through the Helios system. 93% of respondents believe that their participation would decrease if online voting were replaced with traditional paper voting during national or regional forum meetings. 98.6% of respondents believe that remote electronic voting facilitates their intra-party functioning.

Other interesting findings include that 71.4% of respondents who are concerned about breaking the secrecy of the vote do not understand the way the vote is encrypted in Helios. On the other hand, only 44.2% of those who are not worried about breaking secrecy do not understand the vote encryption system. This indicates the importance of the need for sufficient awareness of the operation of the system. Furthermore, respondents (3.8%) who do not want to continue using the Helios system from 87.5% do not find the system intuitive and do not understand the way of vote encryption in the Helios system. Thus, in addition to sufficient awareness, the User Interface of the system could also be improved.

The Helios system is based on all actors taking the maximum possible steps to verify their actions to ensure the integrity of the election. The fact that only 31% of the members performed at least one verification of the presence of a tracking hash in the ballot box may increase the risk of vote manipulation.

The open-ended responses also repeatedly request that alternative voting methods be made available, which, unlike the newer Belenios system, Helios does not offer. In terms of intuitiveness, respondents criticise that voters are often unaware of the option to cast a blank ballot, which is essentially a vote against all options. Elections with only one voting option often end successfully for that option. Respondents are also concerned about breaking so-called perpetual privacy (Haines et al., 2023), as the system displays a permanent tracking hash next to the voter's real name in the publicly accessible ballot box. With the increasing power of quantum computers, the asymmetric cipher could be broken in the future (Bavdekar et al., 2022), which would allow the ballots in the electronic ballot box to be declassified. Critical respondents of Internet voting are also concerned about possible vote manipulation. Respondents also condition the operation of the voting system aside from sufficient transparency.

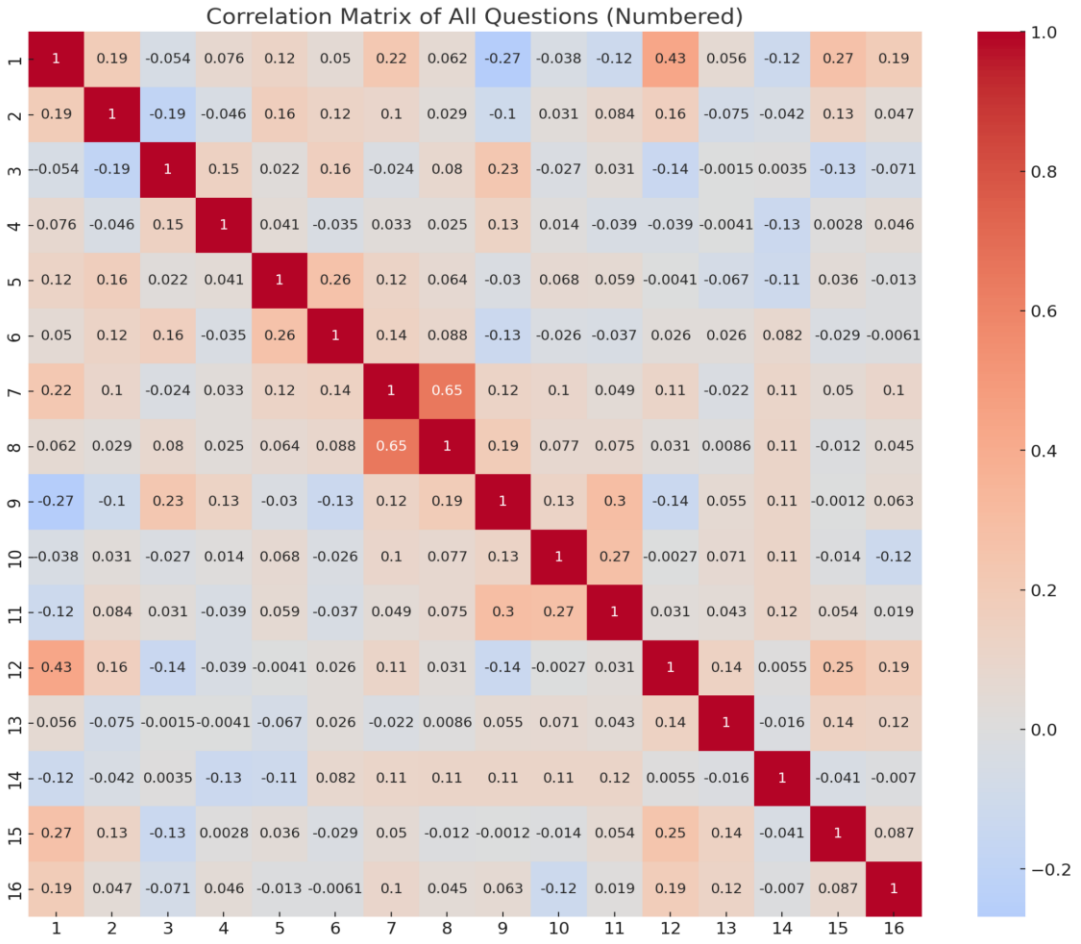

Figure 3. *Correlation matrix of questions numbered in order from Appendix A.*

In the correlation analysis, there is a strong positive correlation of 0.65 between awareness of the possibility to vote repeatedly and the actual use of this possibility. Respondents who find the system intuitive often support the continuation of e-voting, as reflected by a correlation of 0.43. There is a correlation of 0.3 between questions focusing on choice in the presence of a third person and choice according to the third person's wishes. A recommendation might be to add a disclaimer at the beginning of the choice that the choice of options must be made independently without the presence of a third person. The perceived importance of the transparency of the voting system is moderately correlated (0.26) with the verification of the tracking code after the vote is cast.

To assess the integrity of the entire electoral system of the Czech Pirate Party, the Garnett & James (2020) framework can be used, which assesses three main principles. Within the Deliberative Opportunities principle, it can be said that each candidate in the primary elections has the opportunity to promote

himself or herself in the candidate and nomination speeches, where direct communication with voters is possible through the Forum. The Pirates do not put barriers to candidacy, every member has the right to nominate anyone and anyone who gets enough support gets the opportunity to run.

Under the principle of Equality of Participation, the election can be said to be direct, which ensures the right to participate for every member of the Forum. The announced election through the Helios Voting systems within the digital party, taking place at predetermined times, ensures that the election is accessible to all voters with access to the Internet. With i-voting, similar to other voting systems, potential security risks are present, including concerns about vote tampering, etc.

Under the third principle of Electoral Management Delivery, it can be stated that the method of election seeks to be as transparent as possible. Even to the extent that displaying real names in the public ballot box may compromise privacy. On the one hand, the system makes it impossible to cast an invalid ballot by mistake; on the other hand, cases have been reported with the Helios system (Acemyan et al., 2014) where the ballot is not completed even though the voter believes that he or she has cast the ballot. Universal verifiability should provide a mathematical proof to guarantee the correct counting of the votes cast (Adida et al., 2009). The system used entails low implementation and operation costs only within the party's own technical department staff and the hardware used.

In general, the answers to the three basic questions of adoption, ownership and contingency planning defined by Garnett & James (2020) can also be stated, where the Helios Voting technology is known to be combined with other party systems, where the party is the operator of the technology and the owner of the resulting data, and where any voter has the ability to contest an election in the event of a technology failure or malfunction, just as the party's administrative department can call a rerun election.

4 Discussion

In the Czech Republic, political parties that emphasize direct democracy and greater member participation are trying to make intra-party elections accessible through online voting. Parties such as ODS, Freedom and Direct Democracy, ANO 2011 and others continue to let national staff elections be decided indirectly by delegates through traditional paper ballots or by appointment based on leadership decisions. Also because the Czech Pirate Party does not use a quota system in voting, nor does it create any inclusive space for minorities (Lupato and Meloni, 2023), it is a relatively more inclusive system compared to Podemos or the Movement of 5 Stars, which allows members to be more actively involved in intra-party affairs (Deseriis and Vittori, 2019).

Due to the open source nature of the Helios system, it has been subjected to several security analyses (Adida et al., 2009, Bernhard et al., 2012; Acemyan et al., 2014; Marcos del Blanco, Gascó, 2019), and although the system has its shortcomings (Baloglu et al., 2021), it performs well for smaller elections with fewer voters (Panizo Alonso et al., 2018). The downside remains that the Helios system is no longer under active development and academics have focused on developing other open source voting systems such as Belenios or have moved on to developing commercial voting tools.

Voting systems for intra-party democracy of political parties and movements are regulated in a very limited way. One exception is France, where internet voting systems are subject to minimum requirements from the CNIL (La Commission nationale de l'informatique et des libertés, 2019). Countries such as Switzerland and Estonia have adopted regulations for internet voting, but these primarily apply to national politically binding elections (Von Nostitz et al., 2021). In contrast, laws in Germany do not allow for internet primary elections of political parties without traditional paper confirmation, as the requirements from national politically binding elections are transferred to intra-party democracy (Fitzpatrick & Jöst, 2022). Furthermore, Recommendation CM/Rec(2017)5 on standards for e-voting applies to members of the Council of Europe (Council of Europe, 2017). The importance of adhering to the

standards is compounded by the fact that, as in some municipalities in Canada, online voting is the only possible channel of election for Pirates (Essex & Goodman, 2020).

The lack of legislation regarding compliance with mandatory minimum standards for political parties' online voting systems increases the risk of vote manipulation and the number of security threats, as election organizers are not forced to transparently publish the source code to verify the correct functionality of the system, ensure monitoring, auditing, or other security analyses. Basic security analyses are only possible when using open source systems such as Helios Voting (Panizo Alonso et al., 2018) or Belenios (Cortier et al., 2020), or when developers actively collaborate, as in the case of Scytl's iVote (Marcos del Blanco, Gascó, 2019) or nVotes (Marcos del Blanco et al., 2020), or based on election observation data such as Neovote (Blanchard et al., 2022), where it can be inferred from the observation itself that the Neovote system does not meet the CNIL requirements (La Commission nationale de l'informatique et des libertés, 2019). Based on recommendation CM/Rec(2017)5 (Council of Europe, 2017), a baseline assessment of the entire electoral process can be made, although it is difficult for the evaluator to answer whether all requirements are met (Brunet & Essex, 2023).

Collaboration with academics and other cryptography experts is essential to verify that the system works as intended and that the results match the reality of the vote. Even if it is only an intra-party primary, the consequences of a breach of voting integrity can be similar to those of a political national binding election. For example, if a major political party were to select a presidential candidate through an intra-party vote, a person who does not actually have the support of his or her own political party could become president in the event of an electoral victory.

5 Conclusion

This study evaluated the i-voting system of the Czech Pirate Party based on the software Helios, focusing on its democratic and technical attributes. Our findings demonstrate that the Helios system successfully enhances member participation and transparency, similar to other digital parties. While Podemos and Movimento 5 Stelle have encountered issues with limited member initiative and transparency (Deseriis & Vittori, 2019; Von Nostitz & Sandri, 2021), the Czech Pirate Party's use of Helios provides a more transparent and participatory model.

Key insights from our research include the high satisfaction rate among party members with the Helios system, the stable voter turnout over time, and the system's compliance with basic security standards. The transparency of the system is considered important with respect to credibility. On the other hand, the display of real names in the ballot box is seen as a potential privacy threat in the future, so the possibility of replacing real names with aliases is offered.

Our study's limitations include its focus on a single case, which restricts the generalizability of the findings. The Czech Pirate Party represents a unique context with a specific set of values and technological literacy among its members, which may not be applicable to other political parties or cultural contexts. Additionally, the sample size and the specific demographic characteristics of the Czech Pirate Party members limit the extent to which these findings can be generalized to other political organizations.

Future research should explore multiple case studies across different political and cultural settings to better understand the broader applicability of i-voting systems. Comparative studies with other digital parties, particularly those using different voting platforms, can provide deeper insights into best practices and potential pitfalls in the implementation of i-voting systems. Further investigation into the long-term security and privacy implications of i-voting, particularly in light of emerging technologies, is essential. The experience with the Czech Pirate Party's system could help to develop a national recommendation, along the lines of the French CNIL (La Commission nationale de l'informatique et des libertés, 2019), which could define basic requirements for other secret online elections held in parties, institutions, organisations

and other departments. Moreover, research on how different demographic groups within political parties interact with i-voting systems could provide valuable insights into improving accessibility and inclusivity. Exploring alternative voting methods and their integration into existing platforms like Helios could also enhance voter confidence and participation.

In summary, the Czech Pirate Party's implementation of the Helios i-voting system represents a significant advancement in integrating digital tools into political processes. The system has proven effective in fostering internal democracy and engaging a digitally-oriented voter base. However, continuous evaluation and adaptation are necessary to address emerging challenges and ensure the integrity and inclusivity of the democratic process. The experiences of the Czech Pirate Party can serve as a valuable model for other political organizations seeking to adopt digital voting systems, but they must consider the specific needs and contexts of their own memberships.

This work contributes to the current discussion of decision-making voting platforms in political parties. Compared to Podemos and Movimento 5 Stelle, Helios offers more transparent conditions for its users (Deseriis & Vittori, 2019). A crucial difference is the scale of participation: the Helios platform was created for an effective scale of only a few thousand users, whereas Participa (Podemos) and Rousseau (Movimento 5 Stelle) platforms are designed for hundreds of thousands of members. Unlike the German Pirate Party, which used LiquidFeedback, Helios does not allow for vote delegation and tries to maintain an egalitarian approach to voting (Deseriis, 2021). The overall ease of voting for members is relatively high, and the platform can be described as user-friendly (Deseriis, 2023).

Additional Information and Declarations

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Conflict of Interests: Tomáš Martínek is a member of the Czech Pirate Party. The second author, Michal Malý, who critically analysed the findings, is not a member. The authors approached the analysis with a critical eye to ensure that a trustworthy and secure online voting system would enable the preservation of a functional intra-party democracy.

Author Contributions: T.M.: Conceptualization, Data Curation, Investigation, Funding acquisition, Project administration, Supervision, Validation, Visualization, Software, Resources, Writing – Original draft preparation. M.M.: Methodology, Formal Analysis, Writing – Reviewing and Editing.

Institutional Review Board Statement: Ethical review and approval were waived for this study due to prior approval from political party leadership.

Informed Consent Statement: The anonymous questionnaire survey was conducted on the basis of the consent of the Bureau of the Czech Pirate Party. Each participant of the anonymous survey was informed about the anonymous nature of the survey, including other documents and consent, in an invitation e-mail.

Data Availability: The data that support the findings of this study are openly available in Zenodo at https://doi.org/10.5281/zenodo.10829926.

Appendix A

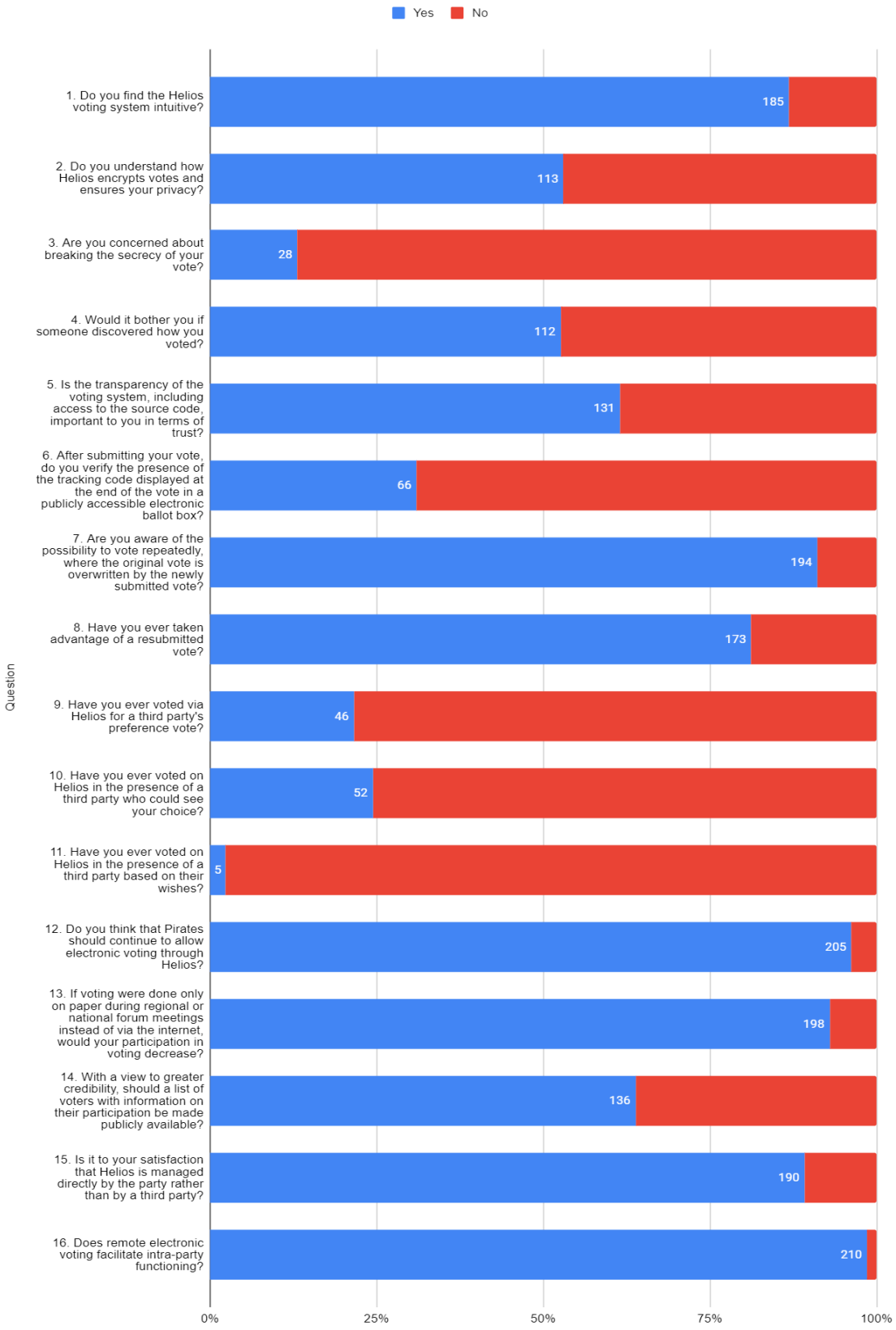

Figure A1. *Results of the Helios survey among Pirates members, N=213. Source: (Martínek & Malý, 2024).*

Appendix B

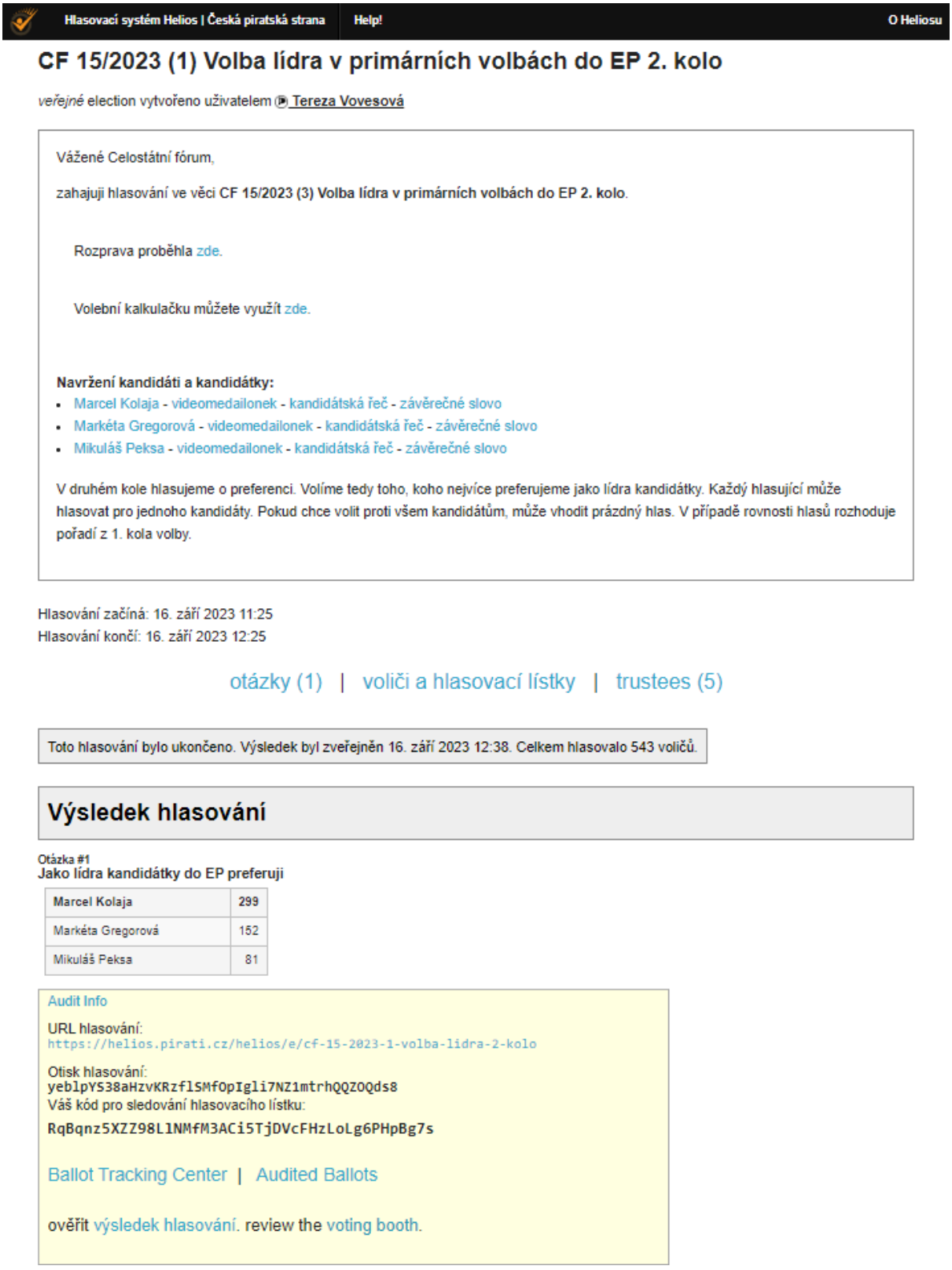

Figure B1. *The web page of the Helios.pirati.cz system with the published results of the second round of the election of the leader for the Euro elections. The final results page contains at the top the name of the election, below the name of the election administrator, below the information about the voting methods and candidates displayed to all voters even before the election, including links to the candidates' speeches and other information about the candidates, below the start and end dates of the voting, below links to the questions, the list of voters and the list of trustees, below voting information including the total number of voters, below the results for each candidate, and in the expanded yellow box, the supporting documentation for individual audit verification including the vote imprint and ballot tracking code.*

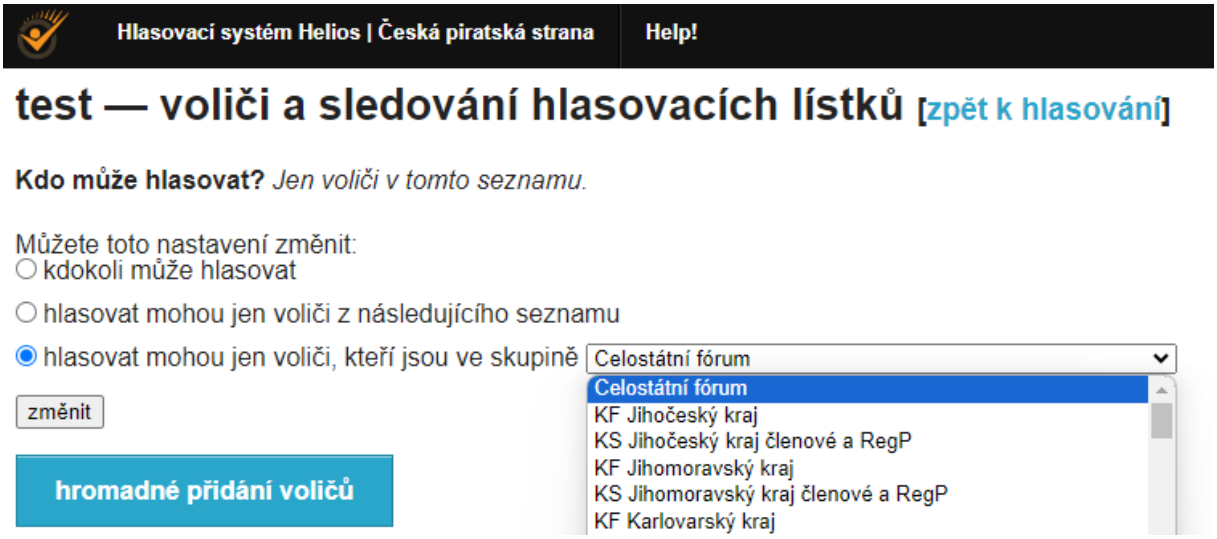

Figure B2. *The page for adding voters to the election. In addition to the basic Helios options, Pirates allows election administrators to select a third option where voters who are in the selected group are selected to vote. A group can be a national forum that includes all party members, or a regional membership group such as a regional or local forum, or a regional or local association that includes registered supporters. Uploading voters is done when the blue bulk add voters button is pressed. The source of the actual data is the linked Octopus application.*

Figure B3. *Publicly accessible electronic ballot box page. Pirates in the ballot box display the real names of voters next to the ballot tracking code, which may compromise privacy in the future. In this case, it is an electronic ballot box from a county primary election to cast a write-in ballot for a county election. The name of the election is displayed at the top, with who can vote defined below, a search, and then a public list of voters.*

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