

Voting software to support election preparation, counting, and tallying

Case Study of the Technische Universität Darmstadt

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Abstract: At the Technische Universität Darmstadt (TU Darmstadt) more than 27,000 voters have the possibility to cast a vote in several annual elections. Currently this is done on paper and the election outcome is counted by hand. The election is very complex due to the number of different departments, groups, and boards resulting in a large number of different races. Consequently this leads to a high administrative effort, and is also a potential for many accidental mistakes. This paper analyses whether, and under which conditions, the software called UniWahl4 in combination with a scanning and counting software called VividForms could be used in elections at the TU Darmstadt in order to simplify the process, reduce mistakes, and ideally to reduce the costs. As a result, we identify advantages, missing functionalities, and possible improvements for this particular solution. Based on this, we provide recommendations for future computer assisted elections at the TU Darmstadt. This paper also supports other universities in their decision to use this solution because, currently, neither scientific studies nor field reports are available for UniWahl4 and VividForms.

Keywords: eVoting, computer assisted election preparation, scan based counting

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1. Elections at the TU Darmstadt

Currently, there are 23,100 students studying at the Technische Universität Darmstadt (TU Darmstadt). Moreover, 270 professors, 2,150 scientific members, and 1,750 administrative members are working at the TU Darmstadt¹. Correspondingly, more than 27,000 people are eligible to cast their vote in the annual election. This election² spans several races namely for the student parliament, for the council of students association, for the department councils, for the

¹ http://www.tu-darmstadt.de/universitaet/profil_1/zahlenundfakten/index.en.jsp, Retrieved Feb 28, 2011.

² There are even more small elections; but which are not taken into account for this paper.

university parliament, and for the boards of directors. Not every voter is eligible to vote in all of these races; some are group-specific, others depend on the department affiliation. Not all of these races run every year and some are not run for all four groups of voters (students, professors, scientific and administrative members). For instance, only students vote in the student parliament race. The university distinguishes between two different types of elections. The election is called a *large election* when all groups are eligible to cast a vote for their representatives in the university parliament and the department councils. Every second year just students vote in these two boards and all scientific and administrative members just vote for their boards of directors. This election is then called a *small election*. Other races like the representative of the student parliament are held every year.

These different races (depending on the number of different departments, the four different groups of voters, and the different boards) result in a large number of unique ballot sheets which are necessary for each election. For example in 2010 there were 89 (in 2009: 75). Most (55) of the ballot sheets are for the races of the board of directors. Moreover, every voter gets more than one ballot sheet, e.g. the students of the Faculty of Architecture got three and all others got four. The election organization gets even more complex because different legal regulations³ are in place for different races; for instance, in general the university runs a party-proportional representation and the constitution of the students (StSTUD, 2010) requires the application of the Sainte-Laguë algorithm⁴ for the assignment of seats, while the legal foundation of the TU Darmstadt (WOTUD, 2004) requires the application of the largest remainder method (according to Hare-Niemeyer⁵) for all other races. In 2010, sixteen races have been held using the Sainte-Laguë algorithm and 73 using the Hare-Niemeyer algorithm. If only one party exists (which happens quite often) or only one seat will be assigned (boards of directors) the university runs a plurality voting system (WOTUD, 2004). In 2010, 30 races (88.24% of all 34 races with party-proportional representation) nominated only candidates of one party. As the number of free seats varies for each group and for each board, the rules to cast a valid vote are different in each race.

So far, the elections are held in polling stations using traditional paper ballots as well as through postal voting. In 2010 the voter turnout was 23.84% amongst all voters (23.73% amongst students), and 30.51% amongst all voters (29.78 % amongst students) in 2009⁶. In the following, we will explain the processes implemented at the TU Darmstadt for the three phases of an election; namely the pre-election phase, the election phase, and the post-election phase.

Pre-election phase. In the pre-election phase all documents like the list of candidates per board and group of voters, ballot sheets, documents for postal voting, counting sheets, tallying tool in Excel, and election result reports are created manually. The election officer first enters the candidate information per race into a document⁷ which is then used as basis to compile all other documents. The data is manually copied and pasted from this document to the others (all either templates in Word or Excel). This whole process is very complicated, time-consuming, and obviously error-prone. Ballot sheets are printed on papers with different colours to simplify the

³ The legal foundation of the 'Wahlordnung der Technischen Universität Darmstadt' (WOTUD, 2004) is the 'Hessisches Hochschulgesetz i.V.m' (HHG), the 'Grundordnung der Technischen Universität Darmstadt' and the 'Satzung der Studierendenschaft der TU Darmstadt' (StSTUD) in the respectively valid version.

⁴ , <http://www.wahlrecht.de/verfahren/stlague.html> (German only), Retrieved Feb 28, 2011.

⁵ <http://www.wahlrecht.de/verfahren/hare-niemeyer.html> (German only), Retrieved Feb 28, 2011.

⁶ http://www.intern.tu-darmstadt.de/dez_ii/wahlamt_1/wahlamt.de.jsp (German only), Retrieved Feb 28, 2011.

⁷ Using Word or Excel templates.

delivery of the right ballot sheets for a particular group of voters but also to simplify the sorting for the counting phase.

Election phase. The polling stations are open for four days from 10.30 am to 2.30 pm. There are two different polling stations at two different locations; both close to or in the canteen. The voter can decide where to cast his vote because the polling stations are connected with an online voter register over the TU Darmstadt intranet. As it is no easy task for the poll workers to decide on Election Day which group of voters gets which ballot sheets, every poll worker is in charge of a particular group of voters (students, professors, scientific and administrative members). The voter gets his corresponding ballot sheets and an envelope, casts a vote in the polling booth, puts the ballot sheets in the envelope, and puts this envelope into the ballot box. There are different ballot boxes – one for each group. During the four election days, in 2010, 20 poll workers per day were required.

Post-election phase. After having closed the polling station, the ballot boxes are carried to a central place, where all votes including the postal votes are counted. Before starting the counting, the envelopes are opened and the ballot sheets are sorted according to the races. Stacks of 50 ballot sheets per race are built. At every table four people count in pairs of two while in general there is one additional person supervising and observing this process. Votes are counted using counting sheets⁸ per race and candidate. In general, one person of the team reads aloud the chosen candidates or mentions that the vote is invalid to the other one in the team, who adds a bar for the corresponding candidate in the counting sheet. After the counting the tallying starts where the seats of the party-proportional representation are assigned using the largest remainder method or Sainte-Laguë. Note that the results of the plurality voting system can be entered directly in the report of results.

In 2010, 40 poll workers counted and tallied the votes. In 2010 they had to count 18,276 votes (bear in mind, there were 89 different types of ballot sheets). It was even more effort in the large election 2009 where the poll workers had to count 22,565 votes on 75 different ballot sheets⁹. Although neither cumulative voting¹⁰ nor vote splitting¹¹ is used, the utilisation of a counting sheet frequently leads to errors and due to the high number of voters and different types of ballot sheets and rules to cast a valid vote, the poll worker often have to stay until late at night. As a result it is natural, due to the human factor in elections that the poll workers take a pass on recounting or work inaccurately.

Due to the large number of voters, different groups, different departments, and different boards, and consequently many different types of races and corresponding ballot sheets, the actual election causes a *high administrative effort in particular during the pre- and post- election phase*. Moreover, the whole process is *error-prone* caused by the huge number of *manual steps, different races with different rules for valid votes and different tallying algorithms*. Therefore, we analyse in this paper whether computer assistance for the pre- and post- election phase¹² can improve the situation and thus decrease the administrative effort and increase the accuracy of the election

⁸ Next to each candidate's name is a free space where the poll worker can make a bar for every valid vote (for the corresponding candidate).

⁹ http://www.intern.tu-darmstadt.de/dez_ii/wahlamt_1/wahlamt.de.jsp (German only), Retrieved Feb 28, 2011.

¹⁰ In cumulative voting, voters can cast multiple votes for one candidate (e.g. three for one candidate instead of one for three candidates).

¹¹ In vote splitting, the voter can cast multiple votes and can cast these for candidates from different parties.

¹² Electronic voting or in particular online voting has for now not been considered for the TU Darmstadt caused by the decision of the Federal Constitution Court 2009. This may be a topic for further research.

result without changing the vote casting process for voters. In particular, we analyse whether, and under which conditions, the software called UniWahl4 in combination with a scanning and counting software called VividForms can be applied for the above mentioned elections at the TU Darmstadt.

We decided to analyse this particular solution because UniWahl4 was developed primary for elections at universities and it has been used for many years at 55 institutions at least to support the pre-election phase. Further, UniWahl4 provides an interface to VividForms to tally the votes scanned and counted by VividForms which is used for example at the University of Potsdam. Moreover, VividForms is a part of EvaSys Education which is developed by Electric Paper especially for organisations in the education field and thus used by many universities. It is already used by the '*Hochschuldidaktische Arbeitsstelle (HDA)*'¹³ of the TU Darmstadt for course evaluations. Correspondingly, the university already has experience with this software and owns the corresponding scanners and licences.

In Section 2, we describe how UniWahl4 supports election preparation and explain scanner based vote counting with VividForms as an extension to UniWahl4. In Section 3, the feasibility analysis of UniWahl4/VividForms for elections at the TU Darmstadt is proposed. Here, the required functionalities are compared with the supported ones in particular related to the ballot sheet layout, supported legal regulations, and precision of the scanner based counting. Before we summarize our results and deduce recommendations for future elections at the TU Darmstadt in Section 5, we analyse in Section 4 other projects introducing electronic voting for lessons learned to take these into account for our recommendations.

2. UniWahl4 and VividForms

This section introduces UniWahl4 and its functionalities. In addition, the software called VividForms as basis component for scanned based counting is introduced and the interaction between these two components is explained.

History. In 1998 Prof. Frens Peters and his team from the University of Applied Science in Hannover implemented the UniWahl4 software which is continually improved and extended. So far, 55 universities and universities of applied science bought the software¹⁴. The company Electric Paper developed EvaSys Education for the education field to provide computer assistant course evaluation which is used in many universities. In 2005, the developers of UniWahl4 and Electric Paper¹⁵ started a common project with the goal to integrate scanning and automatic counting of votes in UniWahl4. Correspondingly, licences from both companies namely UniWahl4 and Electric Papers are required¹⁶ to use the full functionality¹⁷ for UniWahl4.

¹³ The '*Hochschuldidaktische Arbeitsstelle*' is a central scientific institution at the TU Darmstadt which supports the further improvement of teaching by advising, evaluation, projects, studies and education.

¹⁴ <http://www.uniwahl-soft.de/Download/Installationen-Tabelle-kurz.pdf> (German only), Retrieved Feb 28, 2011.

¹⁵ Electric Paper provides data acquisition and data evaluation software for several areas of application. EvaSys Education is especially for organisations in the education field and mainly used to create questionnaires, read them in by a scanner and evaluate the data automatically (<http://www.electricpaper.de/produkte/evasys-education.html>) (German only), Retrieved Mar 2, 2011.

¹⁶ Starting in 2011, the scanning and evaluation software will become part of the UniWahl4 software and the whole solution will be sold by UniWahl4. As further information about this new product is not yet available, we will not take this new development into account for our paper.

¹⁷ Two other options are the application of electronic tallying with EvaSys in the absence of UniWahl4 and the tallying script developed and used at the Otto-von-Guericke University Magdeburg. As the first one has

UniWahl4. The software UniWahl4 assists election authorities in all steps of an election. They can set up different races, defining title, rules to cast a valid vote, and the candidates. The software supports different legal regulations and election types including cumulative voting or belated nomination¹⁸ as well as personalised, bounded and combined lists¹⁹ for party-proportional representations and plurality voting. The software automatically switches from a party-proportional representation to a plurality voting system when just one party is nominated. It also supports different tallying algorithms namely D'Hondt, Sainte-Laguë, and Hare-Niemeyer and offers the possibility to use a lottery for the assignment of free seats. During the electoral process all necessary documents such as;

- time tables with all dates and deadlines in the electoral process,
- election overviews with all races and number of free seats,
- election announcements as pdf or html
- documents for postal voting,
- ballot sheets
- counting sheets
- election result reports

can be automatically generated by UniWahl4. The election officer defines text outputs and layouts of all these documents. For example it is possible to represent the candidate names on the ballot sheet in a table with multiple columns. According to this a ballot sheet contains a maximum of around 50 candidates. Afterwards they have the possibility to change the ballot layout in Word before printing the ballot sheets. To simplify the input of data for candidates and voters (to generate for example documents for postal voting) a voter register can be integrated in UniWahl4. In the post-election phase the electoral office can enter the results in UniWahl4 by editing the number of valid votes in the field next to the candidate. Further fields exist to enter the number of valid and invalid ballot sheets (Peters, 2010b).

VividForms. VividForms is a part of the software EvaSys Education from Electric Paper. The marked ballot checkboxes are detected by their filling degree and the user can set the preferred settings. For example it is possible to specify that a fully filled ballot checkbox is interpreted as a revision and the user can declare from which threshold on a checkbox is identified as marked.

Combination of UniWahl4 and VividForms. UniWahl4 provides an interface to the VividForms Reader and VividForms Scanstation to load scanned votes. Further, it provides a new interface called VividForms Creator. This interface was developed by Electric Paper. VividForms Creator adapts the ballot sheets created with UniWahl4 in a way that the other two components are able to properly scan and interpret the scanned image. Every ballot sheet has marked edges so that the scanner can identify the position of the ballot sheet and as a result also the position of the several ballot checkboxes. In addition every ballot sheet contains a barcode which defines the related election in order to associate the filled ballot checkboxes with particular candidates (compare to Figure 1c). Therefore it is not necessary to sort the ballot sheets by races before scanning. VividForms Creator also generates an electronic version of the ballot sheet which is imported to

several disadvantages (in particular regarding usability) and as information about the second one is missing, these options are not considered in this paper.

¹⁸ In belated nomination the voter has the possibility (during the casting of votes) to nominate and vote for a further person which is not nominated so far.

¹⁹ When a personalised list is used the voter casts several votes for candidates (of several lists). When a bounded list is used the voter casts votes for several lists (but not for the candidates in the lists). When a combined list is used the voter has the possibility to cast votes for several candidates and lists (combined the principle of personalised and bounded lists).

the VividForms Scanstation and an xml-description for the VividForms Reader. With this information, the votes can be scanned, counted and imported to UniWahl4 for the final tallying. Afterwards, it is possible to change the design of the ballot sheets or add comments as long as the position of the ballot checkboxes stays the same. Note, not all UniWahl4 functionality to create races and ballot sheets is available if it is used in combination with VividForms to import the scanned and counted votes. Examples include paper formats other than DinA4 like landscape, DinA5, DinA3 or duplex which are not supported. In addition it is not possible to integrate several races on one ballot sheet because every type of vote has its own barcode for identification. The use of a table with multiple columns to present the candidates is supported but the name of each candidate has to fit in one line. Most of the legal regulations are implemented but the use of bounded or combined lists and vote splitting is not supported.

3. Feasibility analysis

After having understood the election with all the different races at the TU Darmstadt and the functionality of both UniWahl4 and the VividForms extension, we analysed the feasibility of these solutions for the election at the TU Darmstadt. As a result, we identify advantages, missing functionalities, and possible improvements for this particular solution. Our analysis is divided in two parts: First, we created the 2010 election with the 89 different races in UniWahl4 (which we got for free for our research) and then we visited the developers of UniWahl4 at the University of Applied Science in Hannover for a workshop. Here we could ask questions and observe the scanning and counting of votes with VividForms and how the result of the counting is imported to UniWahl4. We scanned a stack of ballot sheets more than one time, folded a couple of ballot sheets, used coloured paper (light yellow, which is currently not used at the TU Darmstadt) and added some invalid ballot sheets. Furthermore we could gather experiences how long electronic tallying takes.

The goals of these two case studies were to analyse;

- (1) whether the solution as a whole is user-friendly by identifying where we had difficulties to proceed,
- (2) whether the provided functionality is sufficient for the TU Darmstadt election in 2010 including
 - o providing all information on the ballot sheets which are currently provided
 - o supporting all different ballot formats and tallying algorithms,

In addition we analysed

- (3) whether and where the election administration process could be simplified with this solution, and
- (4) whether the election results would be more reliable and accurate as with manual counting.

Our results are categorized according to the different phases of the case studies.

Installation. It was easy and straight forward to install UniWahl4 on the local PC. The accessibility of VividForms on the other hand was problematic. At the TU Darmstadt VividForms is installed on a server and can be accessed by a web interface. It was neither possible to additionally install it on a local PC nor use this server version. The last one was not possible as it is necessary to replace some of the VividForms files by those delivered with the UniWahl4 software. The problem was that the HDA were evaluating lectures and were afraid to replace files of the running system. In addition, it is recommended to install both components on a local PC which is used only for elections. This has two reasons: First, other functions of the course evaluation are not disturbed and second, the evaluation part cannot interfere (or even manipulate) the counting process. This makes sense. However, it means that the TU Darmstadt would need at least one additional VividForms license. Note, the installation will become much easier as soon as VividForms is also

integrated in UniWahl4 and as a result just one software package has to be installed. However, the cost will increase.

Election, races and ballot sheet generation. It took us a while to get used to the UniWahl4 software although the manual (Peters, 2010b) is very detailed. In particular we had problems to identify which text field and which option in the software causes text at which position on the ballot sheet and causes which layout. The software uses a cloze and fills the blanks with the appropriate information. It was confusing that some text fields were global ones and thus modify all ballot sheets and others like the name of the board and the name of the voter group modify single ballot sheets. The cloze is made for an election where all races are related to one board why we had to generate several UniWahl4 data files to adapt the layout of the TU Darmstadt ballot sheets (one file for every board). The layout of the original TU Darmstadt ballot sheets could not be copied but those designed with UniWahl4 contained all important and necessary information from the original TU Darmstadt ballot sheets (compare to Figure 1c)). However, this does only hold without the application of VividForms . VividForms could not carry over the text layout and some design layouts constructed in UniWahl4. For example the ballot checkboxes next to the candidates to mark a selection on the VividForms ballot sheets become tiny (0.35 cm) and show up on the left side of the candidates' names which looks like an itemization²⁰.

It is possible to cover all the different regulations applicable for the election at the TU Darmstadt. The number of seats and thus votes can be defined per race. The software can automatically switch per race from a party-proportional representation to a plurality voting system when just one party is nominated. Nevertheless, if electronic counting with VividForms is used just personalised party-proportional representation is supported. Correspondingly 95,51% of the races in 2010 could be scanned and automatically counted with VividForms. But the two largest races (student parliament and university parliament), where all 23,100 students are eligible to cast a vote, are party-proportional representations with more than one nominated party and still have to be counted manually. UniWahl4 supports both required tallying algorithms: largest remainder method and Saint-Laguë. However, both tallying algorithms cannot be used for one election but after having entered the number of votes per candidates it is possible to switch between the two algorithms for the same election. Correspondingly, one would get to result documents both for the whole election and the electoral office and would have to take the results for each from the proper result document. This solution seems confusing and error prone. If only the DinA4 format is supported, it would be preferable to have the option to have two races on one ballot sheet. Then it would save paper and the scanning process would only take half of the time. However, this is not supported in the current versions (refer to Figure 1).

Scanning and Counting. First the user has to define which degree of blackening leads to a marked ballot checkbox. When coloured paper is used, additionally a threshold value for the intensity of the sheet has to be defined. These values are based on experience and are hard to judge at the beginning. However, the manual (Peters, 2010a) gives some proposals which the software also uses as default settings. The required time for scanning and counting depends in a large part on the duration the scanner needs to scan the ballot sheets. In addition the computer has to analyse the ballot sheets and the electoral office needs to check the invalid and not identified votes. Often it is a matter of only a few ballot sheets but this could result in a high administrative effort such as at the TU Darmstadt, when 25,000 votes have to be evaluated. The number of invalid votes in the election 2010 has been around five per cent which leads to more

²⁰ As soon as the components become one software package they are going to extend the functionality on UniWahl4 in combination with VividForms. Thus, there will be no differences whether an electoral office uses just the election preparation functionality of UniWahl4 or also the VividForms scanning and counting of votes.

than 1,000 ballot sheets which have to be checked. This effort could be reduced because the poll workers have to sort them anyway and can remove all empty pages and invalid votes at the same time. So far an inconvenient protocol indicates what percentage of colour which ballot

Figure 1: Ballot sheets generated by a) the TUD, b) UniWahl4, and c) VividFormsCreator

checkbox on which ballot sheet contains. On the basis of this information the user has to choose the right picture in a multi-tiff file, check it and where appropriate insert the vote manually. The number of valid and invalid ballot sheets is counted in several edit fields. To insert an individual vote this way seems to be fault-prone and not very user friendly. Furthermore there is no protocol which contains how many votes have been inserted manually and how many by a scanner, and accordingly how many votes candidates got from scan based counting and from manual counting.

Simplifying the administrative processes. Even when scan based counting is not used UniWahl4 significantly reduces the administrative effort of the electoral process. So far the electoral office has to copy the data of every race in several templates to create the website, ballot sheets, counting sheets and election result reports. Through the use of UniWahl4 the information has to be inserted just once and following all needed documents can therefore be generated automatically. Furthermore when the user wants to set the candidates he has the option to load the voter register (which also contains the data of the candidates) and extract the needed information from there. Also in the post-election phase the electoral office benefits from the software. After the counting it is no longer necessary to tally the votes for the proportional representations by a tool. All counting sheets can be inserted in the software which calculates the results for all races according to their associated legal regulations and generates the reports of election results²¹.

When additional electronic counting is used the administrative process can be simplified even more. So far during the counting the poll worker has to decide whether a ballot sheet is valid or not, by counting the number of marked candidates and checking against associated number of votes. Prior to this the electoral office sorts the ballot sheets by associated board and groups of voters to simplify this step. When electronic counting is used the results of the scanned ballot sheets could be imported directly in UniWahl4 and the decision whether a ballot sheet is valid or not is made by the software. Furthermore when just one UniWahl4 file is used it is no longer necessary to sort the ballot sheets, although it is still recommended for reasons of clarity.

²¹ Some legal regulations are global settings and valid for all races in one election.

More reliable and accurate election results. Afterwards, the precision of the electronic tallying has been analysed. With a plausibility check the distinction whether a vote is valid or not can be taken. But this is bounded by the degree of blackening of the ballot checkboxes. Therefore, an invalid vote with drawings or comments on the front or back cannot be recognized and it is necessary to sort them out. Like in the evaluation software it is possible to delete a casted vote by completely blackening the ballot checkboxes. Nevertheless this setting is questionable because the right threshold value between a filled ballot checkbox and a thick cross has to be figured out. When the electoral office decides not to allow this feature this should be brought to the voters' attention because students could recognize a similarity with the evaluation system and mistakenly use checkbox filling. To wrinkle the ballot sheets did not cause any problems with the scanner so far. According to the interviewed universities²² until now nobody reports about paper jam or picking of more than one page at the same time. But some problems occurred with copied pages. Often the anchor points could not be identified or they disappeared during the copying, thus, the votes have to be added manually. It is possible to set which steps the software should calculate. The casting of lots should be deactivated to afford more transparency to the voter. All replicable calculations like the usage of the largest remainder method and Saint-Laguë should be calculated by the program to minimize the administrative effort and the error-proneness. Another disadvantage of the program is that it is not open source, but it is possible to inspect the source code by appointment. Because this assurance has been made by the University of Applied Science in Hannover it is just valid for the components they have built like UniWahl4 and soon also VividForms Creator. Whether VividForms Reader and VividForms Scanstation can be inspected has to be enquired with Electric Paper.

4. Electronic voting at other universities

Before we summarize our results and deduce recommendations for future elections at the TU Darmstadt, we analyse other projects introducing electronic voting for any lessons learned. As there are so many projects, we decided to take only those from other German universities into account as well as the large federal Austrian project from 2009.

University of Osnabrück. The first legally binding online vote at a German university took place at the University of Osnabrück in February 2000 (Lange, 2002 & Will, 2002). 106 of the 10,000 Students cast their vote using the online voting system *i-Vote*. Quite a few problems and a few vulnerabilities have been identified (Philippsen, 2002 & Lange, 2002). For example many voters received their signature cards too late and others had problems with installing the card reader. In addition, the server was down several times and the tallying software did not tally the stored votes properly.

Lesson Learned 1: It is important to run test elections especially when voters need to install new hardware or software to let voters become used to it and further improve the system. Furthermore, besides the technical aspects the concept describing the organisational processes is also very important and needs to be tested in advance.

University of Applied Science in Hannover. A few months later the students at the University of Applied Science in Hannover could use online voting as well. The university designed their own online voting system as a student project. The voters received a PIN and a TAN and the communication was secured by SSL. Thus, additional hardware and software was not required. Problems like those in Osnabrück did not occur. However, the project has not been continued

²² In the course of writing this paper the University of Applied Science in Hannover, University of Potsdam, University of Tübingen, and the Otto-von-Guericke University Magdeburg gave us an interview.

because the goal to raise the voter turnout was not achieved²³. Furthermore, for long-term work the system has to be improved, however this may be too expensive.

Lesson Learned 2: A cost benefit analysis should be applied before the project and election officials should be involved in the development process to make the administration as easy as possible for them.

Jena University. In May 2010 the University of Jena decided to test online voting with the Polyas system²⁴ for the election of the 'Graduierten Akademie'²⁵ board with 451 voters. Costs, effort, and election turnout were the same as before²⁶. Therefore, the university plan to provide online voting for the large election in 2011.

Lesson Learned 3: It might be helpful applying electronic voting first to a small election or small group of voters to clarify a lot of questions (regarding administration and costs) and to get familiar with the system. Note that a rerun in small elections or with a small group of voters is not so expensive.

Austrian Federal Student Parliament Election. 2009 the 'Bundesministerium für Wissenschaft und Forschung' initiated the first, legally binding online vote in Austria (BMWF, 2010) for the student parliament. This was done without discussing the idea with the students which led to tempered reactions, heated debates, bad press, complaints to the Austrian 'Verfassungsgerichtshof' (Sokolov, 2009), low voter turnout, and people trying to manipulate the system. In addition, in spite of preliminary tests, an error in the electoral register caused irregularities. Some voters could not cast a vote and others voted more than once.

Lesson Learned 4: The reaction of the students in Austria shows how important it is to involve the voters in the realisation of a new voting system. In addition, this large project shows that you need to start the project some time in advance to have enough time to test every component.

Karlsruhe Institute of Technology. The 'Europäisches Institut für Systemsicherheit' at the Karlsruhe Institute of Technology built a voting machine called Bingo Voting²⁷. The goal was to implement a system providing individual and universal verification. In 2008 the system was used in the election for the student parliament and the electoral committee realised extensive benefits. The new system was finalized just one day before the election. Technical problems with the chip card occurred and vote casting took too long. Furthermore, it is unclear whether the developers and administrators had the possibility to break the election secrecy²⁸ (Wolf, 2008).

Lesson Learned 5: This example shows that enough time should be scheduled to develop and analyse new software before using it in an election. In doing so technical errors can be avoided and weak spots detected. Also a test in an election with fewer eligible voters like at the University of Jena would have been useful at this point. The developers could test in advance how user-friendly the new voting system is and how long it takes to cast a vote.

²³, <http://www.stud.fh-hannover.de/~peters/Internetwahl/bericht.pdf> (German only), Retrieved Feb 28, 2011.

²⁴ <http://www.micromata.de/en/index.jsp> (German only), Retrieved Feb 28, 2011.

²⁵ The 'Graduierten Akademie' is an umbrella organization for all graduate schools within Jena University.

²⁶ CAST Seminar "Elektronische Wahlen", Darmstadt, Nov 24, 2010, this information is available on request.

²⁷ <http://www.bingovoting.de/> (German only), Retrieved Feb 28, 2011.

²⁸ <http://www.usta.de/sites/www.usta.de/files/protokolle/stupa/080702.pdf> (German only), Retrieved Dec 23, 2010.

5. Summary and recommendation

In this paper we summarize the election regulations, rules, different races, and processes currently implemented at the TU Darmstadt. This description shows that the processes are very complex, require a high administrative effort, and are very error-prone. Specifically the manual generation of ballot sheets and the manual counting of so many votes from different races with different rules to cast a valid vote may lead to a lot of accidental mistakes. This might influence the accuracy of the election result.

We analysed the application of the UniWahl4 software in combination with VividForms. We demonstrated in our first case study that UniWahl4 provides all functionalities to use the software in order to improve the processes in the pre- election phase. It might be required to create more than one election to get a ballot sheet layout similar to the previous ones but this seems to be feasible. From our point of view it might take some time for the first election to create all the different races but afterwards, it is much easier because all the required documents like the list of candidates per board and group of voters, ballot sheets, counting sheets, and report of election results and even the postal vote documents can be generated automatically if the election register is imported into UniWahl4. UniWahl4 without the VividForms extension can also be used for the tallying. We recommend using UniWahl4 only for the tallying but not for the counting as the manual counting (clicking on a candidate for each vote he got) seems to be very error-prone, too. Using the tallying functionality has the advantage that you can use the election result report functionality as well. Note that currently you need to create more than one election to handle the different ballot sheet layouts and the different tallying algorithms (2010 in total five, one for every board) and correspondingly you get several election result reports. Thus, we recommend that UniWahl4 extend the software in a way that the TU Darmstadt could implement all their races in one election and would correspondingly just get one election report for all the races.

The scan based counting with the VividForms extension can only be recommended for the TU Darmstadt to a limited extent. In general, we would recommend a scan based counting but the functionality provided does not cover what is required. Mainly, the large races with around 23,000 eligible voters like the election of the university parliament and the student parliament in 2010 are a bounded list which is currently not possible to be counted electronically. Currently, only the small elections could profit from this electronic voting system. Thus, we recommend that UniWahl4 extends the functionality to enabling automatic counting of these types of ballot sheets.

The ballot checkboxes to mark a candidate are very small and irritating. Thus, we recommend for a future version of UniWahl4 enabling the user to define the size of these boxes. Further, it is discussed in Section 3 that the software does not store information on how many votes a candidate got from the scan based counting and how many from manual counting. Correspondingly, this information is also not provided in the election result report. However, this information helps to detect errors. Thus, we recommend adding this information to the election result report.

To conclude, we can already recommend using UniWahl4 in the current version for the election preparation phase at the TU Darmstadt. We would also like to see the above recommendations implemented in a later version to also be able to recommend the scan based counting and tallying to the TU Darmstadt election authorities. Introducing UniWahl4 will reduce the administrative effort but will produce costs. If the university decides to go for a more computer assisted election preparation with UniWahl4, this should not be a big deal and the lessons learned from the projects mentioned in Section 4 are not relevant. However, before starting an internal project to introduce UniWahl4 with scan based counting, these lessons learned should be taken into account. That is, there should be enough time to get used to the software particularly for the counting and tallying process. Special training might be required but for fewer poll workers.

Another lesson showed that it is important to test a new voting system before using it. Therefore before using UniWahl4 for tallying as well, during the first elections the results of the manual counting and tallying (under the use of the regular tool) should be compared with the outcomes of the scan based counting and tallying by UniWahl4. In the beginning, as mentioned in *lessons learned 3*, this could be done for just some races to minimize the additional effort.

Moreover, we recommend developing a concrete process description for the post-election phase. For instance, the used scanning software is not able to identify invalid votes caused by comments, marks or paintings on the front or backside of the ballot sheet. Therefore they have to be sorted out prior to the scan based counting and need to be entered manually afterwards. Furthermore, also after having tested the systems, the electoral office might want to manually cast some of the scanned votes and compare the result to convince people that the scan based counting works. However, the description should also deal with the case that there is a difference between manual counting and scan based counting. In addition, the rules and tasks of the observer should be defined and should describe how to decide about votes that the counting software could not interpret.

We believe that an improved version of UniWahl4 will reduce the administrative effort and increase the accuracy of an election result. Further, we believe that by taking the lessons learned into account and carrying out a proper post-election process such a project would be successful.

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