Requirements Engineering Project

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Summary

Chapter 1
Introduction

This project develops a solution for a real-life problem: the low efficiency of the actual election system.

Starting from a precise definition of the issue, we analyzed its context, studying the domain and the needs of the stakeholders (with researches and interviews as well). Through the goal model analysis, we defined different alternatives to solve the problem, which have been summarized in four possible options.

These solutions have been accurately studied in terms of economical, schedule, operational and technical feasibility, letting us choose the most convenient one: *the proposal of introducing an electronic voting system inside the polling booths and a national database, to allow voters to vote in every city*.

Then, the chosen alternative has been studied deeply, in terms of tactical goals, use cases, class diagrams and sequence, state and activity diagrams. Doing so, we defined the composition of the system and its interaction with the different stakeholders.

Finally, as a summary for the whole work and as a contract with the final user, we listed the composite system, functional and non-functional requirements, together with the domain assumptions.

This concludes the analysis of the requirements of the system. If approved, the project will be then designed and developed.

Chapter 2
The problem

In Italy, as in many other countries, the election system requires the voter to be physically present in the polling station. He/she has to show a voting card and his/her passport, receives a piece of paper and goes in a polling booth, where he/she makes a cross in correspondence of the candidate he/she wants to vote. At the end of the elections, the polling clerks read all the sheets of paper and count the different votes.

This system prevents illegal operations, such as threats or votes evidences, and for this reason it cannot be replaced with an Internet-based technology. Anyway, there are some problems. First of all, people who live far away from their home cities without having a new residence (for instance off-site students) are forced to go back home if they want to vote, spending time and money. The government also has to give a partial reimbursement to them, using public funds. Secondly, this system creates a huge waste of paper, and in general of money (indeed elections are dramatically expensive). Thirdly, the polling clerks have to count manually the votes, not only wasting a lot of time, but also making many mistakes possible. And sometimes voters make mistakes too, because the rules of "how to draw exactly the cross" are very strict.

In other words, this election system works, but with many problems. A software system could solve them. If all the polling stations had, inside the booths (we still want to prevent illegalities), a screen showing the possible candidates and allowing one to vote them, people could choose without risking to invalidate their vote, polling clerks could see the results without having to count sheets manually, outcomes would be available immediately after the elections, and there wouldn't be that waste of paper and money. Also, adding an access to a national database, people would be able to vote in the polling station closer to them, no matter if they are far from their home city; consequently, the government would not have to reimburse them. The whole system would save millions of money.

This is a case in which technology could solve a serious real-life problem.

<u>List of problems of the actual system:</u>

- Waste of public money (about 400,000,000€ per election)
- Waste of paper
- Waste of space: the sheets of paper must be preserved for years
- Long time to have the results (no less than one day) and uncomfortable mechanical work, because sheets of paper are counted manually
- Possible mistakes in the manual count and/or in the several shipments of the sheets of paper
- The votes could be counted again because of these possible mistakes, wasting again time and money
- People are forced to vote in their residence city
- The government has to reimburse off-site people to go back home, in order to vote
- The polling clerks have to track activities in a lot of different registers (one for male voters, one for female voters, one for male voters' cell phones, one for female voters' cell phones, and another one for off-site voters – like soldiers)

- The rules of “how to vote” (like how to draw the cross) are very strict, and votes can be easily invalidated
- The police must sleep in the polling station to watch over the sheets of paper

All these problems occur very often, because there are elections every 1-2 years (political, administrative or primary)

Chapter 3
The context

3.1: Stakeholders

Basically, there are three kinds of involved parts in this system: citizens who vote, candidates who receive votes, and all the entities and people that take part to the election process. Also, if the system must be improved, people who work on the solution must be considered stakeholders as well.

List of the stakeholders:

- Voters
  people who are invited to participate to elections; they go to their polling station during the election days and express their preference
- Candidates / Parties
  people or group of people who candidate themselves as representative of the citizens: they hope to receive a good number of votes in order to participate actively to the political life
- Election staff in the polling stations: polling clerks, presiding officer, secretary, count assistants
  people who work in the polling stations; they have to check and mark the voters in the registers, give them the sheets of paper, monitor the general situation and count the votes of their polling station
- Election commission:
  people who receive from the State the task to organize, at high level, the elections
- Police
  people who monitor the progress of the elections, protect them from irregularities and intervene in case of problems
- State / Government
  entity that periodically needs new elections in order to have a government or another public institution which follows the citizens' preferences
- Employees in public institutions: municipality, province, state
  people who receive the sheets of papers from the polling stations and have to transmit them to the superior institution or to preserve them; they are also responsible of their own polling stations
- Workers on the solution: requirements analysts, designers, programmers
  people who have been told to improve the actual system, and have to work on it

3.2: Stakeholders goals

Every stakeholder has some basic aims that wants to satisfy during the election process, and perceives in the actual system some problems which obstruct them. Here there is a list of the main points[1].

- Voters
  - To have a system to vote
  - To be able to vote in a certain place
  - To be able to vote the candidate they prefer
  - To be sure that their votes remain secret
  - To be sure that the system is safe and avoids violations
  - To know the results

- Candidates[2]
  - To have a totally secure system, which reflects the real preferences of the citizens
  - To be able to check that the elections have been performed without irregularities
  - To know the results

- Election staff
  - To verify that a certain person can vote
  - To give voters the access and the tools to vote
  - To monitor people who are voting
  - To compile the different registers
  - To reduce the bureaucracy
  - To have a safe system
  - To perform in the best way the counting work after the elections
  - To reduce as possible the mistakes during the counting work and their responsibilities in them

- Election commission
  - To organize the elections
  - To prepare the material for the elections
  - To send the material to the polling stations
  - To select the staff

- Police
  - To intervene in case of irregularities
  - To reduce the possibility of intervention
  - To bring the results to the municipalities

- State

[1] Some goals and problems have been formalized thanks to the contribution of some stakeholders who have been interviewed. For more details, see Appendix 1

[2] Of course the main goal of every candidate is to receive as many votes as possible, but we will not consider this aspect because it is not related (or it should not be) to the election system

    - To perform the elections, in order to have a government
    - To manage money
    - To manage paper
    - To manage time
    - To manage space
    - To have a system which reduces discomforts for citizens as possible
    - To have a totally secure system
    - To involve people, having an high participation rate
    - To know the results

- Employees in public institutions
    - To count and sum the results
    - To be sure that the results obtained are without mistakes
    - To manage and preserve the physical data
    - To submit material to the superior institutions

- Workers on the solution
    - To create a new system
    - To earn money for the system they create
    - To create a fast, efficient and safe system
    - To avoid complaining, trying to satisfy as much needs as possible

3.3: Stakeholders problems

List of the involved parts, with the problems that they perceive in the current system:

- Voters
    - Have to be in their residence city to vote
    - Could have to spend time and money to vote
    - Have to go to the polling station, to show voting card and passport, to go inside the polling booth and to express their vote
    - Have to be careful in drawing the cross, in order not to invalidate the vote unintentionally
    - Can never be sure that elections have been performed in a completely regular way
    - Have to wait for long to have the results
    - Can be confused because of the huge number of parties and lists, and the lack of detailed and impartial information about the single parties programs

- Candidates
    - Risk elections with irregularities because of the many mistakes possible
    - Have to wait for long to have the results

- Election staff
    - Have to find the voters and fill in a lot of different registers
    - Have to be really careful in compiling the modules and giving the sheets of paper

    - Have lots of responsibilities during the voting phase
    - Have to count manually the sheets of paper (a long and monotonous work)
    - Have to know and remember lots of rules and particular cases
    - Have to be quickly and efficiently organized
    - Most of the times there are problems in the count, and they are forced to stay in the polling station until they solve them
    - Are responsible for mistakes in the count

- Election commission
    - Have to prepare and send a huge amount of material (sheets of paper, registers, pencils, …)
    - Need a lot of time to organize elections
    - Have to find a very large staff

- Police
    - Has to sleep in the polling station
    - Has to be available and intervene for any kind of security problem
    - Has to take the sheets of paper to the municipality in a secure way

- State
    - Has to pay the whole system (400,000,000€)
    - Has to reimburse the off-site people
    - Has to allow people who are resident abroad to vote by correspondence
    - Is responsible for the waste of money, paper, time and space

- Employees in public institutions
    - Have to count and sum the results
    - Have to submit the results to the superior institution, in a secure way
    - Have to preserve the sheets of paper

- Workers in the solution
    - Have to conciliate the needs of the other stakeholders, creating a solution which solves the problems

3.4: Domain properties

Goals and perceived problems are a good starting point to analyze the system and understand where and how, possibly, to change.
Still, there are some general constraints that must be considered.

Properties of the domain:

- The vote evidence must be avoided: people mustn't be able to take photos to their votes, or to be watched while they're voting

- One person can vote only one candidate
- One person can vote only one time per elections
- Votes can be collected and summed in a totally secure system: no external intromission is allowed
- The vote is private, free and secret
- No one must be able to look at other people's preferences
- People must not be associated to their vote, and it must be impossible for everyone to discover who voted who
- Results must be available only at the end of the elections, in order not to influence people who have not voted yet
- Someone must intervene in case of any problems
- The elections last two days

Chapter 4
Alternatives

4.1: Goal model analysis

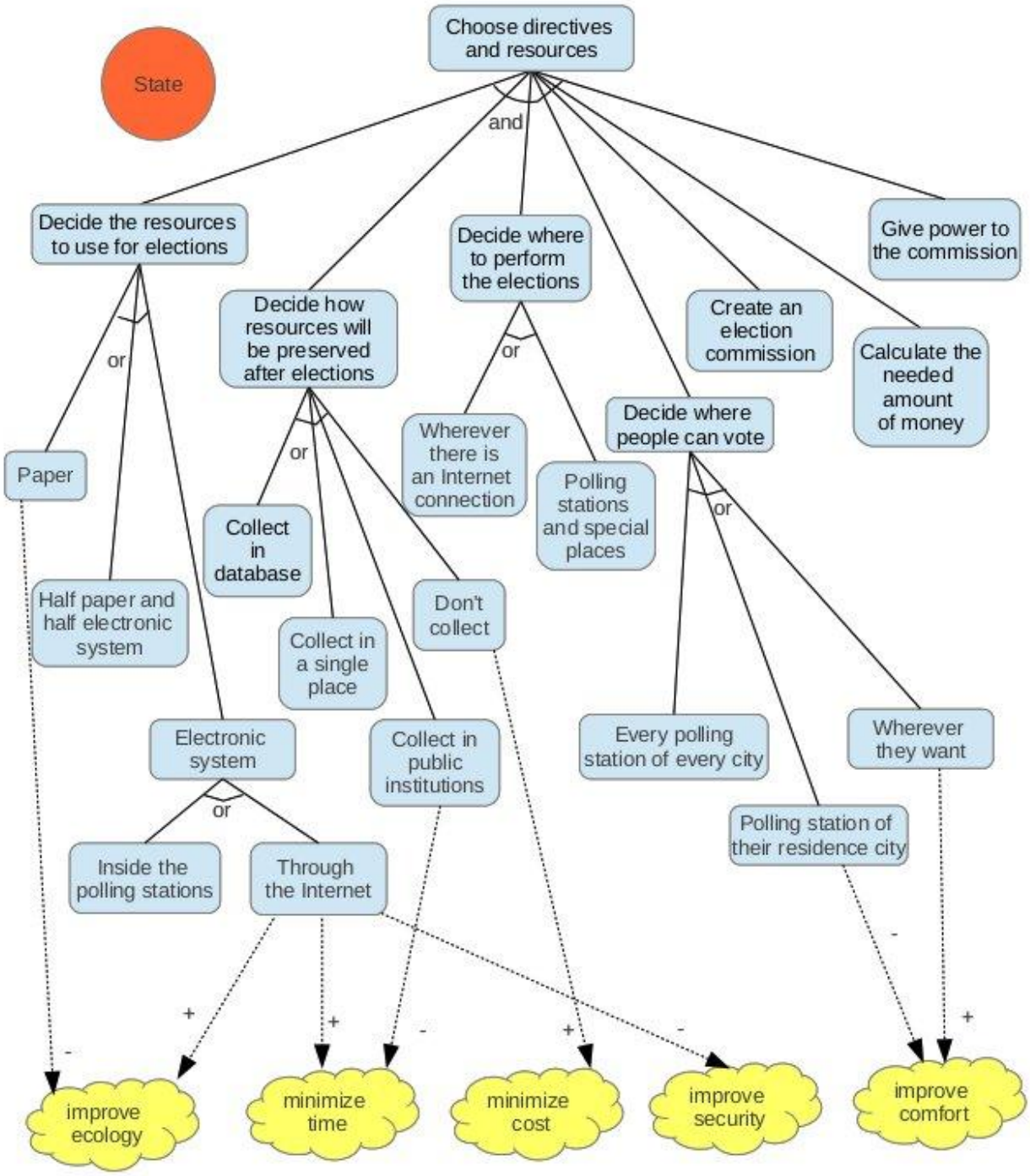
The problems of the stakeholders listed in the previous pages can be grouped into more general problems of the whole system[3].
Then, every problem can be turned into a generic goal, and the strategic goal analysis is applied to explore and evaluate possible solutions.

Problem 1:

- state has to pay
- state wastes paper, money, space and time
- state has to reimburse who travels
- voters have to be in their city
- voters spend time and money to vote
- employees have to preserve the sheets of paper

general problem: waste of resources & uncomfortable organization
goal: choose directives and resources
actor: state

[3] A first analysis of common problems of multiple stakeholders can be found in Appendix 3 – Extra 2

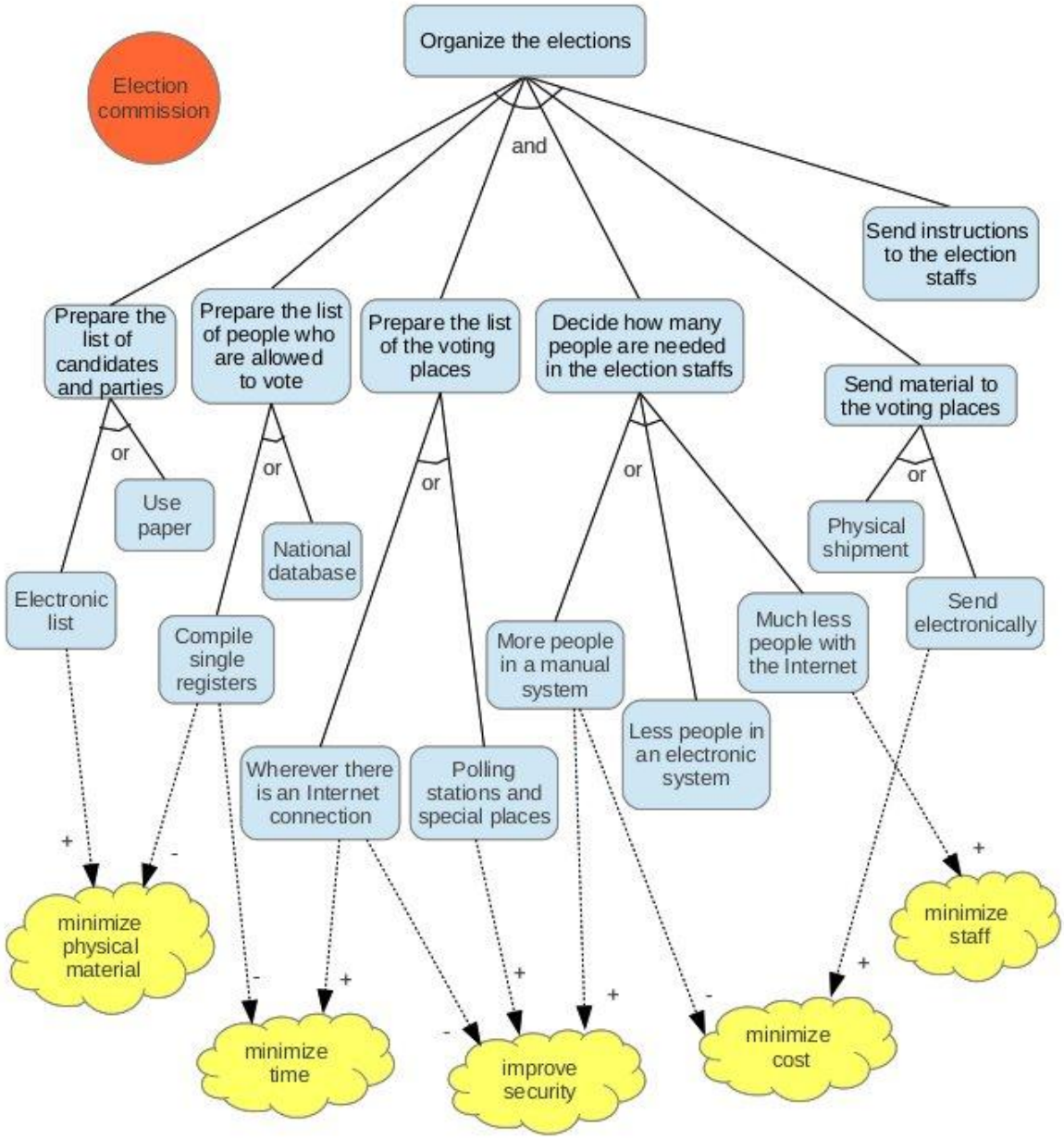

State
Choose directives and resources
and
Decide the resources to use for elections
Decide how resources will be preserved after elections
Decide where to perform the elections
Create an election commission
Give power to the commission
Calculate the needed amount of money
or
Paper
Half paper and half electronic system
Electronic system
or
Inside the polling stations
Through the Internet
Collect in database
Collect in a single place
Collect in public institutions
Don't collect
Wherever there is an Internet connection
Polling stations and special places
Decide where people can vote
Every polling station of every city
Polling station of their residence city
Wherever they want
improve ecology
minimize time
minimize cost
improve security
improve comfort

CHOOSE DIRECTIVES & RESOURCES	Paper	Paper & electronic system	Electronic system	Collect material resources	Collect digital resources	Don't collect resources	Vote in polling stations of resident cities	Vote in every polling station	Vote on the Internet
Minimize cost	Very bad: lots of expenses for each election	Good: improvement in the actual system	Very good: expensive the first time, but then very few expenses	Bad: collection has a cost	Not good: servers must be bought	Perfect: no expenses	Very bad: people spend money and state reimburse them	Very good for people, ok for state	Good: almost free for everyone
Minimize time	Bad: sheets require time to be prepared	Good: improvement in the actual system	Very good: almost immediate	Bad: collection requires time	Good: collection is almost immediate	Perfect: no time required	Very bad: forces people to travel	Good: people can reach the closest one	Very good: almost immediate
Improve ecology	Very bad: waste of a lot of paper	Good: improvement in the actual system	Perfect: best way to help the environment	Bad: waste of space and pollution	Ok: some servers needed	Very good: no waste of space	Ok: reserve place such as schools for the elections	Ok: reserve place such as schools for the elections	Good: no waste of resources
Maximize security	Good: external intromissions are uncommon	Bad: possible external intromissions	Bad: possible external intromissions	Very good: possibility to count again for mistakes	Very good: possibility to check again for mistakes	Not good: doesn't give the possibility to check for past mistakes	Good: use the actual system	Good: use the actual system	Bad: no way to prevent the voting evidence (take photos, have a person behind, …)
Improve comfort	Very good: the user reads and writes	Ok: the user has to learn, but the system can be easy	Ok: the user has to learn, but the system can be easy	/	/	/	Very bad: uneasy system for people who live far	Very good: much more comfortable	Very good for most of the people, but others don't have a computer or Internet

Problem 2:

- election commission prepares and sends the material
- election commission finds the staff
- election commission needs time
- state allows vote by correspondence

general problem: long organization to prepare the elections
goal: organize the elections
actor: election commission

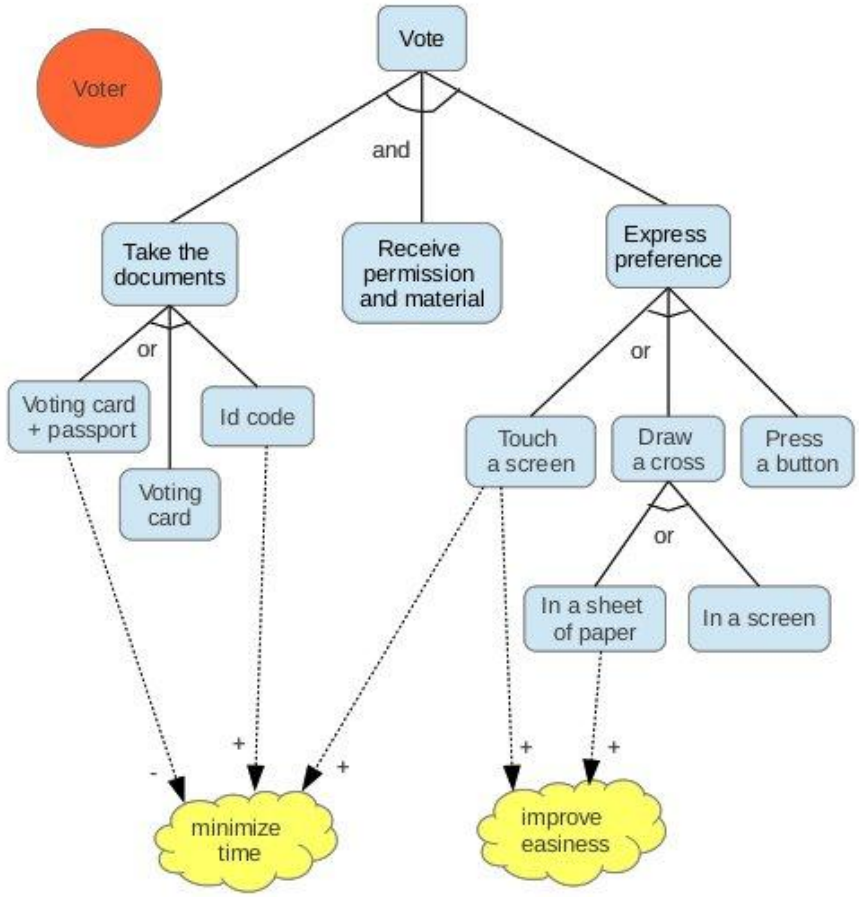


ORGANIZE THE ELECTIONS	Paper candidates list	Electronic candidates list	Paper registers	Database	Vote in polling stations	Vote everywhere	Send physically	Send electronically
Minimize cost	Very bad: prepare millions of sheets of paper	Perfect: write only once the electronic list	Very bad: prepare thousands of registers	Very good: buy only once the servers	/	/	Very bad: lots of shipments needed	Perfect: no costs
Minimize time	Bad: time to print everything	Very good: few time required	Ok to prepare, bad to consult	Very good to prepare and perfect to consult	Ok: prepare a list of stations	Good: enable every used of the system to vote	Bad: lot of time required	Perfect: almost instantaneous
Minimize physical material	Very bad: a lot of material used	Very good: few material	Very bad: a lot of material used	Very good: few material	Bad: lots of places must be furnished	Very good: most of users already have material; prepare few for the others	Very bad: lots of shipments needed	Very good: no physical material
Maximize security	/	/	/	/	Good: the commission can list stations	Bad: can't keep track of a list of places	Good: intromissions less possible	Bad: possible external intromissions
Minimize needed staff	/	/	/	/	Bad: need staff for each polling station	Very good: few people needed	Bad: many people needed	Very good: few people needed

Problem 3:

- voters have to show card and passport, sign and be allowed
- voters have to follow strict rules for the cross

general problem: strict rules for the voter
goal: vote
actor: voter



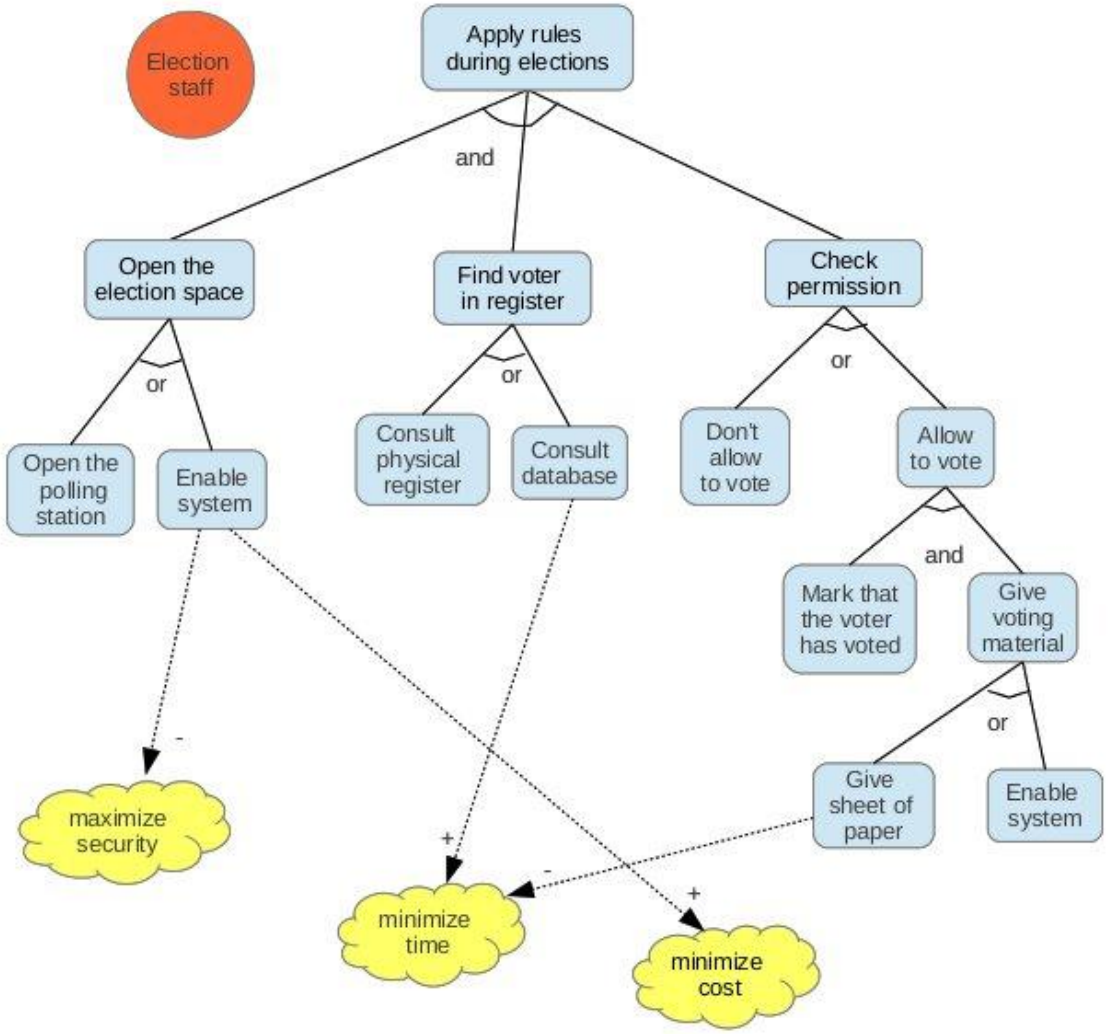
VOTE	Show card + passport	Show card	Have id code	Draw a cross	Touch a screen	Press a button
Improve easiness	Bad: two documents required	Very good: show the card	Good: give your id number	Perfect: immediate	Very good: immediate if you understand	Bad: could become difficult for some people (such as old ones)
Minimize time	Bad: more time for identification needed	Very good: instantaneous	Very good: instantaneous	Perfect: immediate	Perfect: immediate	Ok: more time than the others, but acceptable

Problem 4:

- staff has to find the person and compile the registers
- staff has to give the sheets of paper

- staff has to remember lots of rules

general problem: long bureaucratic procedures
goal: apply rules during the elections
actor: election staff

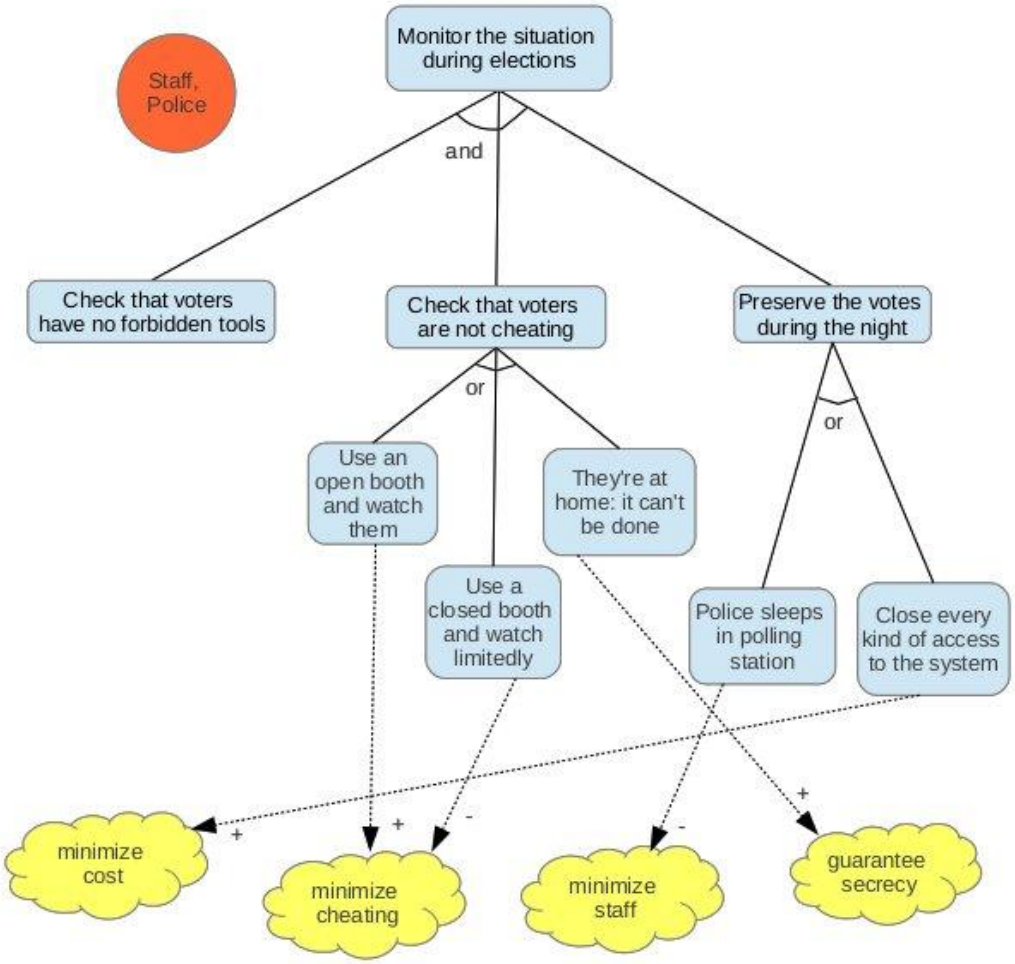


APPLY ELECTIONS RULES	Open polling station	Enable system	Check in register	Check in database	Give paper	Enable vote
Minimize cost	Bad: need physically people	Very good: done from everywhere by someone	/	/	/	/
Minimize time	Bad: time to go to the station and open it	Very good: instantaneous	Bad: time required	Perfect: instantaneous	Bad: people have to vote one by one	Perfect: instantaneous
Maximize security	Very good: secure	Very bad: possible external intrusions	Ok, but the long manual work could cause mistakes	Very good if the database is well-done	Good: more possibilities to monitor people	Very bad if done not in the station: impossible to monitor people

Problem 5:

- police has to be careful and control
- police has to sleep in the station
- police must intervene for security reasons

general problem: security during the elections
goal: monitor the situation during the elections
actor: staff, police

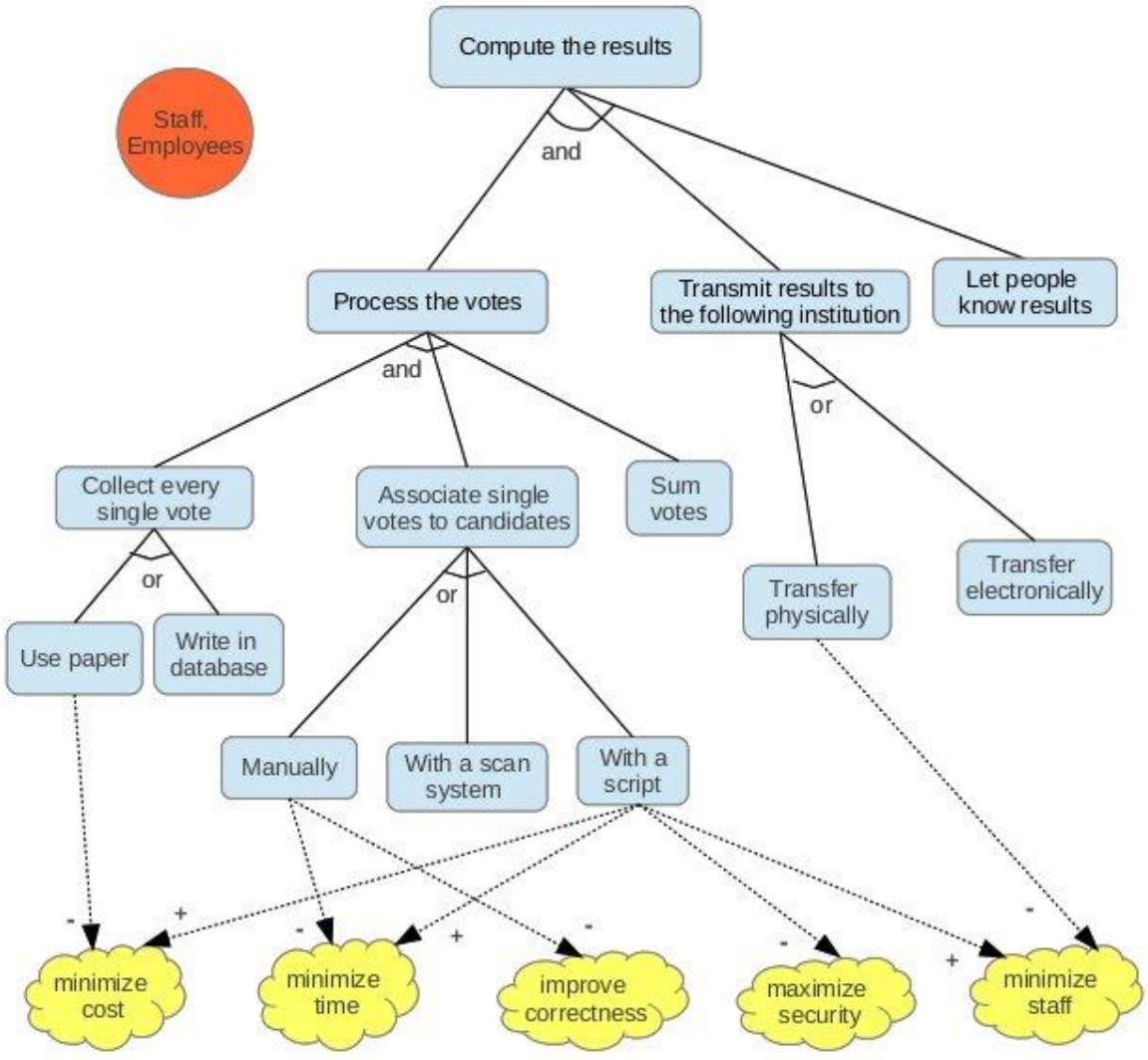


MONITOR THE ELECTIONS	Open booth	Closed booth	Home: can't monitor	Sleep in stations	Close access to the system
Minimize cost	/	/	/	Very bad: expensive present of police required	Good: few staff needed
Minimize cheating	Very good: voters can be monitored	Ok: the voter has limitations, but could cheat	Very bad: whoever can cheat	Good: police checks for problems	Bad: if the system has bugs there could be external intrusions
Minimize staff	Bad: staff and police required for each station	Bad: staff and police required for each station	Very good: few people needed	Very bad: police for each station needed	Good: few staff needed
Guarantee secrecy of vote	Bad: risk that someone sees the vote	Very good: nobody but the voter can enter the booth	Very good: the voter can find a place and moment not to be watched	/	/

Problem 6:

- voters have to wait for results
- candidates have to wait for results
- staff has to be quickly
- voters can't be sure of correctness
- candidates can't be sure of correctness
- staff counts manually the votes and is responsible for them
- employees have to sum the results
- staff has to count manually the votes
- staff is forced to stay in the station until every problem is solved
- police take the material to the municipality
- employees send the material to the superior institution

general problem: long time to have the results & possible mistakes and irregularities in the counting phase & long bureaucracy in transmitting the results
goal: compute the results
actor: election staff, employees in public institutions



COMPUTE THE RESULTS	Collect paper	Collect in database	Associate manually	Associate with scanner	Associate with script	Transfer physically	Transfer electronically
Minimize cost	Bad: a space where to collect is needed	Good: expensive servers in the beginning, but then no costs	Very good: no expenses for extra material	Ok: cost of the scanners in the beginning	Ok: cost of the software	Bad: shipment is expensive	Perfect: costless
Minimize time	Bad: sheets must be processed one by one	Perfect: immediate	Very bad: a long manual work	Bad: sheets of paper must be scanned one by one	Perfect: immediate	Bad: it requires a lot of time	Very good: almost immediate
Improve correctness	Bad: sometimes mistakes in collecting happen	Perfect: data are collected correctly	Very bad: many mistakes possible	Bad: barcode reading could not be perfect	Perfect: performed by computer	Bad: some sheets could be lost	Very good: data transfer has no mistakes
Maximize security	Very good: it is difficult to cheat intentionally	Bad: someone could modify the data	Bad: only people involved, possible cheating	Bad: someone could cheat and read a barcode more times	Ok: no cheating if the system is totally safe	Ok: usually good, but it could be risky	Good if the system is secure
Minimize staff	Bad: people are needed to put the sheets somewhere	Very good: the system does everything	Bad: many people for each polling station needed	Bad: many people for each polling station needed	Very good: the system does the work, few people needed	Bad: many people needed	Very good: few people needed

What can be deduced from this goal analysis[4] is that paper is the most time-consuming and money-wasting system, but still has the most guarantees about security. If it has to be replaced with an electronic system, saving lots of resources and improving performance, a particular attention must be dedicated to the safety problem.

[4] For a deeper analysis of the goal modeling results, see Appendix 3 – Extra 1

4.2: The PIECES framework

PIECES

- **Performance**: is the system time adequate?
  - Too much time to organize elections
  - Too much time to send the material
  - Too much time to reach the place where to vote
  - Sometimes too much queue during voting
  - Too much time to process the results
  - Too much time to collect the material

- **Information**: do users get timely and useful information?
  - Media spread information about candidates and parties, but they are rarely impartial
  - The voting paper is organized in a confusing way
  - Rules about how to vote are clearly written, but are very strict and in some cases confusing
  - Inside the polling station there is no way to have information about parties and programs

- **Economics**: are services cost-effective?
  - 400,000,000€ spent per election is the most serious problem
  - New ways of voting could improve a lot the system

- **Control**: are there controls to guarantee privacy and security?
  - Lots of redundant controls during the computing results phase
  - Still some mistakes possible (wrong reading, wrong cross, wrong association, …)
  - Still some irregularities possible (vote for who did not do it, find an agreement with the rest of the staff, …)
  - No way to be sure that everything happened regularly

- **Efficiency**: does the system make a good use of resources (people, time, …)?
  - Waste of money
  - Waste of paper
  - Waste of time
  - Waste of pencils
  - Waste of needed people

- **Services**: are current services reliable?
  - There exist small cases of fraud, but in general results are reliable
  - The system is inflexible to new or exceptional situations

4.3: Possible alternatives

As a result of problems identified and goal analysis, it is possible to select some alternatives:

1. **Keep the actual system**

since the current system, despite its wastes, actually works (and seems one of the best solutions for the security problem), one alternative is to continue to use it

2. **Electronic database + electronic voting system in polling stations**
   to help people to vote everywhere and to facilitate registration, a database could efficiently replace the physical registers; also, the voting system could become electronic (but still based on polling stations for security reasons), to facilitate the voting and the counting phases
3. **Electronic database + actual system**
   again, a database could replace the physical registers and allow people to vote everywhere, but the voting system could remain based on sheets of paper, to guarantee security in the best way
4. **Voting system on the Internet**
   exploiting the principle of allowing people to vote everywhere, an Internet-based system could be another solution; it guarantees easiness of voting and counting

4.4: Cost-Benefit analysis

See the cost-benefit files for this[5].

4.5: Feasibility study

Based on the previous step, here there is the **feasibility matrix**:

	1: ACTUAL SYSTEM	2: DATABASE + ELECTRONIC VOTING	3: DATABASE + PAPER VOTING	4: INTERNET
OPERATIONAL FEASIBILITY	Actual dynamics do not change. However, most of the stakeholders have interests in changing the system.	The new system would change the tools for voting, but dynamics would remain more or less the same. Users will appreciate the new system, because it's easier than the actual one and allows to vote everywhere. Also, the project would be supported by authorities, because of its better use of resources.	The voting system remains the same, but with this alternative user can vote wherever they are, a solution for a seriously perceived problem. Also, the election staff would find easier to locate and register voters.	Generally, young people will appreciate the system, whereas for old people it will be very uncomfortable. The problem of voting evidence can't be overcame, and this goes against government regulations and privacy feelings of users.
35%	20	100	80	20

[5] The *cost-benefit analysis* files, attached with this report, are a list of *costs*, *benefits* and *costs-benefits* for each alternative. But, if *costs* are more or less easy to compute, to talk about *benefits* is more difficult. Contrary to most of the systems, here we are in a case in which there is no profit. There is no way to stop spending money, because elections must always be performed; so the only *benefit* returned is a social one. In this case, we decided to consider as a *benefit* all the money that the examined alternative saves respect to the actual system.
In this kind of system, it becomes very difficult to compute the *ROI* value, because in some alternatives (namely 1, 2 and 3) *costs* are always superior to *benefits*: it never happens that, from a certain year, the situation changes. For the alternative 4, the less expensive one, instead, it is the opposite: *benefits* are always superior to *costs* (of course supposing that *benefits* are just the saved money).
For this reason, we chose to compute normally the *cumulative net result* for every year and to use its average value.

TECHNICAL FEASIBILITY	Does not require the introduction of a new technology.	Polling stations must be deeply modified. A technological infrastructure must connect all of them, both for the database and the voting system. It requires the purchase of the two pieces of software (the voting one is the most complex, but the actual technology allows to create it), of many national servers were to collect the votes, and of some computers and voting screens for each polling station.	Polling stations must be a bit modified, introducing at least one computer in each one, to interface with the database. This means that a database software must be created, with the consequent purchase of some national servers.	As for alternative 2, two pieces of software must be purchased: one for the voting system and another one for the database. Again, many national servers are needed. Regarding hardware, most of the people have computers and the Internet access at home; but an alternative must be provided for who doesn't: at least some computers for each city.
25%	90	60	80	70
SCHEDULE FEASIBILITY	No need to implement a new system.	It's the alternative which requires most of the time: creation of the two pieces of software, and introduction of computers and screens in all the polling stations. Training personnel could be easy, but still requires some time. The whole preparation requires many months (5-6) before the elections, but there's no constraint in choosing when to start the system exactly	It doesn't require much time: just 1-2 months before the elections to arrange the servers and install computers in the polling stations. There's no constraint in choosing when to start the new system exactly.	It doesn't require much time: just 1-2 months before the elections to arrange the servers and install some public computers. There's no constraint in choosing when to start the new system exactly.
10%	100	70	85	80
ECONOMIC FEASIBILITY[6]	- 1,015,170,690 €	- 461,568,504 €	- 1,260,893,103 €	712,058,249 €
30%	0	50	0	100
RANKING	**38.5%**	**72%**	**56.5%**	**62.5%**

4.6: Summary of the preliminary study

The steps analyzed so far have identified the election issue and its involved stakeholders, with the list of problems that they perceive in the current situation. These problems have been the starting point of a deeper analysis, which was aimed to find a way to solve them. For this reason, every stakeholder has been associated with one or more generic goal, and goals have been explored to conduct to different alternatives to achieve them. Every alternative, then, has been discussed in terms of soft goals, and evaluated.

As a result, we have been able to study the quality of every proposal, and to present four possible alternative solutions. These ones have been studied in terms of operability, technology, time and, above all, cost-benefits. They finally got a rank, which will be the starting point of a new analysis.

[6] As explained before, this is the average value of the *cumulative net result*, a measure that we retained appropriate to quantify the different economic feasibility of the different alternatives, since this is a system with a particular behavior.

As it can be noticed from the results of the feasibility matrix, the second alternative (the electronic one) has the greater score, whereas the actual system has the lower one, to indicate that a change is needed. The third solution is an improvement of the first one, but still less powerful than the others. Finally, the Internet solution seems to be a good one, even though there is the voting evidence problem that must be overcame in some way, in case.

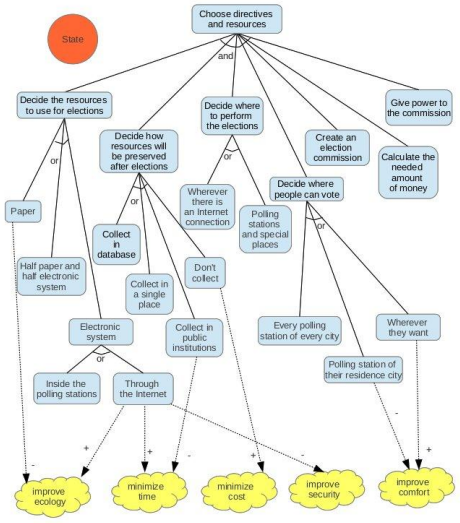
Further analysis can be conducted, to study deeper the three alternatives (especially the second one) and in case apply one of them.

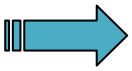
Chapter 5
The solution

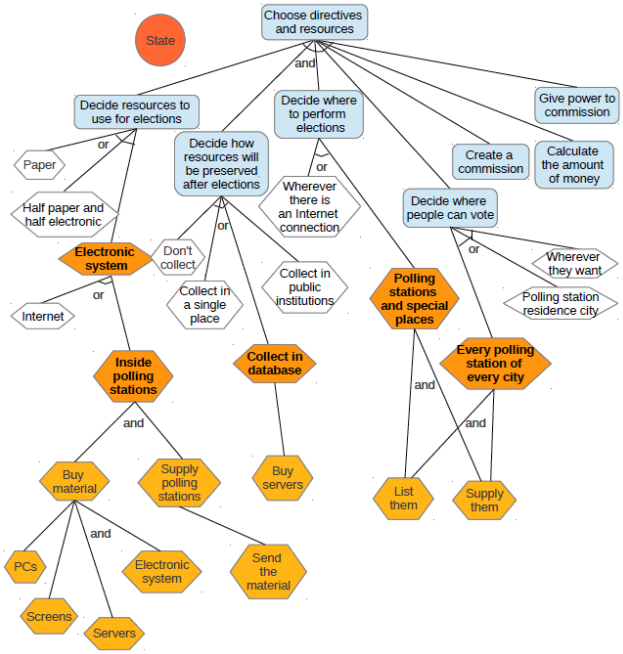
5.1: Tactical goal analysis

In the previous part, the main problems of the actual voting system have been grouped into six generic goals, and the strategic goal analysis has been applied. We decomposed every goal until we arrived to single tasks, which have been evaluated according to their positive or negative contributions in reaching soft goals.
This work was the preliminary elaboration and evaluation of different alternatives.

Now that we have already chosen the right alternative, we can focus on it and decompose further the strategic models in tactical goals, in order to show how to satisfy them.

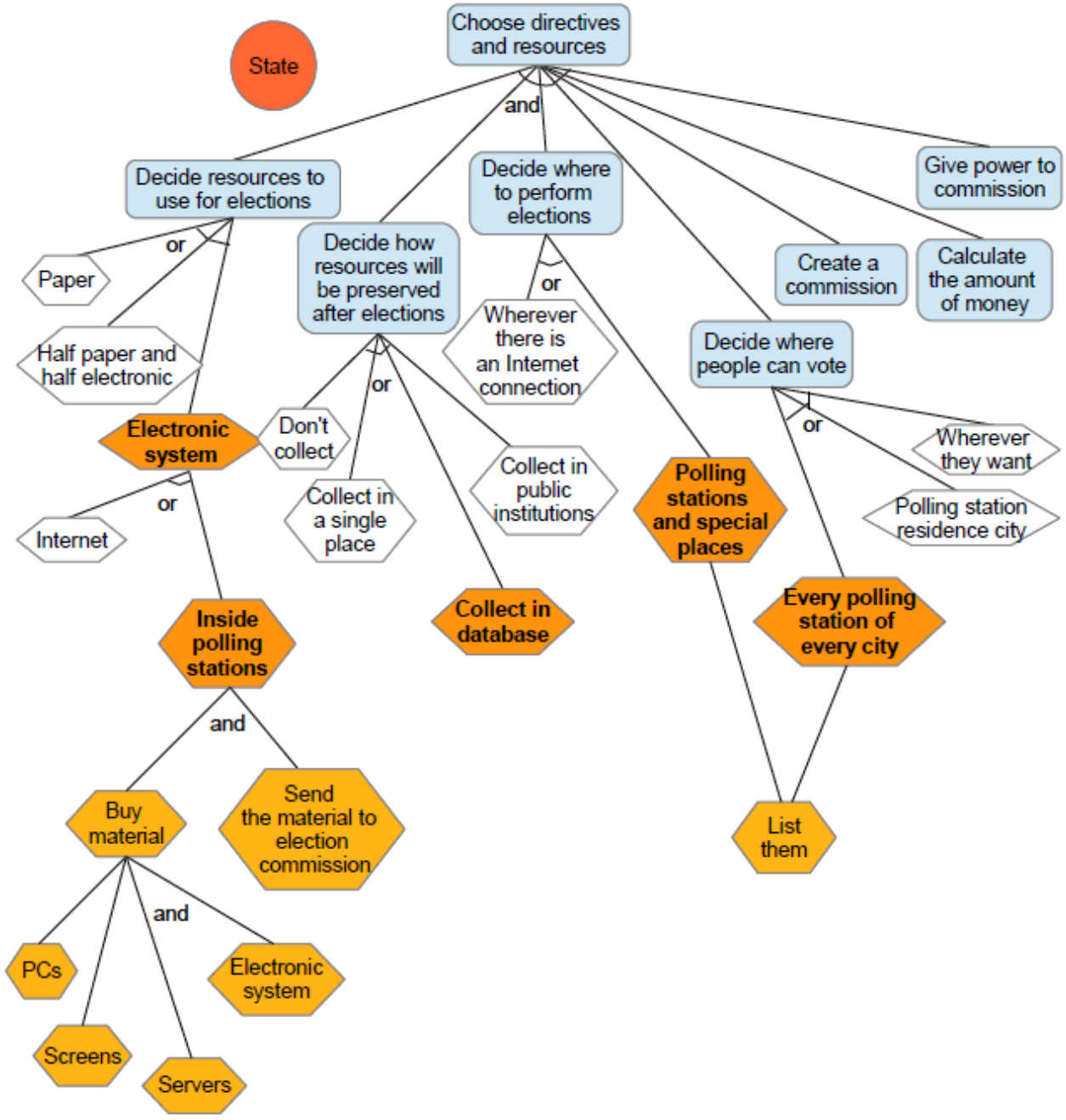






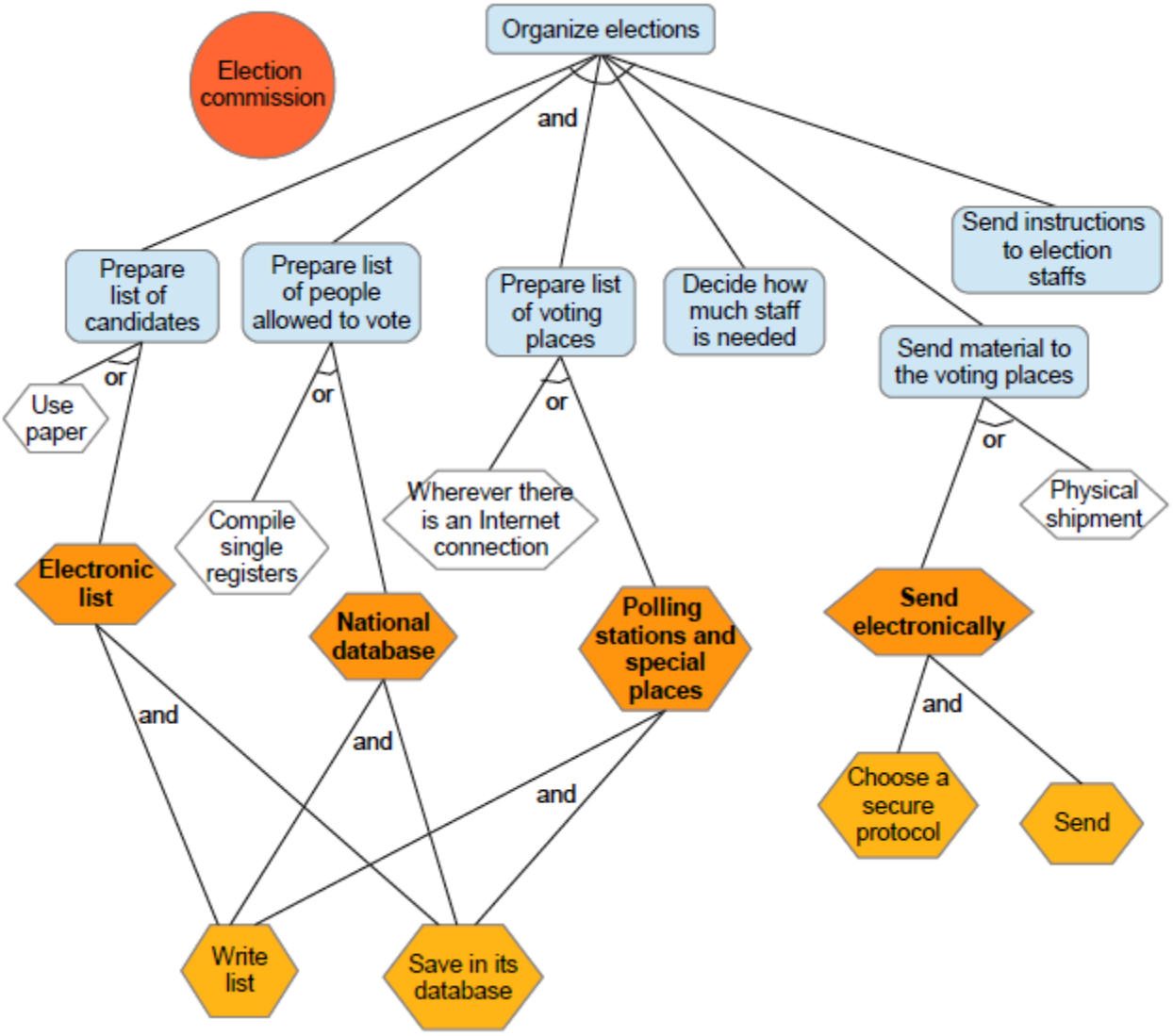
CHOOSE DIRECTIVES & RESOURCES	Paper	Paper & electronic system	Electronic system	Collect material resources	Collect digital resources	Don't collect resources	Vote in polling stations of resident cities	Vote in every polling station	Vote on the Internet
Minimize cost	Very bad: lots of expenses for each election	Good: improvement in the actual system	Very good: expensive the first time, but then very few expenses	Bad: collection has a cost	Not good: servers must be bought	Perfect: no expenses	Very bad: people spend money and state reimburse them	Very good for people, ok for state	Good: almost free for everyone
Minimize time	Bad: sheets require time to be prepared	Good: improvement in the actual system	Very good: almost immediate	Bad: collection requires time	Good: collection is almost immediate	Perfect: no time required	Very bad: forces people to travel	Good: people can reach the closest one	Very good: almost immediate
Improve ecology	Very bad: waste of a lot of paper	Good: improvement in the actual system	Perfect: best way to help the environment	Bad: waste of space and pollution	Ok: some servers needed	Very good: no waste of space	Ok: reserve place such as schools for the elections	Ok: reserve place such as schools for the elections	Good: no waste of resources
Maximize security	Good: external intromissions are uncommon	Bad: possible external intromissions	Bad: possible external intromissions	Very good: possibility to count again for mistakes	Very good: possibility to check again for mistakes	Not good: doesn't give the possibility to check for past mistakes	Good: use the actual system	Good: use the actual system	Bad: no way to prevent the voting evidence (take photos, have a person behind, ...)
Improve comfort	Very good: the user reads and writes	Ok: the user has to learn, but the system can be easy	Ok: the user has to learn, but the system can be easy	/	/	/	Very bad: uneasy system for people who live far	Very good: much more comfortable	Very good for most of the people, but others don't have a computer or internet

Goal 1: choose directives and resources



If the voting system will be electronic and elections will be performed inside polling stations, the state has to buy the needed material to furnish them, including screens, servers and the voting system.
Voting places must be listed, in order to compute quantities.
Then, after the creation of a commission, the whole material will be sent to it, which will be responsible for the following steps.

Goal 2: organize the elections

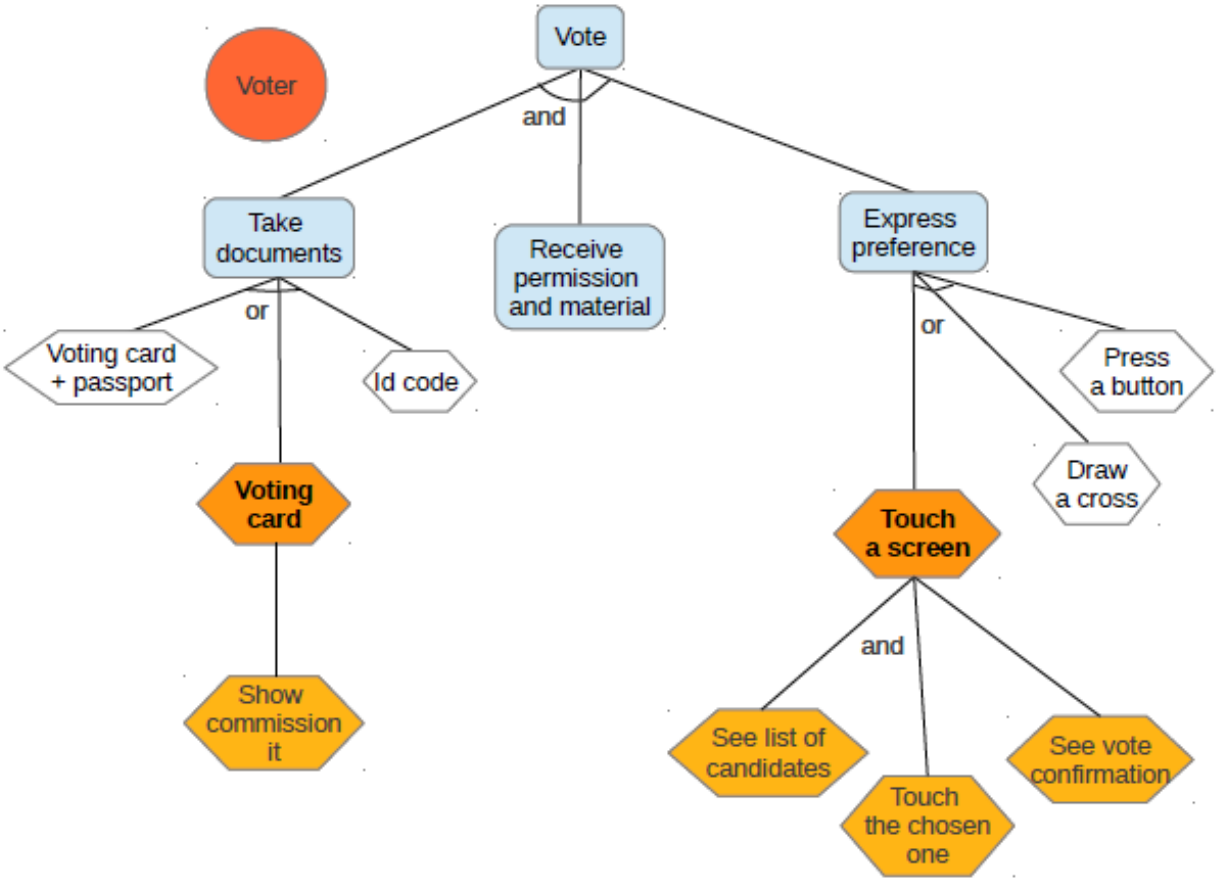


The election commission is created by the state, and has the task to organize and coordinate the elections at a national level.

It creates three kinds of lists: one for the candidates, one for the voters and one for the polling stations. Lists will be saved in the database, and then they will be accessible from every polling station during the election days.

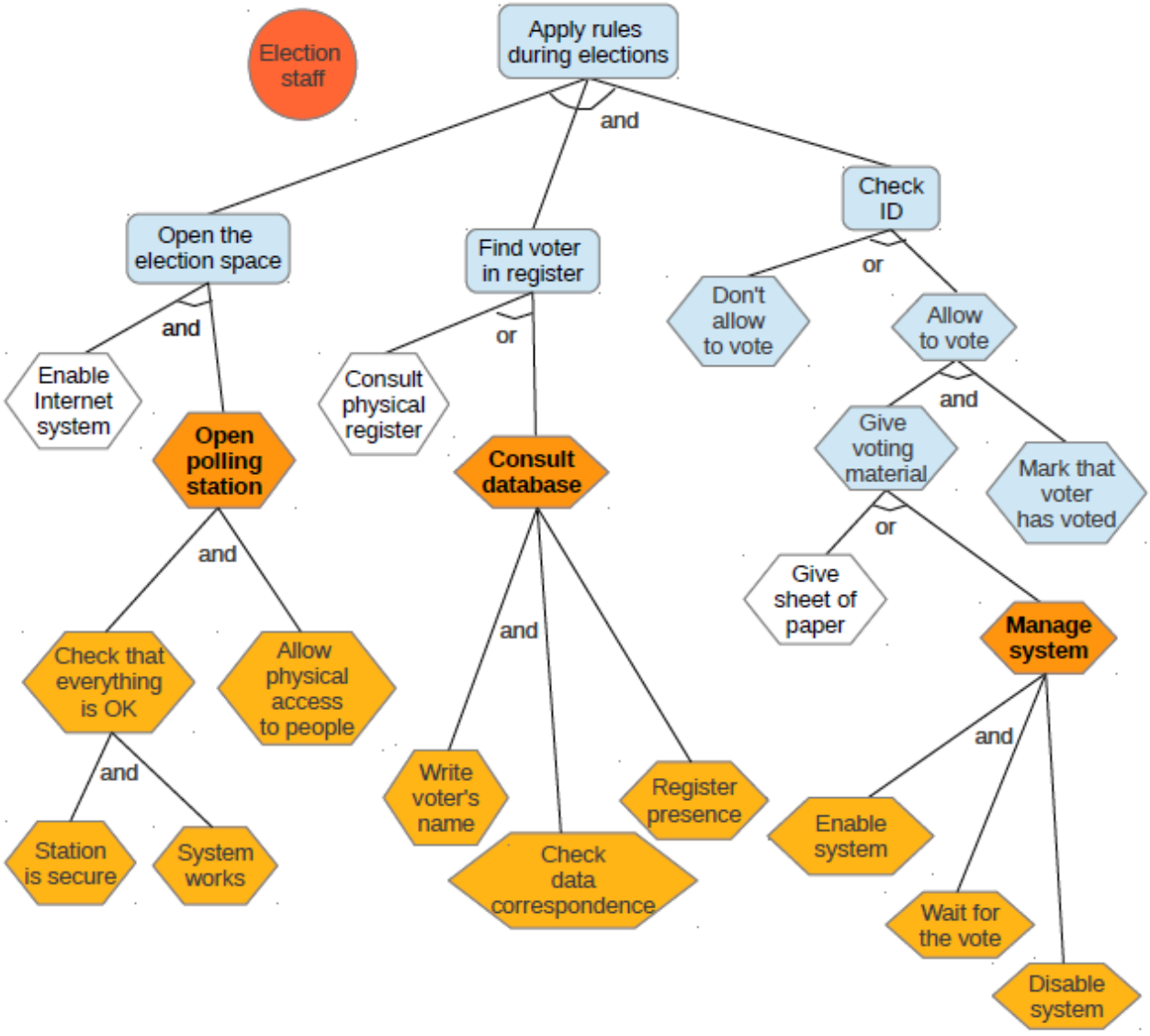
Also, the commission receives from the state the material needed to perform elections, and sends it electronically to the single polling stations.

Goal 3: vote



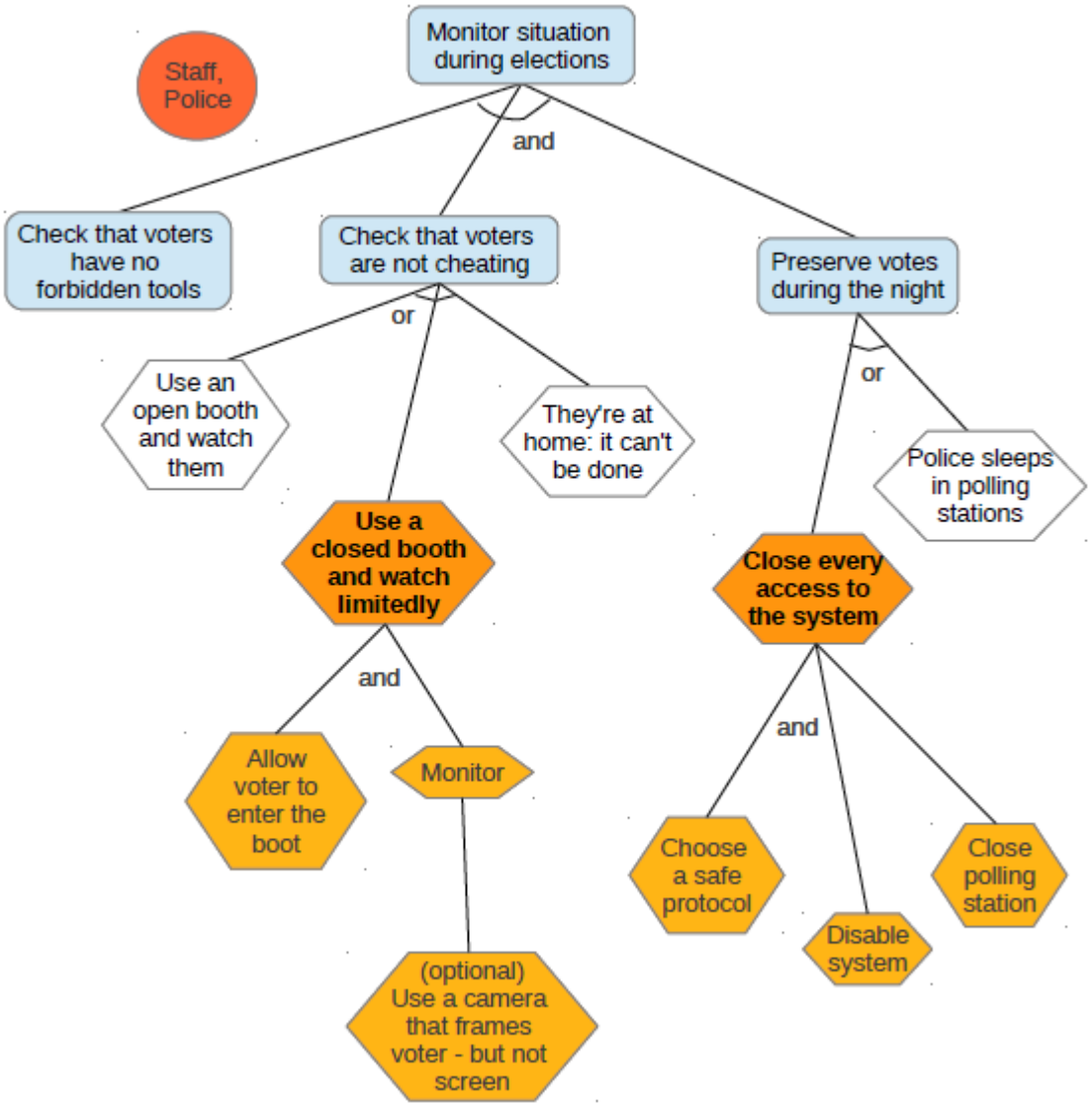
Citizens are allowed to vote in every polling station of the Country.
To do this, they only need to go to the voting place, show their voting card, receive the permission to vote and choose the candidate they want to vote, through an easy system in which they just have to touch and confirm the chosen one.

Goal 4: apply rules during the elections



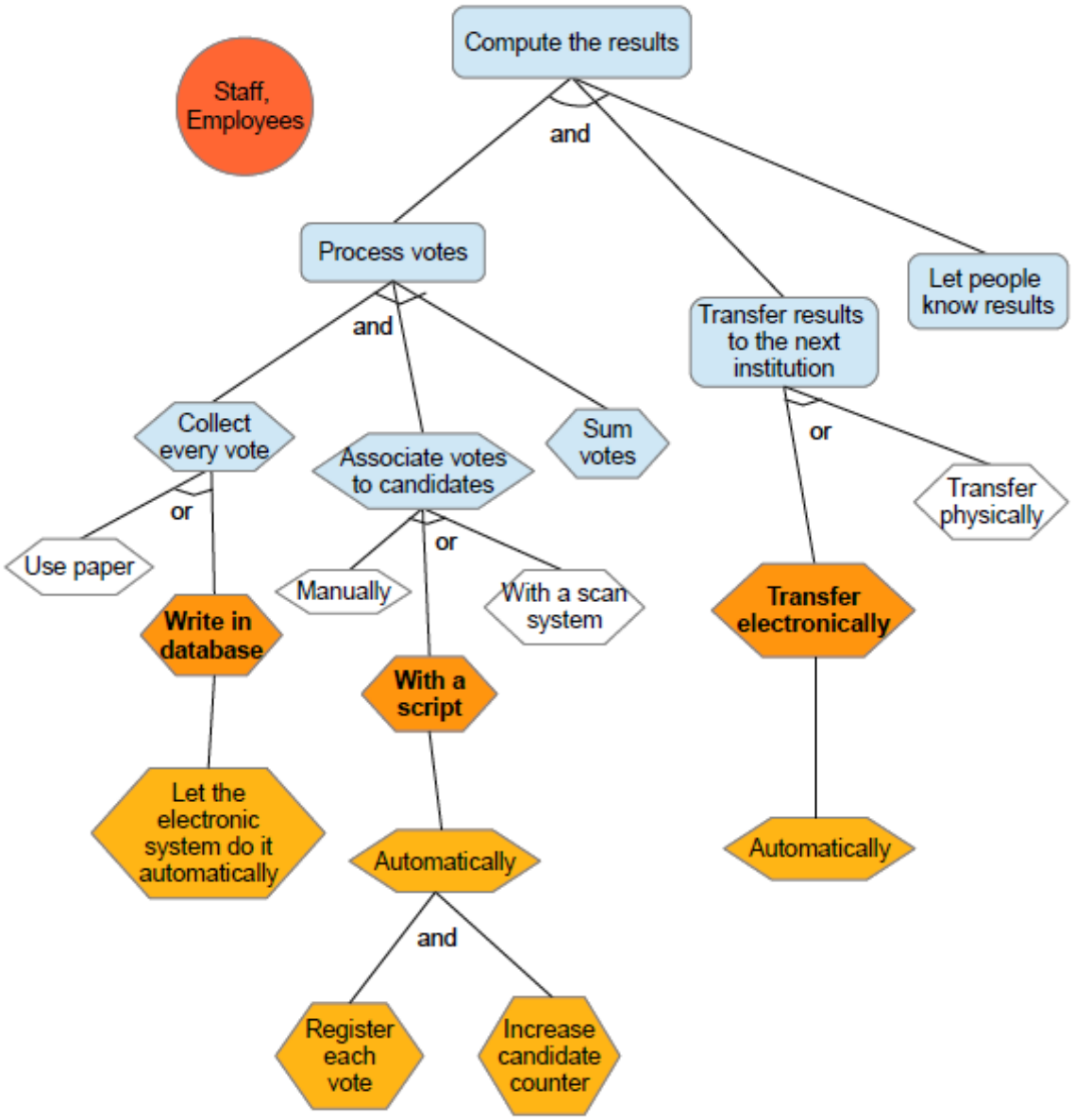
The election staff is responsible for the regular progress of the elections inside a polling station. This means that it has to apply some bureaucratic rules.
The first thing that must be done is to open physically the station and check that everything is secure and works, before allowing people to enter it.
Then, every time that a voter enters, the staff must check his/her voting card consulting the database and checking the correspondence of data. If the voter is allowed to vote, than it registers his/her presence and manages the voting system, enabling it before the vote and disabling it after.

Goal 5: monitor the situation during the elections



During the elections, the staff has to monitor the situation and to avoid every kind of irregularity, with the support of police.
Voters must be asked to give forbidden tools (such as cell phones) to the staff, and they must be prevented from irregular operations (such as taking photos to the vote). For this, they could be monitored through a camera inside the polling booth, which frames them but obviously not the screen.
During the night, there is no more the need to make the police sleep in the station, since there are no more sheets of paper to preserve. To disable the system through a secure protocol is enough.
After this, the polling station must be physically closed.

Goal 6: compute the results

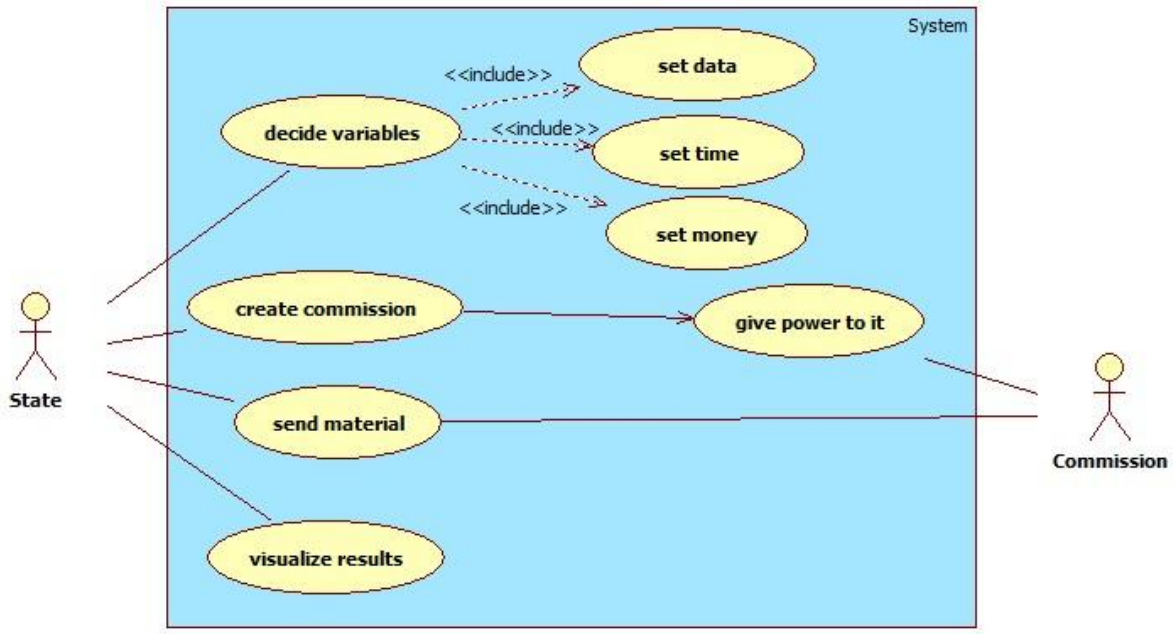


During the elections, the electronic voting system collects every single vote, associating it to its relative candidate. This happens in every polling station, and is supervised by the election staff.
After the election days, these local results must be (electronically) sent to the public institutions. The employees working there will receive them and will wait for the contributions of the all polling stations. Then, results will be transferred from municipalities to regions, and from regions to state. At a national level, global results will be easily computed.

5.2: Use cases

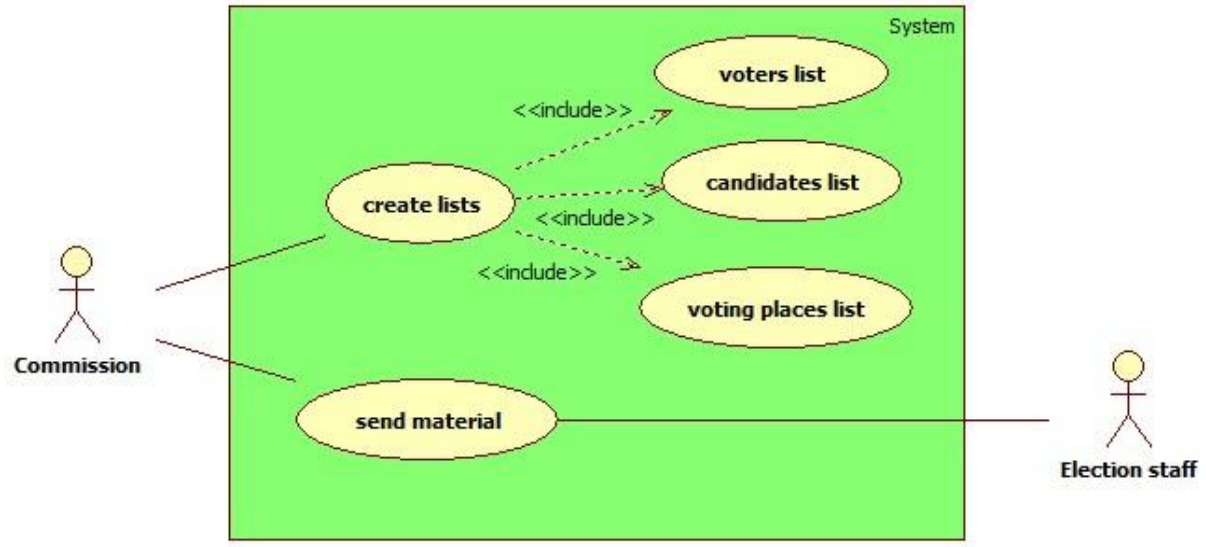
Every actor described in the previous goal analysis has a precise way to interact with the election system, in order to satisfy its needs and aims. The functions and services offered by this system, as they are perceived and used by actors, can be obtained from the tasks studied in the *tactical goal analysis*, and are represented in the following use cases diagrams:

Use case 1: state (*goal 1*)



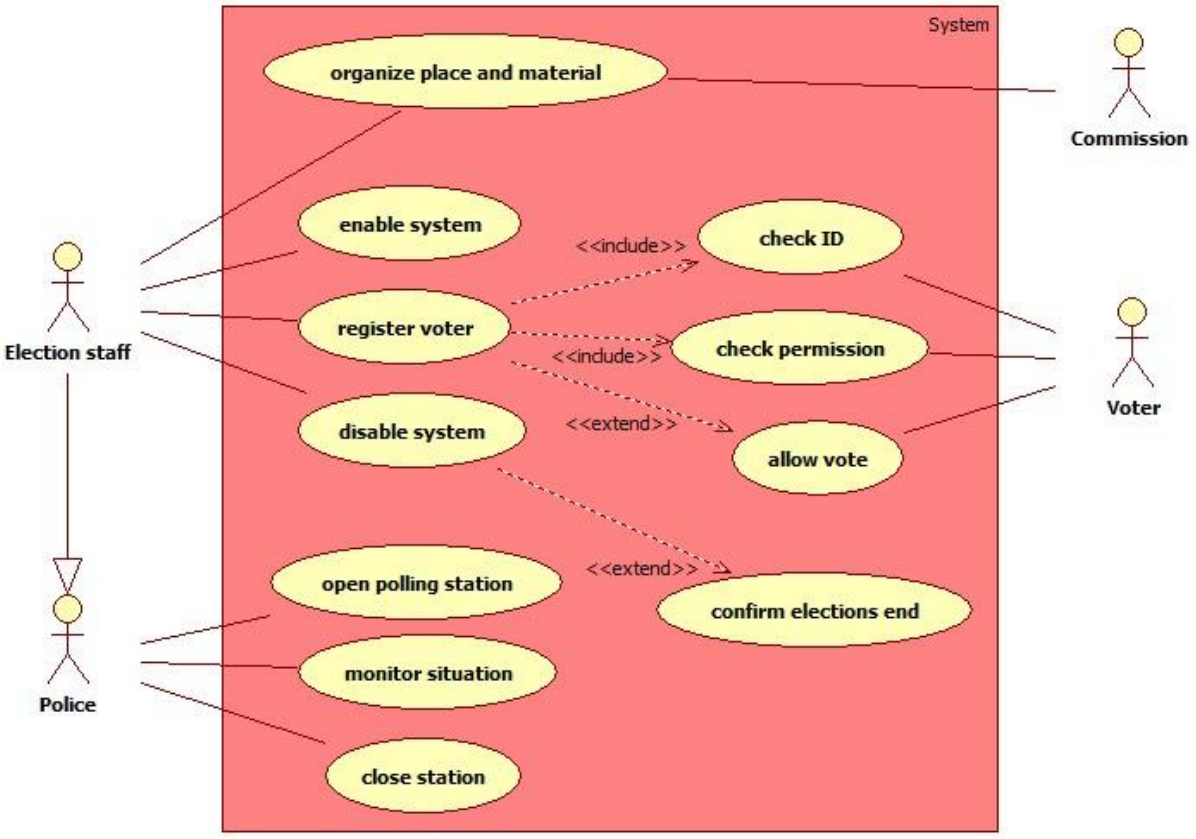
The state actor has its part in the election system by performing four main tasks: taking the basic decisions about elections, creating the election commission, sending the material to the commission and receiving the final results to determine the end of elections.
The basic decisions about elections are the settings of data, time and money. The *include* relationship is used here to indicate that the “decide variables” function includes these three operations, that must be performed every time. Indeed, it is a state’s role to take the most important decisions about the execution of the elections.
Then, the election commission detains the power for the following phases, and can proceed.

Use case 2: election commission (*goal 2*)



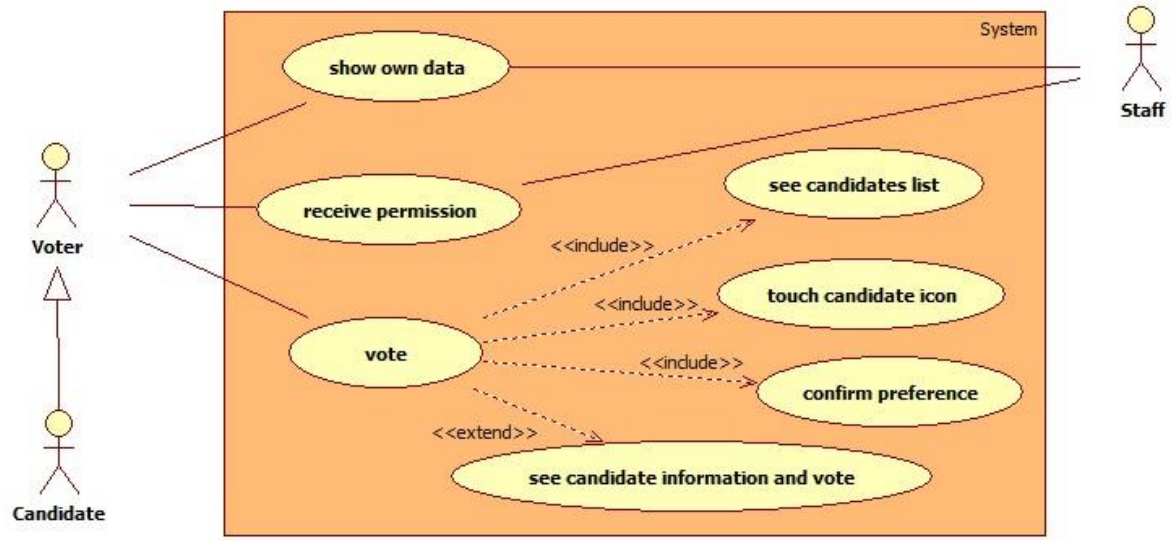
The commission works for elections preparing three different lists: one for voters, one for candidates and a list of polling stations. Then, the created database and the material received from the state are sent to the voting places, to be arranged from the election staff.
Again, here the *include* relationship is used to indicate that the three lists must be created every time: indeed, they are an essential part for the execution of the elections.

Use case 3: election staff (*goal 4* and *goal 5*)



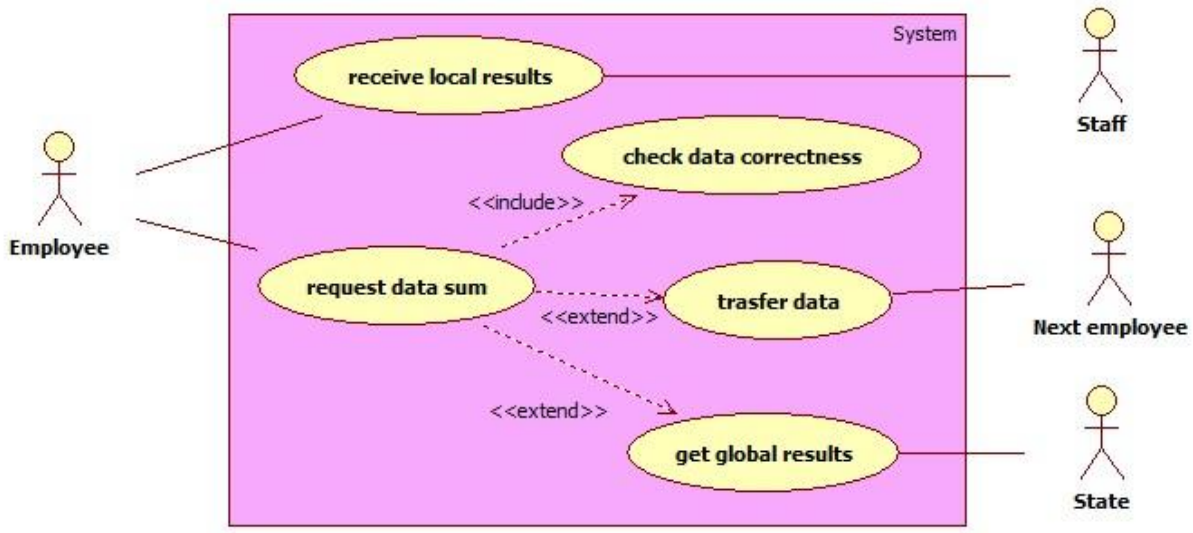
The election staff interacts with the system in several ways. First of all, it performs the same role of police, by opening and closing the voting place, and monitoring the situation during the elections.
Then, it organizes the polling station with the material received from the election commission.
When elections start, it enables the system time by time, registers the voter and disables the system. If elections are over this is a final disable, and the staff has to confirm the end of elections.
The registration of the voter *includes* every time the check of ID and of permission, through the documents received from the voter. In case of no irregularities, the voter is allowed to vote: this part is optional, so it *extends* the "register voter" phase.
For the same reason, the disable of the system can be enriched by the "confirm elections end" function, but only if elections are over (otherwise the system is normally disabled at the end of every election day).

Use case 4: voter (*goal 3*)



The voter interacts with the election system during the voting phase. This is done by showing the voting card to the staff, receiving the permission and expressing the candidate preference. Candidates are allowed to vote too, so they behave exactly like voters.
The voting phase consists of three essential steps: the display of the list of candidates, the touch of the chosen icon and the confirmation of the vote; they all are *included* in the vote.
Also, we consider a system which displays optional information about the candidate, such as the belonging party or the program. Of course information is shown only if the voter requests it, so we consider this as an *extension* of the vote.

Use case 5: employee (*goal 6*)



Employees have their role in the election system at the end of the voting phase. They receive local results from polling stations (monitored by the election staff), and request their sum. This *includes* the check of their correctness, because eventual mistakes must always be prevented.
Then, they can transfer these results to the next institution (if the state has decided that results must be collected at different territorial levels) or directly have the global outcome and forward it to the state. These two are *extensions* of the "request data sum", because they are executed in different cases.

5.3: Entities and relationships

Analyzing the whole problem domain, as described in the first task of assignment1 (*step1 – choose a project*), we can identify the following important concepts (marked in red):

In Italy, as in many other countries, the **election system** requires the **voter** to be physically present in the **polling station**. He/she has to show a **voting card** and his/her passport, receives a **piece of paper** and goes in a polling **booth**, where he/she makes a cross in correspondence of the **candidate** he/she wants to vote. At the end of the elections, the **polling clerks** read all the sheets of paper and count the different **votes**.

This system prevents illegal operations, such as threats or votes evidences, and for this reason it cannot be replaced with an Internet-based technology. Anyway, there are some problems. First of all, people who live far away from their home cities without having a new residence (for instance off-site students) are forced to go back home if they want to vote, spending time and money. The **government** also has to give a partial reimbursement to them, using public funds. Secondly, this system creates a huge waste of paper, and in general of money (indeed elections are dramatically expensive). Thirdly, the polling clerks have to count manually the votes, not only wasting a lot of time, but also making many mistakes possible. And sometimes voters make mistakes too, because the rules of "how to draw exactly the cross" are very strict.

In other words, this election system works, but with many problems. A **software system** could solve them. If all the polling stations had, inside the booths (we still want to prevent illegalities), a screen showing the possible candidates and allowing one to vote them, people could choose without risking to invalidate their vote, polling clerks could see the results without having to count sheets manually, outcomes would be available immediately after the elections, and there wouldn't be that waste of paper and money. Also, adding an access to a national **database**, people would be able to vote in the polling station closer to them, no matter if they are far from their home city; consequently, the government would not have to reimburse them. The whole system would save millions of money.

This is a case in which technology could solve a serious real-life problem.

Also, from the use cases we can make another list of concepts, related to the solution (rather than the problem[7]):

- Use case1: **state**, **data**, **time**, **money**, **material**
- Use case2: **election commission**, **lists**
- Use case3: **election staff**, **police**, **election system**, **elections**, **polling station**
- Use case4: **voter**, **candidate**, **permission**, **vote**
- Use case5: **employee**, **results**

From these steps, we obtain the following concepts:

[7] It is good to analyze both problem and solution, because in the solution we introduced some new concepts

- **Election system / software system**
- **Voter**
- **Polling station**
- **Voting card**
- **Piece of paper (ballot) / vote**
- **Polling booth**
- **Candidate**
- **Polling clerk / Election staff**
- **Government / state**
- **Database**
- **Data**
- **Time**
- **Money**
- **Material**
- **Election commission**
- **Lists**
- **Police**
- **Elections**
- **Permission**
- **Employee**
- **Results**

Some of them are main **entities**, some others are just **properties of entities**, and others are **not relevant** for our case.
Let's distinguish them:

ENTITIES	PROPERTIES	NOT RELEVANT
Voter	Voting card Permission	
Candidate		
Ballot		
Election staff		
Election commission		
Polling station		
Elections	Data Time Money Material Lists Results	
		Systems: election system, database
		Physical entities: polling booth
		Actors: state, police, employee

Entities are the basic concepts that will became classes of our diagram. We have lots of entities, but we decided to consider relevant only seven of them: two main abstract concepts (*Elections* and *Ballot*), one physical place (*Polling station*) and four main actors (*Voter*, *Candidate*, *Election staff* and *Election*

commission). The reason is that our election process is very long, and involves lots of parts, since it is a national event. Therefore, we prefer to focus only on its most important parts, to understand better the evolution of the system and its relationships.
For this reason, we considered other concepts of our problem as secondary: some less-involver actors (*State*, *Police* and *Employee*), some not important physical entities (the *Polling booth*) and the two systems (*Election system* and *Database*), which are not properly entities involved in the situation, but just global parts of the solution.
Finally, some other concepts are not so important alone, because they define properties of other entities. So we consider them as attributes.

Now that we have the classes of our diagram, we can explain them better:

- Election: the most important entity: everything is related to it. It has some properties to determine its state, result and time and money spent.

- Polling station: the physical entity in which voting happens. For our system it is important to know where it is located and how many people can vote at the same time there.

- Voter: the person who goes to the polling station in order to register his/her preference. He/she has some personal data and, above all, a voting card, which is used to register him/her and to give him/her the voting permission.

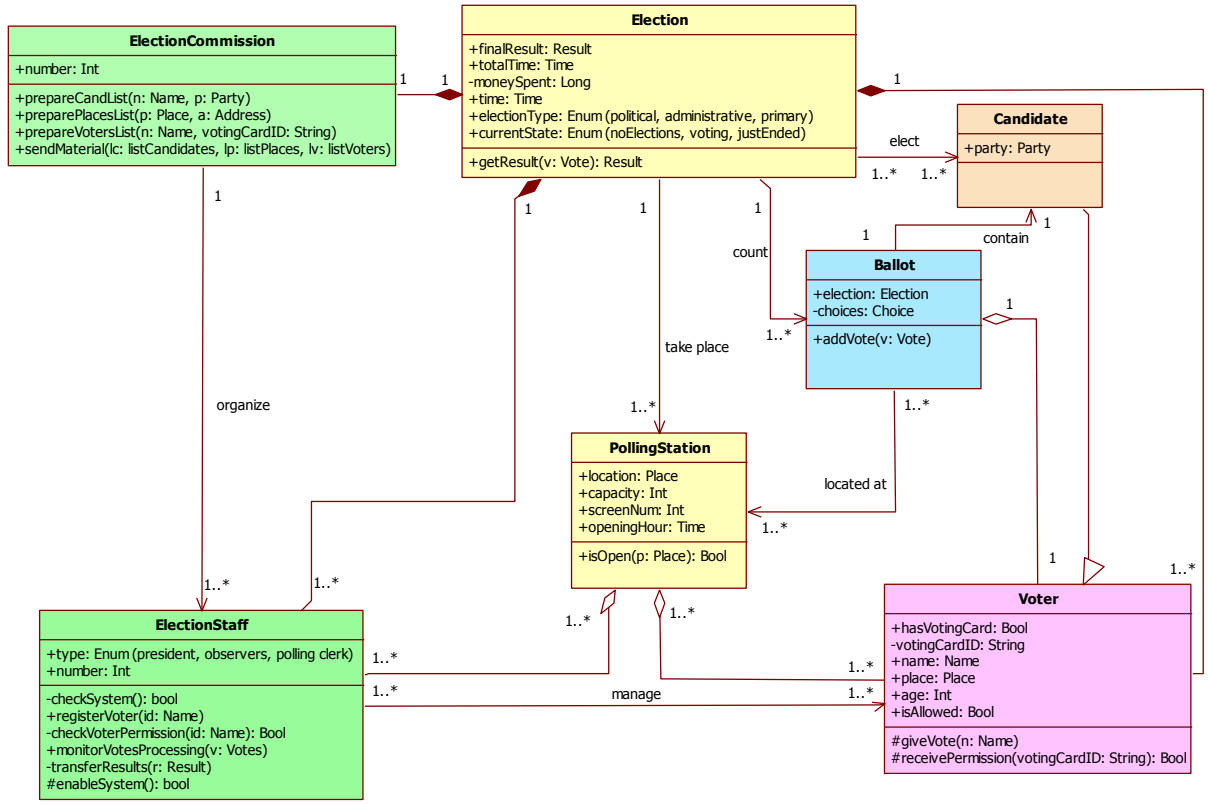
- Candidate: the people who belong to a party and proposed themselves as representative of citizens. Each voter vote for only one of them.

- Ballot: the single vote given from a voter to a candidate. It indicates a precise choice, and its sum determines the result of the elections.

- Election staff: the people who work inside polling station, applying bureaucratic rules and monitoring the situation.

- Election commission: the group of people chosen by the state, who have the task of preparing the lists of voters, candidates and polling stations, and send the material to the single voting places.

Class diagram[8]:



Link between classes can be explained in the following way:

- Inheritance: “is a” relationship: some classes are totally part of other classes. In our case, Candidate is a Voter because he is allowed to vote as all the other citizens.

- Aggregation: kind of association between a whole and its parts. It means that the lifetime of the contained classes does not depend on the lifetime of the containing class. So, for example, if the Polling Station class will be destroyed, the Election Staff class and Voter class will continue their normal life; for the same reason, the Voter class can exist also without Ballot.

- Composition: a stronger version of aggregation, which means a strict dependence between the instances of the container and those of the contained classes. So, if the Election container will be deleted, then the ElectionCommission, ElectionStaff and Voter classes will not exist anymore, because of their strong dependence with it.

- Association: a light kind of relationship, which identifies a general link between the two involved classes. For instance, ElectionStaff and Voter have an association named “manage” towards Voter direction, because the ElectionStaff has the role of checking, coordinating and monitoring the Voter. Also, Election and PollingStation have the “take place” association, because the relationship between them is based on the fact that every Election happens in a PollingStation.

[8] If there is any problem in zooming and reading the class diagram image, it is uploaded here as well: http://i39.tinypic.com/1jn88y.png

- Multiplicities: in the links between classes, numbers represent the occurrences of one class respect to the other one. In our case, since every class is necessary, we have always at least one occurrence, and in some cases more than one:
    - *1* means that there is only one instance of the class. For example, every Voter can compile only one Ballot (per election), and every Ballot is compiled by one only Voter. Also, every Ballot is used from one Election; whereas, of course, every Election can use more than one Ballot.
    - *1..** means that there can be one or an arbitrary number of instances of the class. For example, one or more people of the ElectionStaff manage the Voter, and one or more Voter are managed by the ElectionStaff.
    - In some cases, we have more specific lower and upper bounds[9]. For instance, the number of Ballot used for Election is 1...60,000,000, being 600,000,000 (circa) the Italian population (of course there cannot be more votes than voters). Other parameters based on big specific numbers are the number of polling stations in Italy and the number of ElectionStaff. As an example of lower bounds, Elections probably have a minimum number of Candidate, and some of them are considered valid only with a minimum number of Ballot (the *quorum*. Supposing that, for example, the 25% of votes are required, we would have the following multiplicity of Ballot, with respect to Election: 15,000,000...60,000,000). We can also fix other limits like the number of Voter per PollingStation and assigned to ElectionStaff.

[9] The tool we used for the class diagram did not allowed us to specify this

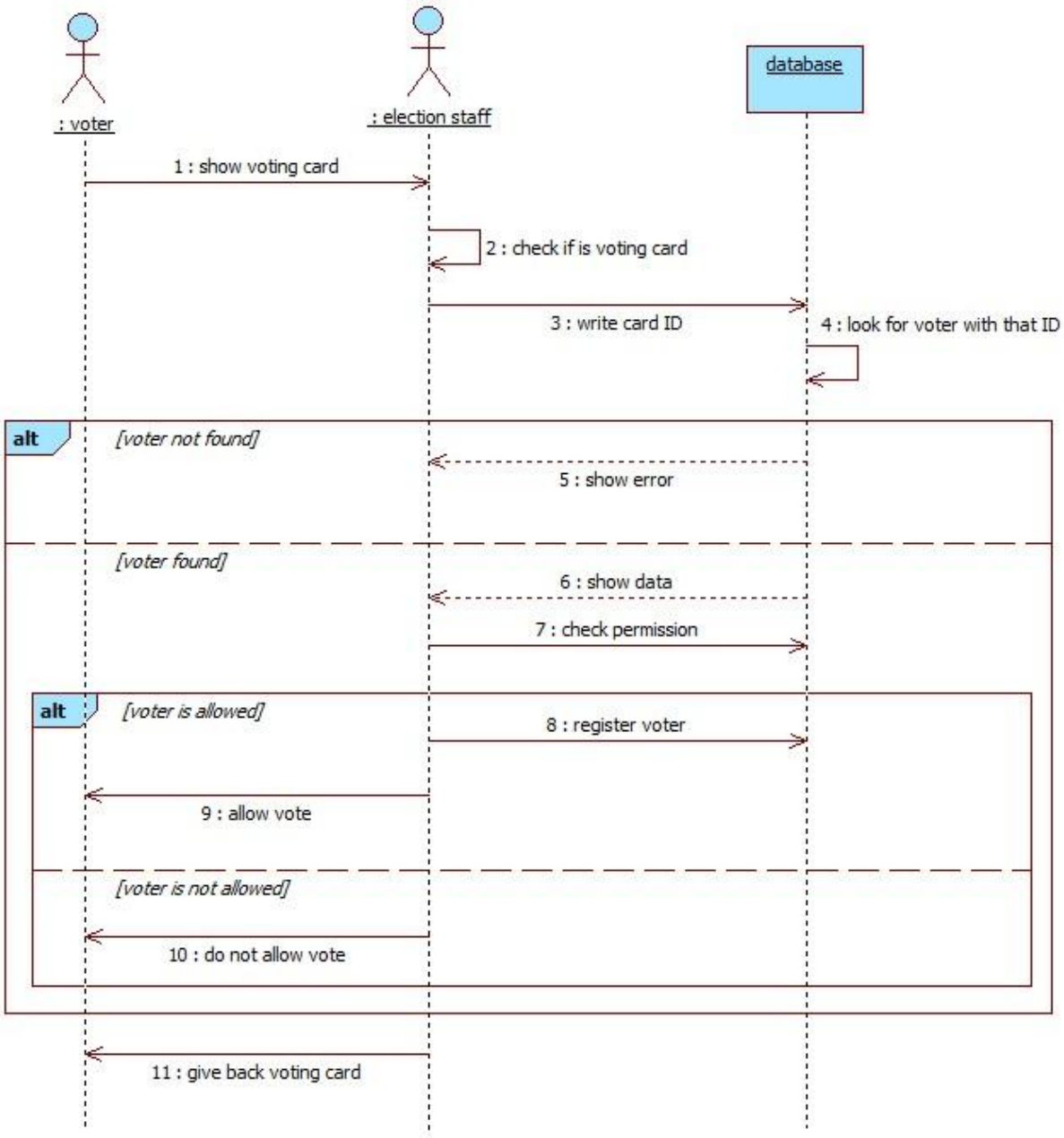
Also, there are same properties that cannot be represented in the class diagram. These are the following OCL constraints:

```
context Election
      --money spent must be less or equal than money that state has
      inv: self.moneySpent <= State.money
      --elections last two days
      inv: self.totalTime = 2days


context Election :: getResult (v : vote)
      --results must be available only at the end of elections
      pre: self.currentState = justEnded
      --after the results, elections are over
      post: self.currentState = noElections


context Voter
      --voter is allowed if he receive the permission = true
      inv: self.isAllowed = receivePermission(votingCardID : String)
      --voter must have the voting card, otherwise he is not allowed to vote
      inv: if self.hasVotingCard = false then self.isAllowed = false
      --voter must be at least 18
      inv: if self.age < 18 then self.isAllowed = false


context Voter :: giveVote(n : Name)
      --a voter can vote only if he/she is allowed
      pre: self.isAllowed = true
      --a voter can vote only one candidate
      pre: n->size() = 1
      -- the voter can vote only once; then he is no more allowed
      post: self.isAllowed = false
      --after voting, the vote is registered
      post: Ballot.addVote(v : Vote)


context ElectionStaff :: transferResults(r : Results)
      --at the end of elections, the president transfers the results
      pre: Election.currentState = justEnded


context ElectionStaff :: enableSystem()
      --the president can enable system only if there are elections
      pre: Election.currentState = voting
      --the president can enable system only if the polling station is open
      pre: PollingStation.isOpen(p : Place) = true

context PollingStation
      --polling stations cannot have more screens than their capacity
      inv: self.screenNum <= self.capacity
```

5.4: Use case executions

Use cases describe the interactions between actors and system in a compact way and exploiting the abstraction. Actually, real operations are more complex than the ones listed there. These sequence diagrams are a way to study more in details the single steps performed.

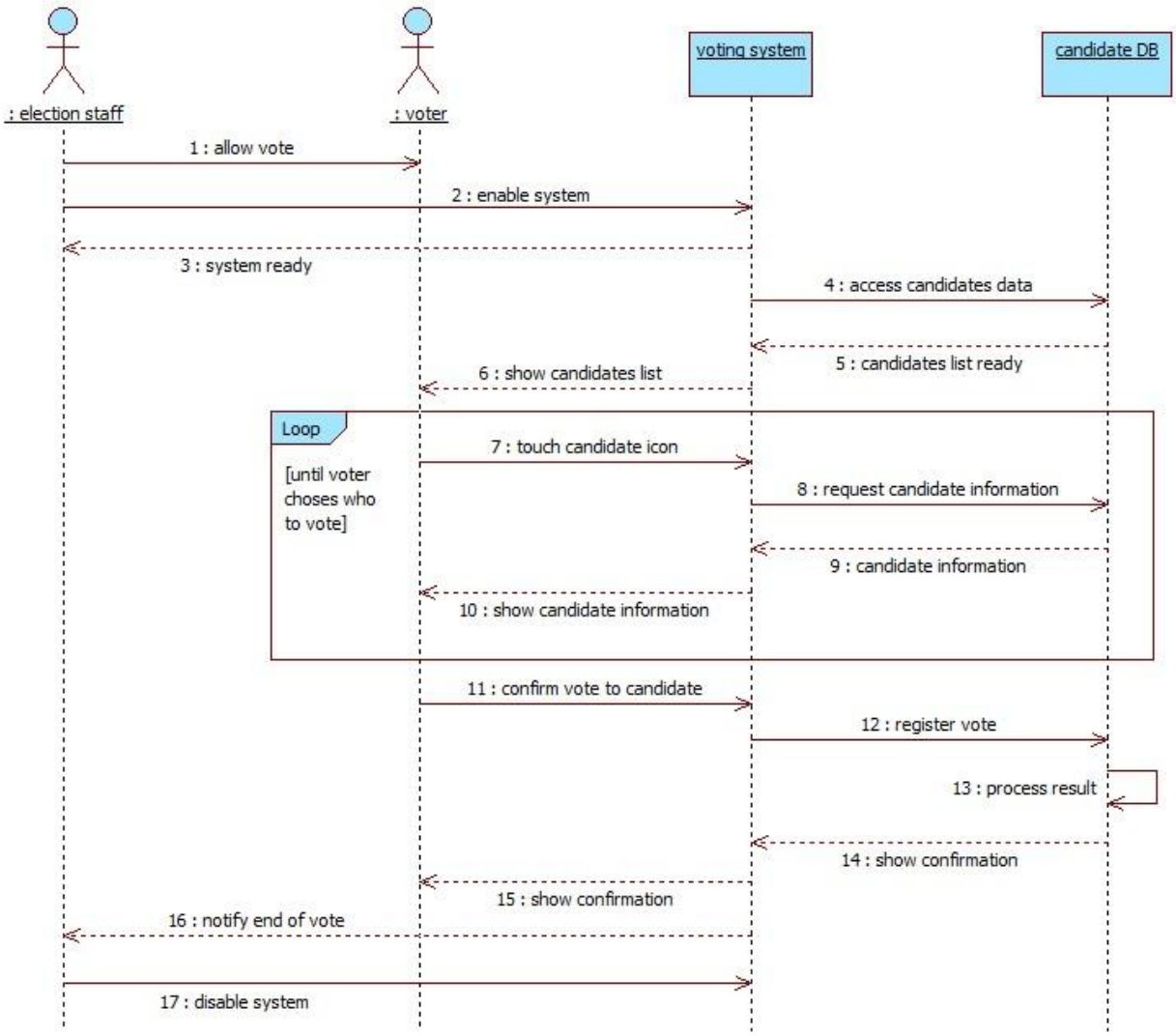
Sequence diagram 1: allow voter to vote



Before the voting phase, the election staff has to give the permission to the voter. It receives the voter's voting card and check if it is ok; then writes its code in the database, which looks for the voter.
If he is found, the staff receives his basic identification information, and check if he has the permission to vote or not. If so, he is registered in the database and allowed to vote.

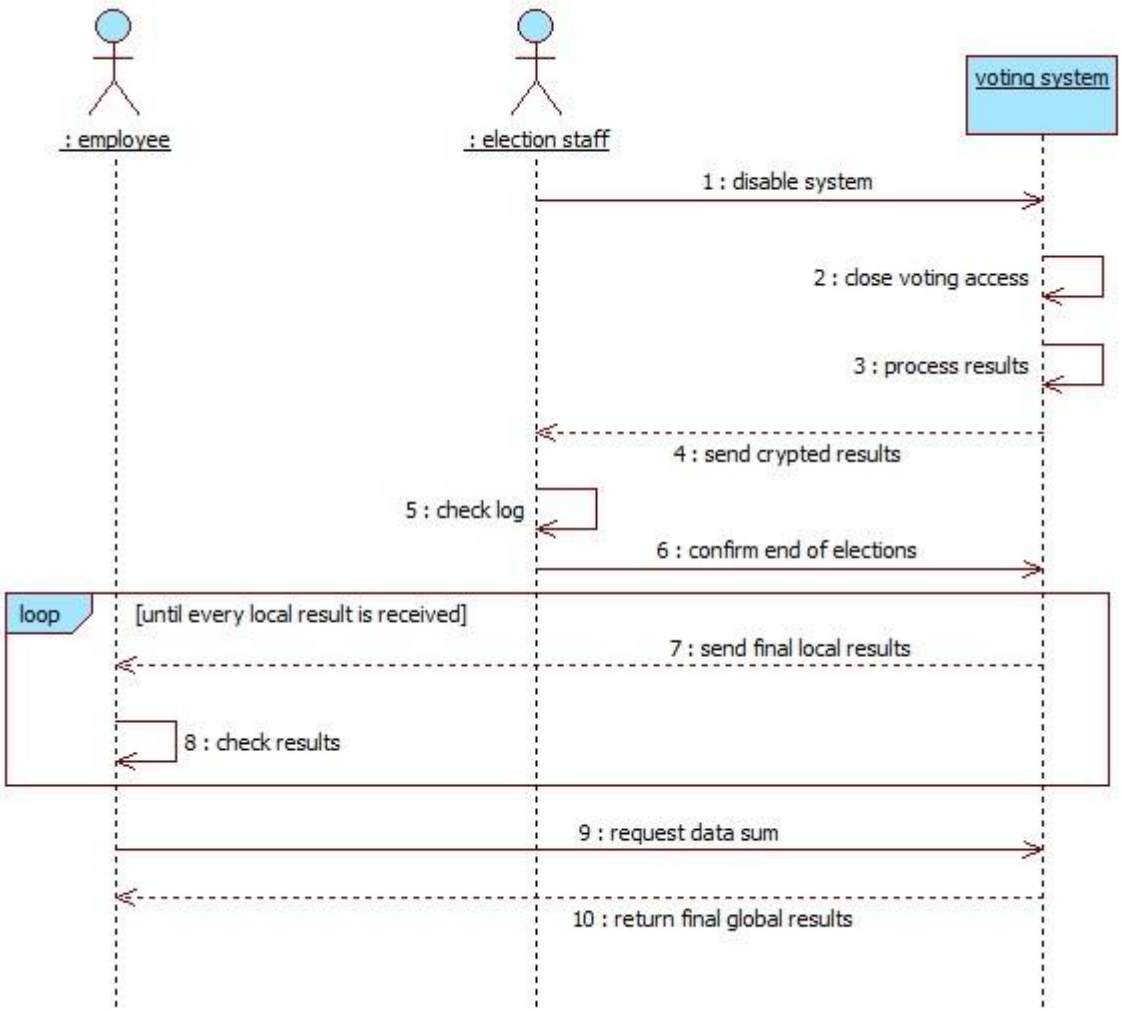
In case the voter is not found or he does not have the permission (because, for example, he has already voted or he is younger than 18), an error is signaled, and the voter is not allowed to vote. In any case, he will receive back his voting card.

Sequence diagram 2: vote



The voting phase starts after that the election staff gives the permission to the voter and enables the system. Then, the system retrieves from the database the list of candidates, and shows it to the voter, who can consult it and see pieces of information about single candidates (which, again, are retrieved from the database).
When the voter has decided the final choice, he/she confirms the vote and receives a feedback.
The system saves the vote and notify the election staff, who can now disable it.

Sequence diagram 3: transfer results

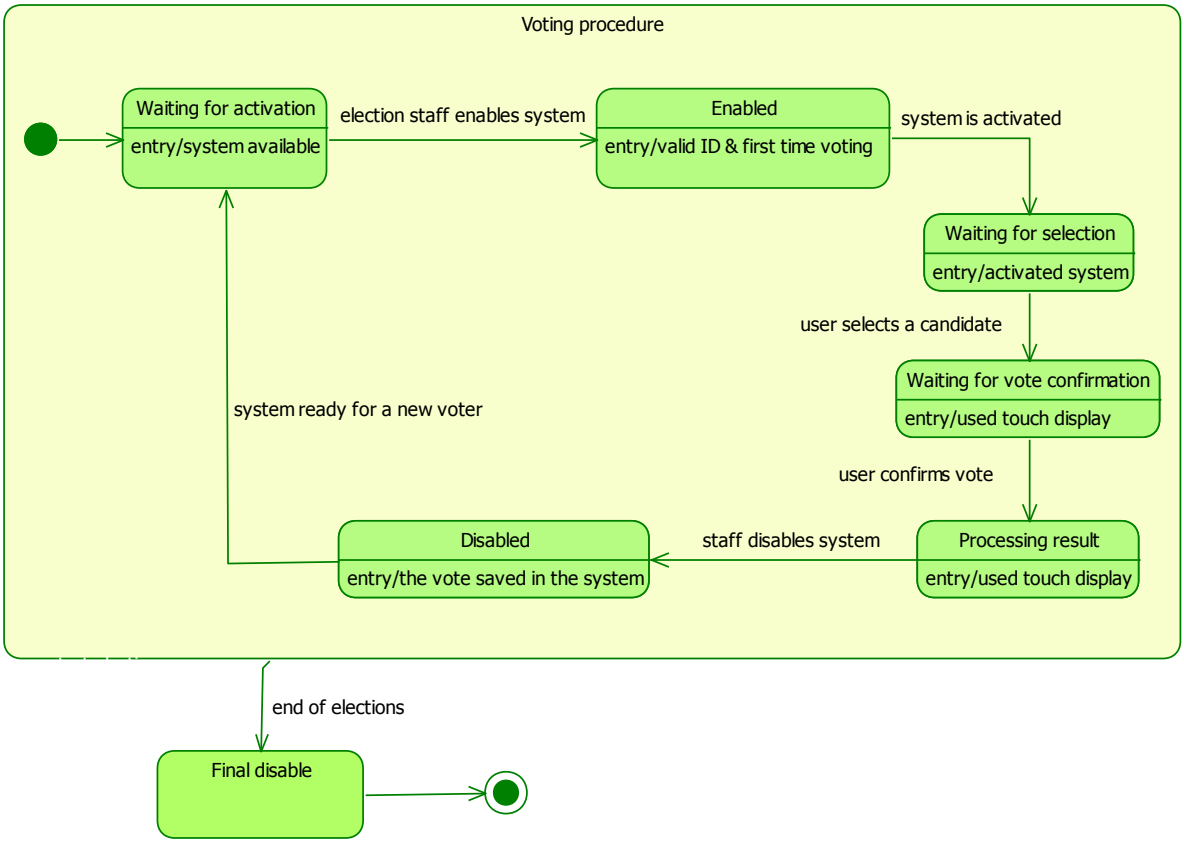


After the end of the elections, the staff disables the system, which closes every kind of further access and processes the voting results.
A brief recap of this process is sent to the staff (showing mainly the operations done, the total numbers and the data correctness), which checks it and confirms definitively the end of elections.
After this, the system sends the results to the employees working in public institutions. They have to wait for every result of every polling station in their territory, and then they can request the total result, allowing the system to compute the sum of the data.

5.5: Business processes

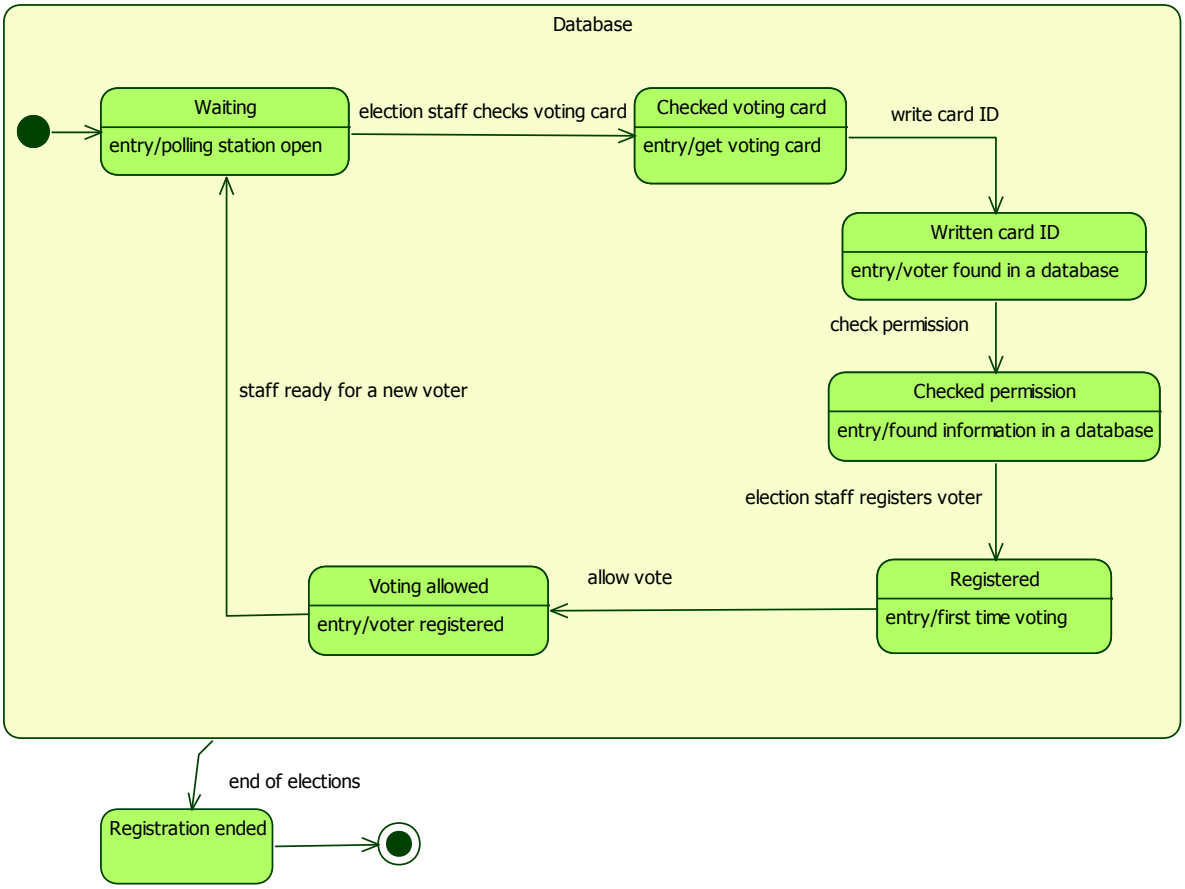
The two main software entities involved in the project are the *voting system* and the *database of voters*. They both are repeatedly used during the progress of the elections, and change continuously state.
These changes are modeled through the following state diagrams:

State diagram 1: voting system



At the beginning of the elections and after every vote, the voting system is deactivated, for security reasons, and it stays in a waiting state (*use case 3*). The election staff enables it time by time, in every moment in which a voter comes and receives the permission (*use case 3*).
When the system is activated, it waits for an input of the voter, which means for the touch of a candidate that it displays in the electronic ballot (*use case 4*).
The system requires the voter to confirm his choice, and then processes and saves the result (*use case 4*).
Then, it is disabled by the election staff, which will activate it again when a new voter will come (*use case 3*).
This process is repeated until the end of the elections, when the system is disabled for the last time by the staff (*use case 3*), and results are sent to employees (*use case 5*).

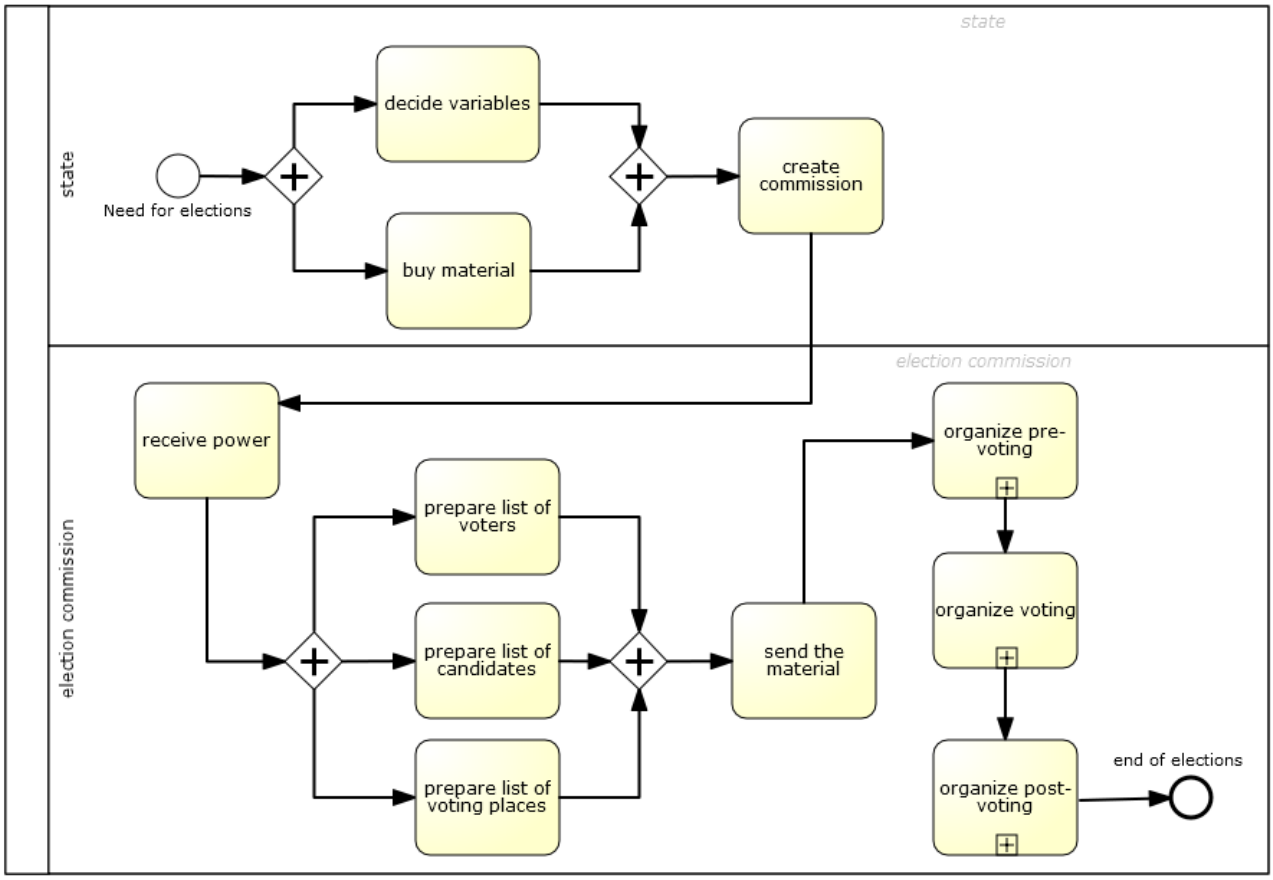
State diagram 2: database of voters



The database of voters is prepared by the election commission (*use case 2*).
Similarly to the voting system, it is used every time that a new voter enters the polling station (*use case 4*). It is exploited by the election staff, which interrupts its waiting state by receiving a voting card and writing its ID in the system (*use case 3*).
The voter with that ID number is searched in the database, and his permission is checked. In case he is allowed to vote, the staff registers him in the system (*use case 3*).
After this, the database waits for another search and registration, and this process is repeated until the end of elections (*use case 3*).

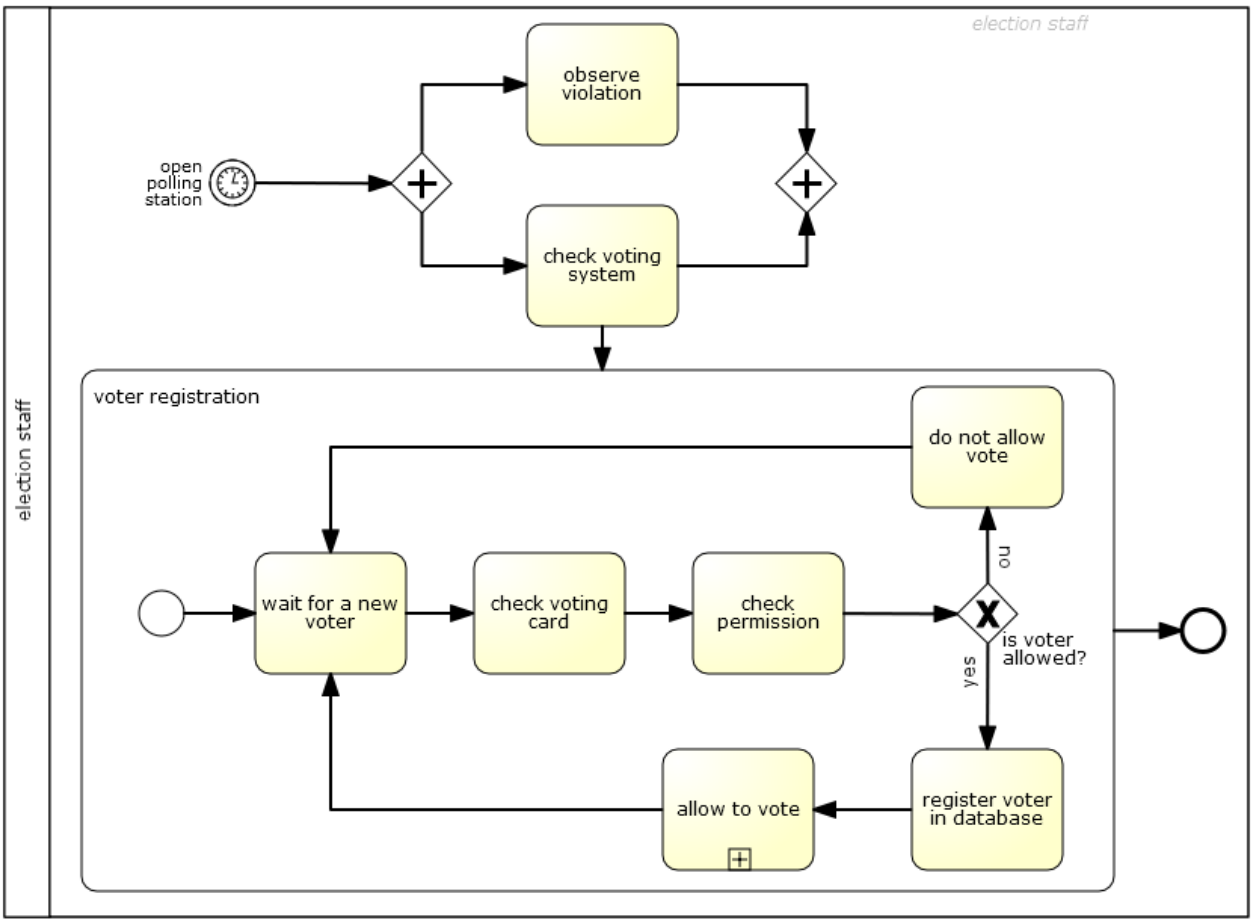
Finally, as a summary of the whole process, here we have four activity diagrams represented with the BPMN language, which combines the use cases and show how the total election system works.

Activity diagram 1: general phase



As we have seen up to now, the whole election process begins when, feeling the need for elections, the state sets the election parameters (date, time, money) and buys the needed material (server, PCs, screens, voting system). Then, it creates the election commission and gives power to it (*use case 1*).
The commission starts its work preparing in parallel the three lists that will be integrated in the database and will became a fundamental part of the voting process: the list of voting people, that one of candidates and that one of polling stations (*use case 2*). After this, the whole material is sent to the polling stations, and three election phases begin sequentially: *pre-voting*, *voting* and *post-voting*. We consider the commission as a general organizer and supervisor of them.
After the post-voting, elections are over.

Activity diagram 2: pre-voting phase

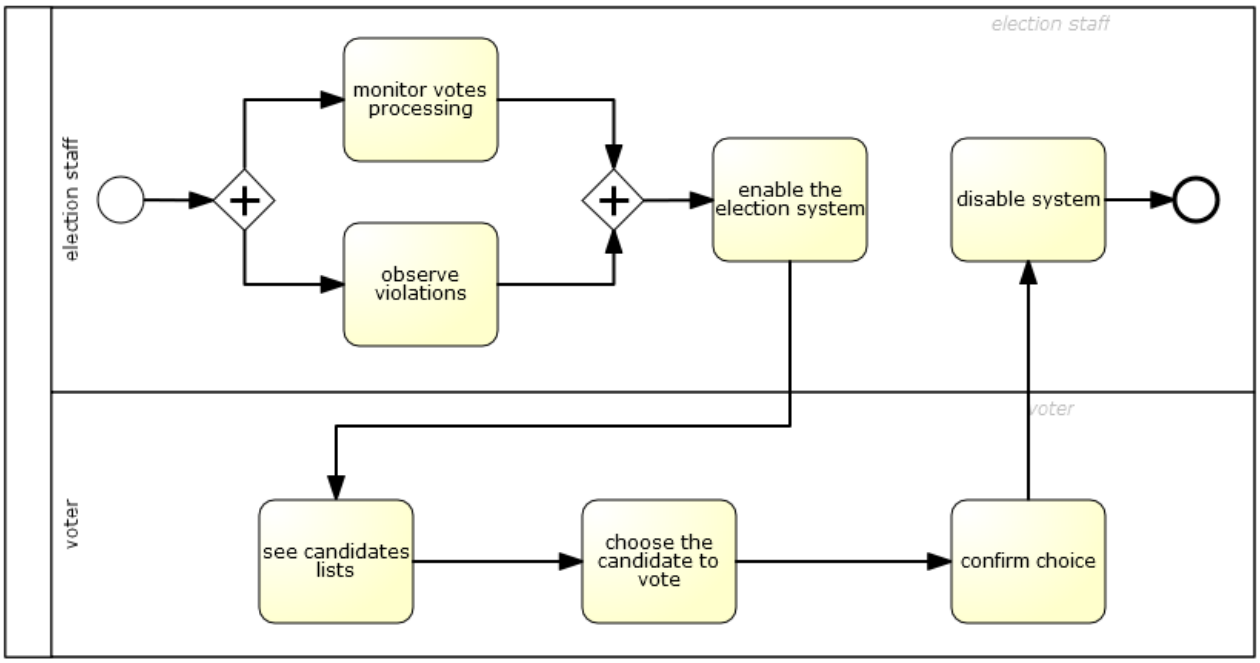


The pre-voting phase is performed by the election staff before every single vote, during the election days. Its purpose is to prepare and organize the environment (polling station, database, system, screen) for voting.

When it is time to open to polling station, the staff monitor its security and checks if the voting system is correctly working.

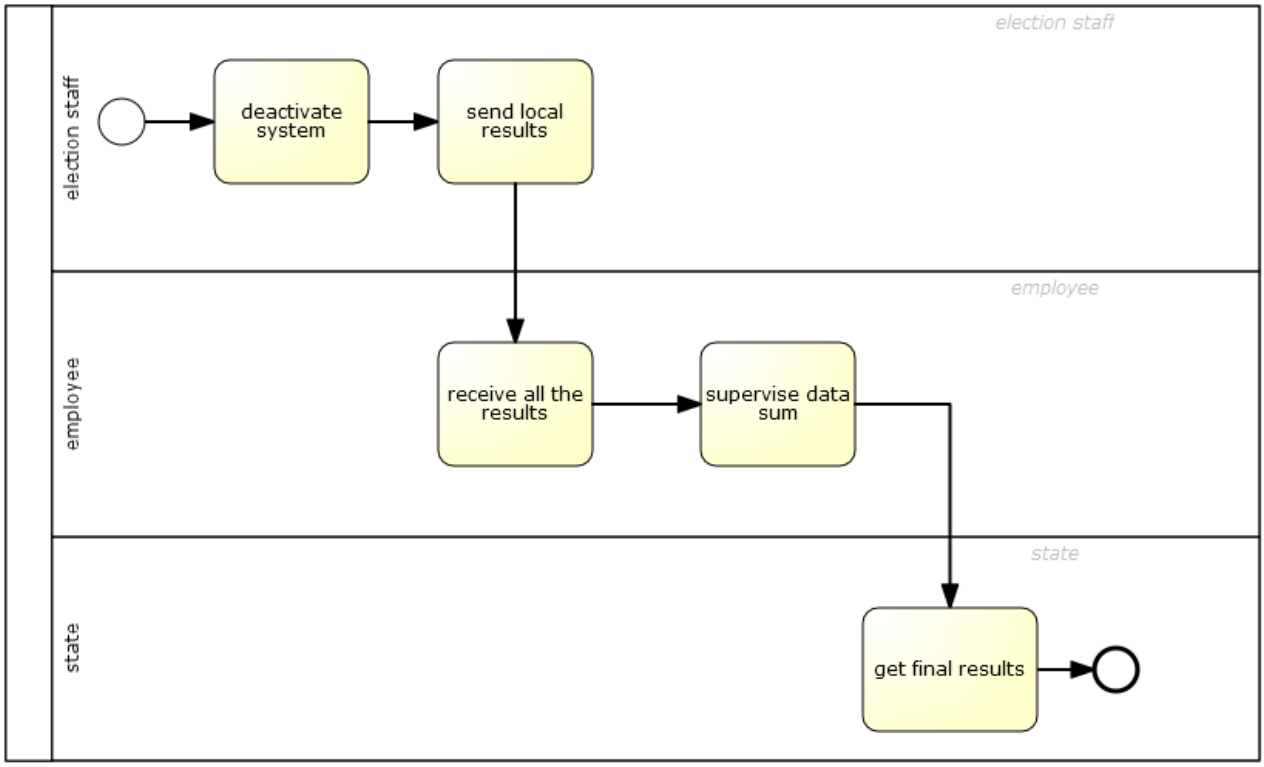
Then, every time that a voter comes, his/her voting card and permission are checked. Depending on the result, the voter goes to the voting phase or is rejected, and the staff waits for a new voter (*use case 3*).

Activity diagram 3: voting phase



The voting phase is repeated sequentially or in parallel (depending of the number of free election staff members and free screens), every time that a voter is allowed in the pre-voting phase.
The election staff, as always, monitors the correct functioning of the system and tries to avoid violations. Then, it enables the system and the screen for the voter (*use case 3*).
The voter see the list of the candidates and choose the one that wants to vote by touching its icon (*use case 4*). The system asks him/her to confirm the choice, and then a feedback is sent to the election staff, which disables the system.

Activity diagram 4: post-voting phase



When election days are over, the election staff disables the system for the last time and send to results to the employees working on public institutions (*use case 3*)
The employees wait for the results from all the polling stations and allow the system to sum them, supervising the correctness of this procedure (*use case 5*).
When results from the whole Country have been collected, they are finally sent to the state.

Chapter 6
Composite System Requirements

The system designed so far has specific requirements on the external environment, regarding the hardware components and necessary actions performed by specific people. These can be summarized in the list of the Composite System Requirements.

ID	DESCRIPTION
CSR1	Every polling station should be equipped with at least 3 screens, 1 computer and the Internet access to the databases
CSR2	There should be a national place with enough servers to handle the amount of traffic and data during the elections (millions of people accessing at the same time)
CSR3	Offices of the election commission should be equipped with at least 10 computers and the Internet access
CSR4	Municipalities where employees work should be equipped with at least 3 computers and the Internet access
CSR5	The election commission should insert and guarantee the update of the databases
CRS6	The database of the results should be kept up-to-date
CRS7	The election staff should keep up-to-date the database of the voters, registering them every time they come to the polling station to vote
CRS8	The election staff and the police should check that voters do not cheat during the voting phase

Chapter 7
Software Requirements Specification

7.1: Domain assumptions

Every property of the system is dependent on some precise assumptions made on the work domain: the Domain Assumptions.

ID	DESCRIPTION
1	Polling stations are or can be easily equipped with Ethernet cables, Internet connection, computers, electricity and power generators
2	Voters go to the polling stations, or have possibilities to vote in other ways in particular cases
3	Every screen inside the polling booths is positioned in such a way that only the current voter can see its display
4	The hardware components of the whole system are preserved safely and in secure places
5	The members of the elections staffs, election commission, police and employees behave in a honest way (and are anyway supervised and responsible for irregularities)
6	The number of polling stations and single screens in cities and towns should be enough to allow all the citizens to vote during the two election days, within reasonable waiting times
7	All the citizens allowed to vote must have a voting card, and must be able to procure one soon if they lose it

7.2: Functional requirements

We can now specify the functional requirements, intended as required behavior of the system we want to build. We divided them by system features, and associated each one to a connected use case.

ID	DESCRIPTION	USE CASE N°
FR1	**DATABASES MANAGEMENT**	
FR1.1	the system shall allow the election commission to create the three databases (voters, candidates and polling stations) before the elections	2
FR1.2	the system shall allow the election commission to modify the databases before the elections	2
FR1.3	the system shall allow the election commission to save the databases	2
FR1.4	the system shall avoid any change in the databases for the whole duration of the elections	2
FR1.5	the system shall allow the election staff to consult the voter database at every	3

	time during the elections	
FR1.6	the system shall allow voters to consult the candidates databases and to read information during the elections	4
FR2	**ENABLING/DISABLING**	
FR2.1	the system shall allow the election commission to enable it definitively at the beginning of the election days	2
FR2.2	the system shall allow the election staff to enable it partially every morning during the election days	3
FR2.3	the system shall allow the election staff to enable its voting part after the acceptance of a voter	3
FR2.4	the system shall disable its voting part after every vote	3
FR2.5	the system shall allow the election staff to disable it partially every night during the election days	3
FR2.6	the system shall allow the election staff to disable it definitively at the end of the election days	3
FR3	**VOTING**	
FR3.1	the system shall display to the voter the database of candidates	4
FR3.2	the system shall allow every accepted voter to express the preference by touching one (and only one) candidate during the election days	4
FR3.3	the system shall ask the voter confirmation of the vote after the touch, before saving the result	4
FR4	**VOTES PROCESSING**	
FR4.1	the system shall collect every preference for a candidate in a secure database, during the elections	2
FR4.2	the system shall allow the election staff to send the local results to the employees, after the elections	5
FR4.3	the system shall allow the employees to receive and read the local results, after the elections	5
FR4.4	the system shall allow the employees to request the data sum, after the elections	5
FR4.5	the system shall allow the employees to see a log regarding the correctness of the votes processing	5
FR4.6	the system shall allow the employees to transfer data to other employees, after the elections	5
FR4.7	the system shall allow the employees to send global results to the state, after the elections	5
FR4.8	the system shall allow the state to see and consult the global results, after the elections	1

7.3: Non-functional requirements

Finally, we have a list of non functional requirements: requirements on abstract qualities of the system. We divided them by kind of quality, and listed for each requirement its description and a way to measure and accept it.

ID	CRITERIA	EVALUATION
NFR1	**SECURITY**	
NFR1.1	the system should allow only accepted voters to vote	never allow the vote if the voter is registered as "not allowed" in the database
NFR1.2	the system should allow a voter to vote only one candidate	after one vote, do not allow the voter to vote anymore
NFR1.3	the system should not associate in any way votes to voters	do not collect the voter ID in the database of results
NFR1.4	the system should not show anyone the previous vote(s)	delete traces of a vote after the confirmation
NFR1.5	the system should be enabled and disabled only by the election staff	ask for authentication to do this
NFR1.6	the system should not allow anyone to consult the results before the end of the elections	keep the results private until the end of election is declared
NFR1.7	the system should allow only the employees to consult the results, after the end of the elections	ask for authentication to do this
NFR1.8	the system should never allow any kind of external intromission and modification or adding of votes	keep always the votes in read-only mode
NFR1.9	the system should not accept votes when it is disabled (partially or totally)	do not allow the votes collecting when it is disabled
NFR2	**SPEED**	
NFR2.1	the system should be ready soon when it is enabled for the first time of the day or at the beginning of the elections	work correctly within 10 minutes
NFR2.2	the system should be quickly ready when the election staff enables it for the single vote	display the candidate list in the polling booth within 5 seconds
NFR2.3	the system should be prompt when the voter asks an information or votes	give an answer within 5 seconds
NFR2.4	the system should be prompt to ask for the vote confirmation	ask for confirmation within 2 seconds after the touch of a candidate icon
NFR2.5	the system should collect the vote quickly	save the vote in the database within 10 seconds
NFR2.6	the system should delete every trace of the vote (except to the new element in the database) immediately after the confirmation	do not show the voted candidate after the confirmation
NFR2.7	the system should disable itself partially quickly, after the vote confirmation	disable the voting screen within 5 seconds

NFR2.8	the system should be prompt when the election staff disables it at the end of the day or at the end of the elections	close everything within 10 minutes
NFR2.9	the system should be reasonably prompt in processing the results	give the results within 2 hours
NFR2.10	the system should be reasonably prompt in transferring the results	send all the data within 1 hour
NFR2.11	the system should be reasonably prompt in visualizing the results	display the results within 5 seconds
NFR3	**RELIABILITY**[10]	
NFR3.1	the system should not contain errors in the votes collecting	test accurately the algorithms
NFR3.2	the system should never lose data	use reliable and tested algorithms, and protect physically the servers which store the data
NFR3.3	the system should not crash during the elections	test accurately this part with simulations to avoid bugs
NFR3.4	the system should not be influenced by an electricity blackout	use power generators inside polling stations
NFR3.5	the system should not contain errors in the votes processing	use reliable algorithms
NFR4	**USABILITY**	
NFR4.1	the system should be clearly understandable for everyone	follow principles of Human Computer Interaction
NFR4.2	the system should have clear instructions for its use	provide instructions in the polling stations and inside the booth
NFR4.3	the system should be similar to the actual one	recall the structure of the sheet of paper normally used for the elections
NFR4.4	the system should allow the correction of mistakes	ask for a vote confirmation
NFR5	**ACCESSIBILITY**	
NFR5.1	the system should be fully usable by people with any kind of disability	include these users in the testing phase
NFR5.2	the system should display icons and texts big enough to be read by old people	include these users in the testing phase
NFR6	**PORTABILITY**	
NFR6.1	the system should be able to manage millions of contemporary accesses	buy the needed number of servers and test this
NFR7	**CORRECTNESS**	
NFR7.1	the system should collect votes correctly	test accurately the algorithms
NFR7.2	the system should sum votes correctly	test accurately the algorithms
NFR7.3	the system should transfer votes correctly	test accurately the algorithms

[10] Evaluations criteria for reliability include a deep testing of the whole system, instead of a number of tolerated errors. This is because no error is tolerated in the elections case.

NFR7.4	the system should summarize the operations done and eventual errors	show a log with this information
NFR8	**RECOVERABILITY**	
NFR8.1	the system should be able to recover data	perform a periodic backup

Appendix 1

Interviews

Here there is a list of interviews to two categories of people: voters and polling clerks (unfortunately there was not the possibility to meet other stakeholders). They have been asked which problems do they perceive in the current situation, and what they would improve or consider in a new system.
Main points of their answers are listed.

VOTERS

1 (C. D. A., 25 years old, male, off-site student)

problems:

- in the last elections I had to go back home (8 hours by train) to vote, missing lectures in the university
- I don't trust in a system in which votes are drawn with a pencil, and humans count them
- some 24 year old friends of mine received sheets for voting the Senate, even though they weren't allowed to do it
- it is never cleared how to unmark the ballot paper
- it is too easy to invalidate unintentionally the vote
- votes can be recounted: a very waste of time
- different parties and lists are not associated to their programs, and this creates a lot of confusion

suggestions for improving:

- allow the off-site voting
- keep the vote secret
- include the null vote
- optimize time
- keep the system safe, from its bases
- use police and reliable witnesses when you have to see and manage the results
- forward the results in a hierarchical way
- exploit the digital signature to be able to understand who did what, in case of security problems
- group the parties according to their programs, and let people see additional information about them

2 (C. C., 23 years old, female, in-site student)

problems:

- you have to be in your city if you want to vote
- the waste of paper is huge
- I have friends who worked as polling clerks, and sometimes I heard sentences as "it wasn't clear to whom the cross was referred, so we decided to assign the vote to ...". This makes the polling clerks' manual counting system not very reliable
- not always the vote remains secret, expecially in little towns. For example, in the last elections there was one small party for Moroccan people; in my town it received only one vote, and only one person from Morocco went to vote, so it is not difficult to understand who voted it. The problem here stays in the fact that people who supervise the voting phase are the same ones who count the votes later

suggestions for improving:

- have a safe system
- distinguish between people who supervise the elections and people who see and manage the results
- don't associate votes with date, time and polling station

3 (F. C., 20 years old, female, in-site student)

problems:

- the counting phase lasts too much time
- polling clerks are not reliable (for instance, almost nobody checks if you have a cellphone)

4 (M. C., 20 years old, male, in-site student)

problems:

- the voting card is useless, and sometimes it happens that people don’t notice that they don’t have the space for a new vote, and they are not allowed to vote

suggestions for improving:

- if the voting system becomes electronic, authorities should avoid possible congestion problems in consulting a huge amount of data at the same time
- base the identification on a passport or an ID card, and not on a stamp in a voting card

5 (L. M., 23 years old, female, off-site student)

problems:

- at the last elections I wasn't able to vote, because I didn't have enough money to go back home (the government would have reimbursed me only 40€, but the flight costed 160€)
- the waste of paper
- the waste of public money, which could be used for lots of more useful things

suggestions for improving:

- replacing paper with an electronic system would be the best starting point

- allow people to vote in the place in which they are; I'm not the only one who couldn't vote because of this problem

6 (M. B., 27 years old, male, in-site student)

problems:

- the manual counting is not reliable

suggestions for improving:

- allow the voter to write down sentences, if he/she wants (as he/she can do now in the sheet of paper - of course invalidating the vote)
- be able to correct mistakes in voting: for example, in case of an electronical system, allow voters to select different possibilities and finally press a button "I finished"
- delete every trace of the vote when the voter lefts the polling booth
- save money

7 (B. T., 49 years old, female, secretary)

suggestions for improving:

- computers are the future, and the election system should exploit them

8 (R. C., 54 years old, male, employee)

problems:

- it's complicated to understand how to draw the cross exactly; people risk to invalidate unintentionally their vote
- there are the polling clerks between citizens and state, who are not so much reliable. Sometimes the vote they assign is the result of an interpretation, and could change from polling station to polling station: how could we trust in this kind of system?

suggestions for improving:

- less bureaucracy

9 (F. M., 59 years old, male, teacher)

problems:

- the actual system is a huge waste of resources
- too much bureaucracy
- too much time

suggestions for improving:

- a safe and secret system
- check that people have the political and civil requirements to vote

- elections must become an experience of open and shared democracy

10 (A. T., 82 years old, female, pensioner)

problems:

- difficulties in seeing and reading the small symbols of the lists

suggestions for improving:

- I don't want a system which uses computers: I can't use them

11 (O. C., 85 years old, male, pensioner)

suggestions for improving:

- despite my age, I would support an electronic system; I just want to be taught in how to use it (also, it could be even easier than the paper system

POLLING CLERKS:

1 (N. B., 23 years old, male)

problems:

- there are a lot of registers for exceptional polling stations, such as the ones in nursing homes and hospitals
- polling clerks have some absurd duties: for example, they have to present the empty sheets of paper opened; otherwise they risk to be denounced
- there is one register for people who have the right to vote and another one for who really votes, and polling clerk has to check in the first one in order to compile the second one
- bureaucracy is really heavy: we spent hours and hours compiling modules and signing
- some rules (as the one of examining the sheets one by one during the counting phase) are rarely respected
- most of the times counts don’t match
- the election staff is forced to stay in the polling station until everything matches
- the counting for the Senate is separate from the one of the Chamber, but sometimes some mistakes are done
- there are thousands of rules and exceptional cases to remember (for instance, what to do if someone dies with the sheet of paper in the hand; or the fact that candidates who assist to the counting phase con touch the election staff but not the sheets of paper)
- the counting phase is a very long and monotonous process: votes are divided per categories, and then counted and counted again
- still, there could be cases of cheating

suggestions for improving:

- create an easier, safer, faster and more efficient system
- an electronic solution should allow some secondary things permitted in the actual system, such as: the possibility to vote again in case of error (invalidating the first sheet of paper); the un-modifiability of registers which contain the votes; the legal responsibility of people who sign the voters in the database

2 (M. M, 22 years old, female)

problems:

- too many registers to compile: one for male voters, one for female voters, one for cellphones of male voters, one for cellphones of female voters, one for off-site voters
- some rules are almost impossible to apply: for instance, we should ask every voter to give us its cellphone; in practice we rarely do it, also because everyone could have another phone or a camera in the bag
- the counting phase is very stressful
- after the counting, the election staff should go with the police to take the material to the municipality, but in practice the police alone does this work

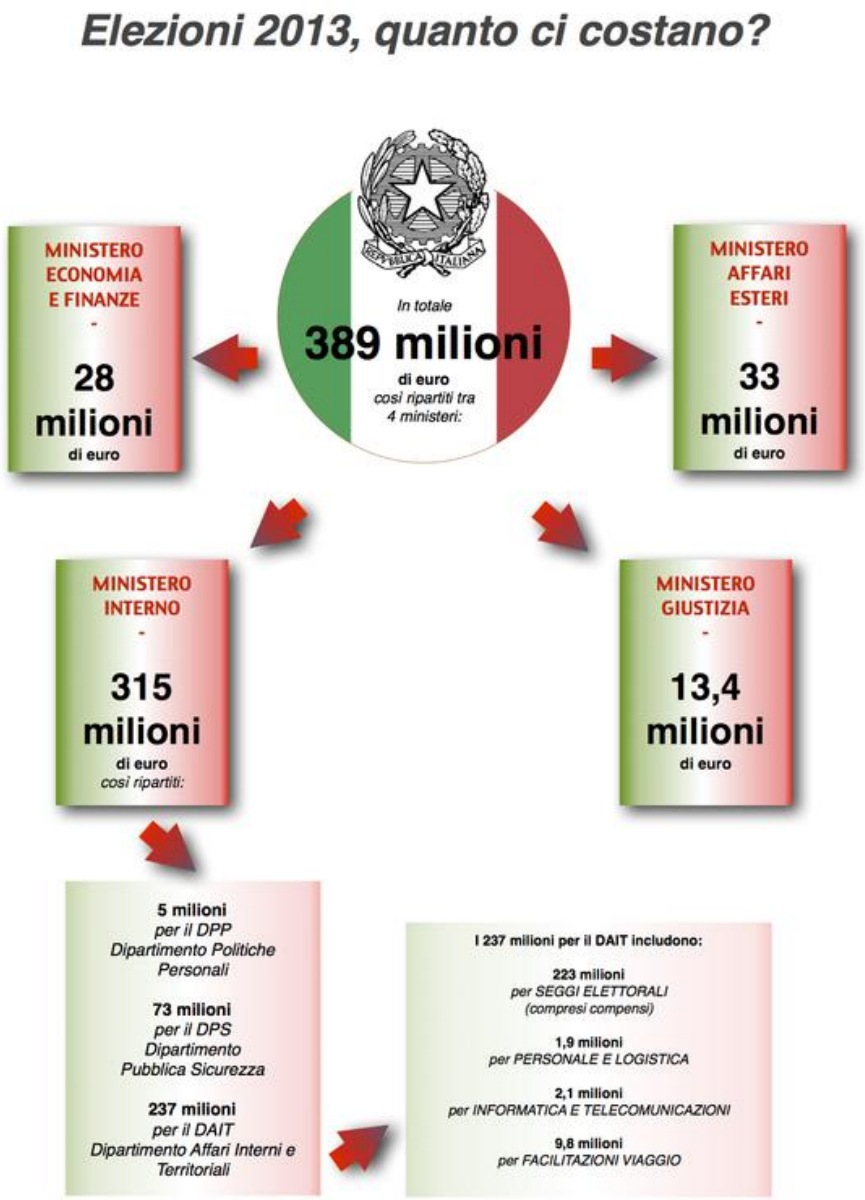
suggestions for improving:

- if registers would be replaced with computers and a database, everything would be easier
- the voting card could have a barcode, to be easier to read
- in case of an electronic system, consider the case in which electricity collapses
- an electronic system would also need an expert in every polling station, in case of problems

Appendix 2

Figures

Figure 1: how much the Italian elections cost. Money are divided into four different ministries, for a total of almost 400,000,000€.
http://www.tgcom24.mediaset.it/politica/articoli/1083186/elezioni-2013-quanto-costa-organizzarle.shtml



Figures 2 and 3: list of Italian electoral districts, with their population and polling stations.

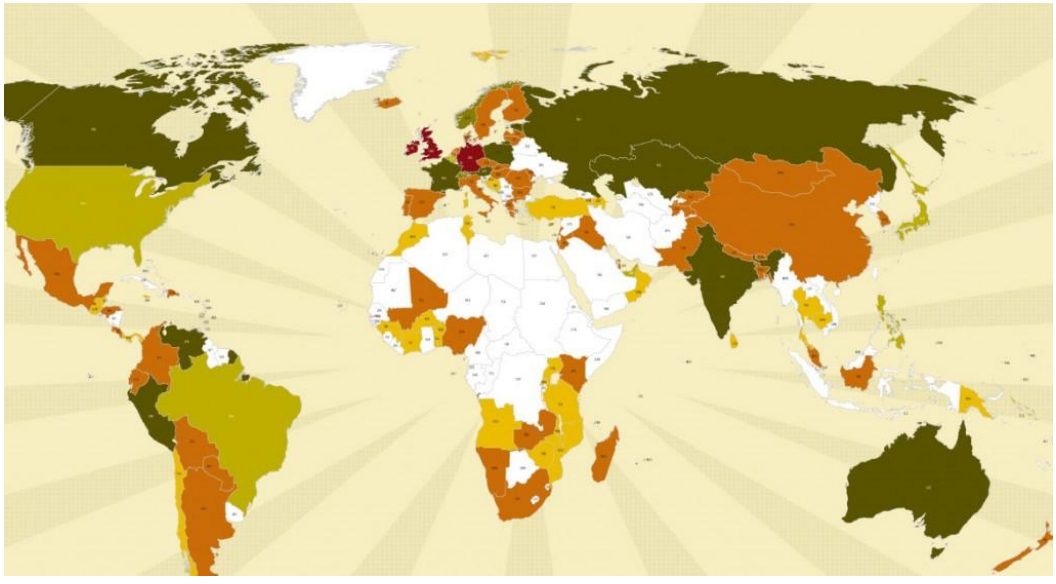
CIRCOSCRIZIONI		POPOLAZIONE 2011	QUOZIENTE: 96.171		SEGGI SPETTANTI
			Quozienti interi	Resti	
I	Piemonte 1	2.247.780	23	35.847	23
II	Piemonte 2	2.116.136	22	374	22
III	Lombardia 1	3.878.549	40	31.709	40
IV	Lombardia 2	4.300.066	44	68.542(*)	45
V	Lombardia 3	1.525.536	15	82.971(*)	16
VI	Trentino-Alto Adige	1.029.475	10	67.765(*)	11
VII	Veneto 1	2.923.457	30	38.327(*)	31
VIII	Veneto 2	1.933.753	20	10.333	20
IX	Friuli-Venezia Giulia	1.218.985	12	64.933(*)	13
X	Liguria	1.570.694	16	31.958	16
XI	Emilia-Romagna	4.342.135	45	14.440	45
XII	Toscana	3.672.202	38	17.704	38
XIII	Umbria	884.268	9	18.729	9
XIV	Marche	1.541.319	16	2.583	16
XV	Lazio 1	3.997.465	41	54.454(*)	42
XVI	Lazio 2	1.505.421	15	62.856(*)	16
XVII	Abruzzo	1.307.309	13	57.086(*)	14
XVIII	Molise	313.660	3	25.147	3
XIX	Campania 1	3.054.956	31	73.655(*)	32
XX	Campania 2	2.711.854	28	19.066	28
XXI	Puglia	4.052.566	42	13.384	42
XXII	Basilicata	578.036	6	1.010	6
XXIII	Calabria	1.959.050	20	35.630	20
XXIV	Sicilia 1	2.393.438	24	85.334(*)	25
XXV	Sicilia 2	2.609.466	27	12.849	27
XXVI	Sardegna	1.639.362	17	4.455	17
XXVII	Valle d'Aosta	126.806	1	30.635	1
TOTALE		**59.433.744**	**608**		**618**

Figure 4: example of a voting paper, with the list of different parties and the space where to draw a cross

Figure 5: list of countries where the voting system is electronic.

Legend:
White: no e-voting
Yellow: voting technologies other than casting votes
Orange: Planning, trials, non-legally binding E-Voting
Light green: e-voting with EVM
green: e-voting with Internet Voting
dark green: e-voting with EVM and Internet Voting
red: stopped or legally forbidden

http://www.e-voting.cc/en/it-elections/world-map/



Appendix 3

Extra material

Extra 1: Some comments on the goal analysis:

Choose directives & resources:

- Paper is totally inefficient in terms of costs, time and ecology; an electronic system would solve most of the problems, but could be dangerous in security
- If votes are not preserved after the elections resources will be saved, but the system is not safe; to collect them in a digital repository could be a solution
- The best place where to allow voting is every polling station of every city; Internet could be an even better solution, but it has some serious security problems

Organize the elections:

- The best list for candidates is electronic: it has no costs and disadvantages
- For the same reason, the best way to collect the names of the votes is a database
- Allowing people to vote everywhere is a good system, but security could become a problem; polling stations solve this, but are expensive
- Send electronically the voting material is the best way, but, again, security must be accurately studied

Vote:

- Using only the voting card or an ID code it's easier than associating and showing two documents
- For people is easier to vote drawing a cross or touch a screen

Apply election rules:

- Enabling an electronic system for voting is very efficient in terms of resources, but, contrary to polling stations, has a serious security problem
- The easiest place where to check the voter is a database
- The home voting can't be monitored; paper is safer, but requires more resources

Monitor the elections:

- Considering many parameters, the closed booth is the best place where to vote; home voting has advantages, but voters can cheat
- Better close the electronic access to the system than make the police sleep in the polling stations

Compute the results:

- The best way to collect different votes is a database; but again, security must be guaranteed

- In order to associate each vote to each candidate, a computer program is undoubtedly the most efficient worker
- Electronic transfer of the results works much better than the physical one

Extra 2: Analysis of stakeholders involved in similar problems