PMI Belgium University Contest

- This document is made by the six winners of the PMI Belgium University Contest, edition 2015.
- The winners have been nominated by a jury from PMI Belgium for the best group assignment for the course “Project Management” given by Mario Vanhoucke at the Faculty of Economics and Business Administration of Ghent University.
- More information on this contest can be found in the paper “PMI Belgium's recognition of young PM potential” published in the Journal of Modern Project Management (cf. http://www.or-as.be/blog/jmpm_2014c).
- Congratulations to the winners!

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Projectmanagement

Dynamic scheduling of a new project

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0. Introduction

Project management is the broad discipline of the planning, the organization and the management of resources in order to successfully complete a project. In the context of this course, we choose to analyze the interesting project of the installation of Wi-Fi hotspots in the city of Ghent. The origin of our idea comes from an interesting collaboration of the members of our group. While brainstorming about a possible innovative project, our group member Miguel, who is on Erasmus in Belgium this year, mentioned the idea of free Wi-Fi hotspots in public places. His hometown Valladolid already implemented this service for its citizens. This made us think further about possible opportunities to adapt this concept of free Wi-Fi in our own student city Ghent. Moreover, this would pose a lot of interesting benefits for the inhabitants, students and visitors of Ghent since today, in our advanced technological environment, a lot of people possess a smartphone or other electronic devices that can give access to the Internet. Therefore, we think it's an interesting and challenging project.

In this paper, we start by giving a general information summary of our project concept followed by some information about the survey we conducted for our installation of Wi-Fi hotspots. We also mentioned a couple of assumptions we have made concerning the data and cost estimations. Moreover the project life cycle gives a short overview of the different steps in our Wi-Fi project and a baseline schedule in ProTrack is made to give a view on the activities of the project. Finally, we carried out a critical chain management, a risk analysis and a project control phase including the earned value management.

1. The project

1.1 General Information

Nowadays, we live in a society where the Internet is an essential element, certainly in a city with approximately 70,000 students. Therefore we decided to develop a project to install free Wi-Fi hotspots in the city of Ghent. The goal of the whole project would be to offer a public Wi-Fi network to provide passers-by free access to the Internet and this by the use of their mobile devices. In order to know where the Wi-Fi hotspots are most desired, we sent a small survey to a couple of students and other people.

We situated the project in a setting of the council elections. We are a company that offers the installation of Wi-Fi hotspots in cities. The current major of Ghent has sent us the request to install a new Wi-Fi system in his city in order to satisfy his citizens. In other words, he wants to enforce his current policy and intends to use this realized project as an asset in his re-election campaign to win votes for the next council elections in 2018. Our company has a deadline and the whole Wi-Fi project needs to be executed two months before the elections, in order that the inhabitants of Ghent can already test this new concept. This results in setting up a main objective of time with considering costs and specifications.

We implemented data retrieved from a similar project that has been realized in the city of Valladolid (Spain). The company who realized this concept in Valladolid was Gowex, who also did similar projects in other large cities in the world for example New York City. Furthermore, Gowex worked together with WIN S.A. to implement public WIFI in the city of Liège and Charleroi. For this reason, we think that the data is similar enough to introduce this innovative and exciting project in Ghent. We linked this project to the course by defining the activities, durations and scheduling them with ProTrack. Since information concerning costs, durations, and resources were rather hard to obtain, we had to make several estimations and assumptions, which was fairly difficult.

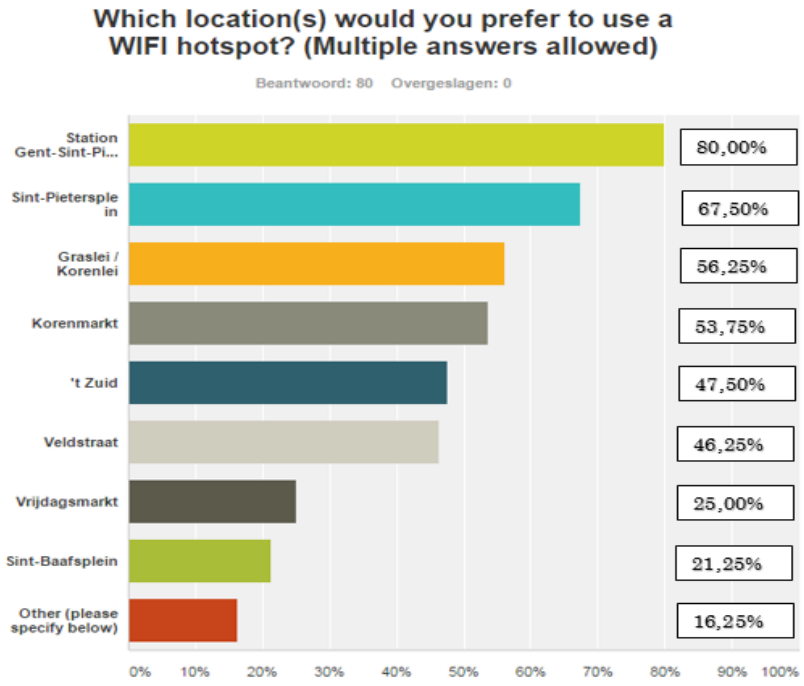
1.2 Survey

The first step we made within the framework of our project, was to conduct an online survey in order to find out firstly if there is a truly need of free Wi-Fi hotspots in Ghent and secondly which locations would be most desirable to install the hotspots. The complete survey is incorporated in Exhibit 1. The table below lists in short the questions we asked.

1	On which devices do you usually consult the Internet?
2	How often do you use the Internet on the previous devices?
3	Would you be in favor of free Wi-Fi hotspots in the center of Ghent? (For example Korenmarkt, 't Zuid…)
4	Which location(s) would you prefer to use a Wi-Fi hotspot? (Multiple answers allowed)
5	Which relation do you have with the city of Ghent?
6	To which age range do you belong?
7	Gender?

We distributed the small survey among people who have or could have a link with Ghent, for example students, citizens and working people but also tourists. Since we are strongly linked with the city of Ghent ourselves, we suggested a couple of possible locations for the Wi-Fi hotspots. Thereby we thought about the most popular places in the center of the city. However, as we are all students, there could be some other desirable places that we don't know. The interviewee is free to fill in these suggestions. We assume that not only the relationship with the city of Ghent, but also the age range and gender will influence the answers and preferences of the interviewees. In this setting we hope to obtain diversified data to meet everyone's needs.

Eventually, we received 80 responses. When analyzing the results of the survey we came to the conclusion that Free Wi-Fi hotspots in Ghent would indeed be a desirable and innovative initiative. 93,75% of the respondents indicated that they were in favor of free Wi-Fi hotspots. Based on the obtained data and the interviewee's preferences we composed a top-then of free Wi-Fi hotspots and decided to choose these hotspots as the locations for installing our free Wi-Fi project. The list of the hotspots is shown in the bar chart below.



«Other» includes Overpoortstraat and Sint-Pietersnieuwstraat. Furthermore, 60% of the respondents use the Internet more than ten times a day. However, most of the respondents (87,50%) were students.

1.3 Data analysis and assumptions

As mentioned above, we obtained some data such as the number of hotspots, total duration, total budget for the installation and some setbacks with their additional costs. We created the activities ourselves using rational thinking because we couldn't get access to this data and also by the help of a summarized information booklet of Gowex, concerning an implementation of Wi-Fi spots that we received by mail. Concerning the employee wages, we made estimations based on an up-to-date wage calculation website (References).

Further, we had to make some assumptions concerning the estimations of the activities. Based on the information tools mentioned above, we tried to estimate the cost of the non-installation activities mostly by defining what type of employees we need and by calculating their wages. We have chosen consciously not to include the sunk costs and other remainder non-specific activity related costs. We did this because we had no specific cost information of non-installation activities and a rough and random estimation would not be accurate. However, most material costs and other relevant non-material costs are included in the installation activity, since we received the necessary data only for that activity.

Another assumption made when applying the information from the booklet to the estimation of costs, is that we have kept in mind that prices and costs are generally lower in Spain,

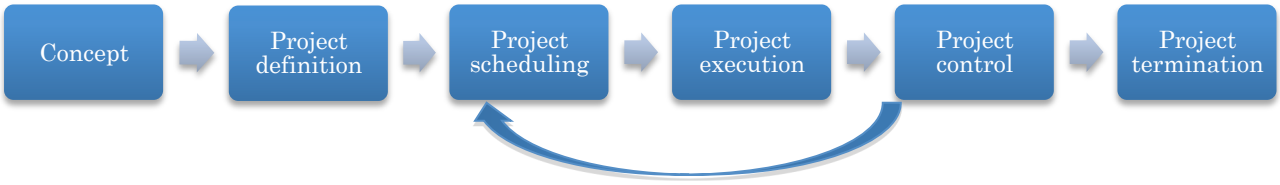
We made a table with all the activities we scheduled which you can consult in Exhibit 2. The definition of the activities is based on following characteristics:

- Name of the activity
- Duration of the activity
- The sequence of the activities
- The resources we use
- Estimation of the cost of the activity

We can divide all the activities in three main groups. In the beginning the activities are more focused on market research and administration. This is followed by activities in software development and implementation. At the end we have created activities for the evaluation of the project. The project consists of 23 activities altogether.

1.4 Project Life Cycle

In order to manage the project in a correct manner, we adopted the Project Life Cycle concept (PLC) based on the 'divide and conquer' principle. The PLC refers to the different phases the project will go through from identification to post evaluation. The identification of these different phases is a first step in reducing the complexity of the project and will be very useful in planning the project and locating the different decision points. We applied the phases of the Project Life Cycle to our project.



Concept phase

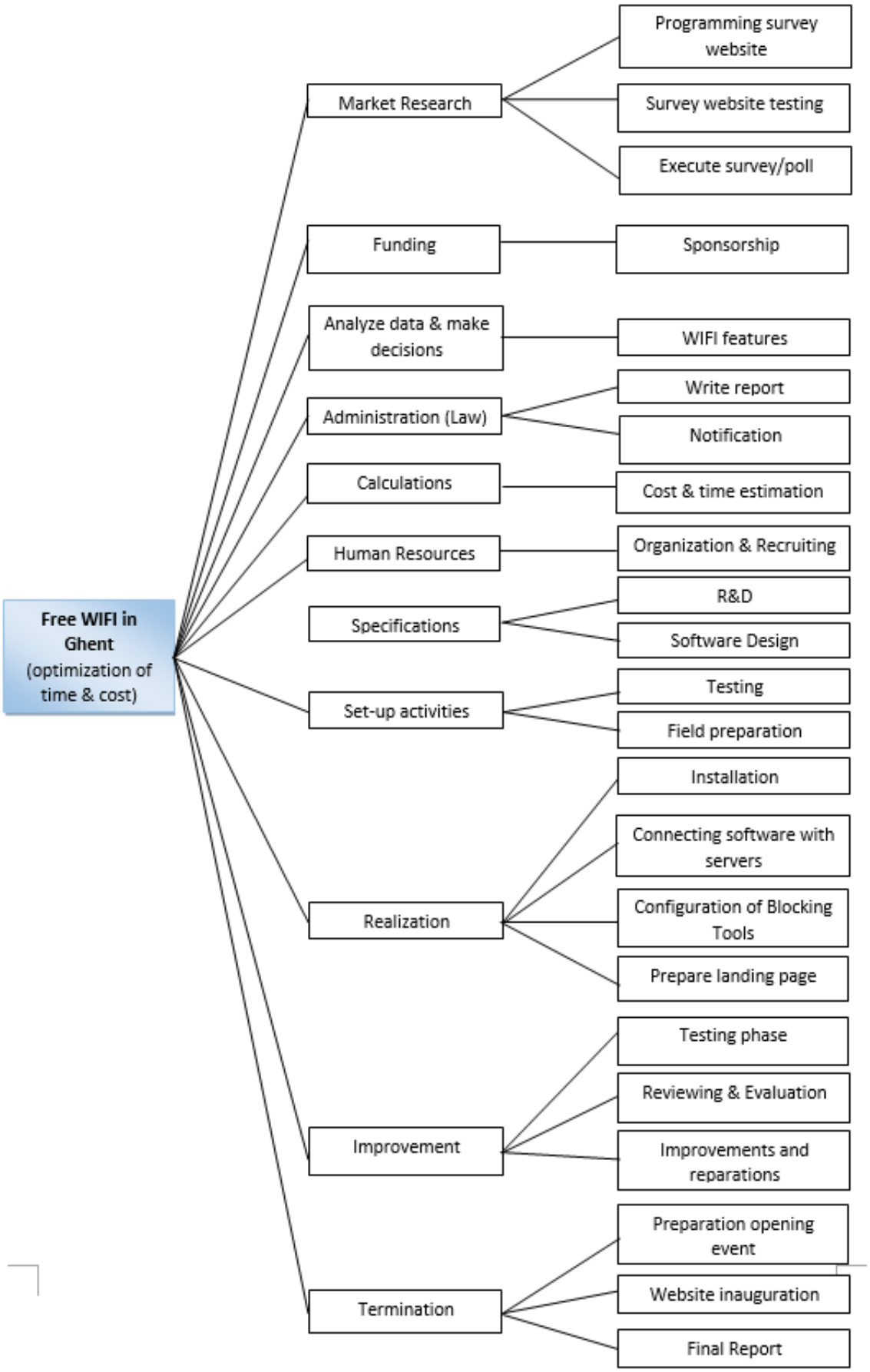
" Identify the need for a project or receive a request from a customer."

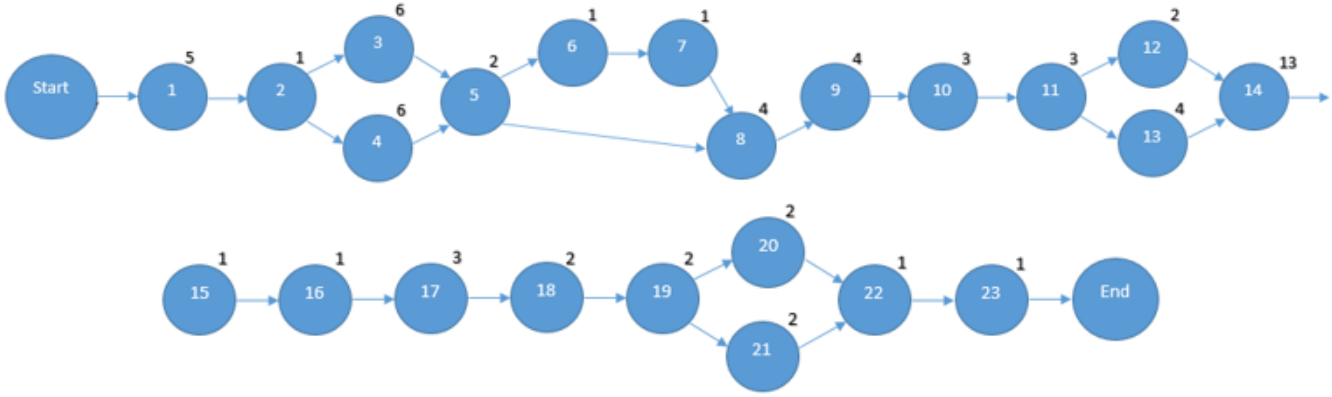
As students we feel that there is a need for a free Wi-Fi network in our city. This idea is already executed in many cities around the world and with the available technologies we see this project as an innovative opportunity. Therefore we have developed a fictive project to satisfy the need of free Wi-Fi hotspots in public areas.

Definition phase

"Define the objectives, the project specifications and requirements and the organization of the whole project."

Once the concept was fixed, we needed to define the project objectives, requirements and specifications. As we have already mentioned, time is the main objective for this project in order to meet the deadline of the elections. After the objective was defined, this resulted into a list of activities based upon technological relations and resource requirements as explained before and which can be consulted in Exhibit 2. In determining the activities of the project, we also designed a Work Breakdown Schedule (WBS). This helped us to translate our project into a project objective, work items and lowest level activities in order to assign the right people and to achieve data and controlling measures. Each level of the WBS has his own functionality and contributes to a graphical representation of the project. Hereafter, we constructed a network in activity-on-the-node format as you can see below. Each activity is represented as a node and the precedence relations of the activity results from the arcs.


Free WIFI in Ghent (optimization of time & cost)
Market Research
Programming survey website
Survey website testing
Execute survey/poll
Funding
Sponsorship
Analyze data & make decisions
WIFI features
Administration (Law)
Write report
Notification
Calculations
Cost & time estimation
Human Resources
Organization & Recruiting
Specifications
R&D
Software Design
Set-up activities
Testing
Field preparation
Realization
Installation
Connecting software with servers
Configuration of Blocking Tools
Prepare landing page
Improvement
Testing phase
Reviewing & Evaluation
Improvements and reparations
Termination
Preparation opening event
Website inauguration
Final Report



Scheduling phase

"Present a timetable for the project activities."

Since we used an activity-on-the-node network we were able to schedule the project in Excel and ProTrack after the determination of every activity's start and finish time. This resulted into estimated activity durations, which we took into account in the network by placing a superscript above each node. However, we will have to keep in mind that it presents just one scenario and that disabilities and other scenarios can occur.

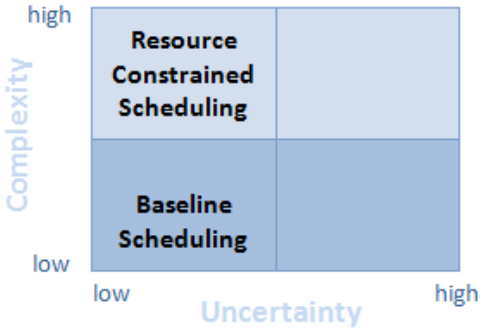
Execution and control phase

The project has to be carefully monitored and controlled. This is an important phase since it determines the gaps between the project schedule and the real project execution. These gaps need to be very closely and frequently observed and redirected. During these two phases, a continuous feedback mechanism is required. Furthermore, we will set up an Earned Value Analysis on different simulated cases to find out whether the Wi-Fi project is able to be finished on time, taking into account the anticipated budget and timing objectives.

Termination phase

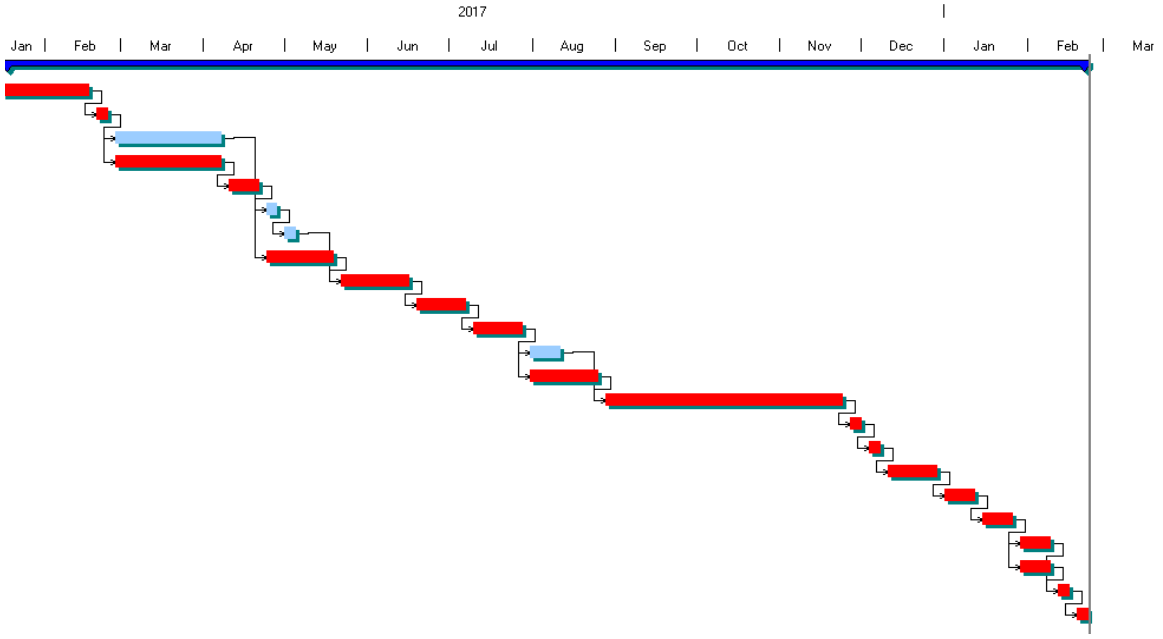
This phase contains the completion of the whole Wi-Fi project. After a critical evaluation of the project, the concept can be implemented and launched in the market.

1.5 Baseline schedule

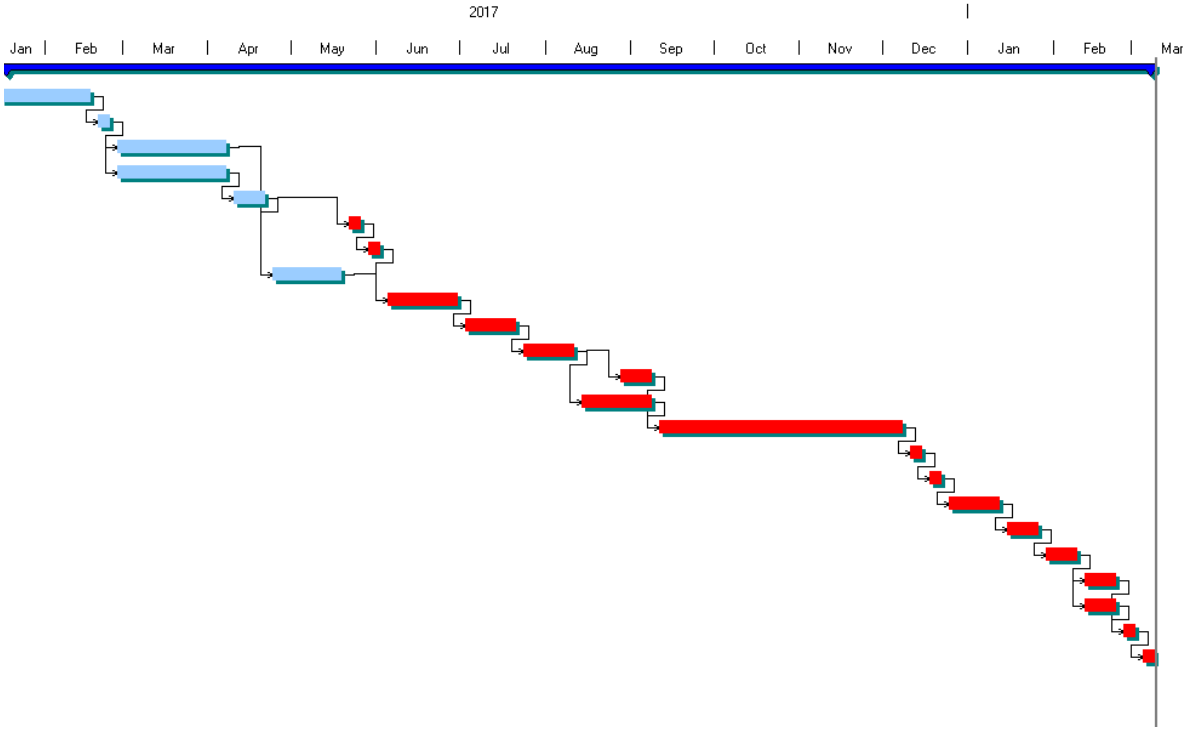


As a first dimension of dynamic scheduling, we executed a baseline schedule of our project in ProTrack. This basic scheduling technique is situated in quadrant 1 of the project mapping matrix.

The following baseline schedule takes into account our assumptions on our own created activities and the assumptions made by Pro-Track but without the presence of resources (or in the presence of unlimited resources). This leads to a reduction of the complexity, on the other hand it represents the project in an unrealistic way. The output from ProTrack results in The Gantt-chart, illustrating the baseline schedule. The chart below shows this activity progress without resources or with unlimited resources and includes the expected start and finish times of all our project activities and the appropriate relations. The critical path is highlighted in red.



When we take into account the resource constraints, the next Gantt-chart gives us a new baseline schedule including the slack caused by the restrictions of the administrative workers. By leveling the resources, the critical path disappears. In this case, we can speak of a critical chain, which is referred to later in the paper. However, ProTrack never shows this critical chain in the Gantt-chart. We find ourselves now in quadrant 3 of the previous introduced project-mapping matrix, namely Resource Constrained Scheduling (RCP). The presence of resources under limited availability results in a much higher complexity of our project baseline schedule.



After applying the realistic scenario with resource restrictions, we were able to determine the important data of our project listed in the table below.

Start time	16 January 2017
Finished time	09 March 2018
Planned duration (PD)	60 weeks
Budget at completion (BAC)	€ 383.400, 13

From this table, we can derive that the total project duration of our project is estimated on 60 weeks. The budget at completion amounts to €383.400,13 and equals the sum of all budgeted costs for the individual activities.

2. Critical chain management

2.1 Critical Chain

When applying the Critical Chain Management, the first step is to create a resource-feasible schedule in which activities start as late as possible. We adapted this on our unrealistic baseline schedule by leveling our resources. We became the final baseline schedule that you can consult on top of this page. This principle resolves the resource conflict of the two administrative workers who have to perform the activity of writing the report for administration and at the same time is needed to perform a part of the cost estimation activity. Besides, after the writing report activity, one administrative worker is needed for the notification to administration, while he is needed at the parallel activity of the cost estimation.

On this schedule the critical chain can be determined, which is defined as the longest chain of activities that considers resources and also technological dependencies. In this chain, the end of each activity will be equal to the start of the next activity. In our Wi-Fi project following four critical chains can be identified:

Critical Chains
1-2-4-5-8-6-7-9-10-11-13-14-15-16-17-18-19-21-22-23
1-2-3-5-8-6-7-9-10-11-13-14-15-16-17-18-19-20-22-23
1-2-3-5-8-6-7-9-10-11-13-14-15-16-17-18-19-21-22-23
1-2-4-5-8-6-7-9-10-11-13-14-15-16-17-18-19-20-22-23

Since the choice of the critical chain is based on the manager's knowledge of the environment of the Wi-Fi project, we choose for example the first CC.

1-2-4-5-8-6-7-9-10-11-13-14-15-16-17-18-19-21-22-23.

2.2 General remark

Since we don't possess enough specific information, we had to create and estimate our own activities. Consequently, information on the safety time implemented in the individual activities is lacking and for this reason we decided not to calculate the buffer sizes. Buffer positions are described below.

2.3 Resource buffer

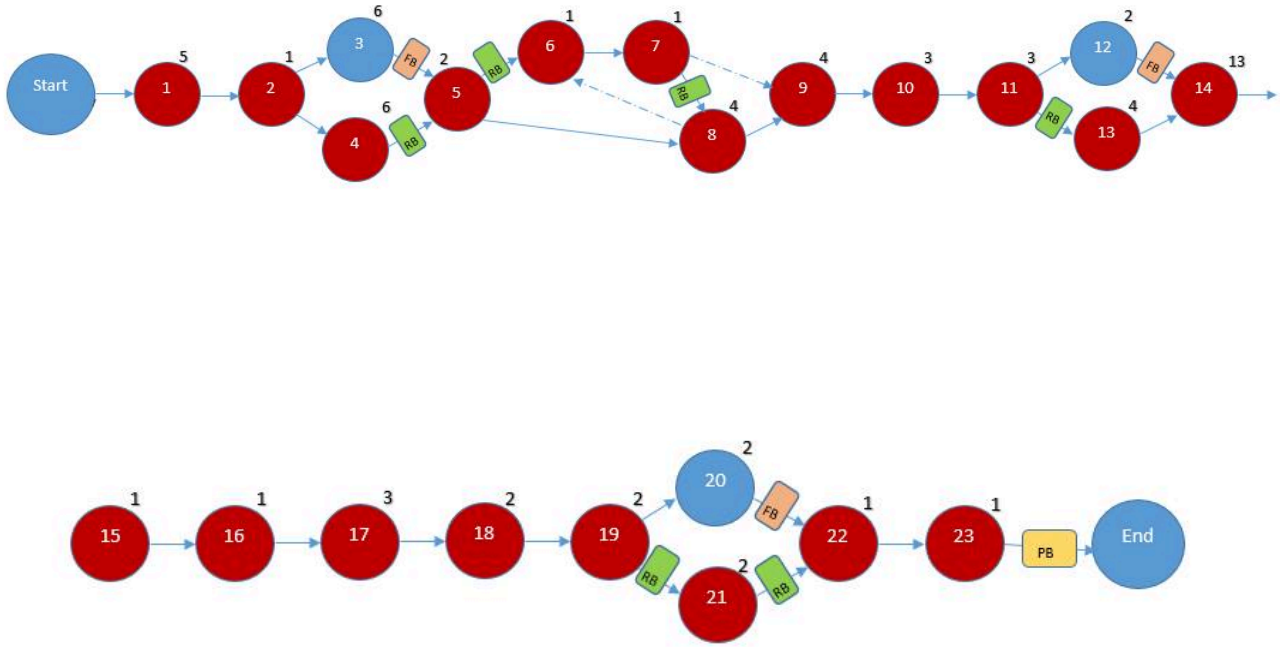
As a consequence of leveling, projects can end late. A solution to cover this issue, is the introduction of resource buffers. This tool doesn't occupy extra time in our schedule but it informs our management when to pay attention and to work on an CC activity. Since activities 1, 2, 3, 10, 13, 14, 17 and 18 impose a fixed cost, resource buffers are not necessary here. We decided to place buffers after activities 4,5,7,11 ,19 and 21 since resource buffer introduction is usually required whenever a resource has an activity on the CC and the precious CC activity is done by a different resource, without considering the fixed cost activities that don't need the variable resources.

2.4 Project buffer

We eliminated safety time from the individual activities and we aggregated a protection for the elimination of the individual safety times at the end of the project under the form of a project buffer. The project buffer is inserted between our last activity of final report and the completion of our project.

2.5 Feeding buffer

These buffers are used to put safety time in the project and to protect the longest path against delays. They are placed between any last activity of a feeding chain and the activity on the critical chain. So in our case, buffers are placed before activities 3, 12 and 20.



2.6 Endnote of CC management

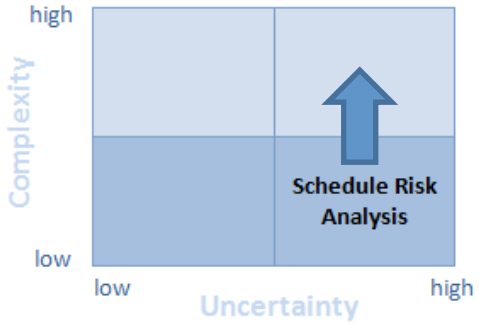
To keep a good insight on our project and to eliminate the unnecessary complexity, we decided not to implement this critical chain management in our ProTrack tool for the risk analysis and project control(EVM) described in following sections.

3. Risk Analysis

This section is contributed to the scheduled risk analysis of our Wi-Fi project. We implemented the risk of the different project activities in ProTrack with the SRA. With simulations of best case and worst case we tried to estimate the possible delays or early finish times. Since our main objective is time, we need to pay a lot of attention to the uncertainty on the final project duration and the budget at completion. The risk analysis contains four phases that we need to follow to perform an optimal risk analysis of the different activities on the baseline schedule:

1. Define point of reference: Our basis for this is our baseline schedule.
2. Define uncertainty
3. Analyze
4. Output interpretation

Furthermore, an important remark is that we start from our limited leveled resource baseline schedule. This presents the most realistic situation in which the project in reality will be executed, in contrary to the theory in the course where SRA was performed on unlevelled baseline schedules, in other words a low complexity situation. Because of the limited availability of the resources, a critical chain now determines the minimal length of the project. This critical chain consists of dependent activities. These dependencies include both technological precedence relations as well as resource dependencies.



The output of our analysis will give an overview of the most important risk characteristics of our Wi-Fi project.

Before analyzing our risk profile, we first determined whether our project structure is more serial or parallel. The serial/parallel structure of a project network can be measured by the SP indicator in ProTrack, who measures the closeness of a network to a serial or parallel network. We can establish a percentage of 81% when we analyze this SP-indicator. This percentage points at a more serial network.

The observation of the high serial grade has some important consequences on the analysis of the sensitivity indices because when a project contains mostly serial activities, the CI, SI and the CRI(r) measures perform rather poor. As a consequence, we put our focus on the schedule sensitivity index.

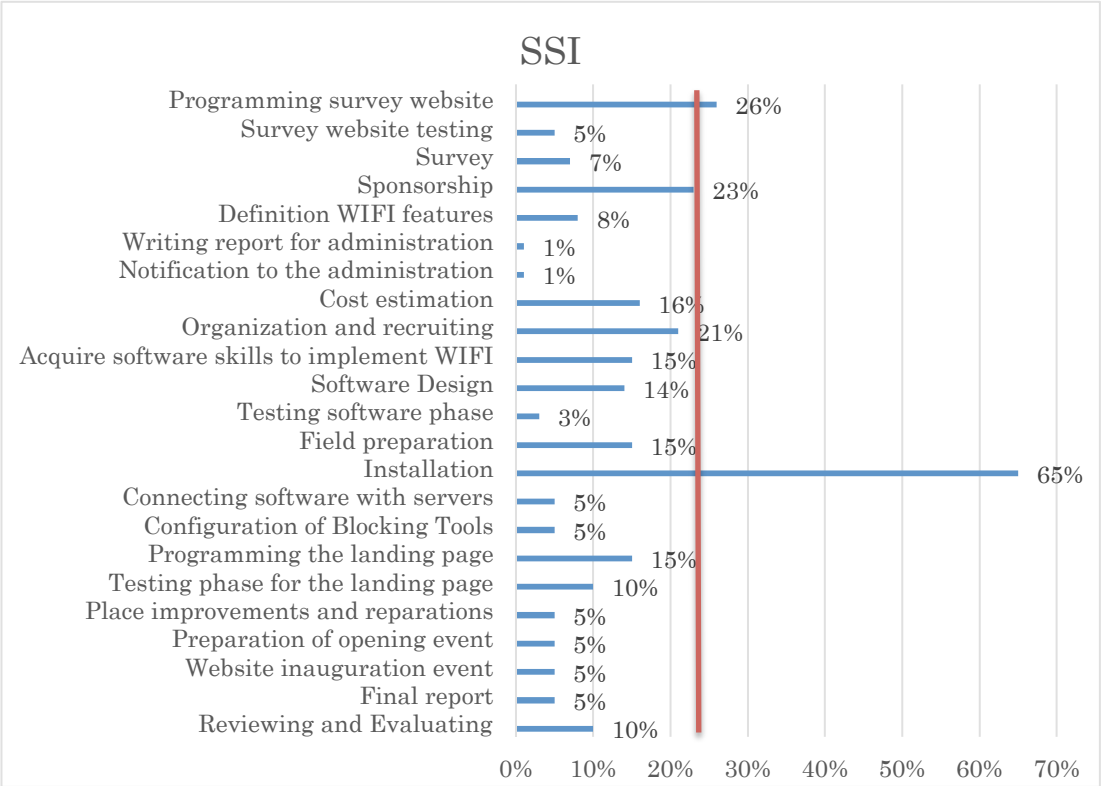
Besides this index, we also used the Spearman's rank correlation and Kendall's tau rank. We made this choice because our activities are complex, problem solving and innovative, which fits with non-linear activities definition.

The Spearman's rank correlation defines its values between -1 and 1 and it allows us to measure the correlation between non-linear activities. Kendall's tau rank measures from 0 (absence of correlation) to 1 (perfect correlation). These measures are included in the Cruciality Index (p) and the Cruciality Index (τ). They measure the relative importance of an activity and the portion of total project duration uncertainty that can be explained by the uncertainty of an activity.

3.1 Time-based

Best-case scenario risk analysis

Sensitivity Report				
Name	**Schedule Sensitivity Index**	**Cruciality Index (CRI-r)**	**Cruciality Index (CRI-rho)**	**Cruciality Index (CRI-tau)**
Programming Survey Website	26%	29%	25%	16%
Survey Website Testing	5%	2%	2%	4%
Survey	7%	7%	5%	3%
Sponsorship	23%	14%	42%	27%
Definition WIFI features	8%	13%	11%	8%
Writing report for administration	1%	8%	7%	2%
Notification to the administration	1%	26%	25%	15%
Cost estimation	16%	13%	14%	8%
Organization and Recruiting	21%	39%	39%	26%
General R&D/Acquire software skills to implement WIFI	15%	16%	13%	8%
Software Design	14%	20%	17%	11%
Testing software phase	3%	17%	19%	12%
Field preparation	15%	24%	21%	14%
Installation	65%	77%	77%	57%
Connecting software with servers	5%	9%	8%	3%
Configuration of Blocking Tools	5%	10%	8%	3%
Programming the landing page	15%	16%	14%	8%
Testing phase for the landing page	10%	33%	34%	21%
Place improvements and reparations	5%	14%	10%	5%
Preparation of opening event	5%	14%	15%	9%
Website inauguration event	5%	17%	15%	7%
Final report	5%	9%	7%	1%
Reviewing and evaluating	10%	19%	20%	13%

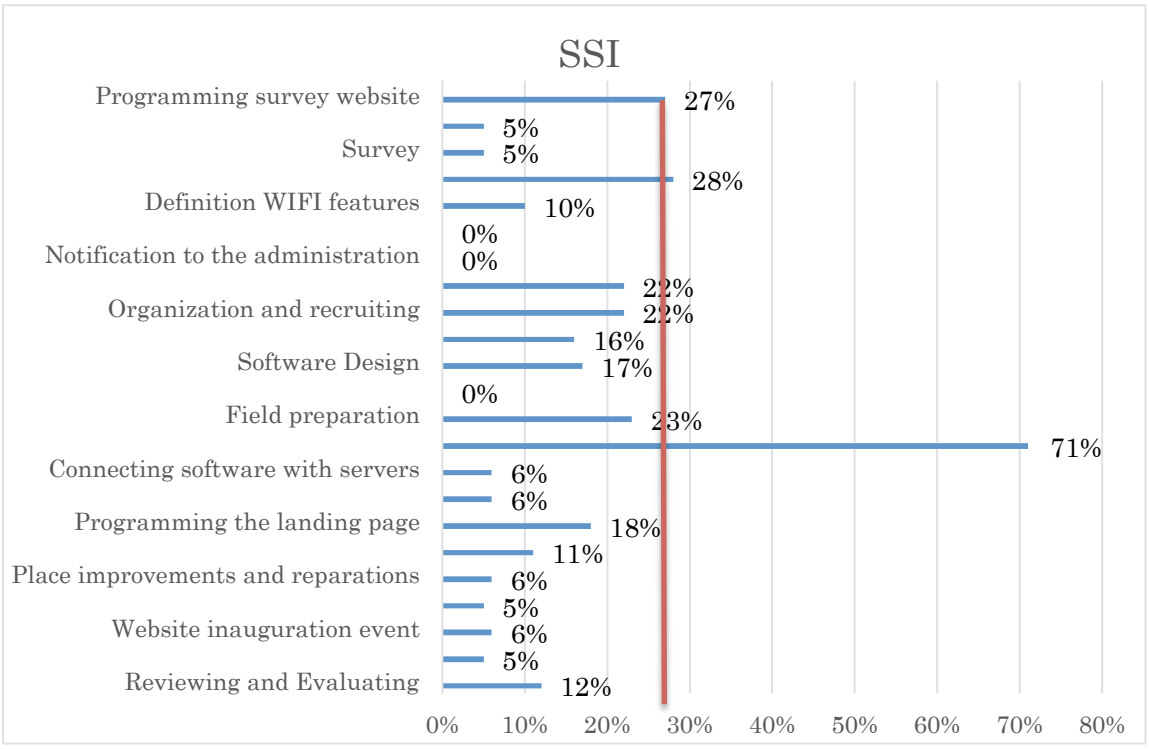


The first scenario we will evaluate is the best-case scenario, which is a rather naïve one. As already mentioned in the general information on the risk analysis, the only index that displays significant results is the Schedule Sensitivity index, since the Wi-Fi project is mostly serial in its activities. The SSI will then lead to significant contributions when taking the appropriate corrective actions. The SSI measures the relative importance of an activity taking the Criticality Index into account. When we look at percentages mentioned by the different activities, we can see that the installation activity has an SSI of 65%, which means that we have to put our focus on this activity since the high percentage alerts to the high sensitivity of the activity. Because when this activity isn't controlled well, we will be confronted with performance problems. The other activities have a SSI index significantly lower than the installation activity and don't need as much control as this activity.

As mentioned earlier, we will also include in our risk analysis the Cruciality Index (p) and Cruciality Index (f). For our best-case scenario, we got a 77% in CRI(p) for the Installation activity and a 57% in CRI(f). The next activity with the highest percentage in the CRI(p) and the CRI(f) is the Sponsorship, who gets a 42% and a 27% respectively. Therefore, we really have to focus on these two activities because otherwise we will have difficulties to achieve our time goal.

Worst-case scenario risk analysis

Sensitivity Report				
Name	**Schedule Sensitivity Index**	**Cruciality Index (CRI-r)**	**Cruciality Index (CRI-rho)**	**Cruciality Index (CRI-tau)**
Programming Survey Website	27%	28%	27%	18%
Survey Website Testing	5%	5%	5%	0%
Survey	5%	5%	6%	4%
Sponsorship	28%	31%	29%	19%
Definition WIFI features	10%	9%	12%	7%
Writing report for administration	0%	9%	11%	4%
Notification to the administration	0%	0%	2%	5%
Cost estimation	22%	26%	25%	17%
Organization and Recruiting	22%	19%	15%	9%
General R&D/Acquire software skills to implement WIFI	16%	11%	9%	5%
Software Design	17%	22%	21%	14%
Testing software phase	0%	21%	23%	18%
Field preparation	23%	17%	14%	9%
Installation	71%	75%	75%	55%
Connecting software with servers	6%	10%	10%	4%
Configuration of Blocking Tools	6%	21%	20%	11%
Programming the landing page	18%	11%	14%	8%
Testing phase for the landing page	11%	24%	22%	13%
Place improvements and reparations	6%	3%	4%	0%
Preparation of opening event	5%	9%	7%	3%
Website inauguration event	6%	23%	24%	13%
Final report	5%	0%	0%	3%
Reviewing and evaluating	12%	1%	4%	1%



The activities that can have the biggest impact on our schedule time when adapting the worst case scenario, is the Installation of the hotspots with an SSI of 71%, followed by Sponsorship (28%) and Programming survey website (27%). These percentages show the criticality of these activities for our project and they also tell us on which activities to focus, since they are critical. Considering the CRI measures, the most critical activities are again the installation and Sponsorship. Furthermore, the third activity that is more crucial for our project in our worst case scenario is the programming of the survey, which has 27% in the CRI(p) and 18% in the CRI(ŧ).

Conclusion

After analyzing the three scenarios, we can conclude that the activity we have to control continuously if we want to achieve our time goal is installation. Besides this installation, we should also pay good attention to the control of two other activities (programming survey website and sponsorship) if we want to be an excellent project manager.
These two activities have a higher percentage than the risk tolerance our firm has introduced for the project. For this reason, every activity passing the line of 25% should be subjected to effective control.

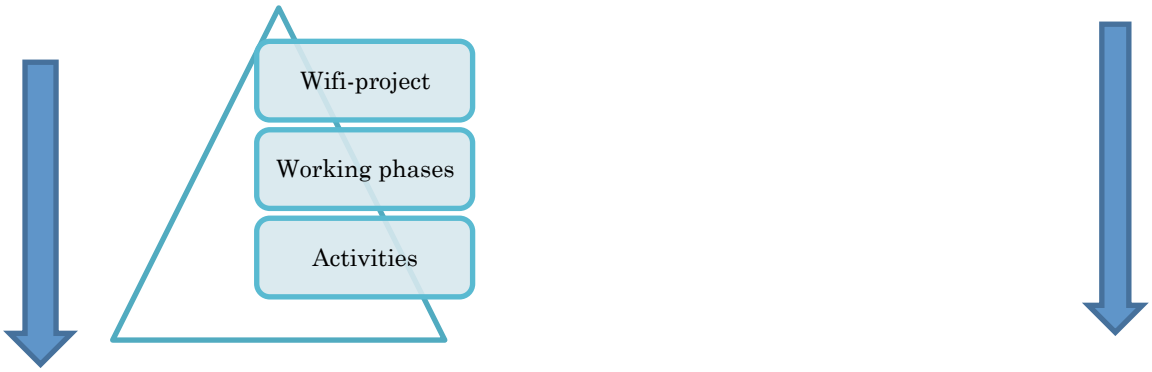
3.2 Cost-based

Since our main focus is time, but also still keeping in mind doing no excessive unnecessary expenses, the previous indices are the most important to focus on. A short explanation of our cruciality indices of the non-linear activities will summarize the most important consideration of risk in the 3 scenarios. As a consequence of the non-linearity, we will look at the CRI(pho) and the CRI(tau).

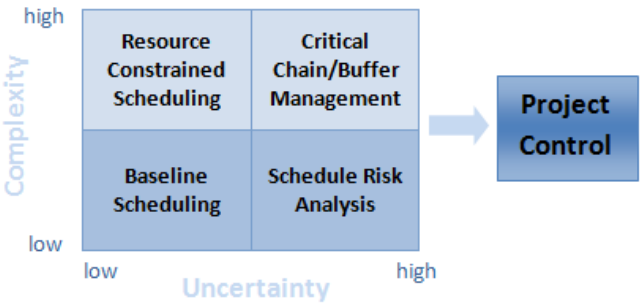
Over the different scenarios, we can notice that the CRI(rho) and the CRI(tau) are the highest for the high cost activities such as Software design, Installation, etc. The extra tables are enclosed in exhibit 4.

4. Efficiency considerations

We analyzed the SSI index as mentioned before. Since it is interesting for managerial decisions and insights, our Wi-Fi project contains a lot of serial activities. When being confronted with serial network activities, the best and efficient way to control the project, is to use a top-down approach in which the performance problem is detected on top and is further analyzed in the lower levels of the project activities. When applying the top-down approach, we developed an extended earned value management analysis.



5. Project control

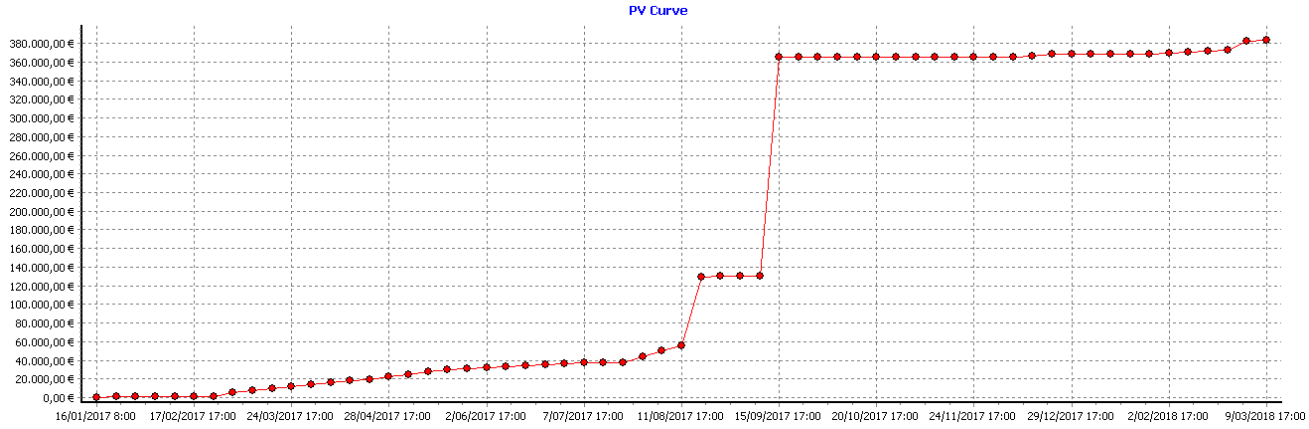


5.1 Earned Value Key Metrics

It's very important to have control over the time and costs of the project. Therefore we use the Earned Value Management tool (EVM). The target of this tool is to have an answer on the following three questions: How are we doing? What will it cost to finish the project? What is the total project duration?

After executing the scheduling phase, as you can read above, we estimated Budget At Completion (BAC) at € 383.400,30 and a Planned duration (PD) of 60 weeks. Because we don't have the periodic dynamic information, we simulated four cases based on the leveled baseline schedule; namely a worst, a best, a neutral and a random case with the baseline schedule as point of reference. In this manner we assume that the project is in progress in order to evaluate the project in monetary terms and to signal problems and opportunities in each of the scenarios.

The program we used for the simulations was ProTrack. On the basis of the Earned Value Key Metrics, which ProTrack calculated, we can make several conclusions for each case by answering the three questions of EVM. These Earned Value Key Metrics (the planned value (PV), the actual Cost (AC) and the earned value (EV)) are measured throughout the entire life of the project simulation at regular time intervals. The values of these key metrics during the whole project life cycle can then be reproduced in the PV curve, the AC curve and the EV curve. In the figure below we implemented the Planned Value curve of our project, that is the cumulative increase of the total budgeted activity cost given the baseline schedule. We see that this graph follows the usual S-form and represents how much value should have been earned according to the baseline schedule at the successive time points. Hence, by comparing the three curves in each of the following scenarios we are capable to make conclusions about the project performance in terms of time (the Schedule Variance) as well as in terms of costs (the Cost Variance).

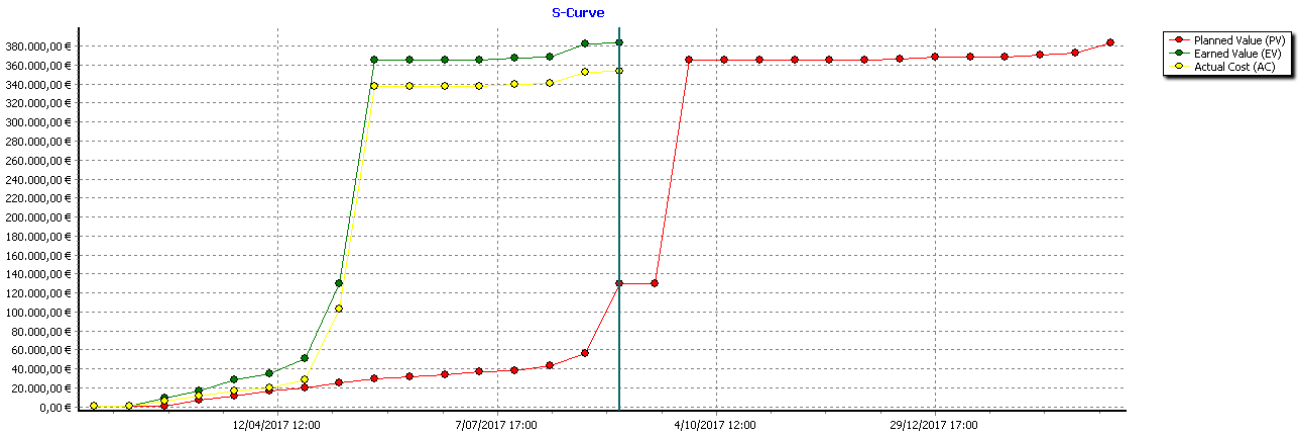


Best-case simulation

In the table below you find a summary of the earned value key metrics of the best-case simulation. You can find the original tracking periods as output from ProTrack of this scenario in Exhibit 5. The tracking periods in this scenario have an interval of 2 weeks.
We can conclude that in this best-case scenario we are seven months ahead of schedule based on the table and the graph below. More specific, we will end the project in 32 weeks instead of the planned 60 weeks seeing that the EV curve lies above the PV curve.

Furthermore, by comparing the estimated AC of the whole project (namely the cumulative actual cost spent at the end date and the EV) with the amount of value that has been earned at this
same endpoint, we can calculate that we are € 29 987,56 under budget. This can also be derived from the graph since the EV curve lies above the AC curve.
However, this is rather a very idealistic and theoretical outcome and will most likely never happen in practice.

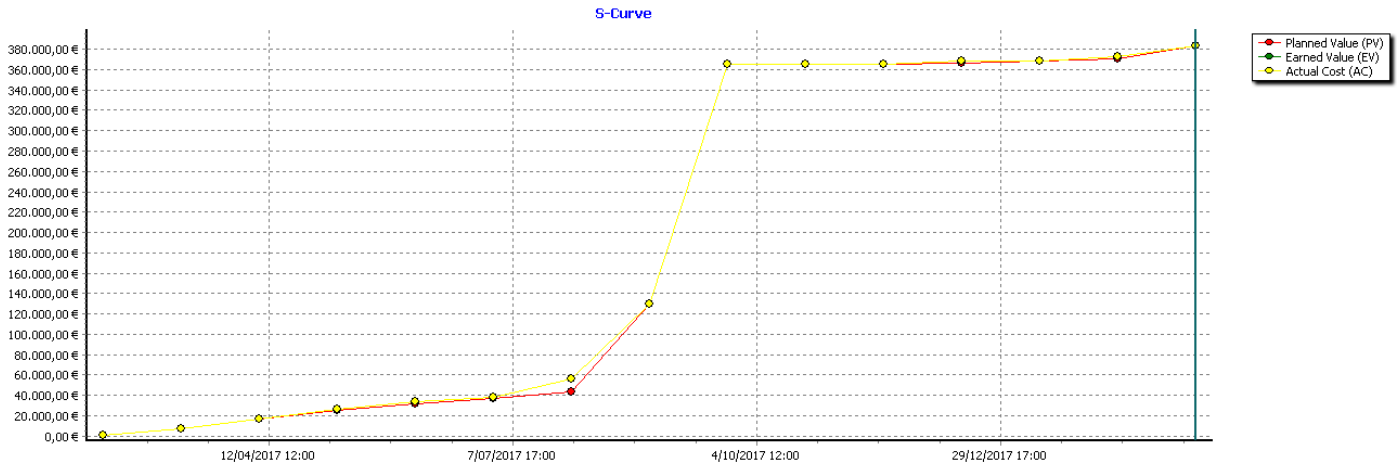
Week ***€***	***2***	***4***	***6***	***8***
PV	800	800	900	7 251,60
AC	800	900	6 561,36	11 015,28
EV	800	900	9 355,19	17 261,20
Week	**10**	**12**	**14**	**16**
PV	11 853,20	16 454,80	19 579,60	24 805,20
AC	16 608,52	19 960,82	28 023,24	102 788,38
EV	28 420, 06	35 133,17	51 211,88	130 173,48
Week	**18**	**20**	**22**	**24**
PV	30 030,80	31 606,40	34 107,20	36 608,00
AC	337 669,38	337 669,38	337 669,38	337 669,38
EV	365 054,50	365 054,50	365 054,50	365 054,50
Week	**26**	**28**	**30**	**32**
PV	37 808,00	43 801,61	55 788,80	130 173,48
AC	339 692,22	340 975,25	352 545,97	353 412,56
EV	367 327,94	369 011,72	382 437,25	383 400,13



Neutral-case simulation

In the neutral-case scenario (tracking period of four weeks), the EV, the PV and the AC turn out with the same value of € 383 400,13 at the end of the project as you can see in the table below and the original table in Exhibit 6. Moreover, during the project the earned value and the actual costs stay the same. After all, the project ends up without delays and cost overrun. In other words, everything happens according to plan and the project will finish on the 9th of March 2018 as the baseline schedule preconceived.

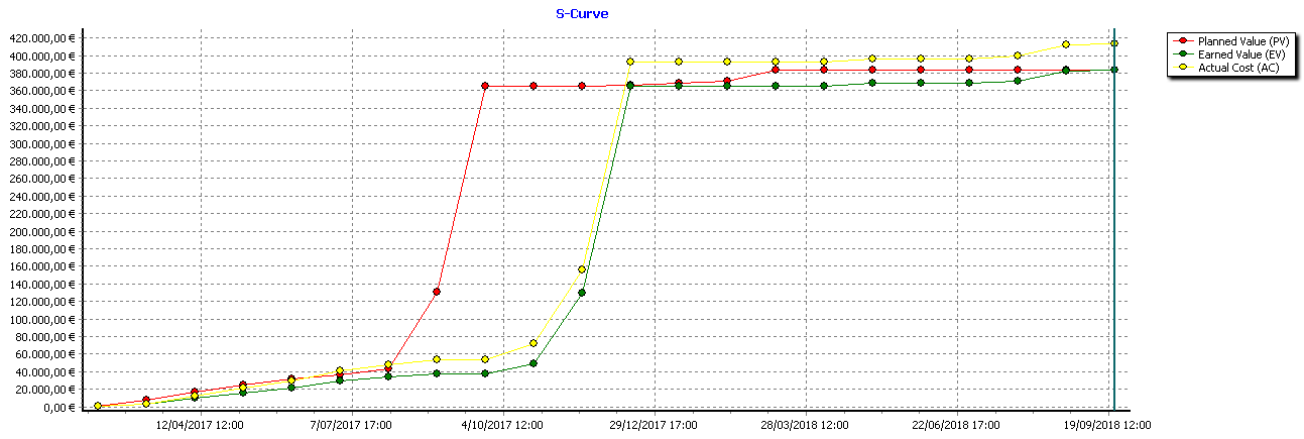
Week **€**	***2***	***4***	***6***	***8***	***10***
PV	800,00	7 251,60	16 454,80	24 805,20	31 606,40
AC	800,00	7 251,60	16 454,80	26 380,80	34 107,20
EV	800,00	7 251,60	16 454,80	26 380,80	34 107,20
Week	**12**	**14**	**16**	**18**	**20**
PV	36 608,00	43 801,61	130 173,48	365 054,50	365 054,50
AC	37 808,00	55 788,80	130 173,48	365 054,50	365 054,50
EV	37 808,00	55 788,80	130 173,48	365 054,50	365 054,50
Week	**22**	**24**	**26**	**28**	**30**
PV	365 054,50	366 552,91	368 651,31	370 313,72	383 400,13
AC	365 054,50	368 651,31	368 751,31	372 793,72	383 400,13
EV	365 054,50	368 751,31	368 751,31	372 793,72	383 400,13



Worst-case simulation

The worst-case scenario as ProTrack defines in its simulation, is when all the activities (critical and non-critical) are delayed. This means we are going to consume the entire built-in buffer, so the buffer consumption is equal to 100%. The final date of the worst-case simulation is the 21st of September 2018 instead of 9th of March; our goal if everything went according to plan. Therefore, we would have a delay of seven months. This delay is problematic and will not permit us to achieve our objective of being ready before the next elections. Besides this schedule variance, there is also a cost variance of - € 29 987.50. The minus indicates a budget overrun. The whole table with the tracking periods (4 weeks) can be found in Exhibit 7.

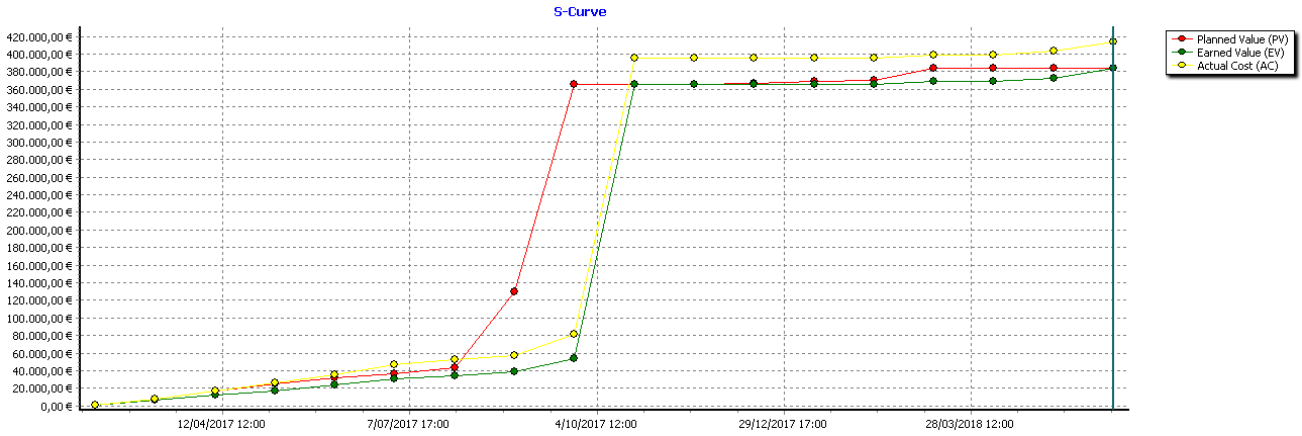
Week **€**	***4***	***8***	***12***	***16***	***20***	***24***	***28***	
PV	800	7 251,60	16 454,80	24 805,20	31 606,40	36 608,00	43 801,61	
AC	800	3 340,24	12 543,44	21 746,64	29 351,88	41 378,68	48 253,58	
EV	800	3 137,23	9 633,61	16 129,98	21 138,66	29 191,21	33 776,52	
Week	**32**	**36**	**40**	**44**	**48**	**52**	**56**	
PV	130 173,48	365 054,50	365 054,50	365 054,50	366 552,91	368 651,31	370 313,72	
AC	53 736,20	53 736,20	71 567,20	156 211,16	392 439,59	392 439,59	392 439,59	
EV	37 808,00	37 808,00	49 374,03	129 430,08	365 054,50	365 054,50	365 054,50	
Week	**60**	**64**	**68**	**72**	**76**	**80**	**84**	**88**
PV	38 3400,13	383 400,13	383 400,13	383 400,13	383 400,13	383 400,13	383 400,13	383 400,13
AC	392 439,59	392 439,59	396 485,94	396 485,94	396 485,94	399 824,19	412 232,19	413 387,63
EV	365 054,50	365 054,50	368 651,31	368 651,31	368 751.31	370 661,38	382 349,72	383 400.13



Random-case simulation

The last simulation we executed was a random one with a percentage early of 33% and a maximum deviation of 58%. The interval of the tracking periods is again 4 weeks. The end date of this simulation is the 1st of June 2018, this is three months later than we estimated in our baseline schedule. The cost of this delay is € 30 478,09, this could be realistic. You can find the tracking periods of this simulation in Exhibit 8.

Week **€**	***4***	***8***	***12***	***16***	***20***	***24***
PV	800,00	7 251.60	16 454.80	24 805.20	31 606,40	36 608,00
AC	800,00	7 884,32	17 087,52	25 607,70	35 389,27	46 391,93
EV	800,00	6 008,92	11 914,72	17 379,74	23 744,52	30 663,74
Week	**28**	**32**	**36**	**40**	**44**	**48**
PV	43 801,61	130 173,48	365 054,50	365 054,50	365 054,50	366 552,91
AC	52 176,91	57 214,39	81 188,79	395 327,88	395 327,88	395 327,88
EV	34 572,72	38 369,90	53 353,91	365 054,50	365 054,50	365054,50
Week	**52**	**56**	**60**	**64**	**68**	**72**
PV	368 651.31	370 313,72	383 400,13	383 400,13	383 400,13	383400,13
AC	395 327,88	395 327,88	399 074,53	399 174,53	403 048,28	413 878,22
EV	365 054,50	365 054,50	368 651,31	368 751,31	372 119,81	383 400,13



Conclusion

After these simulations we can conclude that in the worst-case we are more than seven months late, in the best-case we are seven months early. Hence, the gap between those two extremes for the scheduling gives us a location range where our project will most probably end and an indication about the room for improvement.

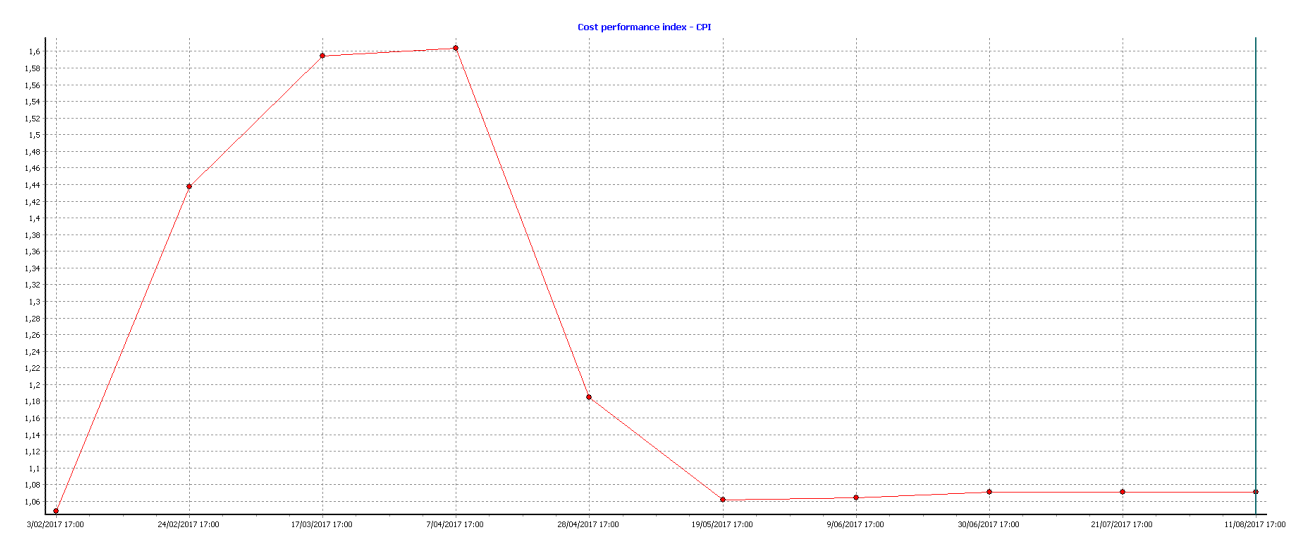
5.2 Performance Measurement

Cost Performance Index: CPI

The Cost Performance Index (CPI) shows how much value you get for each dollar spent on the project. A CPI equal to 1 means that the project is on budget.

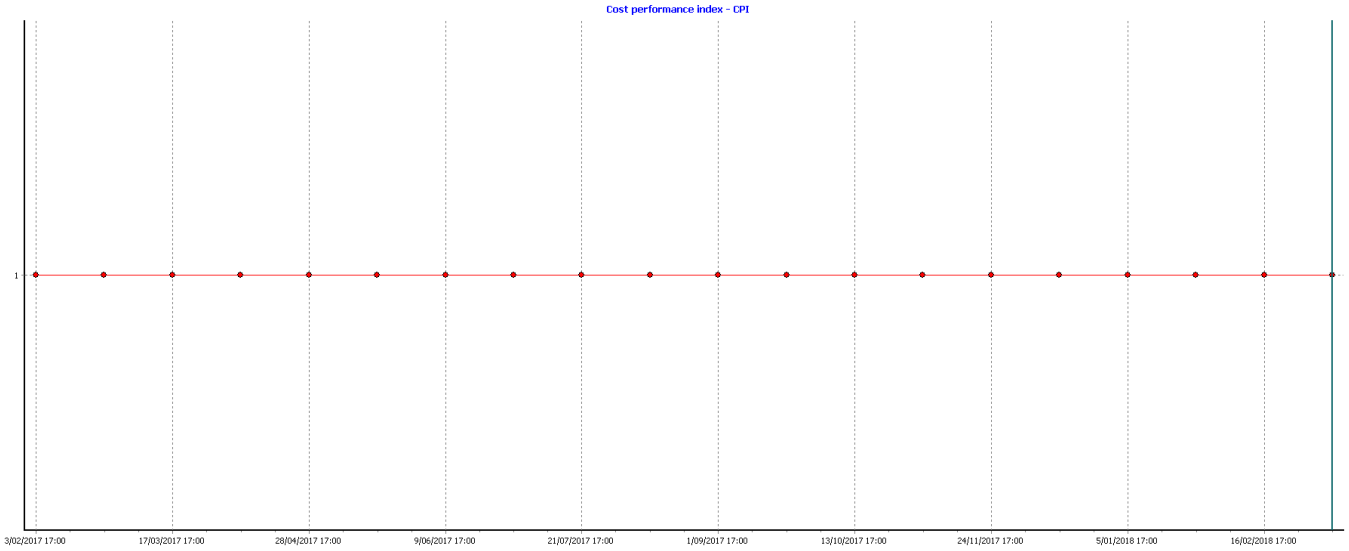
Best-case

In the best-case, we never exceed our budget since the CPI stays above 1 during the whole project. Between the 7th of April and the 20th of April, there is a decrease of our CPI due to the actual takeoff of our project (Cost estimation, recruiting, training,…).



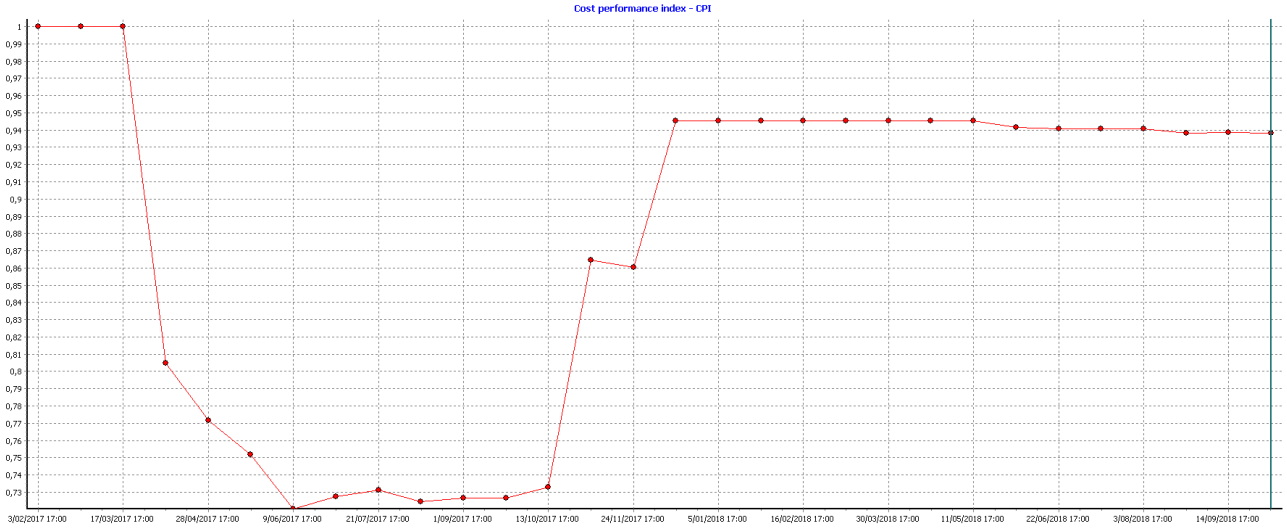
Neutral-case

Here, the CPI is continuously equal to 1.



Worst-case

In the worst-case, the Cost Performance Index indicates that from half March onwards, we face a cost overrun, as the CPI is under 1. This overrun increases until it hits bottom (0.72) in June 2017. Hereafter, the gap begins to close, but from December onwards the CPI stagnates around 94 until the end of project.

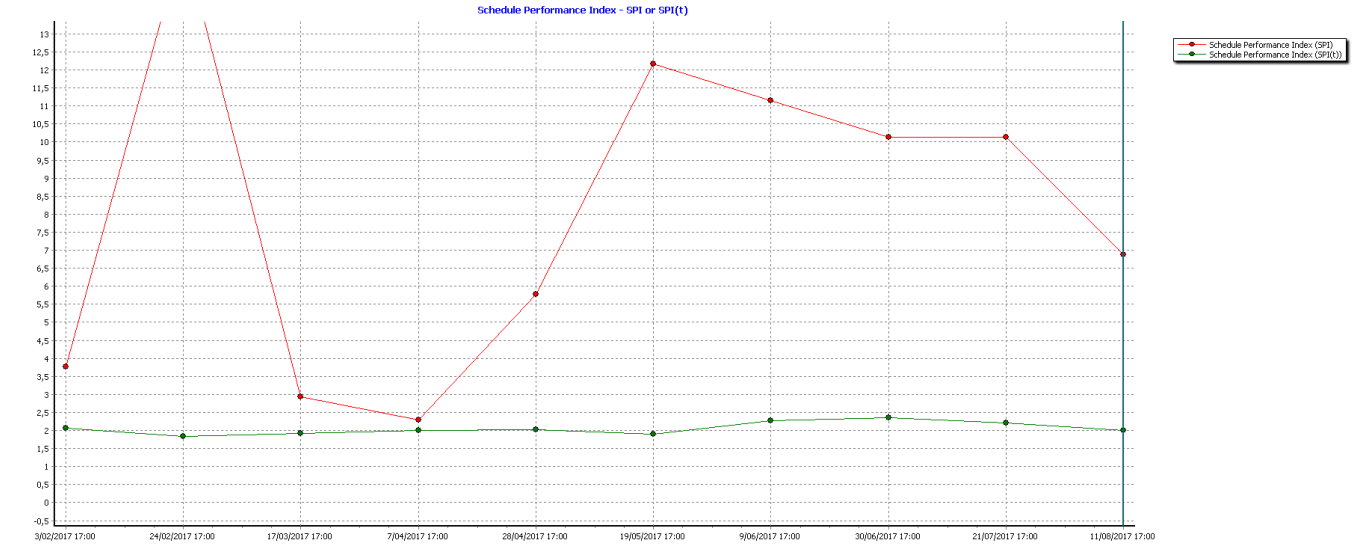


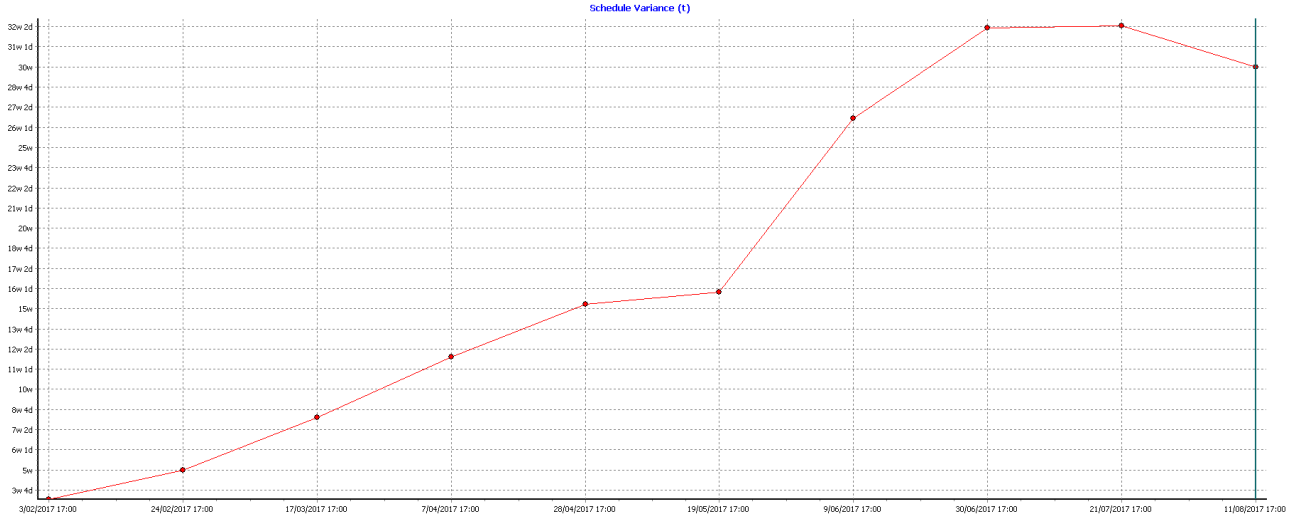
Schedule Performance Index: SPI(t)

Schedule Performance Index shows the efficiency of the time utilized on the project. However, the SPI is unreliable near the end of the project. Hence, we only consider the SPI(t) to measure the progress of our project. SPI(t) is an alternative performance measure based on the calculations of the Earned Schedule. A SPI(t) equal to 1 means that the project is on schedule.

Best-case

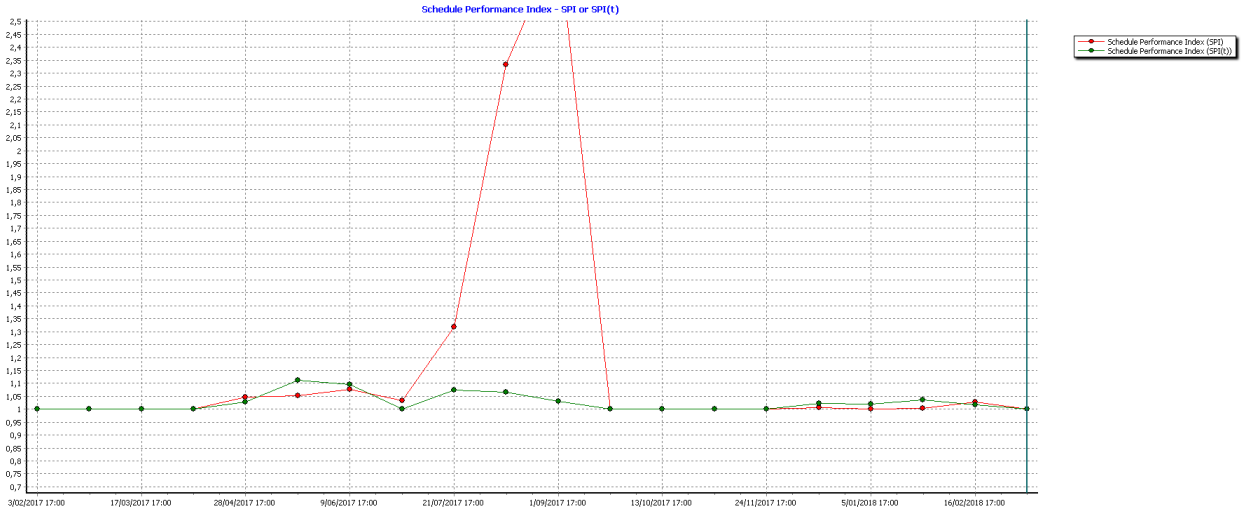
If we are optimistic, the SPI(t) fluctuates around 2. We will never encounter delay or problems during the whole project, as the SPI(t) is stable and always greater than 1. This means that we will be ahead of schedule. The same conclusions can be made when we look at the Schedule Variance (t). This variance indicates how much the project is ahead or behind schedule and it can be expressed in a time dimension, unlike the Schedule Variance which is expressed in absolute terms. A project that is on time has a schedule variance of zero. [Second graph]

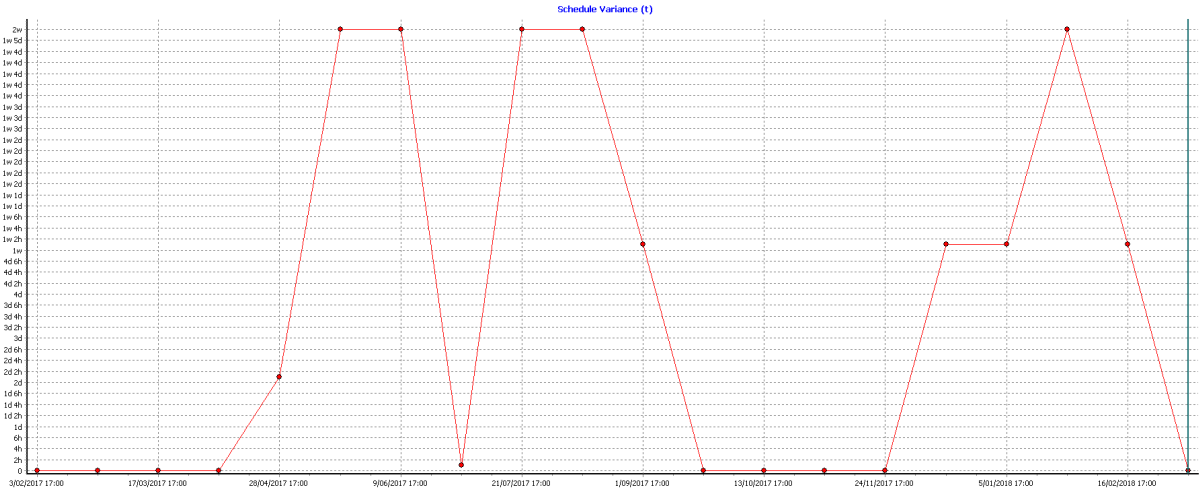




Neutral case

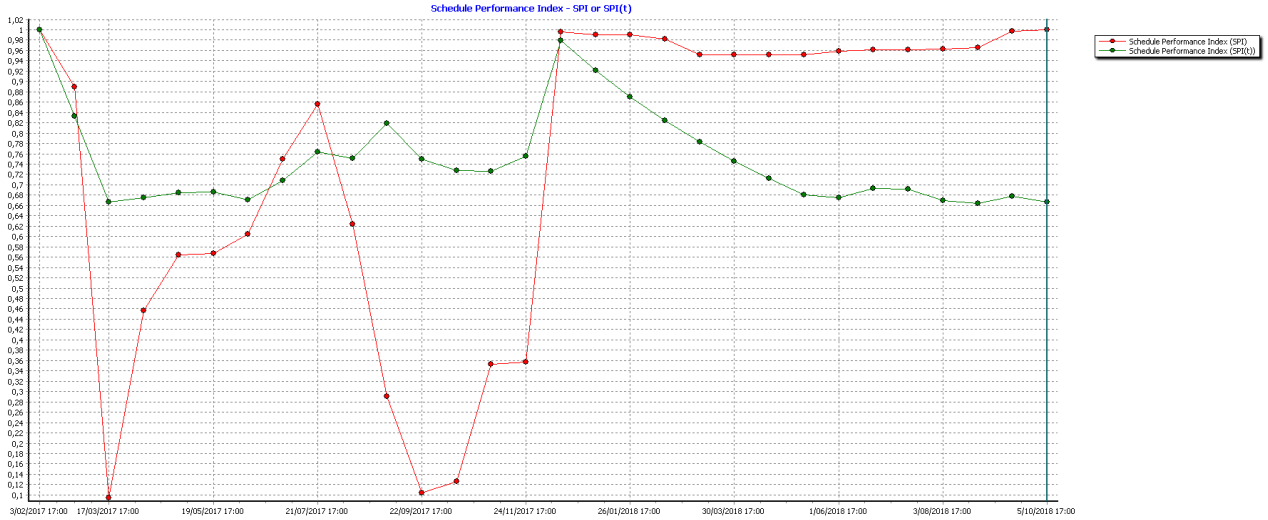
The SPI(t) stays close to (but never below) 1 during the whole project. Hence, the project progress is rather stable: there is no delay and at some moments we are ahead of schedule. You can see the peaks in the Schedule Variance (t) graph at those moments.

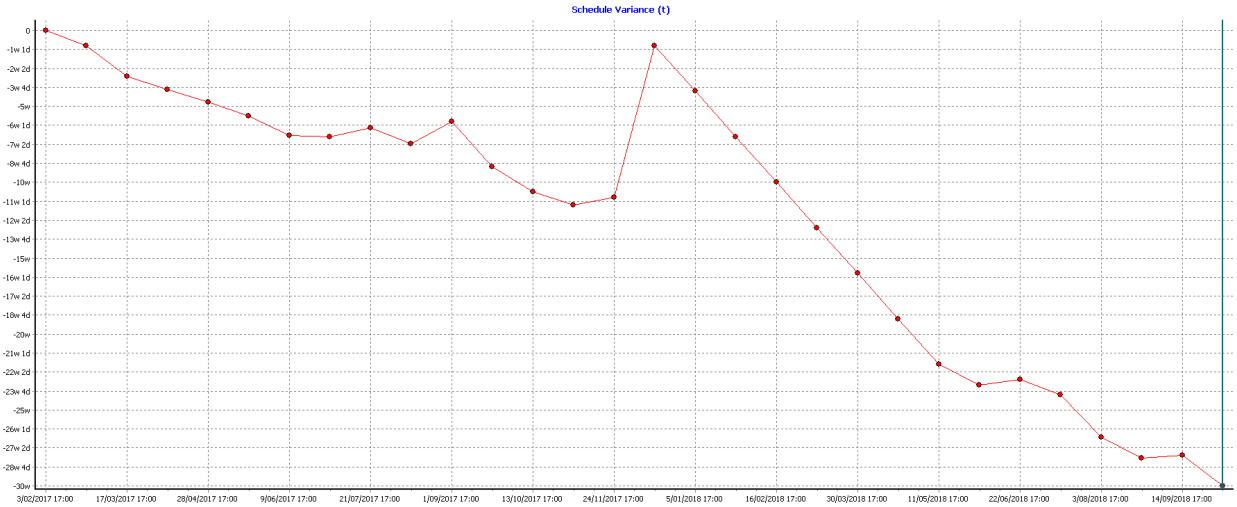




Worst-case

In the worst-case, the project already has accumulative problems in the beginning, since the SPI is going far below 1. Even though this could be a starters mistake, the problems continue with a delay (March until December). As you can see in the graph below, there is suddenly an improvement of the project delay as the SPI(t) increases to 0.96. Nevertheless, it drops again to a low point of 0.66 at the end of the project. The schedule variance (t) gets further and further away from zero.





5.3 Earned Value Forecasting Indicators

One of the primary tasks during the project is making decisions about the future. In order to follow up the performance of the project, we can forecast the total project cost and the time to completion. These measurements are very crucial to take corrective actions when problems or opportunities arise. Since time is our main objective, we can focus more on the EAC(t).

Time forecasting

Three methods for the final project duration can be used. The Planned Value Method does not directly give estimation for the planned duration of the work remaining, but relies mostly on the planned value rate. The Earned Duration Method relies on the Earned Duration metric, which is equal to ED = AD*SPI. The last method is the Earned Schedule Method and relies on the Earned Schedule metric.

	Planned Value Method	Earned Duration Method	Earned Schedule Method
PF=1	PD-TV	AD + (max (PD, AD) - ED)	AD + (PD - ES)
PF=SPI (SPI(t))	PD/SPI	AD + (max (PD, AD) - ED)/SPI	AD + (PD - ES)/SPI
PF=SCI (SCI(t))	PD/SCI	AD + (max (PD, AD) - ED)/SCI	AD + (PD - ES)/SCI

PD: planned duration *AD: actual duration*
ED: earned duration *ES: earned schedule*
TV: time variance

We can now use these various methods in our project. The results for the 3 different cases are shown in the following tables. An overall idea of the estimated project end can be given by these results.

Best Case	Planned Value Method	Earned Duration Method	Earned Schedule Method
PF=1	16/03/2017 (14:00)	16/03/2017 (14:00)	13/03/2017 (15:00)
PF=SPI (SPI(t))		16/03/2017 (14:00)	27/03/2017 (14:00)
PF=SCI (SCI(t))	11/08/2017 (17:00)	11/08/2017 (17:00)	11/08/2017 (17:00)

Neutral Case	Planned Value Method	Earned Duration Method	Earned Schedule Method
PF=1	09/03/2018 (17:00)	09/03/2018 (17:00)	09/03/2018 (17:00)
PF=SPI (SPI(t))	09/03/2018 (17:00)	09/03/2018 (17:00)	09/03/2018 (17:00)
PF=SCI (SCI(t))	09/03/2018 (17:00)	09/03/2018 (17:00)	09/03/2018 (17:00)

Worst Case	Planned Value Method	Earned Duration Method	Earned Schedule Method
PF=1	09/03/2018 (17:00)	09/03/2018 (17:00)	06/04/2018 (16:00)
PF=SPI (SPI(t))	05/10/2018 (17:00)	05/10/2018 (17:00)	05/10/2018 (17:00)
PF=SCI (SCI(t))	05/10/2018 (17:00)	05/10/2018 (17:00)	05/10/2018 (17:00)

PF=1: Future performance is expected to follow the baseline schedule
PF=SPI (SPI(t)): Future performance is expected to be related with the current schedule performance (SPI and/or SPI(t))
PF=SCI (SCI(t)): Future performance is expected to be related with the current schedule and cost performance

Cost forecasting

Cost performance is not the main focus for our project, but nevertheless greatly important.

	EAC estimated cost at completion
Best Case	€ 358.045,91
Neutral Case	€ 383.400,13
Worst Case	€ 408.754,34

6. Conclusion

After an analysis of our project of free Wi-Fi installation, we can make the following conclusions.

Our main objective of the project was time, as we want to present free Wi-Fi to the citizens of Ghent before the elections. The deadline was fixed at the 9th of March after having leveled activities and resources. However, we all know delays and extra costs can appear in real life. For this reason, we simulated three different scenarios (best, neutral and worst-case).

When analyzing the risk of our Wi-Fi project, we can conclude that the activities of installing the Wi-Fi, programming the website, developing the software and searching sponsors are activities that have high risk measures (SSI, CRI). Consequently they should be controlled thoroughly in order to be able to meet the time needs of our client. These activities also have the characteristic to be high-cost. During the analysis it became clear that besides their duration also the costs of these activities have to be kept reasonably.

After executing Earned Value Management, we achieved a range of possible end dates. Based on the EVM key metrics we've gained a view about variations in terms of time and cost, namely delays and leads and cost over- and underruns.

For the cost forecasting there is a difference of 50.000 euros between the best and the worst-case. This means in relative terms that we are moving in a range of 13% from our neutral-case. As our main objective was time, we can accept this deviation.
In contrast, any delay should be carefully controlled because if not, we are going to fail to achieve our objective. For this reason, we have to manage all our efforts and resources to deliver our free Wi-Fi in time.

With this assignment we have learned to use the main project management concepts and new software tools. Moreover, this task was our first management project and made us feel like real project managers. Since we have dealt with difficulties and unexpected problems, it was a valuable experience which is going to help us in our future careers.

7. References

http://www.loonwijzer.be /main/loon/salarischeck

http://www.rmd.jcyl.es/web/jcyl/binarios/164/930/Como%20poner%20en%20marcha%20una%20WIFI%20municipal.pdf?blobheader=application%2Fpdf%3Bcharset%3DUTF-8&blobheadername1=Cache-Control&blobheadername2=Expires&blobheadername3=Site&blobheadervalue1=no-store%2C

8. Exhibits

Exhibit 1: Survey

Free WIFI-hotspots in Ghent

*1. On which devices do you usually consult the Internet?

- [ ] Smartphone
- [ ] Tablet
- [ ] Laptop
- [ ] Notebook
- [ ] Other

*2. How often do you use the Internet on the previous devices?

- [ ] more than 10 times a day
- [ ] 5 -10 times a day
- [ ] less than 5 times a day
- [ ] one time in two days

*3. Would you be in favor of free WIFI hotspots in the center of Ghent? (For example Korenmarkt, 't Zuid,...)

- ( ) Yes
- ( ) No

*4. Which location(s) would you prefer to use a WIFI hotspot? (Multiple answers allowed)

- [ ] Sint-Pietersplein
- [ ] Korenmarkt
- [ ] 't Zuid
- [ ] Veldstraat
- [ ] Vrijdagsmarkt
- [ ] Station Gent-Sint-Pieters
- [ ] Graslei / Korenlei
- [ ] Sint-Baafsplein
- [ ] Other (please specify below)

5. Which relation do you have with the city of Ghent?

- [ ] Student
- [ ] Work
- [ ] Citizen
- [ ] Tourist
- [ ] Other (please specify below)

6. To which age range do you belong?

- ( ) younger than 12
- ( ) 12 - 17
- ( ) 18 - 29
- ( ) 30 - 49
- ( ) 50 or older

7. Gender?

- ( ) Male
- ( ) Female

Exhibit 2: Activity Schedule

	Activity	Duration (in weeks)	#Resources	Resources	Fixed Cost estimation (€)
1 Start: week 1	Programming survey website	5			800
2 Start week 6	Survey website testing	1			100
3 Start Week 7	Survey/Poll	6			1750
4 Start week 7	Sponsorship	6	4	Public relation	13804,80
5 Start week 13	Definition WIFI features	2	2	System analyst	3124,80
6 Start week 15	Writing report for administration	1	2	Administrative worker	1050,40
7 Start week 16	Notification for administration	1	1	Administrative worker	525,20
8 Start week 15	Cost estimation	4	4	2 Administrative workers 2 System analyst	10451,20
9 Start week 19	Organization and recruiting	4	2	HR manager	5001,60
10 Start week 23	General R&D / Acquire software skills to implement WIFI	3			1200
11 Start week 26	Software design	3	4	Software engineer	17980,80
12 Start week 29	Testing software phase	2	2	Software tester	2113,60
13 Start week 29	Field preparation	4			722271,08
14 Start week 33	Installation	13		10 hotspots	234881,02
15 Start week 46	Connecting software with servers	1	1	Software engineer	1498,80
16 Start week 47	Configuration of blocking tools	1	1	Software engineer	1498,80
17 Start week 48	Programming landing page	3			600
18 Start week	Testing phase for the landing phase	2			100

51					
19 Start week 53	Reviewing and evaluation	2	1	System analyst	1562,40
20 Start week 55	Place improvements and reparations	2	2	Technician	2113,60
21 Start week 55	Preparation of opening event	2	1	Marketing specialist	2480
22 Start week 57	Website inauguration	1			9556
23 Start week 58	Final report	1	2	Administrative worker	1050,40

Exhibit 3: Risk analysis (time-based)

Best-case

Sensitivity report

Name	Criticality Index	Significance Index	Schedule Sensitivity Index	Cruciality Index (CRI-r)	Cruciality Index (CRI-rho)	Cruciality Index (CRI-tau)
Programming Survey Website	100%	100%	26%	29%	25%	16%
Survey Website Testing	100%	100%	5%	2%	2%	4%
Survey	22%	61%	7%	7%	5%	3%
Sponsorship	78%	87%	23%	40%	42%	27%
Definition Wifi Features	78%	86%	8%	13%	11%	8%
Writing report for administration	24%	41%	1%	8%	7%	2%
Notification to the administration	24%	43%	1%	26%	25%	15%
Cost estimation	77%	87%	16%	13%	14%	8%
Organization and Recruiting	100%	100%	21%	39%	39%	26%
General R&D/Acquire software skills to implement WIFI	100%	100%	15%	16%	13%	8%
Software Design	100%	100%	14%	20%	17%	11%
Testing software phase	28%	59%	3%	17%	19%	12%
field preparation	73%	87%	15%	24%	21%	14%
Installation	100%	100%	63%	77%	77%	57%
Connecting software with servers	100%	100%	5%	9%	8%	3%
Configuration of Blocking Tools	100%	100%	5%	10%	8%	3%
Programming the landing page	100%	100%	15%	16%	14%	8%
Testing phase for the landing page	100%	100%	10%	33%	34%	21%
Place improvements and reparations	50%	75%	5%	14%	10%	5%
Preparation of opening event	51%	75%	5%	14%	15%	9%
Website inauguration event	100%	100%	5%	17%	15%	7%
Final report	100%	100%	5%	9%	7%	1%
Reviewing and Evaluating	100%	100%	10%	19%	20%	13%

Worst-case

Sensitivity report

Name	Criticality Index	Significance Index	Schedule Sensitivity Index	Cruciality Index (CRI-r)	Cruciality Index (CRI-rho)	Cruciality Index (CRI-tau)
Programming Survey Website	100%	0%	27%	28%	27%	18%
Survey Website Testing	100%	0%	5%	5%	5%	0%
Survey	14%	75%	5%	5%	6%	4%
Sponsorship	86%	98%	28%	31%	29%	19%
Definition Wifi Features	86%	96%	10%	9%	12%	7%
Writing report for administration	0%	36%	0%	9%	11%	4%
Notification to the administration	0%	36%	0%	0%	2%	5%
Cost estimation	100%	0%	22%	26%	25%	17%
Organization and Recruiting	100%	0%	22%	19%	15%	9%
General R&D/Acquire software skills to implement WIFI	100%	0%	16%	11%	9%	5%
Software Design	100%	0%	17%	22%	21%	14%
Testing software phase	0%	52%	0%	21%	23%	13%
field preparation	100%	0%	23%	17%	14%	9%
Installation	100%	0%	71%	75%	75%	53%
Connecting software with servers	100%	0%	6%	10%	10%	4%
Configuration of Blocking Tools	100%	0%	6%	21%	20%	11%
Programming the landing page	100%	0%	18%	11%	14%	8%
Testing phase for the landing page	100%	0%	11%	24%	22%	13%
Place improvements and reparations	62%	92%	6%	3%	4%	0%
Preparation of opening event	41%	87%	5%	9%	7%	3%
Website inauguration event	100%	0%	6%	23%	24%	13%
Final report	100%	0%	5%	0%	0%	3%
Reviewing and Evaluating	100%	0%	12%	1%	4%	1%

Exhibit 4: Risk analysis (cost-based)

Best-case

Sensitivity cost report

Name	Cruciality Index (CRI-r)	Cruciality Index (CRI-rho)	Cruciality Index (CRI-tau)
Programming Survey Website	0%	50%	100%
Survey Website Testing	0%	50%	100%
Survey	0%	50%	100%
Sponsorship	52%	52%	35%
Definition Wifi Features	2%	3%	4%
Writing report for administration	2%	2%	5%
Notification to the administration	8%	8%	2%
Cost estimation	52%	52%	35%
Organization and Recruiting	23%	21%	14%
General R&D/Acquire software skills to implement WIFI	0%	50%	100%
Software Design	65%	66%	46%
Testing software phase	24%	26%	14%
field preparation	0%	50%	100%
Installation	0%	50%	100%
Connecting software with servers	11%	16%	7%
Configuration of Blocking Tools	14%	16%	8%
Programming the landing page	0%	50%	100%
Testing phase for the landing page	0%	50%	100%
Place improvements and reparations	14%	13%	7%
Preparation of opening event	0%	50%	100%
Website inauguration event	0%	50%	100%
Final report	15%	14%	7%
Reviewing and Evaluating	15%	15%	9%

Worst-case

Sensitivity cost report

Name	Cruciality Index (CRI-r)	Cruciality Index (CRI-rho)	Cruciality Index (CRI-tau)
Programming Survey Website	0%	50%	100%
Survey Website Testing	0%	50%	100%
Survey	0%	50%	100%
Sponsorship	52%	51%	34%
Definition Wifi Features	10%	11%	6%
Writing report for administration	5%	5%	0%
Notification to the administration	6%	7%	2%
Cost estimation	39%	39%	25%
Organization and Recruiting	15%	14%	9%
General R&D/Acquire software skills to implement WIFI	0%	50%	100%
Software Design	75%	75%	54%
Testing software phase	22%	22%	16%
field preparation	0%	50%	100%
Installation	0%	50%	100%
Connecting software with servers	7%	6%	1%
Configuration of Blocking Tools	5%	5%	1%
Programming the landing page	0%	50%	100%
Testing phase for the landing page	0%	50%	100%
Place improvements and reparations	10%	9%	5%
Preparation of opening event	0%	50%	100%
Website inauguration event	0%	50%	100%
Final report	3%	5%	0%
Reviewing and Evaluating	15%	14%	10%

Exhibit 5: Best-case (Tracking periods: 2 weeks interval)

General				EVM key parameters				EVM performance measures						
Name	Start	Status date	Overridden/	Planned	Earned	Actual Cost	Earned	Schedule	Schedule	Cost	Cost	Schedule	Schedule	p-factor
27/01/2017	16/01/2017	27/01/2017		800,00 €	800,00 €	800,00 €	27/01/2017	0,00 €	100%	0,00 €	100%	0	100%	100%
10/02/2017	27/01/2017	10/02/2017		800,00 €	900,00 €	900,00 €	20/02/2017	100,00 €	112%	0,00 €	100%	1w 1h	126%	100%
24/02/2017	10/02/2017	24/02/2017		900,00 €	9.355,19 €	6.561,36 €	17/03/2017	8.455,19 €	1039%	2.793,83 €	143%	2w 5d	149%	100%
10/03/2017	24/02/2017	10/03/2017		7.251,60 €	17.261,20 €	11.015,28 €	12/04/2017	10.009,60 €	238%	6.245,92 €	157%	4w 3d	157%	100%
24/03/2017	10/03/2017	24/03/2017		11.853,20 €	28.420,06 €	16.608,52 €	16/05/2017	16.566,86 €	240%	11.811,54 €	171%	7w 2d	174%	94%
7/04/2017	24/03/2017	7/04/2017		16.454,80 €	35.133,17 €	19.960,82 €	23/06/2017	18.678,37 €	214%	15.172,35 €	176%	10w 4d	190%	100%
21/04/2017	7/04/2017	21/04/2017		19.579,60 €	51.211,88 €	28.023,24 €	8/08/2017	31.632,27 €	262%	23.188,63 €	183%	15w 1d	209%	100%
5/05/2017	21/04/2017	5/05/2017		24.805,20 €	130.173,48	102.788,38	25/08/2017	105.368,28	525%	27.385,11 €	127%	16w	200%	100%
19/05/2017	5/05/2017	19/05/2017		30.030,80 €	365.054,50	337.669,38	11/09/2017	335.023,69	1216%	27.385,13 €	108%	16w 1h	189%	100%
2/06/2017	19/05/2017	2/06/2017		31.606,40 €	365.054,50	337.669,38	11/09/2017	333.448,09	1155%	27.385,13 €	108%	14w 1h	170%	100%
16/06/2017	2/06/2017	16/06/2017		34.107,20 €	365.054,50	337.669,38	11/09/2017	330.947,31	1070%	27.385,13 €	108%	12w 1h	155%	100%
30/06/2017	16/06/2017	30/06/2017		36.608,00 €	365.054,50	337.669,38	11/09/2017	328.446,50	997%	27.385,13 €	108%	10w 1h	142%	100%
14/07/2017	30/06/2017	14/07/2017		37.808,00 €	367.327,94	339.692,22	20/12/2017	329.519,94	972%	27.635,72 €	108%	22w 3d	187%	100%
28/07/2017	14/07/2017	28/07/2017		43.801,61 €	369.011,72	340.975,25	30/01/2018	325.210,13	842%	28.036,47 €	108%	26w 2d	194%	100%
11/08/2017	28/07/2017	11/08/2017		55.788,80 €	382.437,25	352.545,97	5/03/2018	326.648,44	686%	29.891,28 €	108%	29w 4h	197%	100%
25/08/2017	11/08/2017	25/08/2017		130.173,48	383.400,13	353.412,56	9/03/2018	253.226,64	295%	29.987,56 €	108%	28w	188%	100%

Exhibit 6: Neutral-case (Tracking periods: 4 weeks interval)

General				EVM key parameters				EVM performance measures						
Name	Start	Status date	Overridden/	Planned	Earned	Actual Cost	Earned	Schedule	Schedule	Cost	Cost	Schedule	Schedule	p-factor
10/02/2017	16/01/2017	10/02/2017		800,00 €	800,00 €	800,00 €	10/02/2017	0,00 €	100%	0,00 €	100%	0	100%	100%
10/03/2017	10/02/2017	10/03/2017		7.251,60 €	7.251,60 €	7.251,60 €	10/03/2017	0,00 €	100%	0,00 €	100%	0	100%	100%
7/04/2017	10/03/2017	7/04/2017		16.454,80 €	16.454,80 €	16.454,80 €	7/04/2017	0,00 €	100%	0,00 €	100%	0	100%	100%
5/05/2017	7/04/2017	5/05/2017		24.805,20 €	26.380,80 €	26.380,80 €	11/05/2017	1.575,60 €	106%	0,00 €	100%	3d 1h	104%	94%
2/06/2017	5/05/2017	2/06/2017		31.606,40 €	34.107,20 €	34.107,20 €	16/06/2017	2.500,80 €	108%	0,00 €	100%	2w	110%	100%
30/06/2017	2/06/2017	30/06/2017		36.608,00 €	37.808,00 €	37.808,00 €	3/07/2017	1.200,00 €	103%	0,00 €	100%	1h	100%	100%
28/07/2017	30/06/2017	28/07/2017		43.801,61 €	55.788,80 €	55.788,80 €	11/08/2017	11.987,20 €	127%	0,00 €	100%	2w	107%	100%
25/08/2017	28/07/2017	25/08/2017		130.173,48	130.173,48	130.173,48	25/08/2017	0,00 €	100%	0,00 €	100%	0	100%	100%
22/09/2017	25/08/2017	22/09/2017		365.054,50	365.054,50	365.054,50	22/09/2017	0,00 €	100%	0,00 €	100%	0	100%	100%
20/10/2017	22/09/2017	20/10/2017		365.054,50	365.054,50	365.054,50	20/10/2017	0,00 €	100%	0,00 €	100%	0	100%	100%
17/11/2017	20/10/2017	17/11/2017		365.054,50	365.054,50	365.054,50	17/11/2017	0,00 €	100%	0,00 €	100%	0	100%	100%
15/12/2017	17/11/2017	15/12/2017		366.552,91	368.651,31	368.651,31	25/12/2017	2.098,41 €	101%	0,00 €	100%	1w 1h	102%	100%
12/01/2018	15/12/2017	12/01/2018		368.651,31	368.751,31	368.751,31	15/01/2018	100,00 €	100%	0,00 €	100%	1h	100%	100%
9/02/2018	12/01/2018	9/02/2018		370.313,72	372.793,72	372.793,72	23/02/2018	2.480,00 €	101%	0,00 €	100%	2w	104%	100%
9/03/2018	9/02/2018	9/03/2018		383.400,13	383.400,13	383.400,13	9/03/2018	0,00 €	100%	0,00 €	100%	0	100%	100%

Exhibit 7: Worst-case (Tracking periods: 4 weeks interval)

General				EVM key parameters				EVM performance measures						
Name	Start	Status date	Overridden/	Planned	Earned	Actual Cost	Earned	Schedule	Schedule	Cost	Cost	Schedule	Schedule	p-factor
10/02/2017	16/01/2017	10/02/2017		800,00 €	800,00 €	800,00 €	10/02/2017	0,00 €	100%	0,00 €	100%	0	100%	100%
10/03/2017	10/02/2017	10/03/2017		7.251,60 €	3.137,23 €	3.340,24 €	27/02/2017	-4.114,37 €	43%	-203,01 €	94%	-1w 4d	77%	100%
7/04/2017	10/03/2017	7/04/2017		16.454,80 €	9.633,61 €	12.543,44 €	20/03/2017	-6.821,20 €	59%	-2.909,83 €	77%	-2w 5d	75%	100%
5/05/2017	7/04/2017	5/05/2017		24.805,20 €	16.129,98 €	21.746,64 €	7/04/2017	-8.675,22 €	65%	-5.616,66 €	74%	-4w 6h	74%	100%
2/06/2017	5/05/2017	2/06/2017		31.606,40 €	21.138,66 €	29.351,88 €	26/04/2017	-10.467,74	67%	-8.213,22 €	72%	-5w 2d	73%	98%
30/06/2017	2/06/2017	30/06/2017		36.608,00 €	29.191,21 €	41.378,68 €	18/05/2017	-7.416,80 €	80%	-12.187,47	71%	-6w 2d	74%	95%
28/07/2017	30/06/2017	28/07/2017		43.801,61 €	33.776,52 €	48.253,58 €	15/06/2017	-10.025,09	77%	-14.477,06	70%	-6w 1d	78%	100%
25/08/2017	28/07/2017	25/08/2017		130.173,48	37.808,00 €	53.736,20 €	21/07/2017	-92.365,48	29%	-15.928,20	70%	-5w	84%	100%
22/09/2017	25/08/2017	22/09/2017		365.054,50	37.808,00 €	53.736,20 €	21/07/2017	-327.246,5	10%	-15.928,20	70%	-9w	75%	100%
20/10/2017	22/09/2017	20/10/2017		365.054,50	49.374,03 €	71.567,16 €	4/08/2017	-315.680,4	14%	-22.193,13	69%	-11w 3h	72%	100%
17/11/2017	20/10/2017	17/11/2017		365.054,50	129.430,08	156.211,16	22/08/2017	-235.624,4	35%	-26.781,08	83%	-12w 4d	71%	100%
15/12/2017	17/11/2017	15/12/2017		366.552,91	365.054,50	392.439,59	8/12/2017	-1.498,41 €	100%	-27.385,09	93%	-1w	98%	100%
12/01/2018	15/12/2017	12/01/2018		368.651,31	365.054,50	392.439,59	8/12/2017	-3.596,81 €	99%	-27.385,09	93%	-5w	90%	100%
9/02/2018	12/01/2018	9/02/2018		370.313,72	365.054,50	392.439,59	8/12/2017	-5.259,22 €	99%	-27.385,09	93%	-9w	84%	100%
9/03/2018	9/02/2018	9/03/2018		383.400,13	365.054,50	392.439,59	8/12/2017	-18.345,63	95%	-27.385,09	93%	-13w	78%	100%
6/04/2018	9/03/2018	6/04/2018		383.400,13	365.054,50	392.439,59	8/12/2017	-18.345,63	95%	-27.385,09	93%	-17w	73%	100%
4/05/2018	6/04/2018	4/05/2018		383.400,13	368.651,31	396.485,94	12/01/2018	-14.748,81	96%	-27.834,63	93%	-16w	76%	100%
1/06/2018	4/05/2018	1/06/2018		383.400,13	368.651,31	396.485,94	12/01/2018	-14.748,81	96%	-27.834,63	93%	-20w	72%	100%
29/06/2018	1/06/2018	29/06/2018		383.400,13	368.751,31	396.585,94	26/01/2018	-14.648,81	96%	-27.834,63	93%	-22w	71%	100%
27/07/2018	29/06/2018	27/07/2018		383.400,13	370.661,38	399.824,19	13/02/2018	-12.738,75	97%	-29.162,81	93%	-23w 4d	70%	100%
24/08/2018	27/07/2018	24/08/2018		383.400,13	382.349,72	412.232,19	2/03/2018	-1.050,41 €	100%	-29.882,47	93%	-25w	70%	100%
21/09/2018	24/08/2018	21/09/2018		383.400,13	383.400,13	413.387,63	9/03/2018	0,00 €	100%	-29.987,50	93%	-28w	68%	100%

Exhibit 8: Random-case (Tracking periods: 4 weeks interval)

General				EVM key parameters				EVM performance measures						
Name	Start	Status date	Overridden/	Planned	Earned	Actual Cost	Earned	Schedule	Schedule	Cost	Cost	Schedule	Schedule	p-factor
10/02/2017	16/01/2017	10/02/2017		800,00 €	800,00 €	800,00 €	10/02/2017	0,00 €	100%	0,00 €	100%	0	100%	100%
10/03/2017	10/02/2017	10/03/2017		7.251,60 €	6.008,92 €	7.884,32 €	8/03/2017	-1.242,68 €	83%	-1.875,40 €	76%	-2d 6h	93%	100%
7/04/2017	10/03/2017	7/04/2017		16.454,80 €	11.914,72 €	17.087,52 €	27/03/2017	-4.540,08 €	72%	-5.172,80 €	70%	-1w 5d	84%	100%
5/05/2017	7/04/2017	5/05/2017		24.805,20 €	17.379,74 €	25.607,70 €	12/04/2017	-7.425,46 €	70%	-8.227,96 €	68%	-3w 2d	79%	100%
2/06/2017	5/05/2017	2/06/2017		31.606,40 €	23.744,52 €	35.389,27 €	3/05/2017	-7.861,89 €	75%	-11.644,75	67%	-4w 2d	78%	95%
30/06/2017	2/06/2017	30/06/2017		36.608,00 €	30.663,74 €	46.391,93 €	24/05/2017	-5.944,26 €	84%	-15.728,19	66%	-5w 2d	77%	97%
28/07/2017	30/06/2017	28/07/2017		43.801,61 €	34.572,72 €	52.176,91 €	20/06/2017	-9.228,89 €	79%	-17.604,19	66%	-5w 3d	80%	100%
25/08/2017	28/07/2017	25/08/2017		130.173,48	38.369,90 €	57.214,39 €	24/07/2017	-91.803,58	29%	-18.844,48	67%	-4w 5d	85%	100%
22/09/2017	25/08/2017	22/09/2017		365.054,50	53.353,91 €	81.188,79 €	9/08/2017	-311.700,5	15%	-27.834,88	66%	-6w 2d	82%	100%
20/10/2017	22/09/2017	20/10/2017		365.054,50	365.054,50	395.327,88	20/10/2017	0,00 €	100%	-30.273,38	92%	0	100%	100%
17/11/2017	20/10/2017	17/11/2017		365.054,50	365.054,50	395.327,88	17/11/2017	0,00 €	100%	-30.273,38	92%	0	100%	100%
15/12/2017	17/11/2017	15/12/2017		366.552,91	365.054,50	395.327,88	8/12/2017	-1.498,41 €	100%	-30.273,38	92%	-1w	98%	100%
12/01/2018	15/12/2017	12/01/2018		368.651,31	365.054,50	395.327,88	8/12/2017	-3.596,81 €	99%	-30.273,38	92%	-5w	90%	100%
9/02/2018	12/01/2018	9/02/2018		370.313,72	365.054,50	395.327,88	8/12/2017	-5.259,22 €	99%	-30.273,38	92%	-9w	84%	100%
9/03/2018	9/02/2018	9/03/2018		383.400,13	368.651,31	399.074,53	12/01/2018	-14.748,81	96%	-30.423,22	92%	-8w	87%	100%
6/04/2018	9/03/2018	6/04/2018		383.400,13	368.751,31	399.174,53	26/01/2018	-14.648,81	96%	-30.423,22	92%	-10w	84%	100%
4/05/2018	6/04/2018	4/05/2018		383.400,13	372.119,81	403.048,28	21/02/2018	-11.280,31	97%	-30.928,47	92%	-10w 3d	84%	100%
1/06/2018	4/05/2018	1/06/2018		383.400,13	383.400,13	413.878,22	9/03/2018	0,00 €	100%	-30.478,09	93%	-12w	83%	100%