

Treball de Fi de Grau

**Grau en Tecnologies Industrials**

**Aplicació d'eines de consens per a la definició i  
valoració d'escenaris de futur de les PIMEs**

**Application of consensus tools for the definition  
and evaluation of future scenarios of SMEs**

**MEMÒRIA - REPORT**

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## Abstract

The main objective of this project is to apply consensus tools in order to make the decision making process in SMEs easier.

Therefore, you will find a wide section dedicated to research upon the field of group tasks, consensus and decision making. The reader will be put into context regarding the current situation of SMEs in the region of Catalonia, Spain. Conclusions obtained during the whole process of research will be later used to try and decide how can they be applied to help this companies solve some of the main issues that they are facing.

A survey will be conducted in order to determine what kind of factors can be associated to determined profiles, which will later be useful for the final purpose of the project.

A deep look will also be taken at the concept of collective intelligence (CI), which is defined by the global intelligence of a group of individuals who work together to carry out different tasks. An experiment will be set in order to, at least, identify some of the main features pointed out of conclusions of the research in the field of CI.

As a final step, a tool will be designed in order to help these companies in the process of forming groups which will later have to take part in decision making and problem solving processes. In order to design this tool, the knowledge previously obtained in the rest of the project will be used.



## Index

|   |    |
|---|----|
| 1 – Preface .....   | 7  |
| 1.1 - Project origin .....  | 7  |
| 1.2 - Motivation .....  | 7  |
| 2 - Introduction.....   | 8  |
| 2.1 – Project goals .....   | 8  |
| 2.2 – Scope of the project .....                                  | 8  |
| 3- Current situation of SMEs in Catalonia .....                   | 9  |
| 4 – Problem analysis and problem solving tools .....              | 12 |
| 4.1 – Consensus in companies.....                                 | 12 |
| 4.2 – Consensus regarded as an obstacle.....                      | 12 |
| 4.3 – Conclusions regarding consensus.....                        | 15 |
| 4.4 – Existing tools.....   | 17 |
| 4.5 – Combination of available tools with existing problems ..... | 21 |
| 4.6 – Chosen combination.....                                     | 22 |
| 5 – Data collection.....  | 23 |
| 5.1 – Tool choice.....  | 23 |
| 5.2 – Survey questions.....                                       | 23 |
| 5.3 – Profile classification of candidates .....                  | 24 |
| 5.4 – Results of the survey .....                                 | 24 |
| 5.5 – Conclusion of the survey .....                              | 29 |
| 6 – Collective intelligence.....                                  | 30 |
| 6.1 – Introduction to collective intelligence.....                | 30 |
| 6.2 – Collective intelligence applied to the project.....         | 32 |
| 6.3 – Groups composition .....                                    | 32 |
| Group 1.....  | 32 |
| Group 2.....  | 33 |
| Group 3.....  | 33 |
| Group 4.....  | 34 |
| Group 5.....  | 34 |
| 6.4 – Proposed task and evaluation method.....                    | 35 |
| 6.5 – Results of the experiment .....                             | 35 |

|                                    |    |
|------------------------------------|----|
| 7 - Development of the tool .....  | 37 |
| 7.1 - Initial approach.....        | 37 |
| 7.2 - Tool concept.....            | 40 |
| 7.3 - Design of the tool .....     | 42 |
| 7.4 - Body of the tool.....        | 53 |
| 7.5 - Examples using the tool..... | 56 |
| 8 – Conclusions.....               | 59 |
| 9 – Greetings.....                 | 61 |
| 10 – Project budget .....          | 62 |
| 11 – Bibliography.....             | 63 |



# 1 – Preface

## 1.1 – Project origin

The origin of this project is based on the continuation of the research process carried out by its two directors, Ramon Salvador and Josep M<sup>a</sup> Monguet (both professors at the Escola Tècnica Superior d' Enginyeria Industrial de Barcelona, UPC). This research is focused on the field of consensus and more specifically, collective intelligence.

## 1.2 - Motivation

As soon as I read the project proposal it strongly caught my eye, especially for two main reasons:

- I have always been passionate about the idea of working in a small company based on a different, innovative idea that can have a real impact in some aspect of society, and be part of the expansion process of this company.
- The opportunity to help to design, or at least to bring up some positive output related to the idea of improving performance of groups, which is the real core of any company and especially those companies that are small but intend to become big someday.

Another strong reason that drove me to choose this topic was my narrow knowledge, and the opportunity to take a deeper look and read sociology papers where I could pick ideas that could be later applied to my own project.

## 2 - Introduction

### 2.1 – Project goals

The final goal of this project is already defined in the title: to use consensus tools in order to facilitate and improve the process of decision making in SMEs in order to open new scenarios full of opportunities. As it can already be observed, the definition is very open and admits many direction changes, which is what has actually happened during the whole process of creation. Although there were some initial ideas, while learning new concepts the interest of the projects has modified its focus without losing its main track.

In a more schematic way, the objectives could be defined as:

- To study and list the needs of SMEs
- To collect, filter and analyse information regarding consensus tools
- To understand the truths and myths regarding consensus in order to maximize the impact of the project
- To set a series of small tests/experiments to contrast theory and reality
- To gather information related to collective intelligence, and study the effect of main parameters
- To design a tool or system that can actually help to improve decision making processes for groups, based on all the previous research

### 2.2 – Scope of the project

There is great research material available online regarding this topic, lots of it provided by some of the most prestigious sources in business and human behaviour fields: MIT Sloan, Harvard Business Review, Stanford Sociology, etc.

Unfortunately, I don't have the means to set experiments which involve big numbers of people during long time periods, as it implies great coordination and scheduling efforts. However, I have been able to take advantage of excellent scientific and business papers' results in order to apply them to this project and make own experiments more profitable.

### 3- Current situation of SMEs in Catalonia

During the last years, a severe financial crisis has hit European countries, causing major recessions and a stagnation of economic activity. Unfortunately, Spain has been especially affected by this crisis, and so has been Catalonia. The evolution of the number of SMEs in each sector can be seen in Figure 1.1, which illustrates how during the years of economic crisis the number of these companies has clearly decreased in the primary and secondary sectors, especially in the construction sector. However, there is a sector that has survived this crisis and has managed to grow along these years: the tertiary sector (services). Despite a temporary stagnation, it has started to grow again. The numbers can be seen in a more clear way in tables A1.1 to A1.5, contained in the annex.

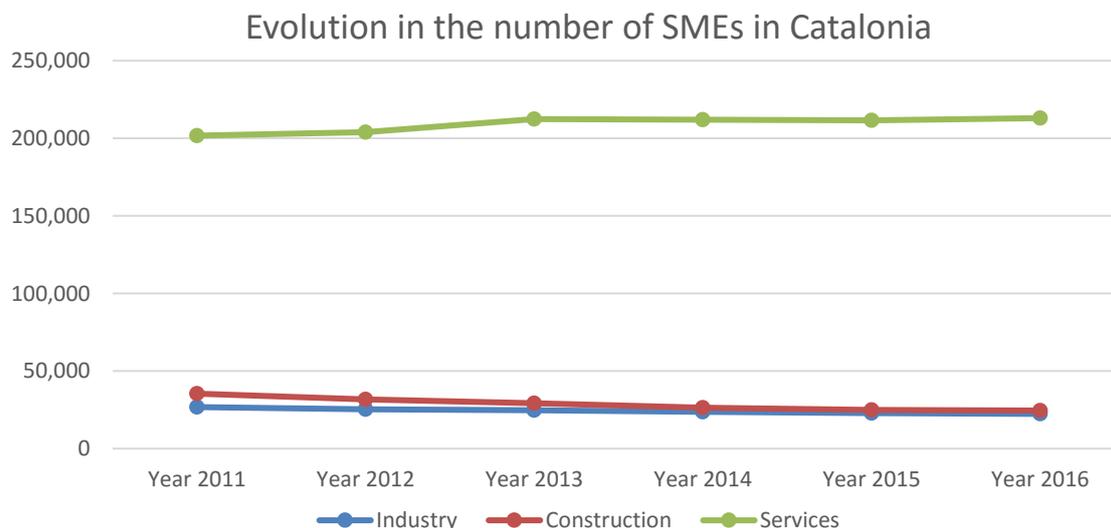


Figure 1 - Evolution of SMEs in Catalonia (source: [www.idescat.cat](http://www.idescat.cat))

The level of domestic consumption, as well as the number of exports, has dramatically decreased. This has caused many companies to lose large sums of money and has even forced many of them to close. SMEs have been no exception, as, according to what M. Sardà states in his article “El patiment e les pimes” (Jan. 2017), during this crisis SMEs have experienced a reduction of 19% in billing and a 23% in occupation in benefit of big companies, which between 2007 and 2014 experienced a 10% increase in the market share.

The study presented in this article concludes that the size and structure of companies are decisive in their response capability and adaptation to the economic context. According to this study, SMEs take 2 years more than big companies to react in front of economic turnarounds. SMEs also depend, in most cases, on banks, which during the crisis have drastically reduced the number of loans they make. During the crisis years banks have drastically cut the number of loans they make, especially to micro and small companies. This has had serious effects on many companies, including the disappearance of many of them.

Just like Joan Ripoll points out in his article “Els reptes de la internacionalització de les PIMEs” (Voces económicas, Jan. 2016), the fact that the domestic demand has decreased has pushed companies to search for international exportations as a way to grow and not disappear. However, there is little to do for these companies in this field due to the difference of size compared to big multinational companies, which control all the exportation flow in the region.

This, together with funding problems, have led to a low competitiveness situation for these companies. This is due to a low productivity and low inversion in R&D. Therefore, the production capacity should be increased if they want to have access to foreign markets. One of the most common situations is the one in which companies have tried to jump to these international markets without being properly prepared to compete. This is based on the problem that these companies have conceived this internationalisation process as a mean of emergency to supplement the downfall of internal consume. However, the right focus is to move the whole direction of SMEs towards this focus.

To sum up, these the major problems that SMEs (especially in Catalonia) are facing nowadays:

- The lack of funding due to the decrease of available bank loans
- The downfall on domestic consume, and the incorrect focus of internationalisation
- The lack of investment on R&D (which is strongly related with the first point)
- The slowness and unproductivity in the process of decision making

- A local legislation that in many cases acts more like a barrier than as a trampoline

## 4 – Problem analysis and problem solving tools

### 4.1 – Consensus in companies

Once the main problems that SMEs are facing have been listed, it is time to list the existing tools which can be used for problem solving. The aim of this project is to take a deep look in those tools that apply a collective problem solving process. Therefore, some light must be put on the different currents that exist regarding this topic.

There are two very differentiated schools of thought; those that believe that consensus is not important, and even more, could actually cause negative effects. On the other hand, you can find those who think that consensus is an indispensable requirement if you want to maximize the output of the whole process.

### 4.2 – Consensus regarded as an obstacle

In their article “The Most Innovative Companies Don’t Worry About Consensus” (Harvard Business Review, Oct. 2014), Maxwell Wessel points out a series of concepts that raise a question: When is consensus beneficial and when can it be prejudicial?

- **Consensus can be a double-edged sword:** whilst it might be beneficial for big, important decisions, the fact of continuously adapting the final output in order to find it can be fatal. This is due to the slowness of the process of achieving consensus, as opportunity cost boosts (tons of time is wasted in the process, time in which salaries are invested). The cost of consensus might be much higher than the cost of experimentation.
- **Testing is vital** in the search of organic growth: it minimizes investment to eliminate uncertainty. In other words, it ensures faster innovation and a lower cost of failure. It is better to have many small failures in the search of a beneficial output rather than one, only big failure in which loads of time, energy and resources have been invested.
- **Finding out which is the consensus tax required:** depending on the context, on the issue raised and the requirements of the output, a different level of consensus will need to be reached. It is responsibility of the

manager that supervises the process to determine which level this should be.

In order to achieve this equilibrium between these different matters, there are a few points that must be taken into account:

- **Not all the investments are the same:** Different processes must be carried out depending on the cost of the test. A test with a relatively low cost that can provide fast results in order to make a forecast must be set without delay, whilst a test with big cost must be approved by consensus (although the level of consensus depends, once more, on the situation).
- **Involve in the decision making process those workers who have the least authority possible:** this will save the time, and therefore the company's money, of those qualified people who have to take care of more important issues rather than taking a look at the process of approving (or not) the realisation of the test/experiment. A less (but enough) qualified worker will act on much shorter time, rather than slowing the process of taking a decision with a non-ending consecution of meetings. Define clearly the purpose of the experiment and boundaries between an experimental investment and an important operational investment.
- **Punish waste of time and resources of any kind, but do not punish failure.**

Other article that moves in the same direction was written by Felipe A. Csaszar and Alfredo Enrione, titled "When Consensus Hurts Companies" (MIT Sloan Management Review, March 2015). Once again, it comments on the variation in the tendency that managers have followed: from searching consensus at any price to determine who is best to take this decision (avoiding consensus) for a given situation. The points raised in this article are the following:

- **There must be someone in charge** of the decision-making process based on the combination of multiple opinions.
- **The outcome of a decision is understood thanks to how the decision was taken.**
- **There must be a board of directors**, headed by the chairman, which takes the company's most important decisions.
- **During the process of decision taking, two kind of errors can occur:**

- **Commission errors (Type I):** The fact of pursuing a project with bad perspectives.
- **Omission errors (Type II):** The fact of not pursuing a project with good perspectives.

### CONSENSUS LEVEL AND ERRORS OF COMMISSION AND OMISSION

In a five-member group, requiring higher levels of consensus for a decision decreases the likelihood of commission errors but increases the likelihood of errors of omission.

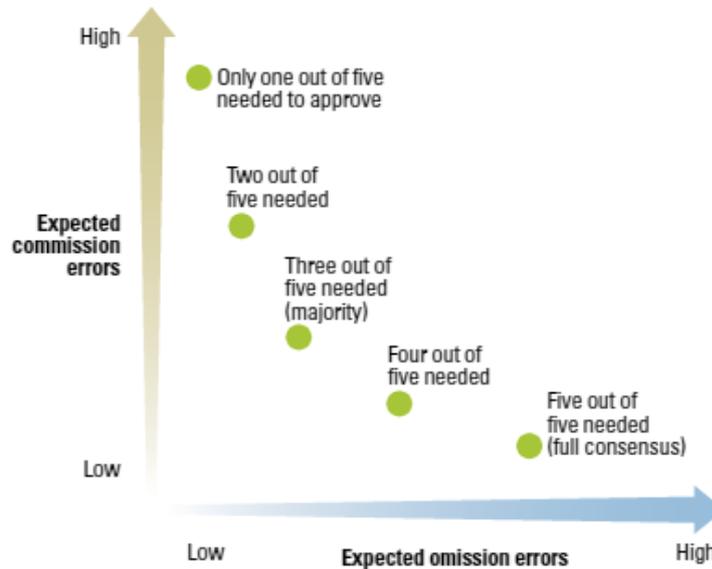


Figure 2 - Type of errors in consensus

(*"When Consensus Hurts Companies"* - MIT Sloan Management Review)

Therefore, the level of consensus is correlated to the level of error you want to expose your group to. A conclusion extracted from this theory (which has been widely demonstrated) is that the best consensus level depends on the relative cost of the errors. Therefore, the appropriate level of consensus will depend on the type of decision that must be made.

In this work it will be fundamental to understand the **cost of error** (can be measured in physical/economic/time resources) in order to choose the direction of decisions taken.

The article also exposes a method to move the decision towards the optimal point **when commission errors are the main concern:**

1. Express those opinions that oppose to the decision that is intended to be taken.
2. Committee (or in this case, manager in charge) must study these opposing opinions in more depth.
3. Expose arguments to those who oppose and wait for them to give a second thought about their position in this matter.

If, however, **the primary concern are omission errors**, responsibility must be moved towards the manager. There is a strategy to make this move achieving the highest amount of consensus:

1. Discuss line between decision lying on CEO or board
2. Give more visibility to opinion of those who have a wider knowledge and support this strategy
3. Suggest delegating decision to board committee who includes the previously mentioned

If both errors seem **equally costly**, the board must be moved towards a majority decision. This is usually accepted as the most common tendency. These steps must be follow in order to achieve this:

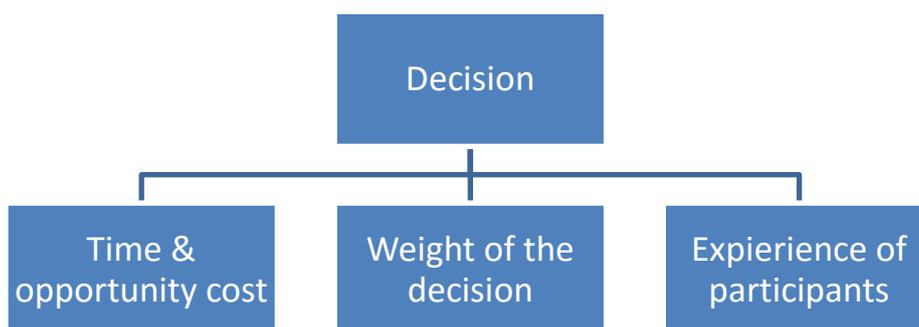
1. Point out that time is essential, and trying to reach full consensus might have an enormous opportunity cost.
2. Present the situation as a win/lose situation, which will force the opposing team to be more flexible with their opinion.

#### 4.3 – Conclusions regarding consensus

The conclusions extracted from these papers which might suppose a positive contribution to the whole work are the following:

- Taking a decision always implies an associated cost, therefore the tool designed as a result of this project must focus on minimizing the time invested in the process of decision making.

- Making the correct questions, together with counting with the smallest number of people necessary to carry out the activity will reduce the cost of the whole process.
- The time of the person with more responsibility inside the company is always more valuable than the least. Therefore, the level implication in the process of decision making must move from people with the least responsibility to people with the most responsibility.
- There is no correct level of consensus needed in order for a decision to be correct, the amount of consensus needed depends on every situation.
- The bigger the weight of the decision being discussed, the higher the manager's (and supervisor's) level of responsibility inside the company will have to be.
- The amount of consensus required should be proportional to the weight of the decision taken. If the cost of commission is low, the required amount of consensus needed is also low, as the amount of resources lost in case of a negative result is little. However, big decisions must be taken backed up by a high consensus level which will give them strength and full support.
- Experiments are a good way of testing different alternatives without spending too many resources. Therefore, in this projects experiments which require little investment (time and effort) will be carried out.



*Orgchart 1- Parameters of the decision*

## 4.4 – Existing tools

Now that aspects regarding consensus have been clearly defined, it is time to list those existing tools that, through the use of consensus, follow a methodology that will help groups to find a solution to the issues they might have to face.

Nowadays, the amount of free, existing material is quite big. The research has been done in this direction to try to keep the whole project budget as low as possible. The tools which better apply to cover the needs of this project via the use of consensus are the following:

- **Force field analysis:**

1. Clearly define the goal/vision of change that has to be made. Write it down in the central box.
2. Identify those forces for change and understand the important of making these changes. Locate them at the left part of the analysis diagram.
3. Assign scores, like for example from 1 (weak) to 5 (strong). The

arrows must have sizes proportional to the scores of the force.

4. After this has been done, you can move in two directions:

Take the decision based on the final result of the sum of forces in each side. The other thing that can be done is to try to force a dialogue in order to convince the forces of one

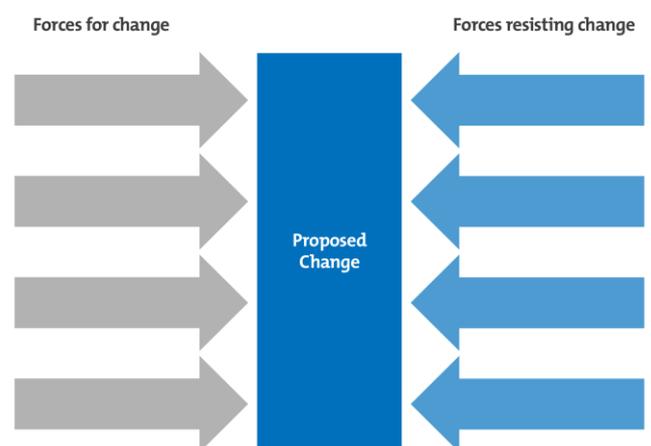


Figure 3 - Force fields analysis first steps

Source: [www.mindtools.com](http://www.mindtools.com)

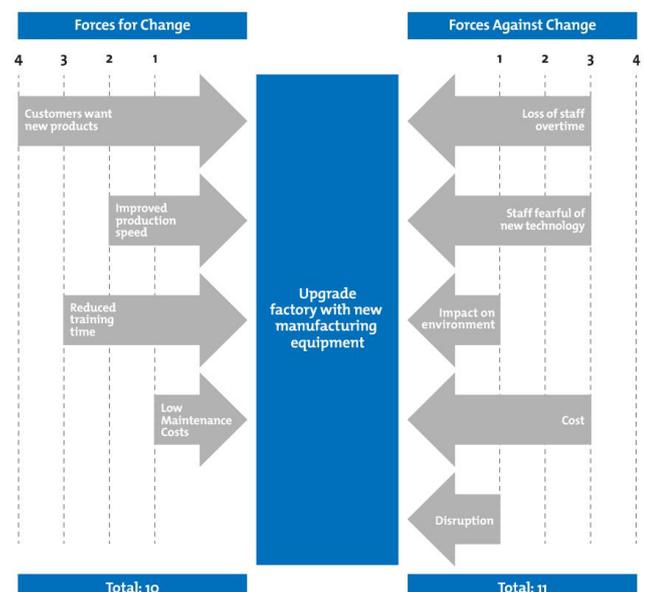


Figure 4 - Force field analysis with scores (example)

Source: [www.mindtools.com](http://www.mindtools.com)

of the sides to back up the other side.

- **Critical success factors (CSFs):** this method is useful when you need a group of people to concentrate on the real issue to be solved and not be distracted by those factors that despite having certain weight, are far from being determinant. This method uses the following steps:
  1. Establish the strategic goals of the project. For each goal, decide which area of the project activity is essential to achieve it. These areas are the CSFs.
  2. Evaluate the list of candidate CSFs to find out which are the absolutely indispensable elements that must be pursued.
  3. Decide how each CSFs will be measured and keep monitoring them to ensure that the decisions made will move them towards the goal of the team.
- **McKinsey 7S Framework:** this method pursues the alignment of all the key parts in a group in the same direction, improve the performance of a group and determine how it is best to implement a strategy. It is true that this method is designed for companies, but some concepts can be extrapolated to groups. Therefore, it has been included in this list. This model involves seven factors which are independent and are split into two categories: “soft” and “hard” elements.
  - ❖ **Soft elements:** Shared values, skills, style and staff.
  - ❖ **Hard elements:** Strategy, structure and systems.

Soft elements are difficult to describe and identify, and it is more difficult to change them as they are mostly influenced by the culture of the team. However, hard elements are easy to define and identify, and the manager can directly influence them. However, it is important to note that **both elements are equally important** in order for the group to be successful.

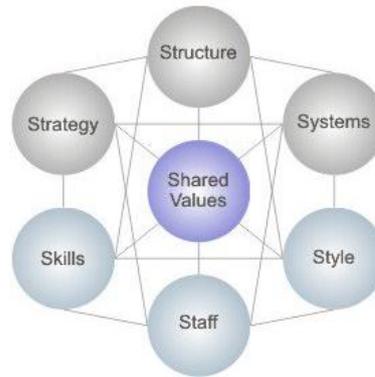


Figure 5 - Interdependency of the elements

| Element              | Definition  | Questions raised   |
|----------------------|---|--|
| <b>Strategy</b>      | The plan designed to beat competitors.  | <ul style="list-style-type: none"> <li>▪ Which is the defined strategy?</li> <li>▪ How does the group intend to reach objectives?</li> <li>▪ How is strategy adjusted for environmental issues?</li> </ul> |
| <b>Structure</b>     | The organization of the team and hierarchy.                                   | <ul style="list-style-type: none"> <li>▪ How do the team members organize and align themselves?</li> <li>▪ Is decision making and management centralized or decentralized?</li> </ul>                      |
| <b>Systems</b>       | Activities and tasks that members due to term in order to get their job done. | <ul style="list-style-type: none"> <li>▪ What are the controls and how are they monitored/evaluated?</li> </ul>  |
| <b>Shared values</b> | Values of the company the group belongs to.                                   | <ul style="list-style-type: none"> <li>▪ What are the core values?</li> <li>▪ How strong are these values?</li> </ul>  |
| <b>Style</b>         | Style of the adopted leadership.  | <ul style="list-style-type: none"> <li>▪ How effective is this leadership?</li> </ul>  |

|               |  |  |
|---------------|--|--|
|               |  | <ul style="list-style-type: none"> <li>▪ Do team members tend to be cooperative or competitive?</li> </ul>   |
| <b>Staff</b>  | Members and their general skills/capabilities. | <ul style="list-style-type: none"> <li>▪ What specializations are represented within the team?</li> <li>▪ Are there gaps in any fundamental competencies?</li> </ul>                                   |
| <b>Skills</b> | Skills and competencies of team members,       | <ul style="list-style-type: none"> <li>▪ Which are the strongest skills represented within the team?</li> <li>▪ Are there any skill gaps?</li> <li>▪ What is the team known for doing well?</li> </ul> |

*Table 1 - Mc Kinsey 7S Framework elements*

Simply putting these points on top of the table will **give the whole team perspective regarding which is the direction it is following**, which might be the points to be improved and how can these points be improved.

- **Use of online forms and statistical data:** A very accessible way of obtaining some first results with a very low time cost is registering a series of questions, wisely chosen (they can even be chosen by applying some of the methods mentioned above) and handing them to a series of selected people. The profiles of these people must be varied, because, just like Mark S. Granovetter states in his paper “The Strength of Weak Ties” (Stanford Sociology Department, May 1973), sometimes the shortest path to the best solution might not be the one which a priori would be the best performing. Therefore, the biggest the variety of people answering to these forms the more enriching the results obtained can be.

These data can then be analysed using diverse statistical methods that will help to put some light on some features that the whole of the participants in the answering process might have.

#### 4.5 – Combination of available tools with existing problems

This next step consists on combining these two factors to try and find the appropriate matches depending on the type of problem and the type of solution that every tool contributes to find.

|  | <b>Force Field<br/>Analysis</b> | <b>Critical<br/>Success<br/>Factor</b> | <b>McKinsey 7S<br/>Framework</b> | <b>Form +<br/>Statistical<br/>Data</b> |
|--|---------------------------------|--|----------------------------------|--|
| <i>International<br/>Markets</i>       | W                               |  | Y                                | Z                                      |
| <i>Funding</i>                         |                                 |  |                                  |  |
| <i>R+D</i>                             |                                 |  | P                                | Q                                      |
| <i>Legislation</i>                     |                                 | X                                      |                                  |  |
| <i>Slowness in<br/>decision taking</i> | R                               |  |                                  | S                                      |

Table 2 - Problem-tool matrix

W, R: Start by stating which points are for the decision and which are against, then assign a related score to every point. Reduce forces against by training and informing staff involved in the decision making, etc. This can be useful to decide on international expansion/projects. This can also help to make decision taking processes work faster.

X: This method can help to identify which are the real issues in legislation that imply a real hindrance in the development of SMEs, especially in the Catalonian legal framework. This can help to extract very specific conclusions that might be valid for many of these companies in order to force changes in the local legislation.

Y, P: Shows the interrelation between different elements (classified as hard and soft) in order to take a decision on the direction of a specific element which wants to be changed or explored (in order to examine the effects of future changes, improve performance or determine the best way to implement a strategy. This can

be used to explore new ways of expansion within the international market, as exploring new directions for the R&D department to take.

Z, Q, S: This method, just as the one used for finding consensus in specific medical issues (Mr. Josep M<sup>a</sup> Monguet's platform, "Onsanity"<sup>®</sup>, is a good example of how this system has real and positive effects) in order to contrast data and aligning different specialists/companies in order to reach a common goal. The possibility of giving a blind grade to a specific issue and then being able to compare it to the rest of grades given to that same issue, together with the opportunity of then changing the direction of the vote (and discussing it, maybe) can help to achieve those common targets. This can be also applied to the decision making of companies, especially in the R+D field, where it's important to evolve as a team, and not individual efforts in different directions.

#### 4.6 – Chosen combination

The aim of this project is to use consensus to create a decision making tool. Therefore, applying all the knowledge acquired during the reading of the previously mentioned scientific papers and articles, it has been decided to apply these methods to create a dynamic and high performing decision making tool. That will be the issue which the project will focus on. As a first step, a participative method such as a survey will be applied to try and establish specific profiles that will later serve as a reference during the process and use of the decision making tool.

## 5 – Data collection

### 5.1 – Tool choice

After taking a deep look at the different possibilities, it was decided to carry on using, for a first instance, an internet survey to do a first analysis of the different profiles available nowadays (or even more, to decide if a profile classification is tangible). The reasons that drove to choose this option are the following:

- It is an affordable tool, as it is free and the access is good.
- It allows to create valid and efficient surveys, being able to answer text questions or answer giving scores.
- It is easier to reach a bigger number of people, as it is sent directly to their mails. People are more willing to participate in a short survey.
- It provides enough information for the objective of this test.

For all these reasons, it can be stated that doing has had a **low opportunity cost** in relation with the whole project.

The specific tool selected to carry out this survey was **Google Forms**®.

### 5.2 – Survey questions

The aim of this survey was, as mentioned before, to establish different profiles in order to make further tasks easier to manage. Questions aimed the following issues:

- Female influence in environment
- Diversity of people in surrounding
- Sociability level
- Sources of knowledge and willingness to share knowledge
- Interaction in meetings
- Willingness to share information
- Adaptability to group tasks

All these aspects are related to personality and background have a great influence in the performance (as it will later be demonstrated) of a person as a member of a group committed to carry out a collective task.

### 5.3 – Profile classification of candidates

The survey was directed to people belonging to different environments, although most of them had in common some features:

- The majority of participants had a Spanish nationality
- The majority of participants were students who were only studying, students who were studying while doing an internship or recently graduated professionals

Classification of profiles was done according to two criteria:

- Gender
- Professional field/ study field:
  - Technical (includes engineering and scientific profiles)
  - Business
  - Social

### 5.4 – Results of the survey

The profiles of people who answered the survey are the following:

|        | TECHNICAL | SOCIAL | BUSINESS |
|--------|-----------|--------|----------|
| MALE   | 10        | 3      | 6        |
| FEMALE | 7         | 8      | 4        |

*Table 3 - Distribution of people who answered the survey*

In general, it is easier to find women with social profile and men with a technical (especially engineering) profile.

After they answered to all the questions, different scores representing the mean of various questions were assigned for each quality:

- **Gender influence:** a 10 points score represents a great female influence in their <sup>1</sup>environment, while a 0 points score represents a great male influence.

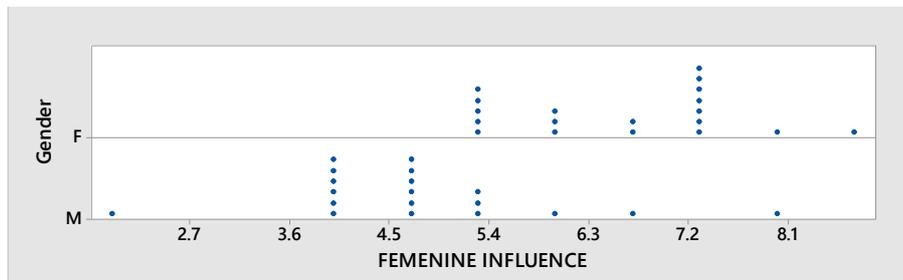


Figure 6 - Dotplot showing gender influence according to gender

It might seem an obvious statement, but this plot confirms that, in general, females tend to have a bigger female influence in their surroundings, while males tend to have a more masculine environment.

- **Diversity of environment:** a 10 points score represents a high diversity of environment, while a 0 points score represents a low diversity of environment.

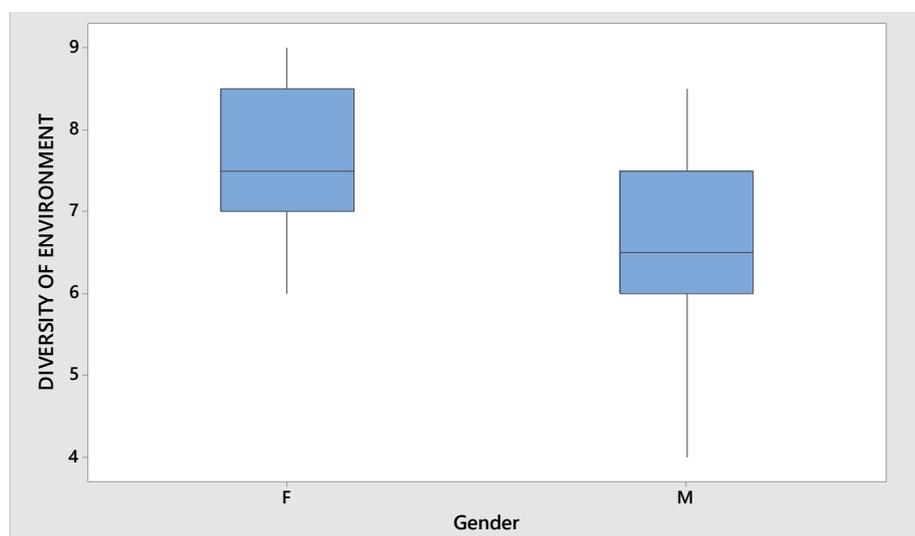


Figure 7 - Boxplot showing diversity of environment according to gender

<sup>1</sup> When referring to “environment”, it specifically refers to family, personal relationships and professional relationships.

The graph chosen for this point is a boxplot, as it faithfully represents that, despite females seem to have a higher mean in this part, it is true that dispersion is also high, therefore this result is not especially relevant.

The data split by field shows no relevant variations.

- **Sociability level:** probably one of the most relevant features of the candidates personality, it measures the ability and interest of an individual to share and absorb information from other individuals.

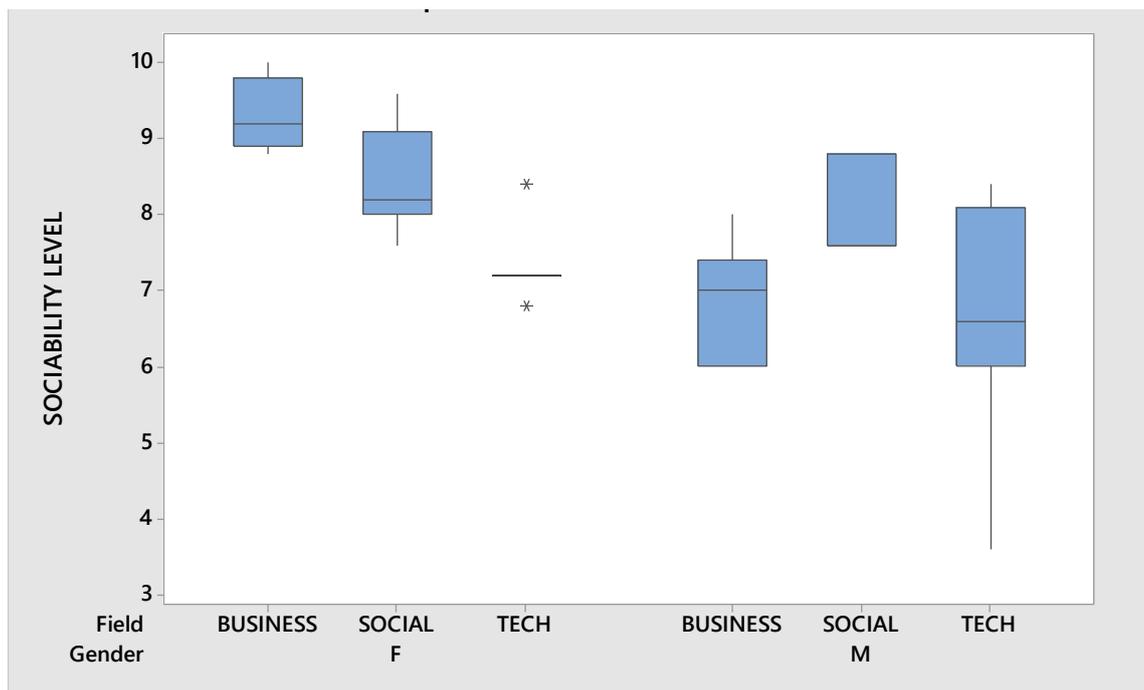


Figure 8 - Boxplot of sociability level divided by gender and field

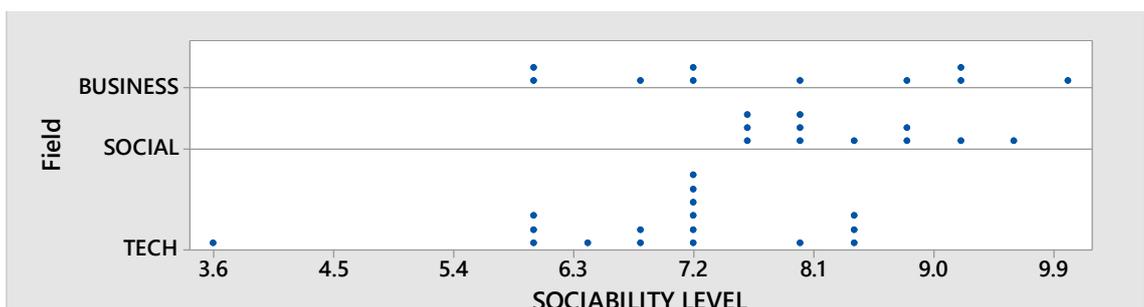


Figure 9 - Dotplot of sociability level divided by field

The conclusions that can be extracted from these graphs are:

- Apparently the mean and median of female individuals sociability level is clearly above the males sociability level.

- Apparently in both cases the mean and median of individuals belonging to a business profile is higher than the one belonging to those with a technical profile, although there is a big variance in the scores of business participants. Regarding social profile, there is much less variance and the mean is also clearly higher than the one for technical ones.
- **Group skills:** the last feature measured expresses preference of individuals for group tasks, and their predisposition to highly perform as group members.

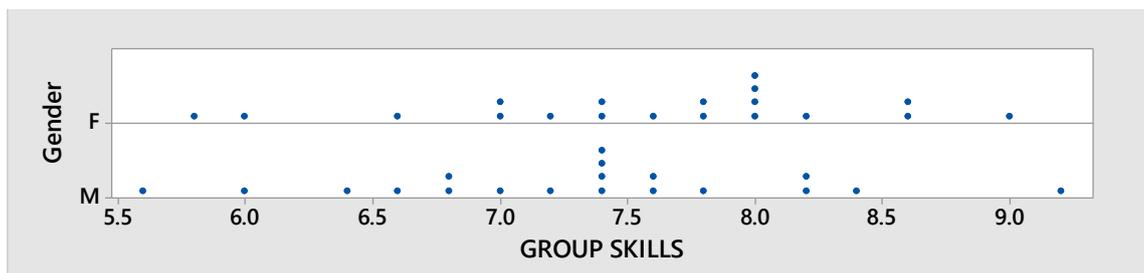


Figure 10 - Dotplot of group skills split by gender

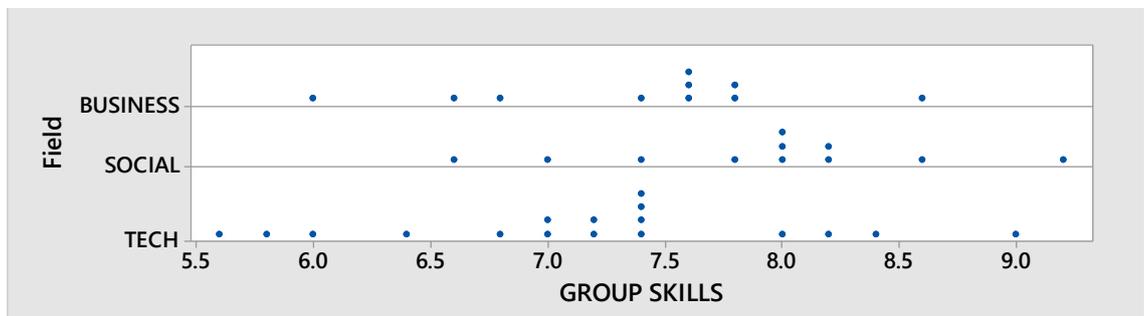


Figure 11 - Dotplot of group skills split by field

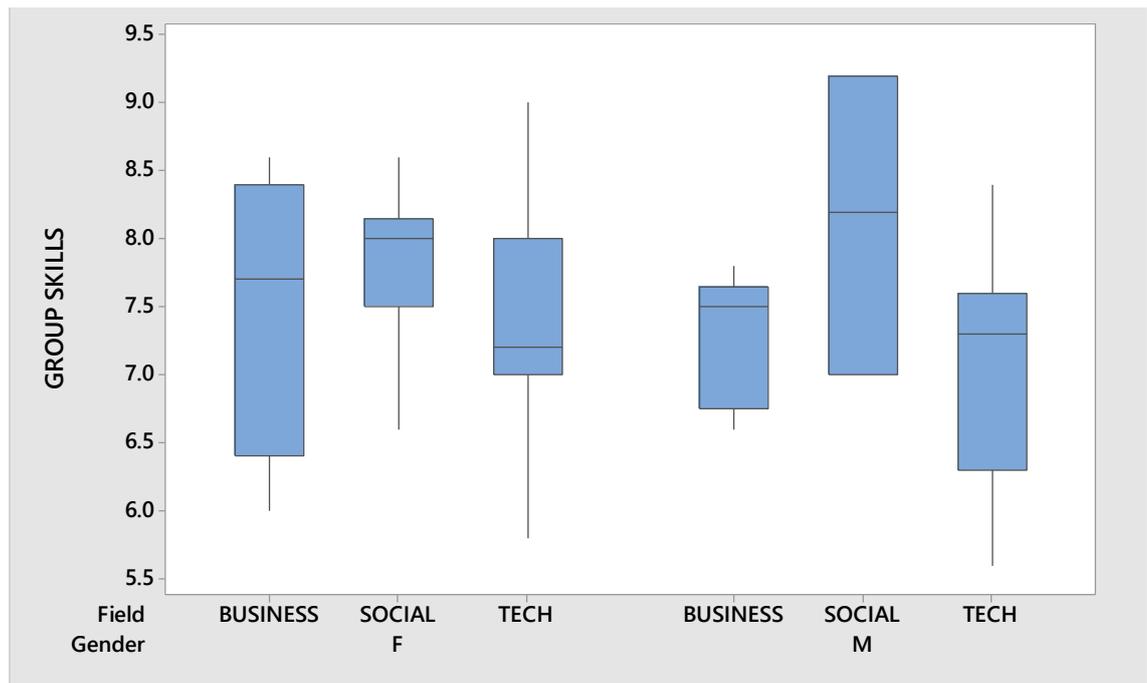


Figure 12 - Boxplot of group skills split by gender and field

The means and medians of both female and social profiles seem to be above the rest of options in both categories, so therefore this seems to be an indicator of their willingness to work in groups. However, it is important to take into account that only 3 individuals who answered to this survey belong to the male-social team. Therefore, that specific case is not especially relevant (although mustn't be ignored).

## 5.5 – Conclusion of the survey

Once these results have been collected and analyzed, the conclusions that have been reached are the following:

- In general, female individuals have a higher sociability level and better group skills.
- In general, individuals belonging to a social professional field or with social studies have higher sociability levels. Both individuals belonging to social and business fields tend to have better group skills.
- It is an obvious statement to say that tasks which involve specific technical issues will not be properly solved without the participation in the decision making process of one or more individuals with a technical background.

## 6 – Collective intelligence

### 6.1 – Introduction to collective intelligence

Unlike many people might think, those groups that perform the best are not necessarily those formed by the most intelligent individuals. It is important to make a distinction between the individual intelligence of the members of a group and the collective intelligence of this group. A higher intelligence of group members does not necessarily imply a higher intelligence as a group. This statement was demonstrated by a group of scientists and professors who performed two sets of experiments and later published an article named “Evidence for a Collective Intelligence Factor in the Performance of Human Groups”<sup>2</sup> (Science, Oct 2010).

Both sets of studies (in which a total of 699 people participated) consisted on different tasks or tests in which groups from 2 to 5 people had to work together and achieve the best performance possible. The result of this experiment threw some light on which are the factors that make groups perform the best. It was carried out based on the results of a study published 30 September by one of the participants, Anita Williams Wooley, which stated that:

- The general intelligence factor (the performance of an individual across a range of different kinds of cognitive tasks) of group members has an influence on the collective intelligence of the group.
- The social sensitivity of members of the group also has a remarkable influence on its collective intelligence.

The output obtained after the experiments was quite similar, although some variations were found:

- Collective intelligence factor is not strongly correlated with the average or maximum intelligence of the group members.
- It is correlated with:
  - Average social sensitivity of group members.

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<sup>2</sup> Authors: Anita Williams Woolley, Christopher F. Chabris, Alex Pentland, Nada Hashmi, Thomas W. Malone (who also participated in the “Handbook for a Collective Intelligence”)

- Equality in the distribution of conversational turn-taking.
- Proportion of females in the group.

It states that, just as the average correlation among the performance of an individual in a set of different cognitive tasks and its general intelligence, the ability of a group to perform one task is correlated with that group's ability to perform on a wide range of other tasks.

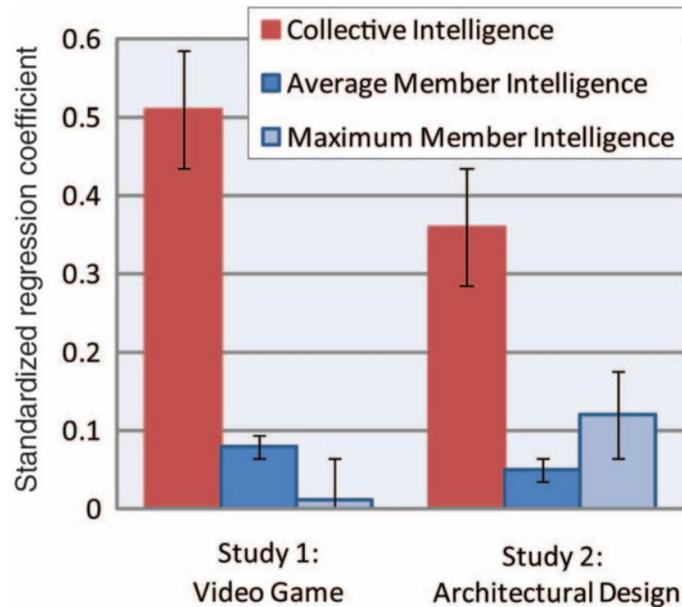


Figure 13 - Correlation among performance and test participant

The statistical results were the following:

| Factors  | Level of correlation/P-value |
|--|------------------------------|
| Average social sensitivity of group members                | $r=0.26$<br>$P=0.002$        |
| Variance in the number of speaking turns by group members* | $r=-0.41$<br>$P=0.01$        |
| Proportion of females in the group**                       | $r=0.23$<br>$P=0.001$        |

Table 4 - Measured factors and statistical data

\*In other words, those groups where only a few members dominated the conversation were collectively less intelligent than those where an equilibrated turn talking was established.

\*\*This result appears to be largely mediated by the social sensitivity level of individuals, where women in the used sample scored better than men.

In a regression analysis done with these three variables all three had similar weights in the statistical model, although only social sensitivity reached statistical significance.

## 6.2 – Collective intelligence applied to the project

The results of the experiments mentioned above threw light on which could be the steps should be followed in order to maximize the performance of a group, and, as a final goal, to use this to help SMEs reach consensus in an optimized way.

Therefore, it was decided to set up an experiment to test how the variation of different profiles, based on the results of the survey and those obtained in the Science magazine experiments, could affect the performance of different groups.

The idea was quite similar to the one applied in those experiments: randomly form a series of groups which carried out an group task in order to measure their performance based on the different profiles of their members and a set of factors in order to measure their possible influence on final results.

## 6.3 – Groups composition

### Group 1



Figure 14 - Members of Group 1 in action

| Member | Age | Gender | Field    | Qualifications | Social Sensitivity |
|--------|-----|--------|----------|----------------|--------------------|
| LS     | 22  | Female | Business | High           | High               |
| GR     | 25  | Male   | Tech     | Very High      | High               |
| AZ     | 22  | Female | Social   | Very High      | Very high          |

Table 5 - Group 1 members' main features

## Group 2



Figure 15 - Members of Group 2 in action

| Member | Age | Gender | Field  | Qualifications | Social Sensitivity |
|--------|-----|--------|--------|----------------|--------------------|
| PR     | 20  | Female | Tech   | Very High      | Very High          |
| JL     | 24  | Male   | Tech   | Medium         | High               |
| LB     | 25  | Male   | Social | Medium         | Medium             |

Table 6 - Group 2 members' main features

## Group 3



Figure 16 - Members of Group 3 in action

| Member | Age | Gender | Field | Qualifications | Social Sensitivity |
|--------|-----|--------|-------|----------------|--------------------|
| JB     | 25  | Male   | Tech  | Medium-High    | Low                |
| JG     | 24  | Male   | Tech  | Medium         | High               |
| CS     | 24  | Female | Tech  | Medium-High    | Medium             |

Table 7 - Group 3 members' main features

## Group 4



Figure 17 - Members of Group 4 in action

| Member | Age | Gender | Field | Qualifications | Social Sensitivity |
|--------|-----|--------|-------|----------------|--------------------|
| AG     | 23  | Female | Tech  | Medium         | High               |
| MM     | 24  | Female | Tech  | Medium         | High               |
| EJ     | 25  | Male   | Tech  | Low            | Medium             |

Table 8 - Group 4 members' main features

## Group 5



Figure 18 - Members of Group 5 in action

| Member | Age | Gender | Field    | Qualifications | Social Sensitivity |
|--------|-----|--------|----------|----------------|--------------------|
| SD     | 23  | Female | Business | High           | High               |
| PZ     | 25  | Male   | Tech     | Medium         | Medium             |
| JB     | 26  | Male   | Business | Low            | Low                |

Table 9 - Group 5 members' main features

## 6.4 – Proposed task and evaluation method

The task proposed was a brief case named “Sugar Bowl” created by Harvard Business School professor Richard G. Hamermesh and plot written by Alisa Zalosh.

It basically consisted on how a series of actions had to be made (economic data was handed to group members) in order to change the negative direction of a small business (a bowling placed located in a medium sized town).

Groups were asked to answer to work out which could be the correct actions in order to change the direction of the business and make it profitable again. The answers were then compared to those proposed by the ones designed by the author. Scores were given for the resemblance of the groups’ answers to the author’s, together with the time taken to give a final answer and the distribution of turn talking.

## 6.5 – Results of the experiment

The results of this experiment are logically not statistically measurable, due to the limited number of groups participating in the experiment. However, it is possible to compare the results obtained and extract some general and valid conclusions.

The results obtained in these tests were the following:

| Group | Answer score (0-10) | Time (min) | Speaking turns (0-10)* |
|-------|---------------------|------------|------------------------|
| 1     | 9                   | 21         | 8                      |
| 2     | 7                   | 18         | 7                      |
| 3     | 6                   | 20         | 6                      |
| 4     | 6                   | 23         | 8                      |
| 5     | 7                   | 25         | 6                      |

*Table 10 - Group results*

\* The lowest scores were given to those groups in which a member spoke during most of the test, while other member or the rest of members didn’t speak as much or didn’t share as many ideas as the rest of participants.

### Conclusions:

- Groups with a higher number of female members tended to talk in a more organized, equal way, in which all members were listened to and a wide range of ideas was produced.
- Groups with a higher member qualifications mean obtained higher scores than those with a lower mean.

- Individuals that had better qualifications than the rest of group members had certain tendency to lead the group, or at least showed high levels of initiative.
- Those groups with a wider variety of studies/work field of its members tended to perform better than those teams which were composed by individuals with similar academic backgrounds.

## 7 - Development of the tool

### 7.1 - Initial approach

#### Objective

The idea of designing this tool is aligned with the final goal of this thesis: to help, through the use of collective intelligence, to solve problems that SMEs might have to face.

#### Which method should be used?

Many scenarios have been approached, as it is debatable whether this tool could be given an intercompany use, or, on the contrary, it could be used as an internal tool inside a company in order to improve the performance of groups in problem solving situations (or even in the development of group tasks).

|                 | Tool idea   | Advantages  | Disadvantages   |
|-----------------|---|---|---|
| <b>Option 1</b> | A tool that, through the use of a database composed of professionals belonging to different sectors, which are willing to take part in this project, creates workgroups. The person who submits a request of a group formation in order to solve a specific problem will choose the parameters that will serve as instructions for the tool to start designing the ideal group to perform | <ul style="list-style-type: none"> <li>Allows the user to choose specific parameters of the group composition: sector of the members involved in the group, number of group members, etc.</li> <li>Energizes the cooperation among SMEs, a sector which a priori is less competitive due to the reduced size of its companies.</li> <li>This tool can be</li> </ul> | <ul style="list-style-type: none"> <li>The need of a database, plus the need of this database to be dynamic, might imply an organizational problem</li> <li>The tool might end up repeatedly choosing the same members of the database to form part of the task force</li> <li>It's a concept difficult to commercialize</li> </ul> |

|                 | this task according to the available profiles inside the database.  | used both in intercompany and internal scenarios   |  |
|-----------------|---|--|--|
| <b>Option 2</b> | An online tool that allows any interested users to take part in the process of problem solving. The participants first complete a form in order for the tool to relate a collective intelligence quotient to every specific participant (based on a statistical model). The tool will then take into account those answers which, based on the CI quotients available among the participants, and schedule a (virtual or face-to-face) meeting for them to work as a group and solve the issue. | <ul style="list-style-type: none"> <li>• This tool can be used both in intercompany and internal scenarios</li> <li>• Allows the collaboration of participants with a wide range of professional and social profiles to work together</li> </ul> | <ul style="list-style-type: none"> <li>• The individual CI quotient of every participant can only be established by doing a statistical approximation, and not with real evidence</li> <li>• It is hard to get a group of different people which are not part of a group (database) to schedule a meeting and work together. Some kind of incentive would be needed.</li> <li>• It's a concept difficult to commercialize</li> </ul> |
| <b>Option 3</b> | A tool designed to optimize work groups inside a same company in order to improve the performance of the group (especially  | <ul style="list-style-type: none"> <li>• Enables an objective view on how a specific group develops its tasks, in order to measure the global CI quotient.</li> </ul>  | <ul style="list-style-type: none"> <li>• Not applicable in a intercompany scenario</li> <li>• The number of available participants might be limited by the</li> </ul>  |

|  |   |  |   |
|--|---|--|---|
|  | <p>focused on problem solving issues). There is an initial group already created by a manager inside the company, and this group is submitted to a short group test in which both group skills and the result of the test are measured. The tool will then suggest a wide range of possible solutions to improve the performance of this group.</p> | <ul style="list-style-type: none"> <li>• It's easy to commercialize and its application in real scenarios is feasible.</li> <li>• Allows a realistic approach to the problem, and the cost of maintenance is low, as only an internal database of the company's workers would be required</li> </ul> | <p>size of the company (less range to optimize)</p> |
|--|---|--|---|

*Table 11- Different tool options*

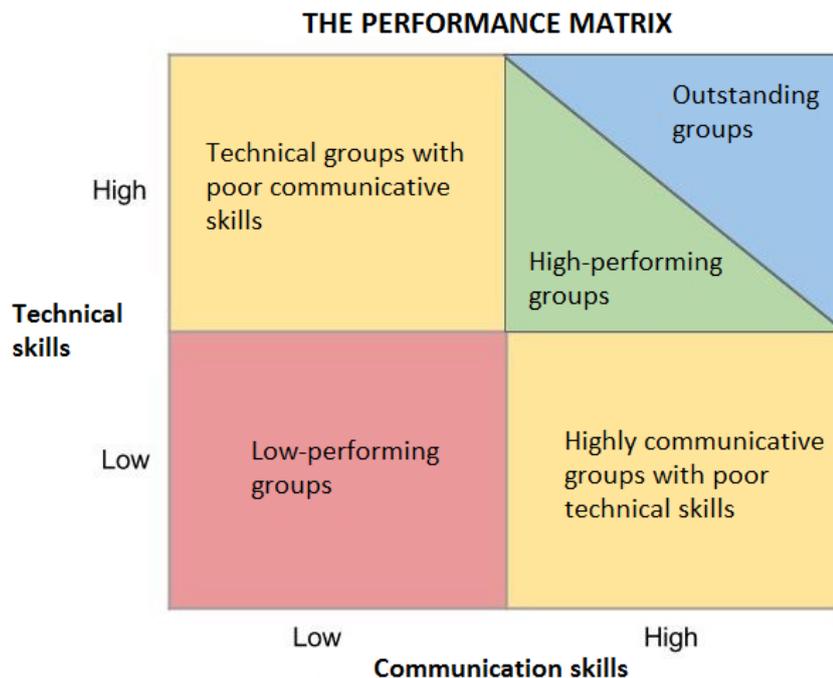
### Chosen option

The option chosen for the development of the tool is **Option 3**. This is because:

- It is the most realistic approach, and has a direct application in existing work groups.
- It does not imply the complications that an intercompany tool could bring.
- It is easy, and probably already exists in many companies, to create a database with its workers and some parameters which can later serve as insights for the tool in the decision making process.
- The fact that the initial group is asked to take a brief test will allow very clear data on how this group works and how it performs, which will undoubtedly give first-hand information on which path to follow. If the process is efficient, a 1 hour test can be extremely profitable for mid and long term tasks.

## 7.2 - Tool concept

The main idea for the design of this tool is based on an adaptation of the Performance-Values matrix found in Dr. Cameron Sepah's (changing parameters but with a common final approach to the matter itself). As you can see in Figure 19, different groups can be seen working with diverse dynamics:



*Figure 19 - Performance-Communication Matrix*

### How to read into this table:

- **Communication skills:** the ability to communicate in a way in which the potential of the group is maximized. This implies the following points:
  - There is an equal distribution of time when talking in turns, so every member of the group gets the opportunity to speak the same time as its partners.
  - Every member's opinion is noted and taken into account when deciding which the appropriate action to be taken is.
  - There is a general agreement in the decision taken and a wide variety of points of view have been analyzed.

- **Technical skills:** technical knowledge which, with a correct use, can be used to reach optimized results.

Groups located in the **red** area are in big trouble: both the results obtained in the test are far from the expected ones, and during the process of working in group none of the communication “musts” were covered. The situation of this group is critical and new members should be added in order to boost the performance and improve the communicative situation, or it should even be dissolved and a new group should be created.

Groups in the **yellow areas** can be experiencing two very different kind of situations:

- a) Those located in the right, lower corner are groups that have high communication skills and follow the points mentioned above, which is very positive in order for a group to succeed in the task they are working on. However, the global performance of the group is not high enough. This is probably due to a lack of specific technical skills that members have, and therefore two possible solutions should be followed: if the knowledge needed to correctly perform in the task is acquirable in a short time frame, this knowledge should be provided to the members of the group. On the contrary, if the knowledge needed is highly technical, the tool will give the instruction for the manager to look for members of the company included in the database that could contribute to the group.
- b) Those located in the left, upper corner of the figure are groups that do have the required technical knowledge in order to properly perform and achieve positive results in the task, but could clearly improve their results with better communicative skills. The tool, depending on the different profiles of group members, should decide whether to give a series of instructions in order to improve these skills or if new members should be added to the group in order to maximize the CI of the whole group.

Groups belonging to any of these two categories should experience changes that pushed them towards the **green** area of the diagram, where groups with both good technical skills and communicative skills can be found. The CI of this groups is already maximized and stand as an example of how a group should work. In extremely positive cases, we can found groups located in the **blue** area.

### 7.3 - Design of the tool

#### Data input

The group will first be submitted to a test to determine its current communicative and technical level. There will be a person in charge of evaluating the performance of the group while doing this activity. The activity will logically belong to the field of those tasks in which the group will participate. The quantitative variables that the supervisor will note down are the following:

| <b>Communicative variables</b>                      | <b>Form of evaluation</b>  | <b>Technical variables</b>                            | <b>Form of evaluation</b>  |
|---|--|---|--|
| <b>Turn speaking is equal and equilibrated</b>      | Score from 1 to 5 (1 corresponding to a totally unequal distribution of turn talking)          | <b>Technical quality in the execution of the task</b> | Score from 1 to 10 (objective score which represents the proximity of the obtained result to the expected ideal result, being 1 the lowest score achievable) [float] |
| <b>Inclusiveness of group members contributions</b> | Score from 1 to 5 (1 corresponding to a very low variety of opinions being taken into account) |   |  |
| <b>Leadership of the group</b>                      | Score from 1 to 5 (1 corresponding to a very unequal leadership of the group)                  |   |  |
| <b>Group organization</b>                           | Score from 1 to 5 (1 corresponding to a very unorganized execution of the                      |   |  |

|  |       |  |
|--|-------|--|
|  | task) |  |
|--|-------|--|

*Table 12- Tool input variables*

There will also be a series of metadata introduced to the tool, which will help it to evaluate the main characteristics which will have influence in the decision making process:

- Number of participants [int]
- Female proportion of group members [%]
- Field which the task belongs to [Technical, Human Relations or Business]

### **Database of company members**

On the other hand, the tool will also require a list with those members in the company that could be available for any work group formation process. The database will include a series of lists, every list corresponding to a member. Each list will contain the following data:

| <b>Data</b>                                | <b>How it's measured</b>  |
|--|---|
| <b>Name of the member</b>                  | [string]  |
| <b>Professional field (they belong to)</b> | <ul style="list-style-type: none"> <li>• Technical</li> <li>• Human Resources</li> <li>• Business</li> </ul>  |
| <b>Social skills</b>                       | Ranging from 1 to 5, being 1 low social skills. These social skills will have been measured previously and entered in the database by a person in charge. |
| <b>Expertise level</b>                     | Ranging from 1 to 5, being 1 a low expertise in the professional field the member works in  |
| <b>Academic performance</b>                | Ranging from 0 to 10, taken into account as it appeared as a significant variable in the previous statistical   |

|               |   |
|---------------|---|
|               | analysis  |
| <b>Gender</b> | <ul style="list-style-type: none"><li>• Female</li><li>• Male</li></ul> |

*Table 13- Database Variables*

### Internal tool process

Once these inputs have been introduced and the tool has been connected to a database which includes the data mentioned above, the tool will follow these steps:

1. In order to **classify** the situation, the tool will take into account 2 global scores:
  - a. A **communication score** based on the mean of the 4 communicative variables
  - b. A **technical score** based on the technical quality in the execution of the task
2. This will allow the tool to locate the current situation of the group in the following matrix:

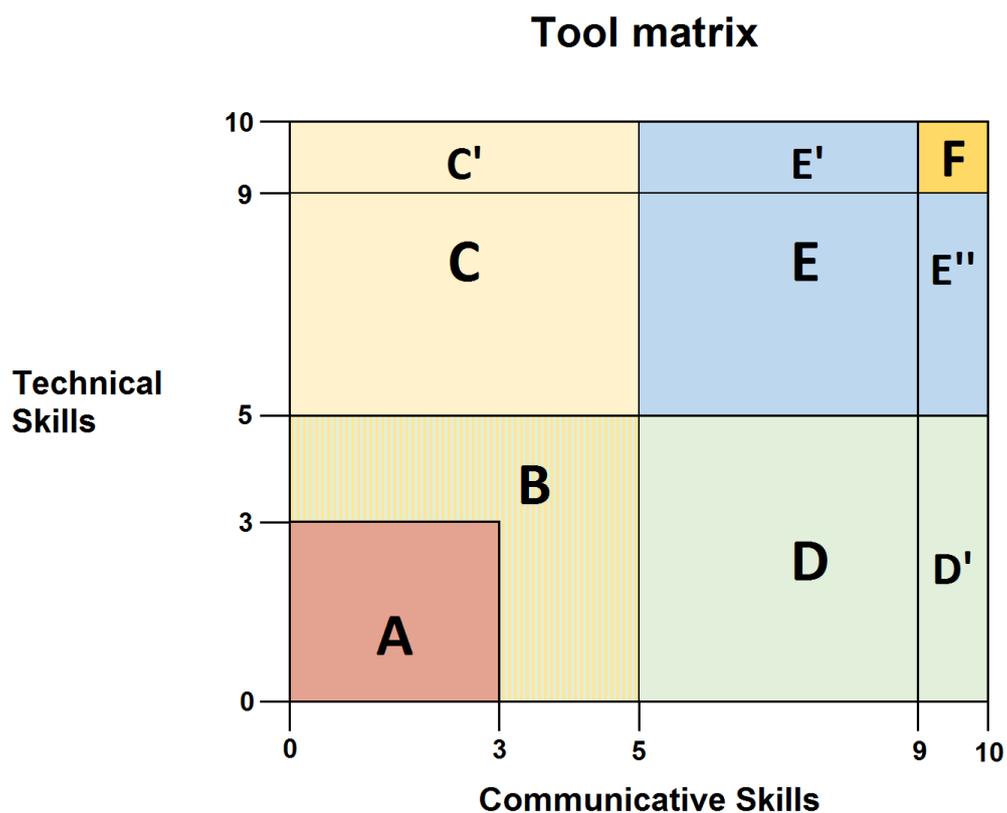


Figure 20 - Tool matrix

These are the scenarios that the tool contemplates:

| Case     | Communicative Score (CS) | Technical Score (TS) | Explanation  | Decision taken by the tool  |
|----------|--------------------------|----------------------|--|---|
| <b>A</b> | < 3                      | < 3                  | The performance of the group was very poor in both communicative and technical skills, failing both of them in a clear way. Therefore, the performance of this group is considered as <b>very poor</b> .     | The performance is far too low in order to use this group composition for problem solving. Group should be dissolved and a new, optimized one should be created.  |
| <b>B</b> | $3 \leq CS < 5$          | $3 \leq TS < 5$      | The performance of the group was low in both communicative and technical skills, failing both of them with low (but not poor) scores. Therefore, the performance of this group is considered as <b>low</b> . | With the current group members, a proper performance won't be achieved. The CI factor and technical level of this group must be increased. This will be made by adding both people with high technical skills and people with high communicative skills who will increase the global CI of the group. |
| <b>C</b> | < 5                      | $5 \leq TS < 9$      | The performance of the group was low regarding communicative skills, but was high regarding  | The communicative skills of this group are too low in order to achieve a proper   |

|           |     |                     |  |  |
|-----------|-----|---------------------|--|--|
|           |     |                     | <p>technical skills. Therefore, the performance of this group is regarded as <b>intermediate</b>.</p>  | <p>performance. Therefore, a member should be added in order to increase the CI factor of this group. Regarding the technical aspect, performance was high but can still be improved. Therefore, instructions will be given to the manager in order to increase the technical level of group members without adding new members in this direction.</p> |
| <b>C'</b> | < 5 | $9 \leq TS \leq 10$ | <p>The performance of the group was low regarding communicative skills, but was excellent regarding technical skills. Therefore, the performance of this group is regarded as <b>intermediate</b>.</p> | <p>The communicative skills of this group are too low in order to achieve a proper performance. Therefore, a member should be added in order to increase the CI factor of this group. Regarding the technical aspect, the score obtained is already excellent so no moves should be made in this direction.</p>  |

|           |                     |     |  |   |
|-----------|---------------------|-----|--|---|
| <b>D</b>  | $5 \leq CS < 9$     | < 5 | <p>The performance of the group was low regarding technical skills, but was high regarding communicative skills. Therefore, the performance of this group is regarded as <b>intermediate</b>.</p>      | <p>The technical skills of this group are too low in order to achieve a proper performance. Therefore, a member with a high technical level should be added in order to increase the global technical skills of this group. Regarding the communicative aspect, performance was high but can still be improved. Therefore, instructions will be given to the manager in order to increase the communicative skills of group members without adding new members in this direction.</p> |
| <b>D'</b> | $9 \leq CS \leq 10$ | < 5 | <p>The performance of the group was low regarding technical skills, but was excellent regarding communicative skills. Therefore, the performance of this group is regarded as <b>intermediate</b>.</p> | <p>The technical skills of this group are too low in order to achieve a proper performance. Therefore, a member with a high technical level should be added in order to increase the global technical skills of this group. Regarding the</p>   |

|           |                 |                     |  |  |
|-----------|-----------------|---------------------|--|--|
|           |                 |                     |  | communicative aspect, performance was excellent so no moves should be made in this direction.  |
| <b>E</b>  | $5 \leq CS < 9$ | $5 \leq TS < 9$     | The performance of the group was high in both communicative and technical skills. Therefore, the global performance of this group is regarded as <b>high</b> . | Regarding the communicative aspect, performance was high but can still be improved. Therefore, instructions will be given to the manager in order to increase the communicative skills of group members without adding new members in this direction. Regarding the technical aspect, performance was high but can still be improved. Therefore, instructions will be given to the manager in order to increase the technical level of group members without adding new members in this direction. |
| <b>E'</b> | $5 \leq CS < 9$ | $9 \leq TS \leq 10$ | The performance of the group was high in communicative skills and  | Regarding the communicative aspect, performance was high   |

|            |                     |                 |   |   |
|------------|---------------------|-----------------|---|---|
|            |                     |                 | <p>excellent in technical skills. Therefore, the performance of this group is regarded as <b>very high</b>.</p>   | <p>but can still be improved. Therefore, instructions will be given to the manager in order to increase the communicative skills of group members without adding new members in this direction. Regarding the technical aspect, the score obtained is already excellent so no moves should be made in this direction.</p>                                       |
| <b>E''</b> | $9 \leq CS \leq 10$ | $5 \leq TS < 9$ | <p>The performance of the group was high in technical skills and excellent in communicative skills. Therefore, the performance of this group is regarded as <b>very high</b>.</p> | <p>Regarding the technical aspect, performance was high but can still be improved. Therefore, instructions will be given to the manager in order to increase the technical level of group members without adding new members in this direction. Regarding the communicative aspect, performance was excellent so no moves should be made in this direction.</p> |

|          |               |               |  |  |
|----------|---------------|---------------|--|--|
| <b>F</b> | 9 <= CS <= 10 | 9 <= TS <= 10 | The performance of this group was excellent in both communicative and technical skills. Therefore, the performance of this group is regarded as <b>outstanding</b> . | The performance of this group has been excellent and should serve as an example in any process of group formation. |
|----------|---------------|---------------|--|--|

*Table 14 - Available scenarios*

### Decision making process

As explained in the previous part, there are a series of actions that the tool will make depending on which part of the matrix de group is located. In the next table there is a list of all the possible different actions and the criterion followed in each of them.

| <b>Action</b>   | <b>Criterion</b>  |
|---|---|
| <b>Dissolve the group</b>                                 | The tool will create an output message indicating that both technical and communicative skills are too low in order for this group to work out properly.  |
| <b>Add to the group a member with a technical profile</b> | The tool will search in the database for those candidates that work in the same technical field as the task. Next, among the candidates that fit in this condition, the tool will calculate a variable called <b>tech level</b> , which is the mean between the candidate's expertise level in its professional field and its academic qualifications. The tool will recommend the manager to add to the group the candidate who obtains a higher tech level. Therefore, it will return the name of the candidate. If there is no available |

|   |  |
|---|--|
|   | candidate, the tool will return “Nobody”.  |
| <b>Add to the group a member with a social profile</b>            | <p>The tool will firstly exclude those candidates which belong to a technical background, as for what has been demonstrated in CI studies mentioned above, groups with a bigger proportion of technical members tend to obtain a lower CI factor. The tool will then search for the available member with higher <b>social skills</b> factor and will return its name.</p> <p>Another action the tool will follow is check the proportion of <b>female members</b> in the group. If it is below 50%, the tool will also suggest to add female members to the group. The reason for this is that in the same study mentioned before, those groups in which the proportion of female members was more significant, obtained the best results (and therefore a higher CI factor).</p> |
| <b>Recommend to give technical advice to group members</b>        | The tool will recommend the manager to give some technical advice to the group members in order to increase their skills in this field, which will enable the group to move towards proficiency.   |
| <b>Recommend to give advice on communication to group members</b> | The tool will recommend the manager to give the group members a series of instructions to follow in order to improve its communicative skills, which will  |

|  |  |
|--|--|
|  | undoubtedly increase the performance of the group. |
|--|--|

Table 15 - Tool actions

## 7.4 - Body of the tool

The tool has been developed in Python language, which is optimal as it is simple for the designer to develop and for the user to understand.

| Part   | Code  |
|--|---|
| <b>Definition of main variables</b>  | <pre>SCORES = {"1":1,"2":2,"3": 3,"4": 4,"5": 5} GENDER = { "m": "Male", "f": "Female" } WFIELDS = { "tech": "Technical", "HHRR": "Human Resources", "bss": "Business"}"</pre>  |
| <b>Definition of the Database: formed by lists containing information of each individual</b> | <pre>class DBProfile():      def __init__(self, name, working_field, expertise_level, academic_performance, social_skills, gender):         self.name = name         self.working_field = WFIELDS[working_field]         self.expertise_level = SCORES[expertise_level]         self.academic_performance = academic_performance # Must be 0-10         self.social_skills = SCORES[social_skills]         self.gender = GENDER[gender]</pre> |
| <b>Input variables based on the results obtained in the test</b>                             | <pre>class TestResults():      def __init__(self, tspeak, incl, lship, sorg, tqual, n_ppl, wf, f_prop, prof_database):         self.turn_speaking = SCORES[tspeak]         self.inclusiveness = SCORES[incl]         self.leadership = SCORES[lship]         self.s_organization = SCORES[sorg]          self.technical_quality = tqual # Must be 0-10</pre>  |
| <b>Definition of metadata belonging to the group</b>   | <pre>self.number_participants = n_ppl self.working_field = WFIELDS[wf] self.female_proportion = f_prop # Must be 0-100 self.prof_database = prof_database</pre>   |
| <b>Definition of action: search for a technical candidate</b>                                | <pre>def search_tech_candidate(self):     max_tech = 0      for el in self.prof_database:         if el.working_field == self.working_field:             tech_level = el.expertise_level + el.academic_performance / 2             if tech_level &gt; max_tech:</pre>   |

|  |   |
|--|---|
|  | <pre> max_el = el max_tech = tech_level  if max_tech != 0:     return max_el.name else:     return "Nobody" </pre>  |
| <b>Definition of action:<br/>Search for a social<br/>candidate</b> | <pre> def search_social_candidate(self):     max_soc = 0      for el in self.prof_database:         if el.working_field != "Technical":             if el.social_skills &gt; max_soc:                 max_el = el                 max_soc = el.social_skills     if max_soc != 0:         return max_el.name     else:         return "Nobody" </pre>   |
| <b>Output of the global<br/>scores obtained in<br/>the test</b>    | <pre> def compute_recommendation(self):     s_result = ( self.turn_speaking + self.inclusiveness + self.leadership + self.s_organization ) / 2     t_result = self.technical_quality      print "Scores - Communicative skills: {} - Technical skills: {}".format(s_result, t_result) </pre>  |
| <b>The results of the<br/>test are very poor</b>                   | <pre> print "Scores - Communicative skills: {} - Technical skills: {}".format(s_result, t_result) if s_result &lt; 5:     if t_result &lt; 5:         if s_result &lt; 3 and t_result &lt; 3:             print "The performance of this group is very poor. Forming a new group should be considered." </pre>  |
| <b>The performance of<br/>the group is low</b>                     | <pre> else:     t_candidate = self.search_tech_candidate()     s_candidate = self.search_social_candidate()     print "The performance of the group is low. Adding people with a social profile would improve the communicative skills of the group, while adding members with a technical profile would increase the global technical skills of the group. {} can be a good candidate with high technical skills, while {} can be a good candidate with high social skills.".format(t_candidate, s_candidate) </pre> |
| <b>If only<br/>communicative skills<br/>are low</b>                | <pre> else:     s_candidate = self.search_social_candidate()     print "Adding people with a social profile would improve the communicative skills of the group. {} can be a good candidate with high social skills.".format(s_candidate) </pre>  |

|   |   |
|---|---|
| <p><b>If only communicative skills are low and female proportion is under 50%</b></p>                                     | <pre> if self.female_proportion &lt; 50:     print "A bigger proportion of female participants in the group will increase the global CI factor of this group, which will positively be reflected in its performance." </pre>  |
| <p><b>And while the technical score is not &gt;=9</b></p>   | <pre> if t_result &lt; 9:     print "Although the score obtained in the technical part is high, it can still be improved with some extra technical knowledge." </pre>   |
| <p><b>If only technical skills are low</b></p>  | <pre> elif t_result &lt; 5:     t_candidate = self.search_tech_candidate()     print "Although the communicative level is high, technical skills of the group remain low. Therefore, {} can be a good candidate with high technical skills. Adding this candidate to the group will improve the global technical level of the group.".format(t_candidate) </pre>  |
| <p><b>And while the communicative score is not &gt;=9</b></p>   | <pre> if s_result &lt; 9:     print "Although the obtained communicative score is high, if the manager could provide group members with some instructions regarding communicative skills, this would increase the global performance of the group." </pre>  |
| <p><b>If the group performance is very high but in one or both communicative/technical skills the score is &lt;=9</b></p> | <pre> else:     if t_result &lt; 9:         print "The performance of this group is very high. However, if its members could improve their technical skills the performance would be outstanding."     elif s_result &lt; 9:         print "Although the obtained communicative score is high, if the manager could provide group members with some instructions regarding communicative skills, this would increase the global performance of the group." </pre> |
| <p><b>If the performance of the group is outstanding</b></p>  | <pre> else:     print "The performance of this group is outstanding." </pre>  |

*Table 16 - Tool body*

You can find the whole code in the annex.

## 7.5 - Examples using the tool

To check that the tool works properly, the 10 scenarios were put to test. Here are the results depending on which part of the tool matrix was the group performance located.

In all screenshots you will find a first set of commands corresponding to the **output of the test and metadata**, which corresponds to the **input of the tool**.

The second set of commands corresponds to the **output of the tool**.

The database used for this test can also be found in the annex.

- **Case A: very poor performance**

```
>>> test_result = TestResults(tspeak="1", incl="2", lship="1", sorg="1",
...   tqual=2.5,
...   n_ppl=4, wf="HHRR", f_prop=50,
...   prof_database=database)
>>> test_result.compute_recommendation()
Scores - Communicative skills: 2; Technical skills 2.5
The performance of this group is very poor. Forming a new group should be considered.
```

*Figure 21 - Case A example*

- **Case B: low performance**

```
>>> test_result = TestResults(tspeak="2", incl="2", lship="1", sorg="2",
...   tqual=3.9,
...   n_ppl=4, wf="tech", f_prop=50,
...   prof_database=database)
>>> test_result.compute_recommendation()
Scores - Communicative skills: 3; Technical skills 3.9
The performance of the group is low. Adding people with a social profile would improve the communicative skills of the group, while adding members with a technical profile would increase the global technical skills of the group. Mary can be a good candidate with high technical skills, while Laura can be a good candidate with high social skills.
```

*Figure 22 - Case B example*

- **Case C: intermediate performance (low communicative skills)**

```
>>> test_result = TestResults(tspeak="2", incl="1", lship="4", sorg="2",
...   tqual=8,
...   n_ppl=8, wf="bss", f_prop=25,
...   prof_database=database)
>>> test_result.compute_recommendation()
Scores - Communicative skills: 4; Technical skills 8
Adding people with a social profile would improve the communicative skills of the group. Laura can be a good candidate with high social skills.
A bigger proportion of female participants in the group will increase the global CI factor of this group, which will positively be reflected in its performance.
Although the score obtained in the technical part is high, it can still be improved with some extra technical knowledge.
```

*Figure 23 - Case C example*

- **Case C': intermediate performance (low comm. skills, outstanding tech skills)**

```
>>> test_result = TestResults(tspeak="2", incl="1", lship="4", sorg="1",
...   tqual=9.2,
...   n_ppl=5, wf="tech", f_prop=60,
...   prof_database=database)
>>> test_result.compute_recommendation()
Scores - Communicative skills: 4; Technical skills 9.2
Adding people with a social profile would improve the communicative skills of the group. Laura can be a good candidate with high social skills.
>>>
```

*Figure 24 - Case C' example*

- **Case D: intermediate performance (low technical skills)**

```
>>> test_result = TestResults(tspeak="4", incl="3", lship="4", sorg="2",
...   tqual=4.2,
...   n_ppl=4, wf="HHRH", f_prop=75,
...   prof_database=database)
>>> test_result.compute_recommendation()
Scores - Communicative skills: 6; Technical skills 4.2
Although the communicative level is high, technical skills of the group remain low. Therefore, Paul can be a good candidate with high technical skills. Adding this candidate to the group will improve the global technical level of the group.
Although the obtained communicative score is high, if the manager could provide group members with some instructions regarding communicative skills, this would increase the global performance of the group.
>>>
```

*Figure 25 - Case D example*

- **Case D': intermediate performance (low tech skills, outstanding comm. skills)**

```
>>> test_result = TestResults(tspeak="4", incl="5", lship="4", sorg="5",
...   tqual=2.3,
...   n_ppl=4, wf="bss", f_prop=50,
...   prof_database=database)
>>> test_result.compute_recommendation()
Scores - Communicative skills: 9; Technical skills 2.3
Although the communicative level is high, technical skills of the group remain low. Therefore, Christian can be a good candidate with high technical skills. Adding this candidate to the group will improve the global technical level of the group.
>>>
```

*Figure 26 - Case D' example*

- **Case E: high performance**

```
>>> test_result = TestResults(tspeak="2", incl="3", lship="4", sorg="5",
...   tqual=6.4,
...   n_ppl=3, wf="HHRH", f_prop=33,
...   prof_database=database)
>>> test_result.compute_recommendation()
Scores - Communicative skills: 7; Technical skills 6.4
The performance of this group is very high. However, if its members could improve their technical skills the performance would be outstanding.
Although the obtained communicative score is high, if the manager could provide group members with some instructions regarding communicative skills, this would increase the global performance of the group.
>>> █
```

*Figure 27 - Case E example*

- **Case E': very high performance (outstanding tech skills)**

```
>>> test_result = TestResults(tspeak="4", incl="2", lship="4", sorg="5",
...   tqual=9.7,
...   n_ppl=5, wf="HRRR",f_prop=20,
...   prof_database=database)
>>> test_result.compute_recommendation()
Scores - Communicative skills: 7; Technical skills 9.7
Although the obtained communicative score is high, if the manager could provide group members with some instructions regarding communi
cative skills, this would increase the global performance of the group.
>>>
```

*Figure 28 - Case E' example*

- **Case E'': very high performance (outstanding comm. skills)**

```
>>> test_result = TestResults(tspeak="4", incl="5", lship="4", sorg="5",
...   tqual=6.2,
...   n_ppl=5, wf="tech",f_prop=80,
...   prof_database=database)
>>> test_result.compute_recommendation()
Scores - Communicative skills: 9 - Technical skills: 6.2
The performance of this group is very high. However, if its members could improve their technical skills the performance would be outs
tanding.
>>>
```

*Figure 29 - Case E'' example*

- **Case F: outstanding performance**

```
>>> test_result = TestResults(tspeak="5", incl="4", lship="4", sorg="5",
...   tqual=9.1,
...   n_ppl=6, wf="bss",f_prop=50,
...   prof_database=database)
>>> test_result.compute_recommendation()
Scores - Communicative skills: 9 - Technical skills: 9.1
The performance of this group is outstanding.
>>>
```

*Figure 30 - Case F example*

## 8 – Conclusions

The main objective of this project, which was the creation of a system to help SMEs evaluate future scenarios with the use of consensus tools, has been reached. It is true that the direction of the project has suffered some variations, and the approach has been different in many cases as it had been expected at the beginning. It could be said that the project as a whole has been an iterative project until it has reached its final form, a tool that based on numerous experiments and statistical demonstrations that produces a valid output with positive effects on group performance.

The first analysis of available consensus tools provided a realistic view of one of the main difficulties the project would face: most of the tools required the physical presence of members in order to put them into practice. However, using a virtual survey drove to the idea of determining if a variety of profiles could be created according to specific features of individuals. This is logically tied to the fact that the survey had to be conducted among people of a near environment, which is not a problem as this project is mainly focused on local SMEs, which are composed of people with the same background.

It is true that it would have been an exceptional experience and source of data to create a bigger experiment involving two or three times more groups than the one involved in this group. However, the obligation of creating random groups which involved people from a near environment, making them work together for a relatively long time and forcing them to physically meet together in a same place made me face many more difficulties than I had initially expected. However, I am widely satisfied with the results obtained as they stick to the statements listed in the article used to present collective intelligence.

The most satisfying and interesting part has been creating a computer tool that is based on all these data. The final output throws practical advice that as demonstrated will improve the performance of groups, and could perfectly be implemented as a real tool.

As a global conclusion, this project has been enriching, it has allowed me to explore extraordinarily interesting aspects of group behaviour which, despite being in front of us through all our lives, might not be evident at first sight. However, not

only there are many factors that actually have an important influence on the performance of the group, but there is a significant correlation between this factors and individual characteristics of members composing the group. Having explored these global and individual factors, in big part thanks to the highly qualified material publicly available, has made it possible to create the final tool. Therefore, I consider that the project has been successfully completed and opens new doors to change and improve the tool presented.

## 9 – Greetings

I would like to say a big thank you to the following people:

- To all the people who willingly took part in the group tasks, trying their best and finding some spare time to be part of this experiment.
- To my friend Guillermo, who assessed me in the creation of the computer tool.
- To my friend Jose Luis, who threw some light when I wasn't sure of which direction to follow.
- To the directors of this project, Ramon and Josep M<sup>a</sup>, who always respected my freedom to choose the direction of the project and came up with different ideas which enriched its content.

## 10 – Project budget

| <b>Concept</b>                      | <b>Quantity</b>             | <b>Total cost</b> |
|-------------------------------------|-----------------------------|-------------------|
| <b>Student working hours</b>        | 270 (20€/h)                 | 5400€             |
| <b>Articles and papers</b>          | 4                           | 27€               |
| <b>Computer software (licenses)</b> | Minitab, Linux, Excel, Word | 3280€             |
| <b>Participants in groups</b>       | 15 (20€/participant)        | 300€              |
| <b>Tech support</b>                 | 10 hours (50€/h)            | 500€              |
| <b>Computer amortisation</b>        | 270 hours/36500 life hours  | 7.5 €             |
| <b>Diets</b>                        | 100                         | 1000€             |
| <b>TOTAL</b>                        |                             | <b>10 514.5€</b>  |

Table 17 - Project budget

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