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Building an Integrated Methodology for Water Management and Assessment in Industrial Plants: The Volvo case

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Building an Integrated Methodology for Water Management and Assessment in Industrial Plants: The Volvo case

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Abstract

This thesis work is the result of a six-month stage experience in Paris in the Smart Water Grid (SwaG) research project, in collaboration between Ecole de Management Léonard de Vinci and Altran Research. The SwaG Project is part of the "Smart Factory" Altran research and innovation program with the final aim of incorporating smart technologies for water management in the future. The present work represents the first phase of the main Project and it lays the foundations to accomplish the cited goal by creating a set of decision support tools able to evaluate different aspects of water management in industries and to choose the best among different technologies used.

Specifically, this study proposes a framework through which classify into defined blocks industrial processes belonging to different domains, a database of Performance Indicators (KPIs) to control all the processes and a step-by-step methodology able to address a new case study and identify the best technology used in it by harnessing a set of indicators.

Questo lavoro di tesi è il risultato di uno stage di sei mesi a Parigi sul progetto Smart Water Grid (SwaG) in collaborazione con l'Ecole de Management Léonard de Vinci e il gruppo Altran Research. Il Progetto SwaG è parte del programma di ricerca e innovazione "Smart Factory" di Altran con l'obiettivo finale di incorporare in futuro le nuove tecnologie nella gestione dell'acqua. Il presente lavoro rappresenta la prima fase del progetto e getta le fondamenta per raggiungere l'obiettivo ultimo del progetto creando un set di strumenti decisionali capaci di valutare diversi aspetti della gestione dell'acqua nelle aziende e scegliere tra diverse tecnologie usate.

Nello specifico, questo studio propone un framework attraverso il quale classificare i processi industriali appartenenti a diversi domini in blocchi definiti, un database di Performance Indicators (KPIs) per controllare i processi e una metodologia con passi definiti capace di affrontare un nuovo caso studio e identificare la migliore tecnologia usata in esso sfruttando un set di indicatori per prendere la decisione.

1. GENERAL CONTEXT AND PROJECT SCOPE

Altran is a global innovation and engineering consulting firm operating in high technology and innovation consulting. The Altran Research department is composed of multisciplinary teams with the aim of building solutions to complex issues posed by ever-changing world.

In a context of resources scarcity, the criticality of the access to water and the hardening of the regulations lead to imagine the industry of tomorrow always more efficient in resources consumption. The use of the water resource and its impact in the industry performance are in fact major issues for industrialists. The management of water consumption is crucial for reasons of performance, cost, security of supply and environmental labeling.

The SwaG Project aims to consider these water management issues in the industry of tomorrow, where new technologies will be implemented. To do that, a preliminary phase of the SWaG project conducted in this work is needed. Specifically, here are presented three methodological bricks for the qualitative and quantitative evaluation of the water use in industry:

- a framework through which it is possible to classify different processes into some blocks as general as possible to be used for different industry domains;
- a database of qualitative and quantitative performance indicators (KPIs);
- a step-by-step methodology to apply both the framework and the database to a new case study, able to provide information through which making decisions.

Through the model proposed in this work, it is possible to model systems of different size and complexity and look for optimization solutions by exploiting gap analysis between different technologies used in processes, and thus by allowing a better use of water.

A case study for whom data about the baseline and seven different technologies (called "scenarios") were already available has been used, in order to understand if the proposed methodology is able to compare and highlight differences between technologies performances by using both specific indicators and aggregation of them.

As future perspective, the next step is to use this methodology not only as a way able to compare different technologies, but above all to provide a tool that will propose innovative solutions.

2. ACTIVITIES, METHODOLOGY AND RESULTS

The following table illustrates the work phases. For every phase, it describes the different macro activities with their respective goals and methodologies. The role of the candidate was "Responsible" for each activity.

Phase	Macro Activity	Goals	Methodology
1. Literature review	1.1 Smart Water Grid indicators review	Understand which studies have been conducted about this topic	Scopus research, selecting information, reading articles, finding frameworks to exploit
	1.2 Smart Cities and Smart Grid indicators review	Use other domains to extrapolate information and use them to build a methodology for SWG	Scopus research, selecting information, reading articles, finding frameworks and collecting KPIs
2. Building an Integrated methodology	2.1 SWaG Framework Creation	Create a set of blocks through which classify case study processes	Using frameworks in literature and creating blocks where needed
	2.2 KPIs Database Creation	Create a KPIs database to use in the next phases	Collecting KPIs in literature and classify them; creating new indicators
	2.3 Step by Step Methodology Creation	Create a list of activities to assess a new case study, able to choose the best technology in a range of solutions	Finding the main step to follow to calculate indicators and macro indicators able to find the best technology
	2.4 Best Scenario Choice	Chose the best scenario using aggregated indicators	Creating a Water Footprint able to compare different scenarios and choosing the best performing one.
3. Volvo Case Study Test and Validation	3.1 Methodology Application to the Volvo case study	Prove that the methodology is working for a specific case study with available data about baseline and scenarios	Using case study data to calculate indicators and to show differences between baseline and scenarios
	3.2 Case Study Results	Find the best scenario using the information provided from the indicators	Aggregating indicators to create macro indicators describing different areas, and choosing the scenario that best improve all of them

2.1 Literature review

This work started with a literature review in order to understand if some studies about frameworks and performance indicators (KPIs) used in the domain of smart water grid were already been conducted. Since no complete publications about that until September 2017 were found, information about frameworks and performance indicators used in this and in other domains were collected, in order to extrapolate a model able to describe and control the Smart Water Grid.

2.1.1 Smart Water Grid indicators review

No papers about how to use Performance Indicators to control water use using smart technologies were found, proving the novelty of this theme as research topic and further strengthening the importance of this work. Nevertheless, some frameworks to describe some parts of the water management were collected and used as a starting point to build the SwaG Framework. The three main frameworks chosen to exploit their information to build the SWaG Framework are: Eco Water, System Architecture, Value of Water.

2.1.2 Smart Grid and Smart Cities indicators review

The other domains chosen to gather information about performance indicators and their classification are Smart Grid and Smart Cities, since they denote broader level of focus and the number of publication about them is growing in the last decades. In order to create and classify a set of KPIs able to describe and control the water management in an industry, indicators used in other domains were collected.

2.2 Building an Integrated methodology

2.2.1 SWaG Framework Creation

As mentioned before, three models from literature were analyzed in depth to find the peculiar characteristics through which building the main part of the SWaG Framework.

EcoWater Project is presented as an example of a broad project related to this theme and from whom it is possible to take ideas to build the SWaG model. In fact, the EcoWater Project has proved to be the more completed framework and for this reason it was chosen as a starting point around which it was possible to build a more complete framework. In fact, the main blocks of the project, as Water Abstraction, Water Treatment, Water Use and Wastewater Treatment are kept in the SWaG Framework. Moreover, the block Water Storage was created to explain a missing part in the EcoWater Project about how to manage the storage of the water between the other processes. Furthermore, the definition of the organization and environment boundaries is necessary to consider input and output of the system. In the present work, the choice of keeping the distinction between Environment and Organization was made.

The Value of Water Framework was used to add the "Multiple Waters Concept" to the framework. In fact, in that project authors stated that not only clean rivers, surface and ground water, but also alternative sources such as rainwater, brackish and saline water, brines and used water, need to be considered to set up a "*holistically integrated system*".

The System Architecture Framework was used for highlighting the difference between three layers described as "*a real-time active sensing layer, an interconnecting layer of water information interconnection layer, and a smart decision layer*." So, the SwaG Framework comprehends a Sensing Layer, where the measure of the water quality and quantity is made through the KPIs; the Network Layer, where the information system lies, and the monitoring and transmission of data is made, and the Application Layer, used as a data resources center of water quality information.

In this work, only the part about the Sensing Layer is detailed, to provide bases to go in depth in the continue of the project using the other two Layers. The SwaG Framework is the following:

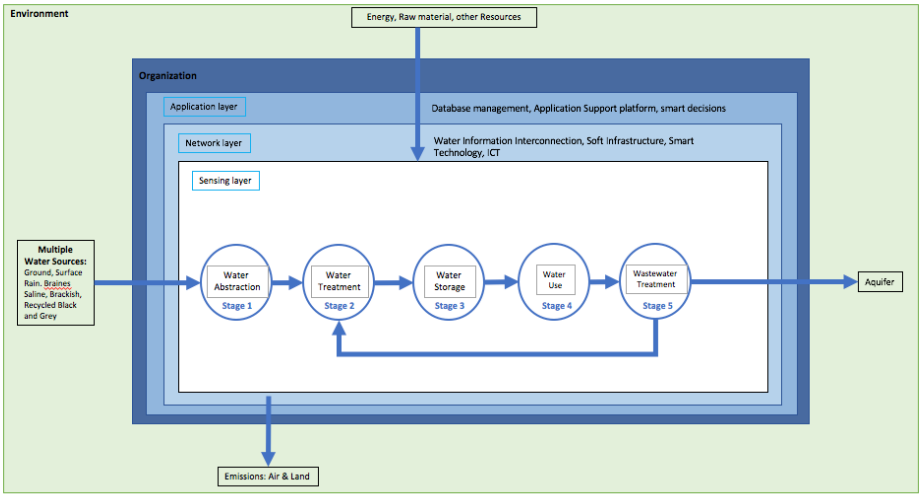


Fig. 1 SWaG Framework

2.2.2 KPIs Database Creation

Once the SwaG Framework has been created, a method to collect and classify indicators in order to create a database that can be used for a specific case study is proposed. The outlying idea is to collect indicators by extrapolating them from literature, classify them into main categories related to the blocks chosen in the SWaG Framework, understand if each of them can be linked to more than a block through a matrix vision, introduce the concept of Water Footprint that will be used to aggregate information extrapolated with the KPIs.

The collection of indicators was conducted by extrapolating information from papers and studies conducted about Smart Water Grid and the other two domains. For this reason, the result is an assortment of 1018 indicator with a different level of granularity. For each indicator, data about the field, the category, the description, the Unit of measure are collected. After collecting all the KPIs from literature review the issue to solve is to understand how to classify them starting from the SWaG Framework. In fact, the choice of maintaining the same pillars defined for the Framework is made, and the rationale behind this is that each block needs to be controlled in order to perform properly and consistently with the other blocks and the whole Framework.

After a first classification of KPIs, it became increasingly clear when linking an indicator to a class, that only one class was not enough explanatory for many of them. On the contrary, most of them could be associated to more than one KPIs, depending on how to interpret its definition. For this reason, a matrix was created to relate each indicator to several blocks and also to provide a clearer visual impact when using the table with the list of indicators.

2.2.3 Step by step methodology creation

A procedure to adapt the framework to a new case study and to choose specific case study indicators from the database is needed. When facing a new case study, the first issue to solve is to understand where to put the system boundaries by separating processes wholly accomplished within the organization and the ones out of it. Then, the internal processes are classified using the blocks of the SWaG Framework.

The next steps are the collection of all the data available about the case study for each process and the choice of the most suitable indicator in the KPIs database representing each data. This can be done by both searching in the database block corresponding to the block of the data, or by using as a query the name of the data. The choice of KPIs will depend strictly from the data owned. If the absence of measurement of a specific value avoid the indicator choice, it is possible to adapt the KPIs to the values disposal by building a new indicator not far from the one present in the list but more consistent to the case study. The presence of at least one indicator for each data of the case study needs to be checked. If this do not happen, a new KPI to explain that data is created, and it is essential to define its formula and its unit of measure. Once a new indicator in created, it can be added to the list and by doing this it is possible to populate the KPIs list with new indicators that can be helpful in the next case study analysis. After having completed the two previous steps for all the processes, all the KPIs from each process are collected and put together in the rows of a matrix. All the processes analyzed are put on the matrix columns, and the matrix is filled with the values of each KPI in each process.

When treating a case study with the availability of process data about different technologies used (called scenarios), it is possible to use the methodology to provide a gap analysis between the scenarios in order to find the best one. This is possible by using the above cited matrix with the subset of indicators to highlight differences and use it to show how the data variation is reflected on which indicators. This can be used as a control for errors because if the data changes and not the correspondent KPI, it means that an error is present, and it needs to be founded and erased before continuing the process. Then, all the KPIs from each scenario are collected and put together in the rows of a matrix, such as for each indicator all the scenario values need to be put together. All the processes analyzed are put on the matrix columns, and the matrix is filled with all the values of each KPI in each process and in each scenario.

To understand how scenarios affect the KPIs calculated for the baseline the KPIs values are normalized by putting the baseline value equal to 1, and the other values as the division between the scenario value and the baseline one. In order to interpret the value significance, it is essential to define if the KPI is favourable when it is high or low, and then harmonize all the indicators using the direction of the majority of them. A graph is then exploited to show how each KPI is far from the baseline and in which percentage it can improve or worsen the performance compared to the baseline.

In order to take decisions about the best scenario, a more aggregated indicator putting together various KPIs and taking into account different aspects is needed. Then, each indicator is assigned to a block of the SwaG Framework, and a weight to aggregate the indicators is chosen. The choice of the weight is left to the methodology user, that knows the industry and its priorities through which evaluate the weights of the indicators. Then, this work proposes anyway to calculate the weight of the indicator with the following procedure. For each indicator, the number of blocks related to the indicator in the KPIs matrix is counted, and the fraction between this number and the total number of blocks is used. Then, the aggregation in a macro indicator can be done by using the weights and by calculating a weighted average. Since each KPI was classified as favourable if positive (or negative) compared to the baseline, and all the KPIs were harmonised to this rule, now it is possible to obtain aggregated information about the comprehensive implications that a variation of a values in a scenario can cause on the final macro KPIs.

To create the final decisional macro indicator, called Water Footprint, the values for each macro KPI corresponding to each scenario are collected and put in another matrix with the aim of showing for each macro KPI which is its value in different scenarios, and for each scenario which are the macro KPIs that best perform. Once the Water Footprint is created, it is possible to make decision about the goodness of the changes that a scenario brings and chose the scenario that best improve the performance of the processes and the industry.

2.2.4 Best Scenario Choice

It is clear that the final choice could depend from different factors, such as politic, risk, environmental, quality considerations. Furthermore, it is essential to check if some threshold about this KPIs can be found in the literature as statistics that can give information through which make comparisons. Since all these considerations cannot be included in a general methodology, in this work only the mathematical side is analyzed. Then, the final values of all the Water Footprints for each scenario are compared and it is highlighted which one has the best value. For example, if it was decided that all the indicators are favorable when they are high (low), the best scenario will be the one that has the higher (lower) total value of the Water Footprint. Not only the total value, but also the value of each macro indicator could contain important information. In fact, some macro indicators could show different trends and these differences need to be considered to understand if there are some scenarios that better perform on a macro KPI even if the final result does not highlight that one as a best.

This consideration can lead to a deeper study to understand which part of other scenarios can be used to improve the macro KPI that shows different behavior in comparison to the others. Through this information, it is possible to understand what to improve by using suggestions from other scenarios where the values are better.

2.3 Volvo Case Study Test and Validation

The Case Study used in the present work is extrapolated from the EcoWater Project and it is used to validate the proposed methodology in a real case study for which the values have been already collected. It concerns the Volvo Group, Sweden, and it will focus on the two manufacturing sites of Volvo Trucks and their respective water supply chain. In the following paragraphs it is shown how the procedure can extrapolate coherent performance indicators from the database created, succeeding in explaining the data available and creating a Water Footprint function through which different scenarios can be compared.

2.3.1 Application of the methodology to the Volvo case

The first step is to model the system and the processes within it using the SWaG Framework, by defining the boundaries of the organization and deciding which process analyze using KPIs. Then, it is possible to start with the KPIs subset specific selection by performing a preliminary scan using the Block classification in the KPIs Matrix and then a more detailed research using a query research method based on values name available.

Firstly, all the KPIs found in the list using the data query are listed in the matrix and an "x" is put in the crossing of the KPI and the relative data took into account. Then, when no more KPIs can be added using this method, a control of the crossing cell between KPIs and data is done to understand which data is not described from an indicator, and so a new KPI is created to have at least one for each data available. Once the previous steps have been completed for all the processes within the industry, the overall set of indicators with their values is collected into a matrix that contains the unit of measure of each KPIs found and relates the indicator with the process for whom the value was calculated.

The next phase includes the comparison of alternative technologies that can improve the final Water Footprint macro indicator compared to the one belonging to the baseline. The scenarios analyzed are the eight proposed from the EcoWater Project: membrane distillation; recirculation of water and degreasing agent; electro-deionisation of recirculated water in phosphating process; silane-based metal surface treatment; resource efficiency in terms of water use, electricity use and material use; pollution prevention; circular economy, focuses on technologies that reuse, recycle or recover. Data about each scenario are collected and the differences with the baseline are shown by highlighting the cell that changes its values and this helps to understand which KPIs will change their values too. Then, the KPIs showing differences will be selected and compared with the respective baseline KPIs to extrapolate useful information. Thus, to summarize the information into a visual way, the KPIs selection matrix is created where different values from the baseline are highlighted with the respective scenario's color. Finally, it is possible to put this information on a graph (Fig. 2) , where it can be noticed how each process contribute to the percentage

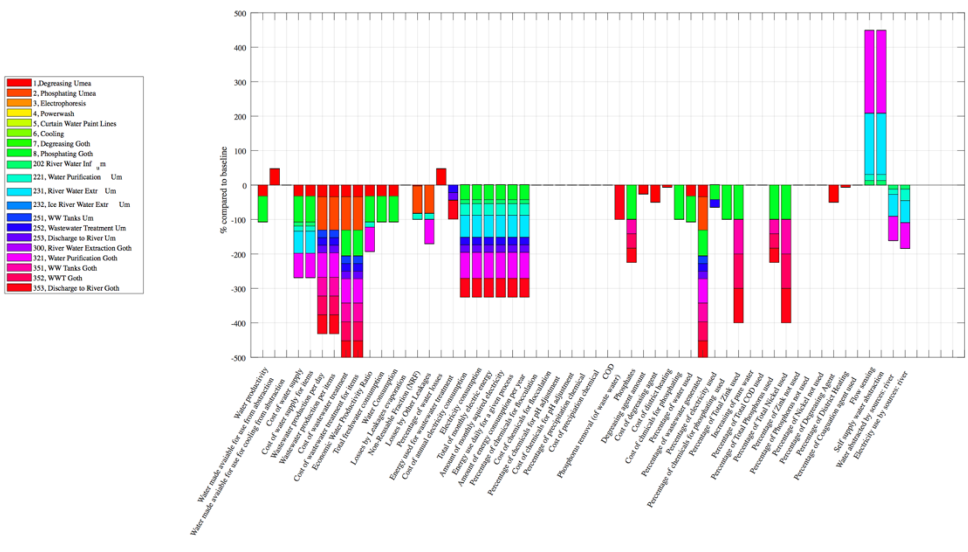


Fig. 2 Process contribution to KPIs percentage variation for a selected scenario

variation of each KPI, and which are the KPIs that most show differences in each scenario. This is useful to understand on which elements each scenario impacts and especially how much each process is affected by this.

2.3.2 Case Study Results

The Water Footprint is created as a vector with 6 rows corresponding to each macro indicator and each value is compared for the seven scenarios. At the end, the choice of the best possible scenario is made by using the sum of all the macro KPIs percentage and by choosing the scenario that has the more negative Water Footprint percentage, since it has been chosen that a favorable value is a lower one. Two scenarios show quite comparable total Water Footprint percentage (-957% and -1072%), so further considerations need to be done, but the values assert that the best scenario is the "pollution prevention" that, in fact, is the sum of three other scenarios, and this can be a methodology goodness evidence.

In Fig. 3 an example of Water Footprint comparison is shown, with the contribution of each macro KPI.

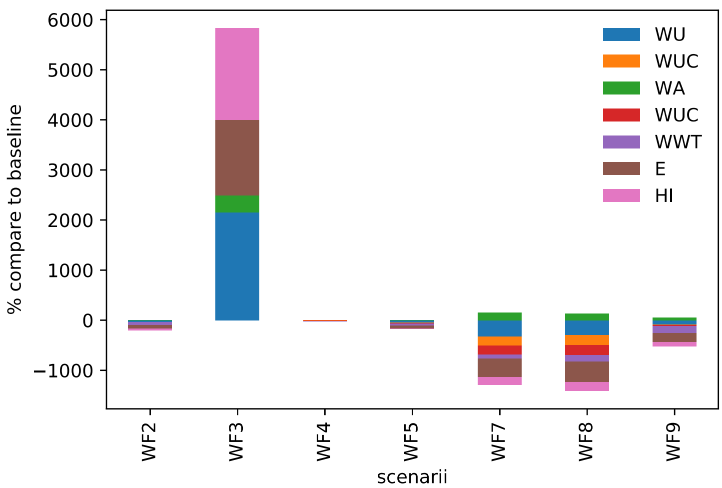


Fig. 3 Scenarios Water Footprint comparison

3. CONCLUSION, LIMITS AND FUTURE DEVELOPMENTS

The present work achieved the original aim to build methodological bricks, embeddable with conventional methodologies, for the qualitative and quantitative evaluation of the water use in industry. In fact, the first main result of this study is the creation of the SWaG framework by integrating literature review information available so far in an original configuration able to provide a tool as general as possible to be used in different industry domains. Then, the second outcome is the collection of indicators from literature and the creation of a database containing all of them. That represents a source of information about qualitative and quantitative indicators around water that can be used in different domains. Furthermore, the outlying idea is to make this database "alive", such as each new case study can add indicators created for it to the list with the purpose of extending the collection of possible performance indicators and enlarging the database. Lastly, a methodology to put together these two innovative tools was created, in order to provide a list of steps to be followed when there is the need to find indicators for a new case study and to compare different technologies using performance indicators and to understand how any process change impacts on the indicators and on the final decision.

Results shown that not only the methodology is able to provide a gap analysis between different scenarios, but it is also possible to identify the best scenario by using the Water Footprint.

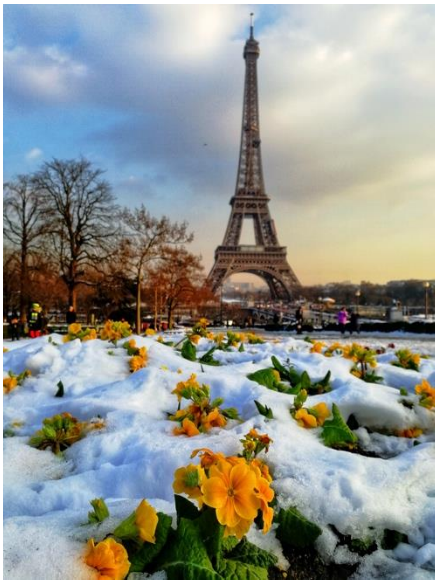
Some limits to this work need to be highlight: the literature review could be not exhaustive; KPIs database is not complete; KPI classification into blocks is manual; the methodology is not yet structured but this is only the "version One"; the presence of only one case study cannot provide evidences; an innovative solution is not provided but the methodology is only able to compare technologies in order to understand which one the best innovative solution is. Furthermore, some choices about the classification and the weights allocation were subjective.

Once all these points are listed, a path for the future research can be traced, by trying to solve the problems stated and to improve the tools proposed. In fact, by testing a consistent number of case studies it is possible to find out how the methodology performs in different organizations and in various domains, and to enlarge the database up to the ideal limit where all the possible KPIs are contained in the database. When this huge amount of data will be available, it might be possible to integrate the database with a machine learning system able to update the system and learning from the decision making KPIs choice. By doing this, in the future it will be possible to recognize immediately the more suitable indicator for a new case study when all the data are put in to it. Thanks to this, it will be also possible to build a tool able to propose an innovative solution. In fact, one of the final goals of the SWaG Project for Altran is to insert new technologies into the water management and understand how this can reduce water use and waste within the organization.

APPENDIX: MY PARIS EXPERIENCE

The present work provides me a deep and real immersion into the enterprise world by the participation to a research study that helps me to develop new skills by addressing real

issues and by providing tangible results. I succeeded into collaborate with both academics and practitioners by following an action research approach and by becoming part of the Altran Research team, helping them in finding a reliable solution to the project issue. Furthermore, the collaboration with the Altran team allowed me to develop communication skills both in English and French, interpersonal relationships, collaboration and innovation skills.



My experience has been a success and it couldn't have been the same without the unusual daily support of Francesco Paolo Appio, and the remarkable proof of confidence that Antonella Martini provided me.

It goes without saying that Paris is much more than amazing and spending there six months gave me the chance of falling in love of this stunning city, able to surprise you every day.

My dream from the beginning was to find a job there, and thanks to the opportunity that this thesis gave me, I perfected my French and I succeeded in finding a job that I like in an international information & technology consulting company in the most beautiful city in the world.