RACO2 : Raising awareness of carbon emissions, time and prices using serious games

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ABSTRACT

This article depicts the project released for the course Data visualization, in winter 2017. It was developed by group of three Data Science Master students.

The project is based on the compulsory topic of transports. In our case, we decided to develop a serious game, using open-data from the SNCF website but also data we collected online using python scripts we developed for this specific purpose.

Our choice to use a serious game to learn from data visualization is directly based on the goal of the project and the audience we are trying to reach. Indeed, the aim is to raise awareness of carbon emissions of teenagers and young adults who are tomorrow's travelling population.

This project is a prototype to show that using visualizations in serious games is a powerful way of getting people interested in a specific topic, in our case, the comparison of transportation means and the search of alternative trips in order to reduce carbon emissions at first but also the price and the travel time.

Index Terms: Serious games—Visualization—Public transport—Ecology ; Human machine interaction—Interactive graphs

1 INTRODUCTION

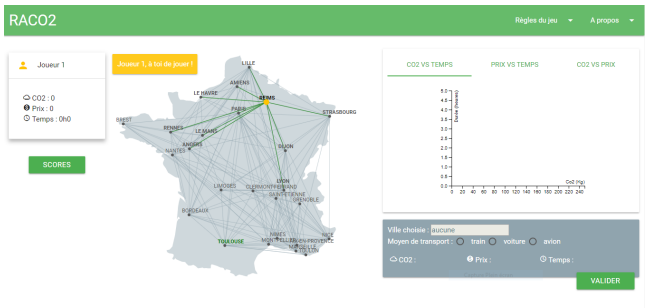

Figure 1: Home view when launching the game

As ecology has been in the spotlight for the last few years, we wish to create awareness that we should all pay attention to carbon emissions when travelling. Our work is thus intended for teenagers, young adults or anyone who enjoy games and who is keen to pay attention to pollution. In this project, we compare three means of transport which are : trains, planes and cars. The goal of this work is to highlight the fact that you may reduce your carbon emissions but not significantly increase your transit time. The aim is to motivate people to choose an alternative mean of transport. The purpose is also to encourage people to reach a good compromise between price, time and carbon emissions for their trips.

With this idea of comparing three important criteria (price, time and carbon emissions), we went through the data on high speed train over time, wondering whether prices would vary according to another criterion. But this study would have been pretty simple. Also, the correlations between these three criteria were easily notable. To go further, we decided to cross these data with data concerning other means of transport. Hence, we added cars and planes. This makes sense as everyone tends to have a car nowadays and flights tend to be cheaper. The train is not the main mean of transport people would think about when planning a trip. At this point, the concept of time lost its interest since the criteria do not vary significantly enough. However, the comparisons become really interesting. Some results are surprising, such as going from Lyon to Toulouse is almost the same cost by plane or by train, but the pollution ratio is really high. But taking the train is four times longer. Thus, depending on our life choices, you may reconsider your plans.

In order to raise awareness without expressing reproach, we decided to create a serious game. It is also a good way to reach a wider audience. We also noticed this does not exist yet, or this is not very popular. Bringing together data visualization and game concept to serve a serious topic is creative. In addition to this, we hope to keep the player's attention all during the whole game by making the visualization interactive. Moreover, one makes his choice based on what is displayed on the graphic elements. Hence, these elements cannot be missed. So, more or less intentionally, the player has to pay attention to the map and the graphs. The aim here is to make the graphic elements an integral component of the game, more than just an annex to it. The role of the viewer is not only to read the summary of data analysis but to understand them in order to act in the game. The concentration and motivation are also raised and the knowledge is better acquired.

In order to give more details about the use of data visualization for serious games, this article first describes the state of the art, that is the articles or projects related to both topics. Then, a detailed description of the game scenario and technical choices is given. We also discuss our innovative game. The last section discusses our choices and some improvements which could be considered.

2 RELATED WORK

This part depicts the state of the art. Several map visualizations can be found, which show transport lines. Several simple graphics, or simple data can be found to justify which mean of transport is better in term of CO2 emission. But none of them let the user play with the data. However, there is no game about such specific topic. In fact some games exist for a larger sense of ecological domain, but none of them about comparison between public transport. In this section, we specify what a serious game is, its benefits for education, and which games already exist. Then, we give a fast overview of existing web services that provide data for learning the CO2 emission for a specific travel and its journey time.

2.1 Serious Games

A serious game is a software that combines a serious purpose, like pedagogy, information, communication or learning, with playful aspect. As a synthetic way, the serious game wraps all the computer games that aren't purely for entertainment.

"A serious game or applied game is a game designed

for a primary purpose other than pure entertainment" - *Wikipedia, in reference of [13]*

Learning and understanding in games is an actual research question that has been showcased by many researchers. Success enables learners to be motivated and concentrated. Experiences have confirmed that understanding a scientific subject in a game was better than in an guided inquiry (Squire et al. 2000). Pieter Wouters, Erik D. van der Spek and Herre van Oostendorp, three researchers from the University of Utrecht in The Netherlands, mention that visualizing knowledge encourage the understanding of the players especially in comparison to text [2].

> "Video games are highly visual and may favor the acquisition of visually encoded knowledge. In that case visually-oriented assessment may reveal learning of knowledge that would probably not have been found with a text-based assessment method." - *Chapter XIV Current Practices in Serious Game Research: A Review from a Learning Outcomes Perspective*

This research favors the national education to manage game in school curricula. Bushnell overcomes the actual situation by saying that adopting the new technologies at school is smart but also inevitable [6]. Indeed the students are attracted to electronic devices and the motivation is multiplied when working on a tablet compared to reading a book.

In fact ecology is a part of the French education program. Since this topic is part of the common program [18]

> "Adopter un comportement thique et responsable" - *Cycle 4 : physique-Chimie*

(Adopt an ethical and responsible behaviour) the department of education, by creating this own serious game [5], tend to promote this kind of pedagogy. Unfortunately, the game's link is no longer available, so that we have to deal with its description. The game was about how to manage a city, in order to be more aware of ecology and to give a sense of responsibility to the citizens. The topic of their game, as other games found on the internet [17] [12], is larger than our. In the other hand, they are not very dynamic. Actually, they are essentially about reading and question / answer.

In our project, we did not want to guide the users too much, because of the main goal we had : discover the data by oneself. Since our visualization is for everyone, users do not have to know anything about the data. We suppose a teenager would not realize all the knowledge he can have in this game on the first play, but he will discover by himself, what is more ecological. More than this, he will learn to make his own opinion on the topic. Stressing environmental dimension is due to the hot topics in news and our own opinions, but the players are free to disagree with that.

Finally, as our game is for teenagers, and furthermore located in France, we now know that it is recognized by the department of education to learn with such a method. Our visualization can easily be part of a small cross-curricular course for CO2 emission comparisons purpose for example.

2.2 CO2 emission

The SNCF offers a visualization [4] comparing the amount of CO2 produced during a travel offered by their railway services, and the CO2 emission for that same journey by car or by plane. This visualization is available for three specific journeys and is not time-interactive. When searching information regarding a travel, CO2 emission is indicated on the top right corner to inform the traveller.

The carbon emission is not the main subject on airline companies websites. Indeed carbon emissions are a great problem for the flights. The CITEPA reports meaningful figures for travels around Europe [1]. Flights prices are often high but this mode of transport makes it extensively exploited. We can understand that the travel time should be the reason of this use.

The car's CO2 consumption is balanced between the flights and the trains since the carpooling has been developed.

We finally question ourselves about our means of transport : what is our priority ? Does the consumption of CO2 affect the choice between the train, the flight and the car ? The ratio between the travel time and the price is an important criterion when travelling.

Three graphic elements on the visualization will propose comparisons between the criteria to support these thoughts.

2.3 French paths visualization

Senseable City Laboratory [16] shows many visualizations about the french rail network, according to several approaches. A purpose is to highlight distance between cities, not in terms of kilometers, but in terms of needed time (by train) between the cities. This distance varies through time, so that we can see a dynamic distorted France map, where the distance between cities represents the needed travel time, at a time of day.

Our serious game shows not only journey times but also prices and CO2 consumption which are three criteria, and this for three modes of transport. So many distinct values inhibit a visualization by one criterion only.

France counts 34 672 cities that would result in an unreadable graph if we decided to display them all. Visualizing a sub-graph is the topic of many ongoing researches [20]. In our project, we use a semantic sub-graph by selecting nodes (cities) on capital basis.

France, as any country, is recognized by its map and it is the best visualization to display a background of it for the viewers. Indeed they won't have to understand and the acquisition of the cities is immediate.

3 Project description

3.1 Scenario

When we launch the game, we have to set a number of players and a play mode. Then, the game starts with the round of Player 1. At this moment, a departure and arrival cities have been chosen. The choice is fixed, based on our observations and experiments on the map. We chose the cities according to their distance, that it to say how many steps you have to take to reach one from another, and also regarding the means of transport available for the trips. The final goal is to go from Reims to Toulouse.

Player 1 can see which cities can be reached from his current position. He can click on each city to get the needed information : transportation mean, cost, carbon emissions and time. He decides whether he wants to travel by car, train or plane, to which city and confirm his choice in the little form on the right of the screen. To assist him in his choice, three graphs can be displayed, comparing cars, planes and trains according to the criteria selected among price, carbon emissions and time. After the validation, it is the round of Player 2 and so on until each player has reached the arrival city. Indeed, the aim is not to be the first to reach the targeted city, because time is not the only criterion observed. Be the first to get to arrival is good but it is not interesting if you produce twice as much CO2 as another player.

At anytime during the game, the overall progress of each player can be visualized. According to this information, a player can decide to change strategy. Indeed, by analyzing the others' choices, he may think about his own choices, thus having a real thought about the right balance we are trying to raise awareness on.

In order to accentuate our goal to raise awareness of carbon emissions, time and prices using means of transport, we propose four play modes :

- An experimental mode : the weights of the different criteria are equals,

- An ecological mode : the weight of the CO2 production counts double. The players should take care about the carbon emissions of their means of transport. Carbon emissions can be compared to the price and the duration of the selected journey on the graphs.
- A mode to minimize the price : this option counts double for the prices of the travels. The players should have a look at the cheapest journeys. That shouldn't be difficult for the player because it is often the real reason behind our purchase.
- A mode to rush your trip : the weight of travel times counts double. Two sub-graphs describe the time depending on the carbon emission separately to the price. Even if the goal is to minimize the time, it is also possible to prefer high prices than high CO2 production.

3.2 Visualization

From a strictly technical point of view, there are three sections on the screen to display interesting visualizations.

- The French map : we chose to represent 25 of the biggest cities of France [8] on the map. Then, using our data, we linked the cities if it is possible to go from one to another regardless of the mean of transport. To ease the understanding of the map and the game for the player, links to cities that can be reached from a current position have a different colour and stronger opacity. However, every link is still noticeable since the player may appreciate to know where he can go next.

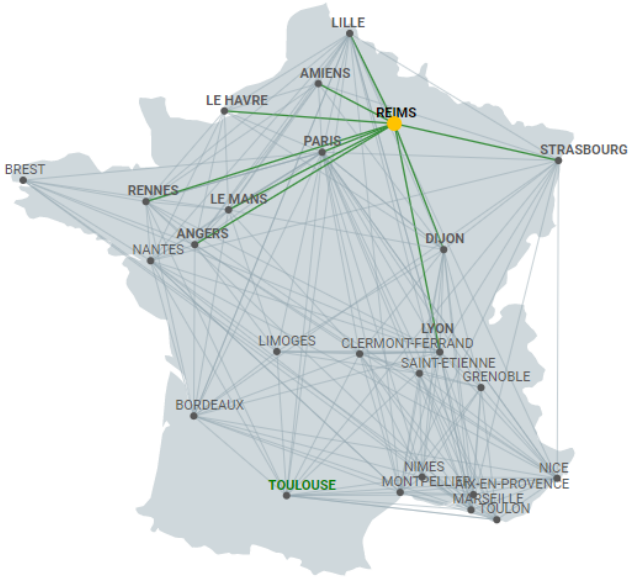

Figure 2: The French map as displayed during the game

- The comparison section on the right side of the screen shows a comparison between car, plane and train, for a given trip and spotting two criteria. For example, if a city can be reached either by plane or train, maybe it is faster by plane, but much cheaper by train and also much less pollutant. Theses values are also displayed below the graph with plain text, but we thought that graphic elements would be more significant. Three versions of comparison are available : CO2 production versus the travel time, the price versus the travel time and the price versus CO2 emission. A pairs to pairs comparisons prevent from overcharging the graphs. The code was strongly inspired by Michele Weigles block [21].

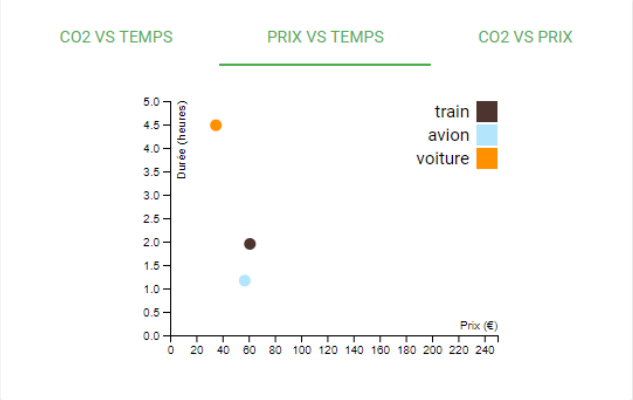

Figure 3: Comparison graphs : 3 possibilities

- Scores : At any time of the game, a player can view the progress of each player. There is no scoring system strictly speaking. Thus, there is no winner, no looser in this game. You can only compare the overall plot appearance and discuss the different strategies that have been chosen. One may be really fast but pay a lot, whereas another pays less but takes slightly longer to get to the arrival city. However, only the players can appreciate the best solution. Scores are displayed using a grouped stacked bar chart. We chose this because it is an easy way to have an overview of the progress of each player, but also to get details and have access to information about each criterion considered in the game. You can see details about means of transport thanks to the colours on the stacks, but also about the costs (co2, price and time) thanks to distinct bars. Moreover, as these are stacked, it also shows the total value, which is the most important at the end of the game. The implementation of the charts is inspired by the blocks of Mike Bostock on blockbuilder [10] [11].

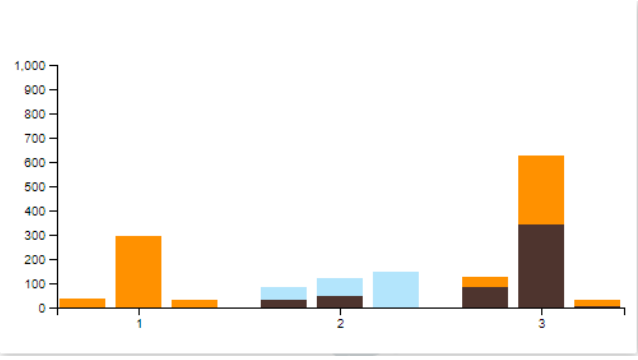

Figure 4: Three viewing areas within the game

The decision we made regarding colours is not trivial. You will notice the game is based on colours pastel grey and green. We chose smooth colors in order not to tire the eyes after a long game. Green is obviously a significant choice when considering carbon emissions. Indeed, the aim of the game is to raise awareness of co2, along with price and time. Thus, we designed the game in keeping with this ecological thinking.

As for public transport's colors, we matched them significantly too. Hence, a plane is represented in blue, referring to the sky, a train is represented in brown as the rail lines and a car is in orange. These choices are based on the thinking induced by an article written at

Stanford University dealing with this issue [19].

However, we chose more pronounced colors such as red or blue to make the players recognizable on the map. Also, we chose colors which are easily distinguished, according to the criteria given in a paper written at the University of British Columbia [15]. The circle that represents them are also bigger. The edges for available trips from a given position are in pronounced green. At first, they were just stronger than the others, but we decided to highlight them more to make the game easier to understand. The arrival is written in green as well in order to remind the destination to the players.

The rules are available in one click on the navigation bar if a player needs help. It's also a great summary to read for curious people.

3.3 Coding tricks and tools

Our project is entirely in web language (HTML/CSS/JS). All the project is executed by the customer, and this is why it is a powerful portable game : no need to access a server, just have the project at home, and you will have access at anytime.

Nevertheless their are some troubles with coding in javascript. The first one is the asynchronous execution of the code. To guarantee a linear execution for some parts of the code, we used *promises*. Their are very beneficial for the structure of the code, and clarify some parts of the execution. But, we chose not to use them a lot, because they can slow the execution.

3.3.1 Files, functions and classes

As we started to code a game, we chose to create classes to structure our code. We keep all the classes in the same directory *model*. In addition to the classes, we divided the code into files for an easier understanding of the structure. Along with the model and the main html files, we can distinguish the following files :

- Comparaison : Display the graph that compares chosen criteria pairs to pairs for the available means of transport, given a travel.
- France : Display the French map, its 25 biggest cities and all the available travels we have in our data.
- Jeu : Initialize and start the game. Then pursue until the end.
- Main : Load data, and initialize global objects.
- Scores : Display the scores in a specific section and update them at each round.

We used classes to distinguish the different structures within the game.

- A player, *Joueur*, has different attributes. At any time in the game, a player spent a precise amount of money, has spent time and has produced a given amount of CO2. Also, at any time, a player has a position, that is, a current city he is in. In addition to this, we keep records of each travel from a city to another in an array called *actions*. Thanks to this records, we can draw the final bar chart of the game to compare the strategies chosen by players.
- A trip, *Trajet*, goes from a city to another, by a given transportation mean. A cost, carbon emission and time are also assigned to each trip. Thus, the actions of a player are composed of a list of trips.
- A city, *Ville*, has a name and a position on the map. Also, we assigned to each city a list of cities than can be reached, for each transportation mean (car, plane and train).
- A score, *Score*, keeps track of the total time spent, the carbon emissions and total price for each player at each round of the game. A list of score is given as input data for the score graphic component.

Each of these structures is kept in a specific class in order to simplify access and handling of data.

3.3.2 D3.js and Maps Tool-Kits

Among the available technologies for this project, we have decided to use the famous D3.js framework. It is already full of resources to display simple charts as well as more complex and advanced data visualizations. Among other things, we need to show a French map. Hopefully, we can rely on an existing project [9]. Is it composed of an interactive French map. Then, we had to place the cities on the map using their coordinates. Then, we had to create lines to link cities in order to represent the whole transport network. The display of these lines depends on the data. If a city is reachable from the current position, the edge is green to insist on this available option.

The hardest thing to do was to combine all the data and also to keep track of the progress of each player.

We decided to render different parameters using visual displays. For example, to distinguish the mean of transport (car, plane or train), we used colours. We decided not to show too many colours on the map as it is already cluttered with edges and cities. But you can easily see the possibilities by using either the graph on the right or the form right below it. In this same logic, we drew only one edge between cities, even if the player can go there by many ways. We kept the map as clear as possible and try to refer to and duplicate the information somewhere else on the screen so that the player knows everything that he needs to know but keeping it simple and understandable.

As a reminder, below is a resume of the main functions we use in d3.js :

- d3.queue() : This function loads data asynchronously. When finished, a given function is executed. We use it to load our data once when loading the page, and then get them in variables. We use js objects to save them for later use.
- d3.geoConicConformal() and 3.geoPath() to display the map center on the France, in a specific scale.
- d3.select() and d3. selectAll() to select html parts in the DOM. This is very useful when creating new objects in a svg. This is clearly one of the most used d3.js function.
- d3.stack() : Used to stack bars in a chart.
- d3 Mouse event : as our project is interactive, we used the event to click and to hover components.

3.3.3 Client Framework

Github allows the users to create web-pages which are using only front-end side. Our data are available in the folders of our project as well as our code developed for the website. Any request is possible from a server but those problems can be solve by getting the data in the directory of the project.

We implemented the serious game by using a front framework that provides nice looking designs. Materialize [14] offers a complete CSS tool with cards and navigation bars and also a great script for animated buttons.

3.3.4 Open Data-sets

To make our visualization, we must have some basic data to rely on. It is essential for us to have open data. As we want to show SNCF data, we therefore get those data on their website [7]. So we chose two of their proposed data-set : one about carbon emissions and another about the prices.

In order to get data for travels by car, we developed a bot to get them from the website ViaMichelin. We decided to eliminate the cities that have more than five hours of travel to homogenize the data. The compute of the CO2 production is done by the number of kilometers multiplied by 0.12 for the average carbon emission of cars given by websites of simulations. This number is also divided by 2 which is an estimation of the number of person per car [3].

The dataset of the flights was filled in the same way. A script downloads the data from a comparator of travel and computes the average value on a full month. The CO2 production is given by CITEPA [1] for each flight.

4 Evaluation

Even though we drew only one edge between cities regardless of the ways to go there, the map is still a bit burdened. However, this is the easiest way to do it. The game is relevant enough to give concrete information, but not too much in order not to overcharge the view and provide the player with too many irrelevant information. We had to find the right balance.

We also made a choice concerning the trips we would allow to make the game interesting. Indeed, technically speaking, you can always travel by car if you want to. So we should have displayed all the edges, as a complete graph between cities. This would result in a loss of interest in the game. Also, the criteria were so high in some cases that it would have been obvious to choose an alternative solution. Therefore, we decided that if the travel time by car was greater than 5 hours, the trip would not be possible. Moreover, we integrated data about the high speed trains (TGV). We could have chosen data from regular trains (TER) instead, or both. But, as it is a game which does not require specific knowledge, we observed that TGV data were significant enough to highlight what we want, that is, the relevance of alternative trip compared to those you think about at first.

5 Discussion

By developing a serious game, we hope to reach a wider audience. Indeed, teenagers may not be keen to read pages about ecology and transportation means. They are more likely ready to play a game, even if they don't know the objective. Also, we assumed that everybody wants to travel, at least once. Thus, anyone can be interested in the comparison shown in the game. You may think of plane first, because you think it is faster, but realize that by train, it is slightly longer but much cheaper and less pollutant.

This game is a prototype, yet fully functional, of a serious game. We implemented all the features we wanted at first but throughout the development, we thought we could improve it by making it look even more like a game such as Monopoly. We could include taxes or pollution alert for example. This would be more playful without changing the original purpose.

6 Conclusion

In this article, we have given a detailed description of RACO2, a serious game which aim is to raise awareness of carbon emissions and alternative transportation means which may be cheaper or less pollutant, sometimes both. Several strategies can be chosen for this game, and there is no optimal solution. That is, there is no winner to the game. The goal is to show these strategies and compare them on criteria such as carbon emissions, price and time spent in transports.

Despite the lack of data availability, we managed to develop a game which is relevant enough. Indeed, our aim was to show that such a game is doable and relevant and so are the choices for visualizations. With the data we collected, which are incomplete but still reliable, we managed to show clearly the interest of travelling by train most of the time. Indeed, there are cities which are far enough and well deserved to test all players behaviours.

The most obvious example is when choosing Reims and Toulouse as departure and arrival city correspondingly. When developing the game, we had the opportunity to test its interest. And these tests revealed an interesting experiment. Within the group, that is to say only three people, we did not agree on what we would call an optimal solution. We tended to refer to the three profiles we then decided to create as play mode. On the one hand, one of us wanted to pay less, travel a bit faster, but pollute a lot by travelling by plane. On the other hand, another preferred a longer journey time but for almost the same price and much lower carbon emissions and chose the train. The last one preferred a balance between the car and the train.

By running our own little experiment on the game, we highlight the relevance of serious games. It is easy to get bored while reading or just looking at something, even colorful graphic elements. However, being fully involved in the presentation is much more gripping. RACO2 is the proof that data visualization can be included in playful context with a meaning and a clear purpose. Also, when testing the game, our conflicts regarding game strategies show that the chosen topic can be discussed. Indeed, not everyone has a clear idea of the costs involved by travelling. Some may not even have a reflection on their choice of transports. Hence, this game is now available to gently encourage them to consider this question : how should I travel ? Am I ready to pay more to pollute less ? Is one hour less worth a much higher price ?

Now that the concept of serious games for visualization is set, there are plenty of improvements to imagine. Currently, the game is quite serious with a simple scenario. This probably implies that the interest is limited. You would play with the purpose of learning something, because you care or you have heard about the topic. However, improving the scenario and adding features would make it funnier. Thus, the morality and thought induced would be more subtle.

References

[1] Calculateur d'mission de co2 de l'aviation. http://eco-calculateur.aviation-civile.gouv.fr/.

[2] Chapter xiv - current practices in serious game research: A review from a learning outcomes perspective. http://biblio.uabcs.mx/html/libros/pdf/9/c13.pdf.

[3] Daily passenger travel. https://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/highlights_of_the_2001_national_household_travel_survey/html/section_02.html.

[4] L'information co2 dcryptée pour vous. http://www.sncf.com/fr/train-emission-co2. Online; accessed 25 November 2017.

[5] Lco-missaire mne lenqułte. http://www.educasources.education.fr/fiche-detaillee-277281.html. Online; accessed 09 January 2018.

[6] Serious games and the future of education. https://www.forbes.com/sites/danieltack/2013/09/12/serious-games-and-the-future-of-education/#77ff4f7b679d.

[7] Sncf open data. https://data.sncf.com/explore/. Online; accessed 25 November 2017.

[8] Toutes les villes.com. http://www.toutes-les-villes.com/villes-population.html. Online; accessed 09 January 2018.

[9] D3js - map. http://www.datavis.fr/index.php?page=map-firststep, January 2017.

[10] M. Bostock. Grouped bar chart. https://bl.ocks.org/mbostock/3887051, December 2017. Online; accessed 04 January 2018.

[11] M. Bostock. Stacked bar chart. https://bl.ocks.org/mbostock/3886208, December 2017. Online; accessed 04 January 2018.

[12] M. C. de la nature. Sila, les nigmes du climat. https://nature.ca/sila/hm_f.cfm, September 2006. Online; accessed 09 January 2018.

[13] J. J. J.-P. Djaouti, Damien; Alvarez. Classifying serious games: the g/p/s model. http://www.ludoscience.com/files/ressources/classifying_serious_games.pdf, June 2015. Retrieved 26 June 2015.

[14] Google. Materialize.

[15] C. G. Healey. Choosing effective colours for data visualization. https://www.cs.ubc.ca/cgi-bin/tr/1996/TR-96-10.pdf, 1996.

[16] p. l. Kristian Kloeckl, X. Chen, C. Sommer, d. Carlo Ratti, and a. d. Assaf Biderman. Trains of data. http://senseable.mit.edu/trainsofdata/. Online; accessed 25 November 2017.

[17] MDDELCC. Un jeu-questionnaire sur les changements climatiques. http://www.mddep.gouv.qc.ca/jeunesse/jeux/questionnaires/climat/Questionnaire.htm. Online; accessed 09 January 2018.

[18] F. D. of Education. Le bulletin officiel de l'ducation nationale. http://cache.media.education.gouv.fr/file/MEN_SPE_11/67/3/2015_programmes_cycles234_4_12_ok_508673.pdf, November 2015. arrlt du 9-11-2015 - J.O. du 24-11-2015 (NOR MENE1526483A).

[19] C. K.-M. S. J. H. Sharon Lin, Julie Fortuna. Selecting semantically-resonant colors for data visualization. http://idl.cs.washington.edu/files/2013-SemanticColor-EuroVis.pdf, June 2013.

[20] B. Shneiderman and Aris. Network visualization by semantic substrates. ieee transactions. on visualization and computer graphics. Vol. 12, No. 5, pp. 733-740, 2006.

[21] M. Weigle. D3 scatterplot example. http://bl.ocks.org/weiglemc/6185069, June 2017. Online; accessed 09 January 2018.