# THE HANDY PROJECT

Project report

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2022-2023

# SUMMARY

# I. INTRODUCTION: THE MODEL & WHY WE CHOSE IT

Simulation tools and forecast models play a major role in the work of an engineer. In the environmental field, these allow one to design solutions for ecological issues. As SIE students, we are inescapably concerned about climate change and ecosystemic disruption. This is why we decided to base this programming project on the dynamics between human species and nature.

Firstly, we aimed to observe the correlation between social inequalities and environmental crisis, leading us to focus our work on the collapsological theory. Collapsology was introduced in 2015 by Pablo Servigne and Raphaël Stevens in their essay "*How everything can collapse: A manual for our times"*, referring to the study of collapsing risks of industrial and globalized civilization.
Then, our main goal is to create a simple simulation model, allowing anyone to have an insight on the impact wealth distribution and resources allocation can have on ecosystems.

Putting all those elements together, we took direct inspiration from NASA's work, which our project derives its name from: the HANDY model. We believe this model, mainly based on the predator-prey Volterra equations, was feasible to program and truly consistent with our project's perspective.
Moreover, we thought this work would be a great opportunity to challenge our programming skills: we were curious to see how far we could go in the creation of a simulation model initially created by a world-wide recognized space agency.
Overall, this "HANDY project" is a way for us to raise awareness about collapsology and different possible scenarios for the future of human civilization.

Through this project, we aim to evaluate the effect resources and wealth allocation have on civilization and nature. In a more global way, we are working on the question:

***To what extent are inequalities and nature depletion linked to a possible civilization collapse?***

# II. DEVIATIONS FROM PROJECT PROPOSAL

As the project went along, we were carried out to modify several elements. Indeed, given a certain time frame and our limited programming skills, we tried to permanently adapt our work, in order to keep a feasible and consistent project.

On the one hand, we had to drop off certain ideas.

Firstly, if we initially aimed to create our own human life evaluating factors, such as energy demand or food wasting, and implement them to the program, we eventually decided to stay restrain on the 10 parameters[1] created by Nasa. We took this decision because we felt those parameters were quite relevant and we preferred, given the deadline, to focus on the precise links between all of them, in order to really deepen our understanding of it.

Secondly, we planned to use the Runge-Kutta method to solve our differential equations in C. However, we did not follow this path; given the fact that we did not study it in our *Analyze III* course, we thought it might be quite a waste of time to use it. Instead, we worked with a more "traditional" tool, being the Euler method, also used by Nasa.

On the other hand, we introduced new unplanned elements to our project.

First, we greatly extended the graphical interface. At the beginning of the project, we imagined this interface as a single window showing a graph to exploit the results obtained with the equations and parameters chosen. Then, after working on the different variables and parameters, we realized the key-role of two of them: the nature's depletion factor $\delta$ (cf. d in the code), and the inequality factor $\kappa$ (cf. k in the code). Therefore, beyond showing a graph of results obtained by date set established before the simulation, we decided to create an interactive interface which could allow one to choose different values of $\delta$ and $\kappa$, which could have a major impact on the outcome, shown by the graph. This interface update includes different paths to orient the user to three different types of society (equitable, egalitarian and unequal), cursors and option to change the values of the two parameters just mentioned before, directly during the simulation process (not in the data set input before running the code).

Then, we also introduced a new variable which we did not mention in our proposal: the Carrying Capacity (CC), which represent in our project the number of Humans nature can carry. This factor, relying mainly on nature's depletion factor $\delta$, allows one to forecast possible collapse; therefore, we thought it would be a truly relevant element to add to our results, especially on our graphs. Moreover, we normalized the four core variables by the maximum CC value, calculated itself with an optimized value of $\delta$[2], in order to increase readability of the graphs.

Although we input multiple modifications in our project, we did not deviate from our main initial overall structure and concept.

[1] Those parameters are the following: Normal (minimum) death rate, Famine (maximum) death rate, Commoner birth rate, Elite birth rate, Subsistence salary per capita, Threshold wealth per capita, Regeneration rate of nature, Nature carrying capacity, Inequality factor and Depletion (production) factor

[2] In our code, $\delta^*$ , $\delta^{**}$, and $\delta^{***}$ depending on the type of society, refers to this optimized value.

# III. APPROACH USED

To code our Handy Model, we thought of a program using both Python and C.
Our simulation is designed as a sort of a game which apart from aiming to obtain the same results as Nasa's one, has the purpose to vulgarize the model.
Regarding the overall structure, we used Python for our graphical interface, and C for calculations.
A key part of our program is the ability for the user to play with the Carrying Capacity (CC) value, directly linked to the nature depletion factor $\delta$, by the following equation:

$\chi = \frac{g(\lambda\delta - \eta s)}{\delta^2}$ **(1)** ; solving this polynomial equation in $\delta$, we found: $\delta = \frac{g\lambda + \sqrt{(g\lambda)^2 - 4\chi\eta s g}}{2\chi}$ **(2)**

Because we found that $\delta$ had a major impact on the scenarios, and given (1) and (2), we thought it would be interesting to easily change $\delta$ value thanks to CC; moreover, CC can appear on the graph and serve as a normalization value for the population variables, whereas $\delta$ cannot.

## A. *Use of Python*

We mainly used Python language for the graphical interface, thanks to the ***tkinter*** library. We thought of our interface as three different windows, between which one can navigate, such as in a web site.
To start, one can run the file "RUN_HANDY.py" which calls the file "fen1.py", using os library. We heavily relied on this library to interact with the operating systems and making back and forth between Python and C files. Fen1 corresponds to the "Home" window, which describes the main features of our project, and orient the user, through few questions, to choose one of the three society types: Egalitarian, Equitable or Unequal.
Then, by pressing the button "Start", the program calls "HANDY_calculs.c", which according to the options chosen by the user (and so the values of the four main variables and the Carrying Capacity), make the calculation (see part B. Use of C below). This last file will generate a data ***txt*** file, called "python_results_file.txt", which we will be used to plot the scenario with typical initial parameters.
Next, "HANDY_calculs.c" calls "fen2.py" in order to display a second window with the graph of the typical scenario, and a CC cursor to allow one to plot other scenario graphs.
Finally, once another value of CC is chosen, "HANDY_calculs.c" calls "fen3.py" which displays the last window, with two graphs: the typical one and the one with the new CC value chosen. This allows to compare the different scenarios, to evaluate the impact of CC and to see the outcome of the scenario (collapse of reach of an equilibrium). The user can, at any moment of the simulation, go back to the first window using the "Home" button, or completely quit the program using the "Quit" button.

## B. *Use of C*

For our program, all the calculating part is carried with C language, in the file "HANDY_calculs.c".
Firstly, we use the Euler method to increment our four variables with time according to precise equations and parameters[3] below:

$$\begin{cases} \dot{x}_C &= \beta_C x_C - \alpha_C x_C \\ \dot{x}_E &= \beta_E x_E - \alpha_E x_E \\ \dot{y} &= \gamma y(\lambda - y) - \delta x_C y \\ \dot{w} &= \delta x_C y - C_C - C_E \end{cases}$$

*Figure 1 : HANDY « prey-predator » equations*

[3] For further information about those equations, please refer to the paper linked in the bibliography

Then, we use two standardizations: a first one, which consist of dividing Xe and Xc by the CC, and Y and W by the nature's capacity $\lambda$ to respect units, and a second one, which depending on the scenario, normalizes the variables by integers factors (set by intervals) in order to increase readability of graphics.

# IV. RESULTS – ANALYSIS & COMMENTS

The ultimate part of the project was to analyze the results of different scenarios found thanks to our program. Depending on the variables and parameters chosen, and so on the results obtained, we classified the scenarios according to three different society types: egalitarian, equitable and unequal, going from the least to the most realistic. In each set of scenarios, we start the simulation with typical parameter values and initial conditions (cf. Figure 2) below, (see in folder "Text" in our code); then, letting the user to vary the Carrying Capacity $\chi$.

| Parameter symbol | Parameter name | Typical value(s) |
|---|---|---|
| $\alpha_m$ | Normal (minimum) death rate | $1.0 \times 10^{-2}$ |
| $\alpha_M$ | Famine (maximum) death rate | $7.0 \times 10^{-2}$ |
| $\beta_C$ | Commoner birth rate | $3.0 \times 10^{-2}$ |
| $\beta_E$ | Elite birth rate | $3.0 \times 10^{-2}$ |
| $s$ | Subsistence salary per capita | $5.0 \times 10^{-4}$ |
| $\rho$ | Threshold wealth per capita | $5.0 \times 10^{-3}$ |
| $\gamma$ | Regeneration rate of nature | $1.0 \times 10^{-2}$ |
| $\lambda$ | Nature carrying capacity | $1.0 \times 10^{+2}$ |
| $\kappa$ | Inequality factor | 0, 1, 100 |
| $\delta$ | Depletion (production) factor | $\delta_{*}, \delta_{**}, \delta_{***}$ |

*Figure 2: table of typical parameters*

In each section bellow, the analysis consists of three main steps: comparing the graph obtained by the program to the one given by NASA's work, evaluating the importance of $\chi$ by establishing several "turning points", and look at the validity/limits of results given by the model.

## A. *Egalitarian Society*

The first society type is the Egalitarian type. This type models a society where there are only worker people, meaning that there is no elite; mathematically, we set $X_E = 0$.
In this sets of scenarios, we start with the following variables:

| | | |
|---|---|---|
| $X_C$ | Commoner population | $1.0 \times 10^{+2}$ |
| $X_E$ | Elite Population | 0 |
| **Y** | Nature | 100 |
| **W** | Accumulated wealth | 0 |

*Remark: in this sets of scenarios, setting the Elite population to 0 means that we do not pay attention to $\kappa$; it is directly also set to 0.*

For the "basic" scenario with the typical parameters value (cf. Figure 1), we obtained thanks to the model a ***soft landing to an optimal equilibrium***[4]. This outcome, which is clearly utopian, points out that the Commoner population reaches the Carrying Capacity, itself equaling its maximum value, at the end.

[4] Here, equilibrium refers to a scenario where it is possible for the society not to collapse, controlling its demography and nature depletion rate.

Then, by varying δ, we can observe different turning points. For example, setting $\chi = 0.4\ \chi_M$ will lower the Carrying Capacity (CC) and make the Commoner population oscillates before converging to the CC; we find ourselves facing **an oscillatory approach to equilibrium.**
Also, setting $\chi = 0.2\ \chi_M$ leads to an irreversible full collapse (type-N collapse)[5] ; this type of collapse allows us to see that over a certain threshold of nature depletion, it is unavoidable to get to a collapse.
Therefore, this first set of scenarios reflects this key-role δ plays into our HANDY model.

### B. *Equitable Society*

The second society type is the equitable one; in real life, this would model a highly communist society, in which resources are perfectly equitably allocated. In this sets of scenarios, we set Elite population to 25% of Commoner population, and both of those social classes are paid equally; we set $\kappa = 1$.

| | | |
|---|---|---|
| **$X_C$** | Commoner population | $1.0 \times 10^{+2}$ |
| **$X_E$** | Elite Population | 25 |
| **Y** | Nature | 100 |
| **W** | Accumulated wealth | 0 |

In this type of society, the typical scenario leads to a soft landing to optimal equilibrium. By changing value of the CC, we obtained several scenarios that were quite similar to the one in the case of an Egalitarian society. We also observed that in order to reach equilibrium, Commoner population had to be superior to the Elite population.
Finally, we were brought to question the following scenario (cf. Figure 3); indeed, we thought that the instant (vertical) variation of nature was not realistic. Unfortunately, even if we were able to consider this as a limit of the model, we could not manage to design a new way of making the Nature variable vary less drastically.

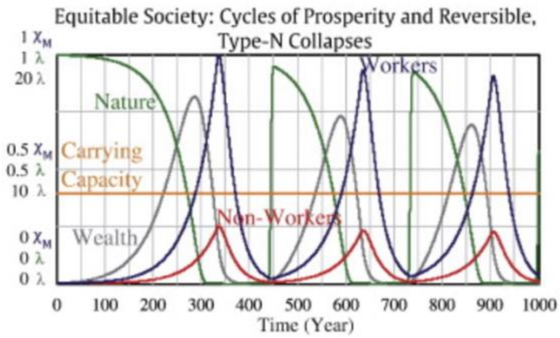


*Figure 3: plot of a reversible type-N collapse*

[5] Type-N collapse refers to a collapse where both Commoner population and nature equal 0 at the end of the scenario.

### *C. Unequal Society*

This third society type comes closest to our current industrial and globalized society. Here, we set particular value for both populations, with Elite population approximately ten times less than Commoners. Also, we set for a typical values' scenario, we set $\kappa$ = 100 in order to clearly see the impact of social inequalities through salary difference.

| | | |
|---|---|---|
| **$X_C$** | Commoner population | $1.0 \times 10^{+4}$ |
| **$X_E$** | Elite Population | $3.0 \times 10^{+3}$ |
| **Y** | Nature | 100 |
| **W** | Accumulated wealth | 0 |

With this set of scenarios, we see that it is difficult to reach an equilibrium; we either achieve a type-L collapse (due to a scarcity of labor, both population collapse but nature does not), or full type-N collapse (both nature and humans fall to zero).
We believe that setting a lower value of $\kappa$ (for example $\kappa$=10), controlling birth rate or increasing the value of the CC (equivalent to decrease $\delta$) could lead to an equilibrium.

# V. CONCLUSION

Overall, this HANDY project has allowed us to have an insight on the impact social inequalities and distribution of resources can have on society. Furthermore, we understand better how the four variables, being the Workers, Non-workers, Nature and Wealth work together, thanks to several mathematical equations. Our model has shown us how it is possible de prevent a possible civilization's collapse, thanks to an additional factor: the Carrying Capacity. Indeed, our project brings to light the fact that modifying the carrying capacity had a direct strong impact on the way nature was depleted by humans, and vice versa. From this perspective, our answer to the key question addressed before would be the following:

**Inequalities and nature depletion are unescapably strongly linked; with increase of social disparities increases nature depletion. In a societal model such as the current occidental one, the HANDY model shows that the population and social inequalities is largely above the Maximum Carrying Capacity, and so has not the ability to escape a future collapse.**

However, this final statement is to be nuanced. Indeed, the Handy model sometimes does not simulate completely realistically simulate nature, and does not consider many factors, such as repartition of food, energy demand, carbon cycle, etc…
Therefore, the results given by our model remains forecasts and are certainly quite distanced from the real future that awaits our civilization.

As a final word, we truly enjoyed working on this project. It was a real opportunity to explore many aspects of programming, in addition to highly developed our coding skills and understanding of Python and C. Furthermore, having the ability to lead this project as we wish was very stimulating, as we could profit from our autonomy and let our creativity speak. The HANDY project is surely a first step into our environmental engineer career.

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