USER MANUAL

Laboratório Projeto II

May 2022

Instituto Superior de Engenharia do Porto
Licenciatura em Engenharia Informática

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Introduction

This user manual was made with the aim to help the employees and users to better understand how the application works and how to use it. It contains every single step on how to use every single feature and has some explanations for a better comprehension of it. This report also has a troubleshooting section where are reunited the possible errors that may occur during the usage of the application and how to solve them.

This application is a software used to easily manage a vaccination process in any country by any health service. With this application the citizen can easily schedule a vaccine and the employees of the health service can easily manage everything that is happening on the center, so it turns the vaccination process more efficient and faster.

To use the app, it is advised that the system has at least 4GB of RAM and can be run on any Operating System as long as JAVA 8 is installed.

The app is not published anywhere, so to have access to it, the user needs to request it directly to the development team. To run the application, open the folder of the project and follow the instructions that are on the file HOW_TO_RUN.txt.

1. Glossary

- ➔ Administrator (ADM)
- ➔ Nurse (NRE)
- ➔ Receptionist (REP)
- ➔ Center Coordinator (CEC)
- ➔ SNS User (SUS)
- ➔ Direção Geral da Saúde (DGS)

2. Roles

Many employees will be able to use this application, with many different roles, so the system is divided by each role. Each role has its own characteristics and specific tasks, so inside its own menu, there are only the tasks that the specific role can perform and its not possible to perform any task from any other role, unless the employee has credentials from another role to use the app.

The roles present on this application are:

a. Administrator (ADM)
   Administrator is responsible for configuring and managing the core information (e.g.: type of vaccines, vaccines, vaccination centers, employees) required for this application to be operated daily by the employees and SNS Users.

b. Nurse (NRE)
   Nurse is responsible for treating the SNS User.

c. Receptionist (REP)

Receptionist is responsible for scheduling SNS User vaccine administration and register them on the system.

d. Center Coordinator (CEC)
Center coordinator has the responsibility to manage the Covid19 vaccination process and monitors the same.

e. SNS User (SUS)
SNS User uses the app to schedule a vaccine.

f. DGS (DGS)
DGS uses the app to manage the vaccination process details.
To make easier to understand what each role can do, the table below was made.

Action / Role	ADM	NRE	REP	CEC	SUS	DGS
Register a SNS User			X			
Register a Vaccination Centre	X					
Register an Employee	X					
Get a list of Employees with a given role	X					
Register a vaccine type	X					
Register a vaccine and its vaccination process	X					
Schedule a vaccine					X	
Schedule a vaccination			X			
Register the arrival of a SNS User			X			
Consult the users in the waiting room		X				

Load a set of users from a csv file	X					
Get a list of all vaccines				X		
Record daily the total number of people vaccinated						X
Record adverse reactions of a user		X				
Record the administration of a vaccine to a SNS User		X				
Check and export vaccination statistics				X		
Analyse the performance of a centre				X		
Import data from a legacy system				X		

Table 1- Table of Actions per Role

Each cross is connecting the role with the task it can perform and the roles initials present are specified above the table.

3. Running the Application

Starting the application, is done by opening the executable present in this folder, and the explanation of how to do it is on the HOW_TO_RUN.txt file present in this same folder.

After opening the app, a menu will appear with 2 different options, as seen in the image below, and one option should be chosen.

3.1 Login

To do the login, it's needed to choose the option "Login" on the Main Menu, and after that a user login and password will be asked to the user and should be inserted by himself. The logins of employees are created by the administrator of the application and the SNS User ones, are created by the Receptionist.

It is impossible to use the application if the user has not any credentials. After inserting the credentials on the application, there are two possible endings, one is operation success and the other one is operation unsuccess. If operation is done successfully a menu with the specific role options will appear, and if not, the user has 3 more tries to login before the program suspends the login function for failing to login too many times. After logging in it is possible to return to the main menu by choosing the option "Return" on the menu before starting to perform any task.
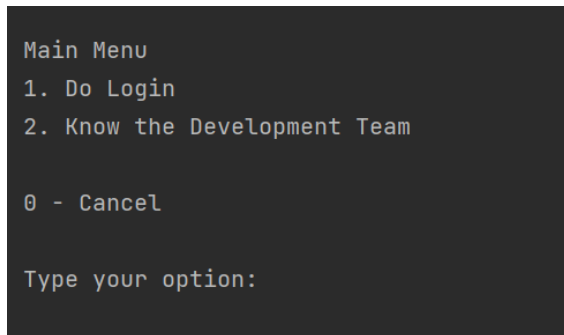
Figure 2 - Main Menu (Console)
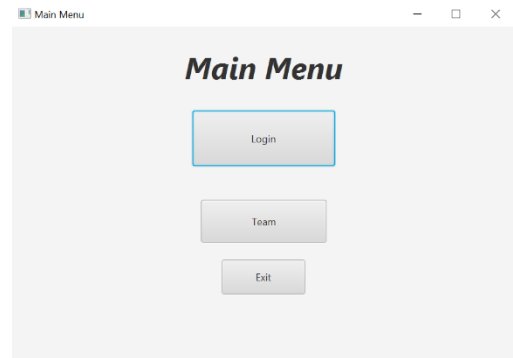
Figure 1 - Main Menu (UI)
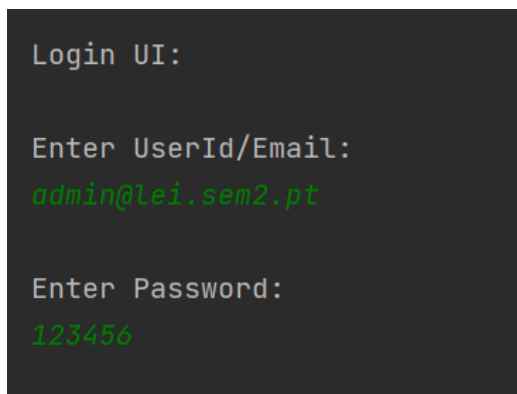
Figure 4 - Login Menu (Console)
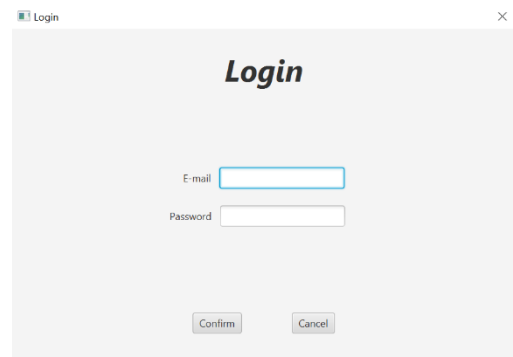
Figure 3 - Login Menu (UI)

3.2 Know the Dev Team

To see who worked and made the application, the user should choose the option "Know the Dev Team" on the Main Menu and after that a list of members that made the application will appear on the screen. It is presented the name and email of each developer on the screen. As said before there is an option on the menu to return to the Main Menu, if wanted.

```
Development Team:
    Tiago Miguel Soares Ribeiro- 1202054@isep.ipp.pt
    Vicente Cardoso - 1180664@isep.ipp.pt
    João Rodrigues - 1210817@isep.ipp.pt
    Bruna Cunha - 1191702@isep.ipp.pt
    Diogo Carvalho - 1200611@isep.ipp.pt
```

Figure 5 - Know the Dev Team Screen

4. Necessary Registrations

In order to perform registrations in the program, the user must be logged in with their account. Details on how to log into the program can be found in "2.1 Login". Certain registrations can only be performed by specific user roles. For example, only administrators can register new employees into the system. As such, each registration case will have an abbreviation (ex.: ADM) to indicate which type of employee can perform that registration.

4.1 How to register an employee [ADM]

After logging into an administrator account, the program will present a menu labelled "Administrator Menu", where it's possible to select one of multiple options corresponding to different administrator tasks, as well as a "Return" option (this option is used to return to the previous menu, and it is also used in other menus inside the program). To register an employee, select the option labelled "Employee" by typing 2 into the console and pressing ENTER.

```
Admin Menu:
1. Vaccine Type
2. Employee
3. Vaccine
4. Vaccination Center
5. Import CSV
6. Import User Entries
7. Register a User Entry

0 - Cancel

Type your option:
|
```

Figure 6 - Administrator Menu

The following menu will appear, showcasing the "Employee Menu". This time, select the option "Register a new employee" by pressing 1 and ENTER.

```
Menu
1. Register a new employee
2. Show existing employees
3. Show list of receptionists
4. Show list of nurses
5. Show list of administrators
6. Show list of coordinators

0 - Cancel

Type your option:
```

Figure 7 - Employee Menu

A new menu (pictured below) will now ask to select what is the role of the still-to-be created employee. There are four choices of employee roles: Receptionist, Nurse, Coordinator and Administrator. Select which role the employee will have by pressing a key from 1 to 4 and then ENTER.

```
Choose the type of employee.
1. Receptionist
2. Nurse
3. Adminstrator
4. Coordinator
```

Figure 8 - Employee Role Selection Menu

The next menu will ask the program user to introduce the information pertaining to the employee that will be registered. This information includes the employee's name, citizen card ID number, home address, email address, phone number, username, user ID and password. It is important to remember that the phone number needs to be a 9-digit number, or else the program will ask to input all the information again. To introduce the employee information, start by introducing the employee's name, then pressing "ENTER". Repeat for all the employee attributes. After all the information is inputted, the program will show the newly introduced employee information and asking to confirm if it's correct. When it's confirmed that all the information is correct, select the "Yes" option by pressing 1 and then ENTER.

```
Check data:
Name: John Doe, Citizen Card ID Number: 111111111
Address: Example Street, 111, Example City, Email: johnsmith@gmail.com, Phone Number: 111111111
User name: JohnSmith, User ID: 111111, Password: password
Do you want to save?
1. Yes
2. NO
|
```

Figure 9 - Confirmation of Employee Information

Finally, a message will inform that the employee information was saved successfully. The employee is now registered in the system. If instead an error message appears, the operation was unsuccessful, and the employee was not registered. See "Troubleshooting" for more information.

4.2 How to register a Vaccination Center [ADM]

To start the process of registering a vaccination center, select the "Vaccination Center" option on the "Administrator Menu" by pressing 4 and ENTER. On the new menu, select the option labelled "Create a new vaccination center".

```
Vaccination Center Menu
1. Create a new Vaccination Center
2. Show existing Vaccination Centers

0 - Cancel

Type your option:
|
```

Figure 10 - Vaccination Center Menu

The next menu will require you to input the information regarding the vaccination centre that is going to be registered. The information needed to be inputted includes the centre's name, phone number, physical address, email address, website link, fax number, the opening and closing hours, slot duration (in minutes) and the maximum number of vaccines that can be given per slot. To introduce the vaccination center information, start by introducing the vaccination center's name, then pressing "ENTER". Repeat for all the vaccination center attributes. Once all the information has been introduced, a new menu will ask you to confirm the information. When confirmed, select the "Yes" option.

```
Check data:
The Vaccination center name is Center 1, phone is 111111111 and fax is 111111111,
Do you want to save?
1. Yes
2. NO
|
```

Figure 11 - Confirmation of Vaccination Center Information

If the operation was successful, a message will pop up informing the vaccination centre was successfully registered into the system. If instead an error message appears, the operation was unsuccessful, and the vaccination centre was not registered. See "Troubleshooting" for more information.

4.3 How to register a Vaccine Type [ADM]

To start the process of registering a vaccine, select the "Vaccine Type" option on the "Administrator Menu" by pressing 1 and ENTER. On the new menu, select the option "Specify a new vaccine type".

```
Menu
1. Specify a new vaccine type
2. Show existing vaccine types


0 - Cancel


Type your option:
|
```

Figure 12 - Vaccine Type Menu

The next menu will require you to input the information regarding the vaccine type that is going to be registered. The information needed to be inputted includes the vaccine type's code, designation and its WHO ID. Once all the information has been introduced, a new menu will ask you to confirm the information. When confirmed, select the "Yes" option.

```
Check data:
Code: 1111, designation: Designation, whowID: 1111
Do you want to save?
1. Yes
2. NO
|
```

Figure 13 - Confirmation of Vaccine Type Information

If the operation was successful, a message will pop up informing the vaccine type was successfully registered into the system. If instead an error message appears, the operation was unsuccessful, and the vaccine type was not registered. See "Troubleshooting" for more information.

4.4 How to register a Vaccine [ADM]

To start the process of registering a vaccine, select the "Vaccine" option on the "Administrator Menu" by pressing 3 and ENTER. A new menu will appear with a list of vaccine types already registered into the system. Select the desired vaccine type for the vaccine that is going to be registered by pressing the key with the corresponding number and then ENTER.

```
----------------------
1)
Your designation is designation1, WhoID is 111111 and code is 111111
----------------------
2)
Your designation is designation2, WhoID is 222222 and code is 222222
Choose the vaccine type number.
```

Figure 14 - List of Vaccine Types

The next window will require you to input the information regarding the vaccine that is going to be registered. The information needed to be inputted includes the vaccine's name, brand, dosage and number of doses. It is also required to select an age group for the vaccine. These age groups include "Child" (for users between the ages of 5 and 12), "Young" (for users between the ages of 13 and 18) and "Adult" (for users over the age of 18). Once all the information has been introduced, a new window will ask you to confirm the information. When confirmed, select the "Yes" option. If the operation was successful, a window will pop up informing the vaccine was successfully registered into the system. If instead an error message appears, the operation was unsuccessful, and the vaccine was not registered. See "Troubleshooting" for more information.

```
Do you want to save?
1. Yes
2. NO
1
Successfully saved.
The name of the vaccine is Vaccine1 and your brand is
```

Figure 15 - Confirmation and Display of Vaccine Information

5. Application Features

5.1 How to import a set of users [ADM]

After logging into the program as an administrator, select the option "Import CSV" in the Administrator Menu by pressing 5 and then ENTER.

In the new menu, select the option "Import CSV file".


```
Menu
1. Import CSV file
2. Show users


0 - Cancel


Type your option:
|
```
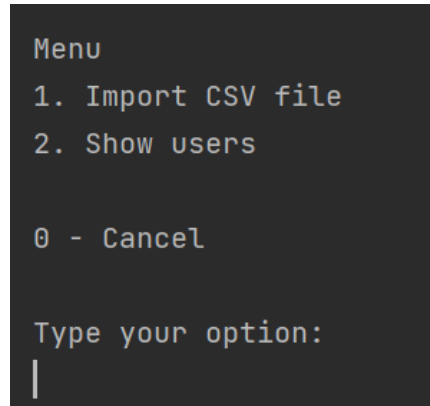
Figure 16 - Import CSV Menu

The program will now ask to introduce a path for the csv file to be saved into. The path needs to be introduced in the following format: "C:\folder\file.csv". After it is introduced, the file will be downloaded into the computer. If an error message appears instead, it was not downloaded.

5.2 How to register a vaccine administration [NRE]

After logging in as a nurse, in the Nurse Menu, select the option "Vaccine Administration" by clicking the button labelled as such. A new window will pop up labelled "Vaccine Administration". On the top left corner is an option called "Vaccine". Clicking it will open a submenu where you need to click the option "vaccinate". Alternatively, you can press the CTRL and N keys on the keyboard instead of clicking the "vaccinate" option.
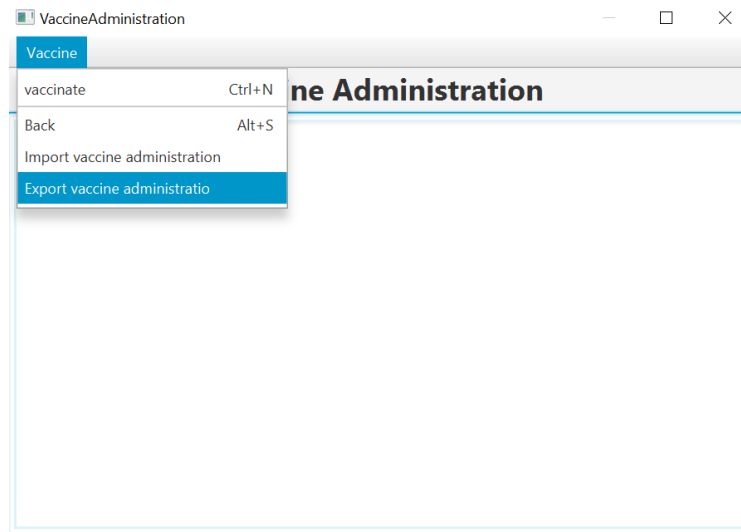
Figure 17 - Vaccine Administration Menu

In the next window, the nurse is required to input the information regarding the vaccine administration. A list of available users appears on the bottom right, whereas on the bottom left there is a list of vaccines to choose from, ordered by brands. The receptionist selects the user and the vaccine with the appropriate number. There also needs to be introduced the dose and lot number. When all the information is introduced, the receptionist needs to click the "Ok" button to save the vaccine administration. If the user does not show up on the list on the bottom right, the receptionist can click on the "Atualizar" button to refresh the list and the user should now appear on the list.
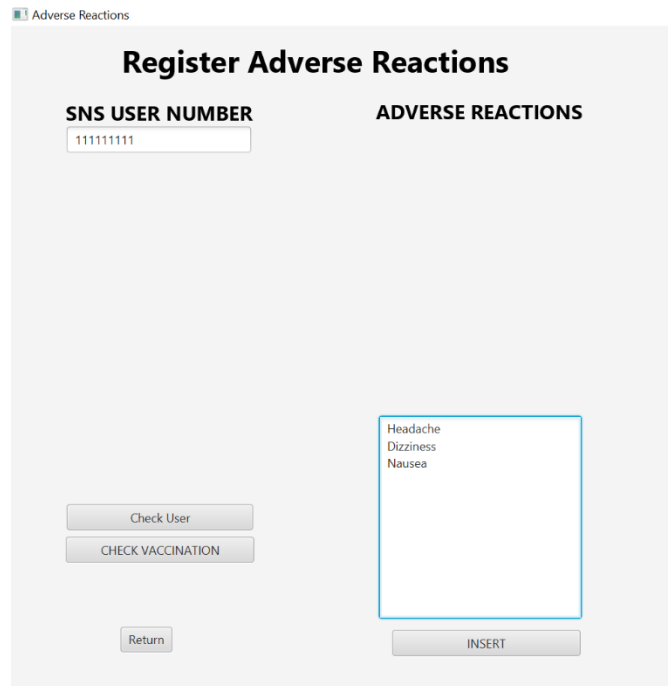
Figure 18 - Vaccine Administration Information Input

5.3 How to register adverse reactions occurred during the vaccine administration [NRE]

The first steps of the process are identical to the previous section (5.2). Instead of selecting "Vaccine Administration" in the Nurse Menu, the receptionist should now select "Adverse Reactions" by clicking the button labelled as such.

On the new window labelled "Register Adverse Reactions", the nurse needs to input the user's SNS number on the text box on the left. Afterwards, the nurse needs to verify if the user is registered in the system and also if they are vaccinated, which can be done by clicking the buttons "Check User" and "CHECK VACCINATION" respectively. If an error message appears when clicking "Check User, then either the user is not yet registered in the system, or the number introduced is invalid (the SNS number is 9 digits). Alternatively, if an error message appears when clicking "CHECK VACCINATION", then the user is not vaccinated yet. Therefore, there can't be any adverse reactions registered for that user.

If both checks are approved, the nurse can now introduce the reactions that occurred during the vaccination process inside the text box on the right. Finally, clicking the "INSERT" button will save the information introduced.

Figure 19 - Adverse Reactions Menu

5.4 How to register an SNS user [REP]

Firstly, log in as a receptionist. Afterwards, to register a user, it is required to input various information. If the log in information inserted is not the required, an error will be thrown. The receptionist will have 3 tries to log in.

Figure 20 - Login Receptionist

After inserting this information, the receptionist will have to add various information regarding the SNS user, such as Name, phone number, address, their email, birthday, sex, and finally their SNS Number and their citizen card number. The SNS number needs to have 9 digits and citizen card number 8. If this is not met their will be an error message.

Figure 21 - SNS User Info

After all the information is registered by the receptionist, a message is shown with all the information regarding the newly registered SNS user. There will be an option to save this information.

Figure 22 - SNS User Info - Save

5.5 How to register the arrival of an SNS user to take the vaccine [REP]

As a receptionist there is also the option to register the arrival of SNS user, just to take a vaccine. This means that the user as already been registered into the system.

Figure 23 - Register or List User Entry

Afterwards a menu appears to choose if the receptionist wants to register a new SNS User into the system so he can take the vaccine. Choose the option "Register new User Entry". If the receptionist chooses option 2, then a list of Users that have entered and been registered is shown.

Figure 24 - List User Entries

First, the receptionist will insert the SNS number and their time of arrival on the center. The system will then verify if and when this user has taken the vaccine, because there cannot be duplicate entries for the same vaccine period. If not then it will show which dosage and which type of vaccine the user will take, and the receptionist will inform the user of all this information. Then all the receptionist must do is confirm the information.

6. Data Analysis and Report [CEC]

To start the exporting data process, it is first needed to login as a Center Coordinator. After logging in, there is only one option available, that is to export the data to a csv file. Pressing that button will trigger the download of said file with the requested data.
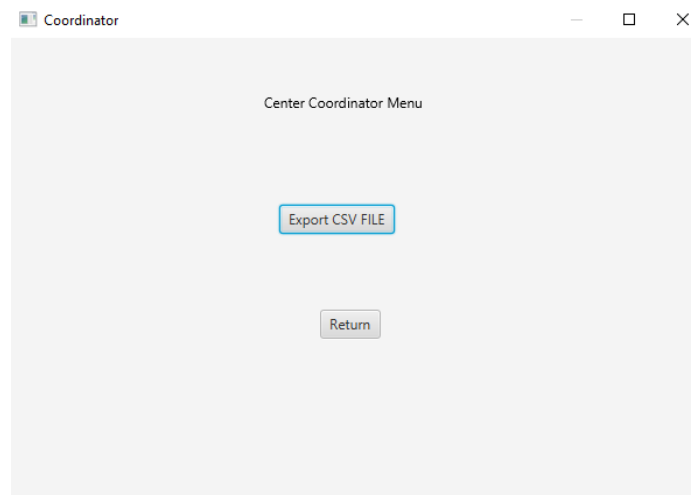
Figure 25 - Coordinator Menu

The user can choose to export the file or return to the login menu. If he chooses to export the file, a pop-up message will appear regarding the state of the action: a success message if done correctly, and an error message if not.
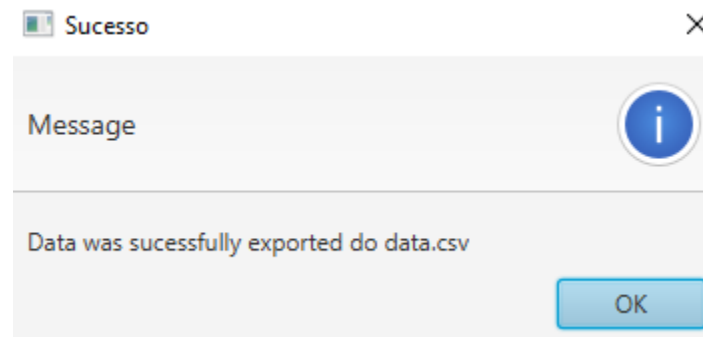
Figure 26 - Data Export Success Message

7. FAQ's

Question: I cannot log into the program. Why?

Answer: You need to be registered in the system to be able to log in. If you can't log in, then you haven't been registered yet. Contact an Administrator to make sure that your account is registered.

Question: When registering a vaccine, the program asks me to select a vaccine type, but there are none. What do I do?

Answer: If the list of vaccine types is empty, then you cannot register a vaccine, since vaccines need to be linked to a vaccine type. You need to register the vaccine type first and only then can you register a vaccine.

Question: Why is the list that I requested from the program empty?

Answer: If a list is empty then the related data isn't registered. For example, if the list of vaccine types is empty then there are no vaccine types yet registered in the system.

Question: My question is not in here. What can I do now?

Answer: In the program's homepage, before you log in, there is an option labelled "Know the Dev Team". There you can find the names and contact information of the development team behind the program. You can contact them if you have any questions regarding the program that are not answered in the User Manual.

8. Troubleshoot

Problem: Vaccination Centre creation error. [ADM]

Cause: Invalid data insertion

How to solve: Make sure that every data inserted is correctly inserted and if it follows the rules of creation of a new Vaccination Centre. The Vaccination Centre name cannot be null; the address cannot be null; the phone number cannot be null, must have specifically 9 digits and must be a number; the email cannot be null; the fax cannot be null and must have specifically 9 digits and must be a number; the website cannot be null; opening hours must be a number and cannot be null and the same applies for closing hours and slot duration.

Problem: Register a SNS User error. [REP]

Cause: Invalid data insertion

How to solve: Make sure that every data inserted is correctly inserted and if it follows the rules of creation of a new SNS User. The name of the SNS User cannot be null; Birth date cannot be null and should follow the following model (DD-MM-YYYY); Sex cannot be null; Address cannot be null; Phone number cannot be null, must be a number and have specifically 9 digits; SNS User number cannot be null, must be a number and have specifically 9 digits; Citizen card number cannot be null, must be a number and have specifically 8 digits.

Problem: Register a User Entry error. [REP]

Cause: Missing Vaccination Center or Invalid data insertion

How to solve: Make sure there is a vaccination center registered. After making sure a vaccination center is registered, make sure you choose one of them correctly by inserting the name of the center on the console and pressing ENTER and then the system will ask you to insert the SNS User data and it must complain with the rules presented in the solution present in the error above.

Problem: Register a Vaccine Type error. [ADM]

Cause: Invalid data insertion

How to solve: Make sure that every data inserted is done correctly. It should follow the following rules: The code cannot be null and must have 4 to 8 characters specifically; The designation and WHO ID cannot be null.

Problem: Register a Vaccine error. [ADM]

Cause: Invalid data insertion or missing Vaccine Type

How to solve: Firstly, check if there is a vaccine type registered or not, otherwise, it will not be possible to create a vaccine. After making sure a vaccine type is registered, it will be needed to check if the information is inserted correctly and follows these rules: Name cannot be null; Brand cannot be null.

Problem: Not showing the list of Vaccine Types. [ADM]

Cause: No Vaccine Types were registered or saved

How to solve: Make sure at least one Vaccine Type was registered and that it was saved, after inserting the data.

Problem: Register an Employee error. [ADM]

Cause: Invalid data insertion

How to solve: Make sure that every data inserted is done correctly. It should follow the following rules: The name cannot be null; Address cannot be null; Phone number cannot be null, must be a number and have specifically 9 digits; Email cannot be null; Citizen card number cannot be null, must be a number and have specifically 8 digits; Password cannot be null; User Name cannot be null;

Problem: Not showing the list of Employees or list of Employees of a specific role. [ADM]

Cause: No employees were registered or saved

How to solve: Make sure at least one Employee was registered and that it was saved, after inserting the data and for the specific role printing, make sure that a employee with that specific role was registered and save before trying to show the list of them.

Problem: Not showing the list of Vaccination Centers. [ADM]

Cause: No Vaccination Centers were registered or saved

How to solve: Make sure at least one Vaccination Center was registered and that it was saved, after inserting the data.

Problem: Importing CSV with Users file error. [ADM]

Cause: Path to file not found

How to solve: Make sure the path to the file where data is going to be imported is correct. It should follow the example: "C:\folder\folder\file".

Problem: Not showing users from the imported CSV file. [ADM]

Cause: No CSV file imported or CSV file empty

How to solve: Make sure a CSV file was imported before and that it was not empty.

Problem: Cannot show the waiting list of a vaccination center ordered. [NRE]

Cause: No Vaccination Center registered or no User Entry in the waiting room list

How to solve: Make sure a Vaccination Center was registered previously and there are User Entries on the waiting room list associated to a Vaccination Center.

Problem: Cannot register a vaccine administration. [NRE]

Cause: No User Entry registered, or data inserted incorrectly

How to solve: Make sure a User Entry is registered before trying to register a vaccine administration and that data is inserted correctly following these rules: User Entry must be chosen using the number correspondent to it on the list; Vaccine must be chosen using the number correspondent to it on the list; Lot cannot be null; Dose cannot be null.

Problem: Cannot register Adverse Reactions. [NRE]

Cause: No Vaccine Administration registered or SNS User not found

How to solve: Make sure a Vaccine Administration was registered previously and that the SNS User number insert is valid from a registered SNS User that has taken a vaccine.

Problem: Cannot export data to a CSV file. [CEC]

Cause: Path to file not found

How to solve: Make sure the path to the file where data is going to be exported is correct. It should follow the example: "C:\folder\folder\file".

---

9. Conclusion

In conclusion, this User Manual compiles every feature of the application and how to use every single one. There is also a troubleshoot and a FAQ area where are answered some of the most recurrent problems and questions that the application user may have. That being said, this application aims to make easier the management of the vaccination process of a country, during a pandemic outbreak or not, and help their users work efficiently with simple registrations and commands and for the citizens to schedule vaccines easily.

We, the development team, hope our application users have the best experience they could have using the application, and we made our best to explain every single feature and possible errors that it could have, and we are open for suggestions and for any question needed, as our contacts will be present in the front cover of this user manual.

10. Annexes

11.1 MATCP

In this annex we are going to talk about Simple Linear Regression and Multiple Linear Regression.

10.1.1 First Approach Simple Linear Regression

In Simple Linear Regression two known variables are related, being one of them dependent and the another is independent, whose behaviour is known. It is simpler to take decisions when we can relate these.

The Simple Linear Regression can be defined as the equations or mathematic model shown below.

$$Y_i = E(Y|x_i) + \varepsilon_i$$
$$Y_i = a + bx_i + \varepsilon_i$$

Figure 27 - Mathematic model

To solve our problems, we used the expression below, where $\alpha + bx_i + \varepsilon i$ is the deterministic component, where α is the y-interception and b the slope. Both α and b need to be determined. Finally, x_i is the value of the observation i of the independent variable, and Yi it is the dependent aleatory variable.

It was asked to apply simple linear regression to study the statistics from a vaccination centre, where there are present 2 dependent variables and 6 independent variables. The 2 dependent variables are "new cases" and "new deaths", and the 6 independent variables are "reproduction rate", "ICU patients",

"hospitalized patients", "new tests", "positive rate" and "people fully vaccinated". These variables have data related to the vaccination centre statistics between 01/02/2021 and 31/05/2021.

Firstly, the objective is to fulfil the Anova table where all the calculations made are together and it becomes easier to make the hypothesis tests and get the other data that are needed. The Anova table is the one shown below.

Fonte de variação	Soma de quadrados	Graus de liberdade	Média quadrática	Estatística de de teste f
Regressão	SR	1	$MSR = \frac{SR}{1}$	$\frac{MSR}{MSE}$
Erro	SE	$n-2$	$MSE = \frac{SE}{n-2}$	
Total	ST	$n-1$		

Figure 28 - Anova Table

In this table "SR" represents the explained variation, "SE" represents the non-explained variation and "ST" it is total variation. "SR" is calculated by the sum of the squares of deviations explained by regression, "SE" is calculated by the sum of the squares of the residues (adjustment errors) and "ST" it is the sum of the previous values, therefore ST = SR + SE. In the column of liberty degrees "n" represents the number of observations and on square average column MSR and MSE represent the average of the "SR" and "SE" respectively.

$$SR = \sum_{i=1}^{n} \left(\hat{Y}_i - \bar{Y} \right)^2$$

Figure 29 - Equation to calculate SR

$$SE = \sum_{i=1}^{n} \left(Y_i - \hat{Y}_i \right)^2$$

Figure 30 - Equation to calculate SE

$$ST = \sum_{i=1}^{n} \left(Y_i - \bar{Y} \right)^2$$

Figure 31 - Equation to calculate ST

Once the table is constructed, it is necessary to calculate the Coefficients of Determination, also called R², is a measure of the fit of a generalised linear statistical model.

The R² varies between 0 and 1, sometimes being expressed in percentage terms. In this case, it expresses how much of the variance of the data is explained by the linear model. Thus, the higher the R², the more explanatory is the linear model, i.e., better it fits the sample, providing a better correlation coefficient, R, which should range between $-1 < r < 1$.

$$R^2 = \frac{S_{xy}^2}{S_{xx}S_{yy}}$$

$$R = \frac{S_{xy}}{\sqrt{S_{xx}}\sqrt{S_{yy}}}$$

Figure 32 - Correlation Coefficient

Figure 33 - Coefficients of Determination

To calculate the S_xx, S_yy and S_xy it was used the following expressions:

$$S_{xx} = \sum_{i=1}^{n}(x_i - \bar{x})^2 = \sum_{i=1}^{n} x_i^2 - n\bar{x}^2$$

$$S_{yy} = \sum_{i=1}^{n}(y_i - \bar{y})^2 = \sum_{i=1}^{n} y_i^2 - n\bar{y}^2$$

$$S_{xy} = \sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y}) = \sum_{i=1}^{n} x_i y_i - n\bar{x}\bar{y}$$

Figure 34 - Sum of squares and crossed sum

The n is the number of observations and the $\bar{x}$ and $\bar{y}$ are the mean of the observable values of the independent and dependent variables, respectively.

From these expressions it is possible to define Confidence Intervals and Hypothesis Tests.

Confidence interval of a parameter is an interval in which we have some confidence that it contains the true value of the parameter. We call this confidence level or degree of confidence level or degree of confidence.

$$\left]\hat{a} - t_c s\sqrt{\frac{1}{n} + \frac{\bar{x}^2}{S_{xx}}}, \hat{a} + t_c s\sqrt{\frac{1}{n} + \frac{\bar{x}^2}{S_{xx}}}\right[\qquad\qquad \left]\hat{b} - t_c s\sqrt{\frac{1}{S_{xx}}}, \hat{b} - t_c s\sqrt{\frac{1}{S_{xx}}}\right[$$

Figure 35 - Confidence Intervals

Hypothesis tests or significance tests are statistical parameters which allow making a decision (accept or reject the null hypothesis H0) between two or more hypotheses (null hypothesis H0 or alternative hypothesis H1), using the data observed from a specific experiment. These can be performed using confidence intervals.

$$H_0 : a = a_0 \ \ v.s. \ \ H_1 : a \neq a_0 \qquad\qquad H_0 : b = b_0 \ \ v.s. \ \ H_1 : b \neq b_0$$

$$T_a = \frac{\hat{a} - a_0}{S\sqrt{\frac{1}{n} + \frac{\bar{x}^2}{S_{xx}}}} \sim t_{n-2} \qquad\qquad T_b = \frac{\hat{b} - b_0}{S/\sqrt{S_{xx}}} \sim t_{n-2}$$

Figure 36 - Hypothesis tests expressions

10.1.2 Applying Simple Linear Regression

As already mentioned, the data where we will apply RLS will be in tables to estimate the number of new cases and numbers of deaths using information on Reproduction Rate, Number of ICU Patients, Number of Inpatients, Number of New Cases, Positive Rate and the Number of Fully Vaccinated Persons.

Each of the observations and estimations (day and week) should be done following the following criteria:

1- each independent variable and each dependent variable.

In this sense, in our study we contrued the Anova tables and the dispersion diagrams of the observations and as we can observe in this specimen, there is a strong indication that the set of points does not, disperse until 2000 new cases and then disperse randomly on a straight line.
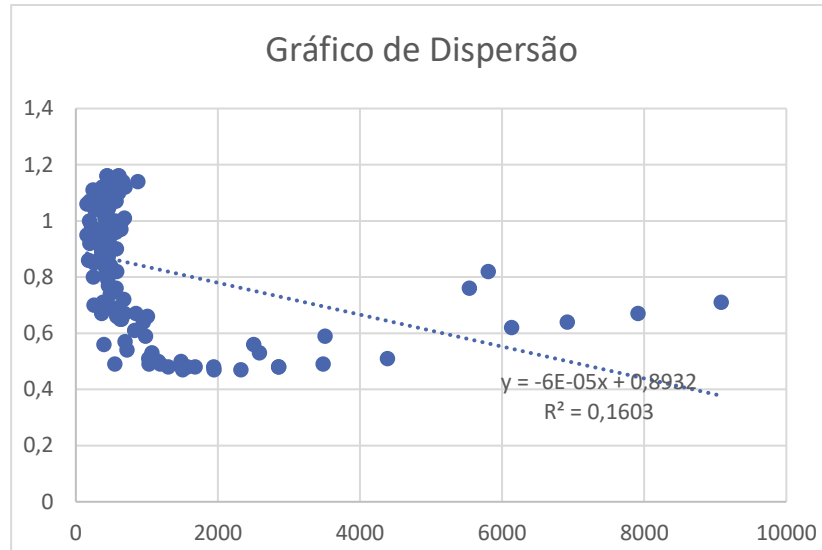
Figure 37 - Dispersion Graph

On the other hand, when we look at the following graph, which refers to observations, we find a greater dispersion of values at 2000 new cases.
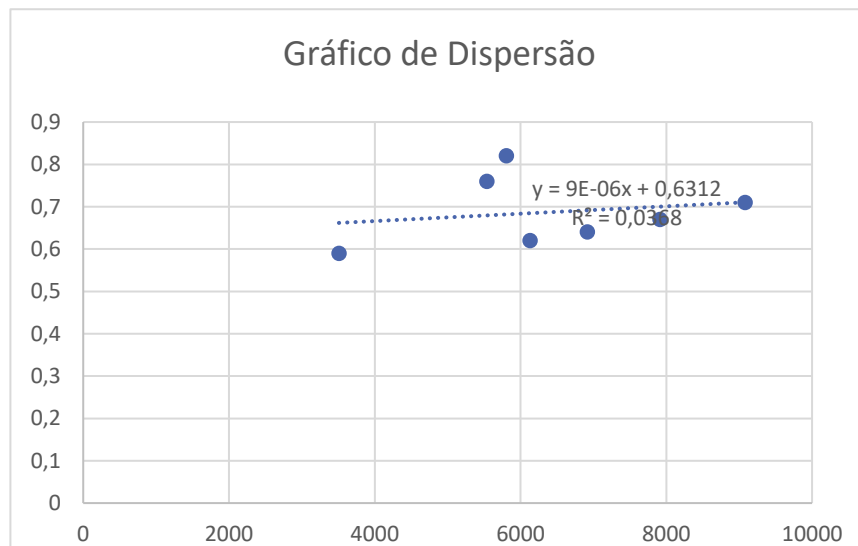
Figure 38 - Dispersion Graph

Anova table to be constructed as follows for daily and weekly calculations, respectively:

ANOVA				
Fonte de Variação	Graus de Liberdade	Soma dos Quadrados	MQ	Estatística de F
Regressão	1	0,920998802	0,9209988	22,53418149
Residual	118	4,822800364	0,04087119	
Total	119	5,743799167		

Figure 39 - Anova Table

Estatística de Teste	
Tb = (b̂ - b) / (S / RAIZ(Sxx))	
Tb =	-4,7470

Figure 40 - Test Statistics

Here we can observe the value of f_0 and compare it with the null hypothesis and conclude that as f_0 > -4.7470 the hypothesis was rejected, agreeing that the regression model is linear.

ANOVA				
Fonte de Variação	Graus de Liberdade	Soma dos Quadrados	MQ	Estatística de F
Regressão	1	0,001468253	0,001468253	0,190808076
Residual	5	0,038474604	0,007694921	
Total	6	0,039942857		

Figure 41 - Anova Table

H(0) : b = 0	vs	H(1) : b ≠ 0
Estatística de Teste		
Tb = (b̂ - b) / (S / RAIZ(Sxx))		
Tb =	0,4368	

Figure 42 - Test Statistics

However, to verify the truthfulness of the significant model, the correlation coefficient is calculated. In our model we obtained the following value:

Sxx=	285780855,9
Syy=	5,743799167
Sxy=	-16223,55775

r^2 =	0,16034662	R=	-0,400433045

Figure 43 - Correlation coefficients for the models

it is possible to conclude that the regression model, which has the number of tests performed as independent variable, is the least significant, since it is farthest from 1. On the other hand, we can observe in the figure below that the degree of significance is higher since f_0 is smaller when compared with the correlation coefficient.

Sxx=	19284682
Syy=	0,039942857
Sxy=	168,27

r^2 =	0,036758839	R=	0,191725946

Figure 44 - Correlation coefficients for the models

Moving on to the calculation of the **Confidence Interval**, as we intend to estimate the true value of "a" and "b" we use the function of sums of squares and cross sums where we obtain the following values for daily and weekly calculations:

â=	0,89324347
b̂ =	-5,6769E-05

$$\hat{a} = \bar{y} - \hat{b}\bar{x}$$

$$\hat{b} = \frac{S_{xy}}{S_{xx}}$$

â=	0,631176999
b̂ =	8,72558E-06

Figure 45 - a and b values

For the confidence interval regression model, 90% and 95% confidence level for parameter "a" and "b" were used. Below we can observe the results for each of the values:

I.C. (95%) =	[0,8560 ; 0,9305]
I.C. (90%) =	[0,8488 ; 0,9377]

I.C. (95%) =	[0,3645 ; 0,8979]
I.C. (90%) =	[0,2910 ; 0,9714]

Figure 46 - Confidence intervals: model

Finally, to explain the explanatory capacity of the model for parameter "a" and "b", with significance levels of 1% and 5%, we used the test statistics Ta and Tb to confirm its rejection:

Firstly, we can observe the rejection of model significance for both percentages of observations made daily but different from this when we move to making exactly the same observations weekly we conclude that for the critical region T_b does not reject for H_0.

Região critica				
a = 0,01 e 0,05				
a = 0,01	tc = t 0,995(118)	2,618136914	RC=]-∞ ; -2,6181[U] 2,6181 ; +∞[	**Rejeita-se Tb para (H0)**
a = 0,05	tc = t 0,975(118)	1,980272249	RC=]-∞ ; -1,9803[U] 1,9803 ; +∞[	**Rejeita-se Tb para (H0)**

Figure 47 - Critical Region (Daily)

Região critica				
a = 0,01 e 0,05				
a = 0,01	tc = t 0,995(5)	4,032142984	RC=]-∞ ; -4,0321[U] 4,0321 ; +∞[	**Não se rejeita-se Tb para (H0)**
a = 0,05	tc = t 0,975(5)	2,570581836	RC=]-∞ ; -2,5706[U] 2,5706 ; +∞[	**Não se Rejeita Tb para (H0)**

Figure 48 - Critical Region (Weekly)

10.1.3 Multiple Linear Regression

The multiple linear regression model is an extension of the simple linear simple linear regression model. It allows describing a relationship between a set of independent quantitative independent variables, X_j (j=1,2,...,J), and a quantitative dependent variable, Y. The aim will be to build a model that fits the data better than the simple linear regression model.

As we saw earlier, the **simple linear regression model** considers only one independent variable, "X", $\alpha + bx_i + \varepsilon i$, whereas the **multiple linear regression model** considers two or more independent variables, X1 and X2:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_k X_k + \varepsilon$$

Figure 49 - Mathematic model

- Y - random variable response
- ε - random variable error
- $\beta_0, \beta_1, \beta_2,..., \beta_k$ are the regression coefficients
- $\beta_1, \beta_2,..., \beta_k$ represent the change in response Y per unit change in Xj when we assume as constant the remaining explanatory variables.

This regression type also has a matrix form:

$$Y = X\beta + \varepsilon$$

Figure 50 - Matrix model

Having the all the matrices presented in the following

$$\mathbf{Y} = \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{bmatrix}, \mathbf{X} = \begin{bmatrix} 1 & x_{11} & x_{12} & \vdots & x_{1k} \\ 1 & x_{21} & x_{22} & \vdots & x_{2k} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ 1 & x_{n1} & x_{n2} & \vdots & x_{nk} \end{bmatrix}, \boldsymbol{\beta} = \begin{bmatrix} \beta_0 \\ \beta_1 \\ \vdots \\ \beta_k \end{bmatrix}, \boldsymbol{\varepsilon} = \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_n \end{bmatrix}$$

Figure 51 - Important matrices

The objective is to fulfill the Anova table where all calculations done are together and it becomes easier to do the hypothesis tests the confidence intervals and other data that are needed. In this sense, Anova table that follows is composed as follows:

Fonte de variação	Soma de quadrados	Graus de liberdade	Média quadrática	Estatística de de teste f
Regressão	SQ_R	k	$MQ_R = \frac{SQ_R}{k}$	$\frac{MQ_R}{MQ_E}$
Erro	SQ_E	$n-(k+1)$	$MQ_E = \frac{SQ_E}{n-(k+1)}$	
Total	SQ_T	$n-1$		

Figure 52 - Multiple Anova Table

Where "SQR" represents the measurement of the dependent variable variation explained by the model, "SQE" the measurement of the variation not explained by the model, "SQT" the measurement of the total variation of observations around the mean, "k" the number of independent variables, "n" the number of observations, "MQR" and "MQE" represent the average of the "SQR" and "SQE" respectively and "f" represents the rejection criterion.

$$SQ_T = Y^T Y - \frac{\left(\sum_{i=1}^{n} y_i\right)^2}{n} = Y^T Y - n\bar{y}^2$$

$$SQ_R = \hat{\boldsymbol{\beta}}^T X^T Y - n\bar{y}^2$$

$$SQ_E = Y^T Y - \hat{\boldsymbol{\beta}}^T X^T Y$$

Figure 53 - Sum of Squares

Once the Anova table has been constructed, which allows us to reject or accept H0 for the significant model, the need arises to verify this veracity by calculating the coefficient of determination and the closer it is to 1 the better.

The way to calculate the termination coefficient:

$$R^2 = \frac{SQ_R}{SQ_T} = 1 - \frac{SQ_E}{SQ_T} \qquad R^2_{ajust.} = 1 - \frac{\frac{SQ_E}{n-(k+1)}}{\frac{SQ_T}{n-1}} = 1 - \left(\frac{n-1}{n-(k+1)}\right)(1 - R^2)$$

Figure 54 - Determinant coefficient expression

From this it is possible to obtain the Confidence Interval and the Hypothesis Tests.

Confidence Interval

Among many possibilities to determine the confidence interval, for our observations, we have chosen the following formula:

$$\left]\hat{\beta}_j - t_{1-\alpha/2}[n-(k+1)]\sqrt{\hat{\sigma}^2 C_{jj}} \ , \hat{\beta}_j + t_{1-\alpha/2}[n-(k+1)]\sqrt{\hat{\sigma}^2 C_{jj}}\right[$$

Figure 55 - Confidence interval expression

        o

- o $\hat{\beta}_j$ – is the X of the matrix of the vector of regression coefficient estimators.

- o $t_{1-\alpha/2[n-(k+1)]}$ – value possible to get through the t-student distribution table.

- o $\hat{\sigma}^2 = MQ_E$ – is the variance.

- o C_{jj} – j - is the element j of the main diagonal of the matrix.

Hypothesis Test

A hypothesis test for the regression coefficients βj's follows the procedure below:

$$H_0 : \beta_j = 0$$
$$H_1 : \beta_j \neq 0$$

Estatística de teste : $T_0 = \dfrac{\hat{\beta}_j}{\sqrt{\hat{\sigma}^2 C_{jj}}}$

Critério de rejeição: $|t_0| > t_{1-\alpha/2,\, n-(k+1)}$

Figure 56 - Hypothesis tests form and expression

It is necessary to make the hypothesis and then calculate the test statistic using the expression. Once this is done, the result, f_0, should be compared with f-α (k,n-k+1) and this concept is obtained through the F-Snedcor distribution using its table. If f_0 is greater, hypothesis 0 is rejected allowing the conclusion that regressor xj has explanatory power, if it is not rejected, H0 allows the conclusion that regressor xj can be "eliminated".

10.1.3.1 Applying Multiple Linear Regression

It was asked to apply multiple linear regression to study the statistics from a vaccination centre, where there are present 2 dependent variables and 6 independent variables. The 2 dependent variables are "new cases" and "new deaths", and the 6 independent variables are "reproduction rate", "ICU patients", "hospitalized patients", "new tests", "positive rate" and "people fully vaccinated". These variables have data related to the vaccination centre statistics between 01/02/2021 and 31/05/2021.

This apply should be within the following requirements:

- All six independent variable and e each dependent variable
- Three selected variables and each dependent variable

1. All six independent variable and e each dependent variable

To determine the fitted model, we start by calculating the vector of least squares estimators:

$$\hat{\beta} = (X^T X)^{-1} X^T Y$$

2,08274E-10		8,6402E-12
1		-3,46945E-17
-1,21503E-12		1
-1,42791E-10		-4,93117E-12
-5,8975E-13		-7,93809E-15
3,59712E-14		-1,249E-16
5.55112E-17		2.60209E-18

Figure 57 - Least squares estimator

And in this sense, we obtain the vector of estimators of the regression coefficients, consequently the model, as we can observe below:

Y1= 2,08274E-10 + 1X1 -1,21503E-12X2 - 1,42791E-13X3 + 3,59712E-14X5 + 5,55112E-17X6

Y2= 2,08274E-10 + 1X1 -1,21503E-12X2 - 1,42791E-13X3 + 3,59712E-14X5 + 5,55112E-17X6

We apply the hypothesis test in order to find the "SQR" "SQE " and "SQT", located in the column of the sum of squares, and summarize the Anova table as follows:

Fonte de variação	Soma dos quadrados	GL	Média quadrática	Estatística de teste		F_tabela
Regressão	285780855,9250	6	47630142,6542	1,627E+14		2,1798
Erro	3,30806E-05	113	2,92748E-07			
Total	285780855,9250	119				Como f0>f, regeita-se H0: Modelo significativo

Figure 58 – Model Anova Table

Looking at the table, we find that f_0 = 1,627E+14 for Y1 and f_0 = 3,40729E+14 for Y2.

Fonte de variação	Soma dos quadrados	GL	Média quadrática	Estatística de teste		F_tabela
Regressão	524434,5917	6	87405,7653	3,40729E+14		2,1798
Erro	2,89874E-08	113	2,56526E-10			
Total	524434,5917	119				Como f0>f, regeita-se H0: Modelo significativo

Figure 59 - Model Anova Table

Considering an $\alpha = 0,05$, we obtain $f\_0.05(118) = 2,1798$. Since $f\_0 > 2.1798$, we reject H_0, we reject both hypothesis tests which allows us to conclude that this regression model is significant.

We then calculate the coefficient of determination and the fitted, which is given by:

Coeficiente de determinação			Coeficiente de determinação	
r^2=	1,0000		r^2=	1,0000
r^2_aj=	1,0000		r^2_aj=	1,0000

The Confidence Interval at 95% and 90% for the Beta1 correlation coefficients are given by:

Intervalo de confiança (95%)

$$\left]\hat{\beta}_j - t_{1-\alpha/2}[n-(k+1)]\sqrt{\hat{\sigma}^2 C_{jj}} \; , \hat{\beta}_j + t_{1-\alpha/2}[n-(k+1)]\sqrt{\hat{\sigma}^2 C_{jj}}\right[$$

$\widehat{\beta 1} =$	2,08274E-10
$\hat{\sigma}^2 = MQ_E =$	2,92748E-07
$C_{11} =$	1,680341467
tc =	1,98
I.C =	]-0,0014 ; 0,0014[

Intervalo de confiança(90%)

$\widehat{\beta 1} =$	2,08274E-10
$\hat{\sigma}^2 = MQ_E =$	2,92748E-07
$C_{11} =$	1,680341467
tc =	1,66
I.C =	]-0,00116427106592835 ; 0,00116427148247693[

Figure 60 - Confidence intervals model

Finally, we perform the hypothesis tests to check if it is possible to admit that the regression coefficient beta_1 different 0 with a significance level of 1% and 5%.

$\alpha = 0,05$

Teste de Hipóteses	
H0:b1=0	
H1:b1=/=0	
tc=	1,98
t0	4,16159E-07
Como t0<tc não se pode rejeitar H0. Pode-se eliminar b1.	

Figure 61 - Hypothesis Test

$\alpha = 0,01$

Teste de Hipóteses	
H0:b1=0	
H1:b1=/=0	
tc=	2,62
t0	4,16159E-07
Como t0<tc não se pode rejeitar H0. Pode-se eliminar b1.	

Figure 62 - Hypothesis Test

In this sense as, t_0<t_c one cannot reject H_0, that is, one can eliminate beta_1.

2. Three selected variables and each dependent variable

To determine the fitted model, we start by calculating the vector of least squares estimators:

$$\hat{\beta} = (X^TX)^{-1}X^TY$$

-632,5111	-4,5643
1070,8717	4,0417
-5,7293	-0,1968
1,5809	0,0616

Figure 63 - Least squares estimator

And in this sense, we obtain the vector of estimators of the regression coefficients, consequently the model, as we can observe below:

Y1= -632,5111 + 1070,8717X1 -5,7293X2 + 1,5809X3

Y2= -4,5643 + 4,0417X1 -0,1968X2 – 0,0616X3

We apply the hypothesis test in order to find the "SQR" "SQE " and "SQT", located in the column of the sum of squares, and summarize the Anova table as follows:

Fonte de variação	Soma dos quadrados	GL	Média quadrática	Estatística de teste		F_tabela	
Regressão	236799718,4269	3	78933239,4756	186,9343		2,6828	
Erro	48981137,4981	116	422251,1853				
Total	285780855,9250	119				Como f0>f, regeita-se H0: Modelo significativo	

Figure 64 - Model Anova Table

Fonte de variação	Soma dos quadrados	GL	Média quadrática	Estatística de teste		F_tabela	
Regressão	514125,8990	3	171375,2997	1928,4244		2,6828	
Erro	10308,6927	116	88,8680				
Total	524434,5917	119				Como f0>f, regeita-se H0: Modelo significativo	

Figure 65 - Model Anova Table

Looking at the table, we find that f_0 = 186,9343 for Y1 and f_0 = 19.

Considering an α = 0, 05, we obtain f_0.05(118) = . Since f_0 > 2.1798, we reject H_0, which allows us to conclude that this regression model is significant.

We then calculate the coefficient of determination and the fitted, which is given by:

Coeficiente de determinação	
r^2=	0,8286
r^2_aj=	0,8242

Coeficiente de determinação	
r^2=	0,9803
r^2_aj=	0,9798

The Confidence Interval at 95% and 90% for the Beta1 correlation coefficients are given by:

Intervalo de confiança (95%)

$$\left]\hat{\beta}_j - t_{1-\alpha/2}[n-(k+1)]\sqrt{\hat{\sigma}^2 C_{jj}} \ , \hat{\beta}_j + t_{1-\alpha/2}[n-(k+1)]\sqrt{\hat{\sigma}^2 C_{jj}}\right[$$

$\widehat{\beta 1} =$	-632,5111
$\hat{\sigma}^2 = MQ_E =$	422251,1853
$C_{11} =$	1,6477
tc =	1,98
I.C =	]-2284,0459 ; 1019,0237[

Intervalo de confiança(90%)

|	
$\widehat{\beta 1} =$	-4,5643
$\hat{\sigma}^2 = MQ_E =$	88,8680
$C_{11} =$	1,6477
tc =	1,66
I.C =	]-24,6514 ; 15,5228[

Figure 66 - Trust Intervals

Finally, we perform the hypothesis tests to check if it is possible to admit that the regression coefficient beta_1 different 0 with a significance level of 1% and 5%

$\alpha = 0, 05$

Teste de Hipóteses		
H0:b1=0		
H1:b1=/=0		
tc=	1,98	
t0	0,76	
Como t0<tc não se pode rejeitar H0. Pode-se eliminar b1.		

Figure 67 - Hypothesis Test

$\alpha = 0, 01$

Teste de Hipóteses		
H0:b1=0		
H1:b1=/=0		
tc=	1,66	
t0	0,38	
Como t0<tc não se pode rejeitar H0. Pode-se eliminar b1.		

Figure 68 - Hypothesis Test

11. Webgraphy

https://moodle.isep.ipp.pt/pluginfile.php/198741/mod_resource/content/6/Teo%CC%81rica%207_2122.pdf

https://moodle.isep.ipp.pt/pluginfile.php/198745/mod_resource/content/6/Teo%CC%81rica%208_2122.pdf

12. Images References