



# User Manual

## DGS Vaccination Manager

The Forty One ®

## **User Manual**

### DGS Vaccination Manager

**Developed by** The Forty One

#### **Contents & Review**

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# 1. Glossary

<b>Terms, Expressions and Acronyms</b>	<b>Description</b>
ACES	Acronym for “Agrupamento de Centros de Saúde” (Group of Health Centers).
Adverse Reaction	An unexpected or unintended effect suspected to be caused by a vaccine.
Administrator	The person with this role registers entities into the system, such as centers, SNS Users, center coordinators, receptionists and nurses enrolled in the vaccination process.
ARS	Acronym for “Administração Regional da Saúde” (Regional Health Administration).
Asymptotic behaviour	Describes how a function behaves near a limit.
Brute Force Algorithm	A straightforward method of solving a problem that relies on sheer computing power and trying every possibility rather than advanced techniques to improve efficiency.
Center Coordinator	The person who manages and monitors the vaccination process.
Community Mass Vaccination Center	Facility created to answer an ongoing outbreak with the vaccination.
Contiguous Subsequence	Is a subsequence made up of consecutive elements of a list.
CSV	Acronym for “Comma-separated values”. It is a file which is a delimited text file that uses comma to separate values.

## 1. Glossary

DGS	Acronym for “Direção Geral da Saúde” (General Health Direction).
Health Care Center	Facility that provides medical and sanitary services.
MLR	Stands for multiple linear regression.
Nurse	Health profession that administers vaccines.
Receptionist	A person responsible to monitor visitors' entrance.
Recovery Period	A period where the patient is recovering from eventual vaccine symptoms.
Recovery Room	The room where the patient waits for their recovery period.
Slot	For a specific amount of time, the maximum number of vaccines that can't be over past.
SLR	Stands for simple linear regression.
SNS	Acronym for “Serviço Nacional de Saúde” (National Health System).
SNS User	Person who uses the SNS services (The same as patient).
SNS User Number	Identifying number of the client in the SNS.
Vaccination Center	Facility that provides conditions for people to get vaccinated.
Vaccine	Is a clinical/laboratory preparation that offers immunity to a particular infectious disease.
Vaccine Type	A specific type of vaccine.

## 1. Glossary

Waiting Room	The room where the SNS Users wait for their scheduled appointment.
Worst-case Time Complexity	The upper boundary of the runtime: it's the algorithm performance given the worst inputs, which means it will never get worse than that, no matter what inputs you throw at the algorithm.

## 2. Introduction

### 2.1. Purpose and Scope

The main goal of this User Manual is to assist the user in using the DGS Vaccination Manager application. In this document, you will find a detailed instructive tutorial for every single feature of the application. It was made to help all users who use the system, by explaining how to do every task, step by step, as well as to help them solve any kind of trouble they find when using the application. This document also answers questions that can appear when using the app.

This user manual is addressed to any type of user, from the SNS user to the system administrator. Using simple language and illustrative images, it is aimed at people of all ages and levels of knowledge.

### 2.2. System Overview

This application was designed to easily support the management of the vaccination system. The application was developed for different kinds of users that have their purpose to use the application. Each type of user has its view of the application, and they can only access the features destined for them. There are five types of users: SNS Users, Receptionists, Nurses, Center Coordinators, and Administrators.

The SNS user is the person that schedules and which vaccines are administered. The accessible app feature of SNS users is:

- Scheduling vaccines.

The Nurse is who is responsible to administer the vaccine and record it into the system. The accessible app features of Nurses are:

- Checking the SNS users in the waiting room.
- Record SNS users' adverse reactions to a vaccine.
- Record SNS users' vaccine administration.

The Receptionist is responsible to check the SNS users' appointments to see if they can take their vaccines. The accessible app features of Receptionists are:

- Scheduling vaccines for SNS users.
- Registering new SNS users.
- Registering SNS users' arrival at a vaccination center.

The Center Coordinator is responsible to coordinate the vaccination center. The accessible app features of Coordinators are:

## 2. Introduction

- Import data from a legacy system.
- Listing all the vaccines.
- Check and export vaccination statistics.
- Analyze his center's performance.

The Administrator is responsible for configuring and managing the core information required in the vaccination system. The accessible app features of Administrators are:

- Registering vaccination centers.
- Registering employees (Nurses, Receptionists and Center Coordinators).
- Checking the employees.
- Registering vaccine types.
- Registering vaccines and their administration process.
- Loading a set of SNS users from a file.

To see the diagram of all the roles features, [\[please see Annex C\]](#).

### 2.3. System Requirements

To run this application, it is required that your system meets the following requirements:

- Intel Pentium @ 1.0 GHz or better;
- 1 GB RAM or more;
- At least 10 mb of disk space;
- Java Runtime Environment version 8.0 or superior.

### 2.4. Install and Set-Up

To run this application, you will need to install the Java Runtime Environment in your system. To do this, you need to download it from its official website. You will find that there are multiple versions for different operating systems. As a conventional user, you may want to select the "Windows" version and the x64 installer; for power users, please install Java version 8.0 or newer.

The installer will walk you through the steps required to successfully install the Java Runtime Environment.

After the installation, to start the application, you will need to double-click the *run.bat* file - this will open the console and a Graphical User Interface (if defined in the configuration properties file).

## 3. Navigating in the App

### 3.1. Log In

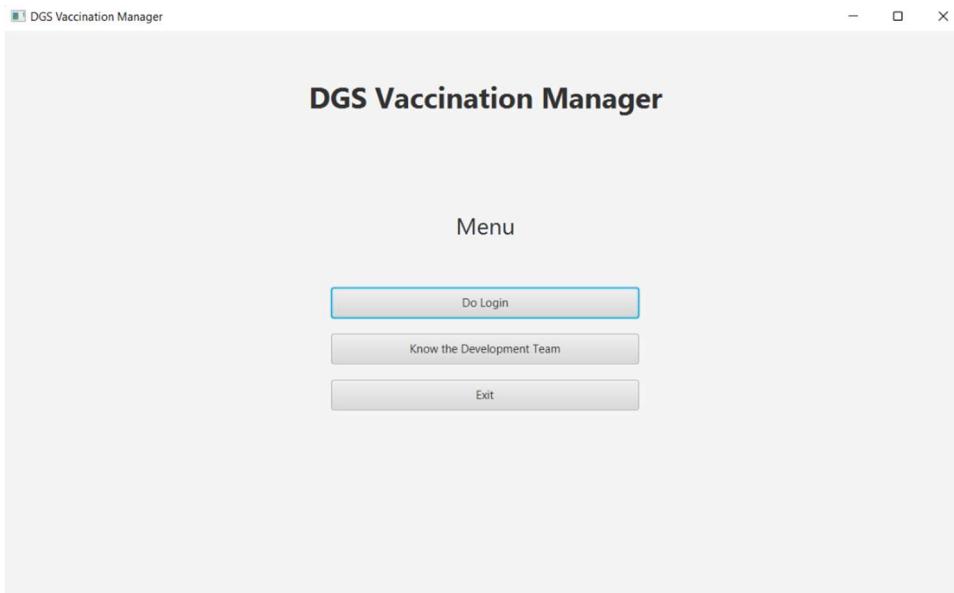
To access all features of the application, you first need to log in to it, using the credentials given to you by the system administrator.



#### Important

For logging in, users need to be registered in the system. Only administrators can register users (Please see chapter 4).

For logging in, first, start the application. Next, on the Welcome page, click in “Do Login”.



Picture 1 - Welcome page of the application

Finally, enter your email and password, and then click on the “Log in” button.

### 3.2. Menu Navigation

After logging in, you can start using the system. The application is organized in menus, having each user role a different menu, depending on their permissions.

In the following table, you can check the different roles that users can have, as well as a full list of their accessible features by their respective menus.

### 3. Navigating in the App

User Role	Permissions/Accessible Features
Administrator	Register Employees; Register Vaccination Centers; Register Vaccine Types; Register Vaccines; Register SNS Users from File; List Employees
Center Coordinator (Employee)	<u>Consult Vaccination Statistics</u> ; <u>Analyse Vaccination Centers Performance</u> ; <u>Import Data from File</u>
Receptionist (Employee)	Register SNS Users; Schedule Vaccines; Register SNS Users Arrival
Nurse (Employee)	List Users in Waiting Room; <u>Register Adverse Reactions</u> ; <u>Register Vaccine Administrations</u>
SNS User	Schedule Vaccines

Table 1 - Accessible features for each user role

Although the Login page and all menus use a graphical interface for interacting with the user, due to technical requirements some options are only accessible by a command-line interface. In the table above, features accessible using a graphical interface are underlined.

### 3.3. Menu Bar

While navigating the app you may notice a bar appearing in almost every screen. This bar is an easy and quick way to have access to some key features of the application at any point.



File   About   Help

Picture 2 - Menu bar

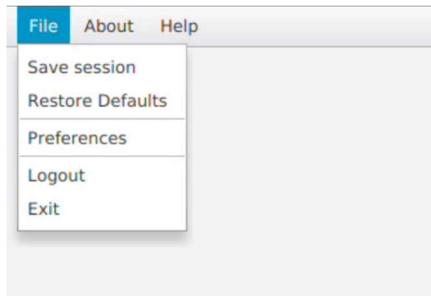
As seen in the previous section, users with different roles have access to different features in the application. The menu bar is no exception, the features are different according to the role the user is logged on.

One of the most important features of this bar is the “Help” tab, that contains a helper text for every screen if you have any doubt about the purpose of the feature you are accessing.

### 3. Navigating in the App

#### 3.3.1. Administrator

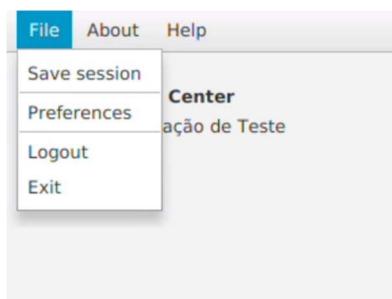
As the main role in the app, the administrator has access to all features in the menu bar. The main difference to all the other roles is the ability to restore the session to default values. [\[Please see chapter 4\]](#)



Picture 3 – Administrator's menu bar

#### 3.3.2. Coordinator

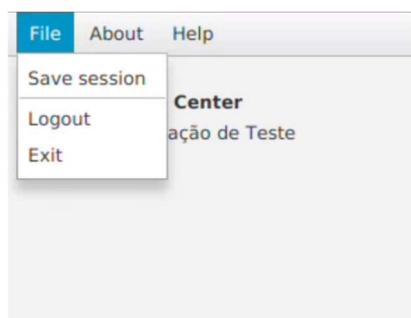
The main feature of the coordinator menu bar is the ability to open the preferences file in the notepad application of the system. When clicking this option, the notepad will open in the system configuration file in order to make changes to the file. [\[Please see chapter 4, section 4.1\]](#)



Picture 4 - Coordinator's menu bar

#### 3.3.3. Employee

The employee menu bar is the simplest one of all, with access to less features. It has only a quick way to access many features of the system.



Picture 5 - Employee's menu bar

# 4. Configurations & Data Persistence



## Important

This chapter is about sensitive data only accessible to administrators and coordinators.

### 4.1. Configurations

In the application directory there is a file named *config.properties* and another called *config.properties.example*. These files are used to configure some features of the application.

These files must be edited manually using a text editor, in the coordinator's and administrator's menu bar [Please check chapter 3, section 3.3] it is possible to find an option named "Preferences" that opens the system's default text editor (notepad for Windows, gedit for Linux and open for MacOS) in order to make the access to the file easier.

```

DGS Vaccination Manager
File About Help
Menu admin@user.com ADMINISTRATOR
config.properties
Open Save
1 Company.Designation = DGS/SNS Portugal
2 OngoingOutbreak.Designation = COVID-19
3 OngoingOutbreak.VaccineTypeCode = 00000
4 Notification.Sender = app.service.sender.ConsoleSender
5 Environment.Test = true
6 LegacyData.SortingAlgorithm = app.service.sorting.OptimizedBubbleSort
7 VaccinationRecordPeriod = 30
8 Environment.UI = gui
9 Algorithm.Performance = Benchmark
10 DailyVaccinated.ExportationTime = 11:36
11 DailyVaccinated.FilePath = out/docs/DailyVaccinatedByCenter-
12 DailyVaccinated.FileSeparator = ;
13 Init.AutoDeserialize.Enabled = false

```

Picture 6 - config.properties as seen on Linux

```

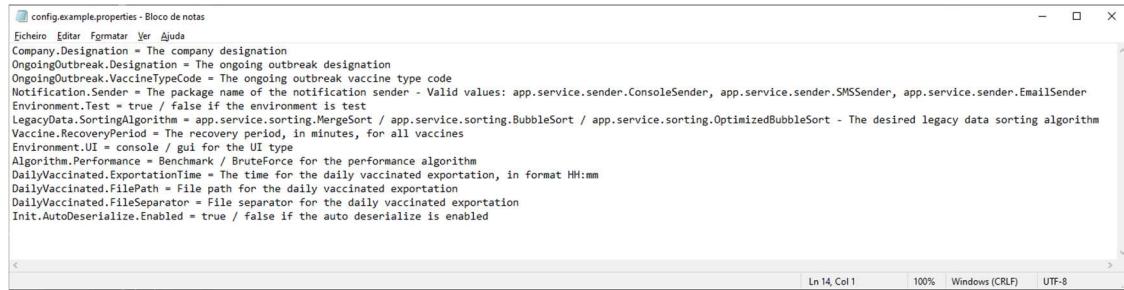
DGS Vaccination Manager
File About Help
Vaccination Center config.properties - Bloco de notas
Company.Designation = DGS/SNS Portugal
OngoingOutbreak.Designation = COVID-19
OngoingOutbreak.VaccineTypeCode = 00000
Notification.Sender = app.service.sender.ConsoleSender
Environment.Test = true
LegacyData.SortingAlgorithm = app.service.sorting.OptimizedBubbleSort
VaccinationRecordPeriod = 30
Environment.UI = gui
Algorithm.Performance = Benchmark
DailyVaccinated.ExportationTime = 11:36
DailyVaccinated.FilePath = out/docs/DailyVaccinatedByCenter-
DailyVaccinated.FileSeparator = ;
Init.AutoDeserialize.Enabled = false

```

Picture 7 - config.properties as seen on Windows

#### 4. Configurations & Data Persistence

In order to make changes to the file it is important to know the format and constraints that are applied to each line. For that there is a file named *config.properties.example* with comprehensive examples for the use of each line.



```
config.example.properties - Bloco de notas
Archivo Editar Formato Ver Ayuda
Company.Designation = The company designation
OngoingOutbreak.Designation = The ongoing outbreak designation
OngoingOutbreak.VaccineTypeCode = The ongoing outbreak vaccine type code
Notification.Sender = The package name of the notification sender - Valid values: app.service.sender.ConsoleSender, app.service.sender.SMSender, app.service.sender.EmailSender
Environment.Test = true / false if the environment is test
LegacyData.SortingAlgorithm = app.service.sorting.MergeSort / app.service.sorting.BubbleSort / app.service.sorting.OptimizedBubbleSort - The desired legacy data sorting algorithm
Vaccine.RecoveryPeriod = The recovery period, in minutes, for all vaccines
Environment.UI = console / gui for the UI type
Algorithm.Performance = Benchmark / BruteForce for the performance algorithm
DailyVaccinated.ExportationTime = The time for the daily vaccinated exportation, in format HH:mm
DailyVaccinated.FilePath = File path for the daily vaccinated exportation
DailyVaccinated.FileSeparator = File separator for the daily vaccinated exportation
Init.AutoDeserialize.Enabled = true / false if the auto deserialize is enabled

Ln 14, Col 1 100% Windows (CRLF) UTF-8
```

Picture 8 - config.properties example file

## 4.2. Data Persistence

In the app directory it is possible to find a file named *data.bin*. This file holds all the application state data and must not be deleted. Deleting this file causes all the data registered in the system to be lost and it is not possible to restore it.

The system does not have a backup system, given so, the following section requires special attention.

When the user runs the application for the first time the file *data.bin* is created. This file can be restored be manually deleting it (not recommended) and by using the administrator option in the menu bar “Restore Defaults”. [\[Please see chapter 3 section 3.3\]](#)

There are some known problems with this feature. Sometimes the file gets corrupted resulting in the app not being able to launch. Some routines try to prevent this from happening by restoring it automatically but if for some reason it cannot succeed in restoring the file the app may prevent you from closing it. In this case, go to the terminal that was launched with the application and press CTRL + C, this will close the process of the app causing it to close.

# 5. Registering and Cataloguing Employees



## Important

All features described in this chapter are only accessible by administrators.

### 5.1. Register a new Receptionist

To register a new Receptionist, you need to be logged in as an Administrator [[Please see chapter 3, section 3.1](#)].

After you log in, select the option “Register an Employee”, which appears in the Administrator Menu. A console-line interface will open.

The system will list the existing user roles. To select the third option (“RECEPTIONIST”), type 1 and then press Enter.

```
Employee Roles
1. RECEPTIONIST
2. NURSE
3. COORDINATOR

0 - Cancel

Type your option:
```

Picture 9 - Selection of the Employee role

Next, enter all Receptionist’s data in their respective fields: for each attribute, type the required information and then press Enter. The restrictions of each field are specified in the following table.

Field	Restrictions
Name	<b>(Required)</b> None.
Address	<b>(Required)</b> None.
Phone Number	<b>(Required)</b> Should start with “+351”, followed by nine digits (E.g.: +351912345678).
Email	<b>(Required)</b> Should follow the email format (E.g.: example@example.com).

## 5. Registering and Cataloguing Employees

Citizen Card Number	<b>(Required)</b> Must be a valid Portuguese Citizen Card Number, with no spaces between the different sections (E.g.: 000000000).
---------------------	--

Table 2 - Receptionist attributes restrictions

After you typed all Receptionist's information, the system will ask to confirm the data introduced.

```
Is this information correct?: (1 or 2)
1. Yes, it is correct.
2. No, it is not correct.

0 - Cancel

Type your option:
```

Picture 10 – Confirmation of the introduced data

If there is any wrong information and you would like to abort the Receptionist's register, type 2 and then press Enter. The system will inform you that the registration was cancelled.

Otherwise, if everything is correct, to confirm and proceed with the registration of the Receptionist, type 1 and then press Enter. The system should inform you that the registration was successfully made.

If an error shows up, please check if you introduced any data that goes against the rules defined in the table above. You might need to repeat the process from the beginning.

### 5.2. Register a new Nurse

To register a new Nurse, you need to be logged in as an Administrator [\[Please see chapter 3, section 3.1\]](#).

After you log in, select the option "Register an Employee", which appears in the Administrator Menu. A console-line interface will open.

The system will list the existing user roles. To select the third option ("NURSE"), type 1 and then press Enter.

## 5. Registering and Cataloguing Employees



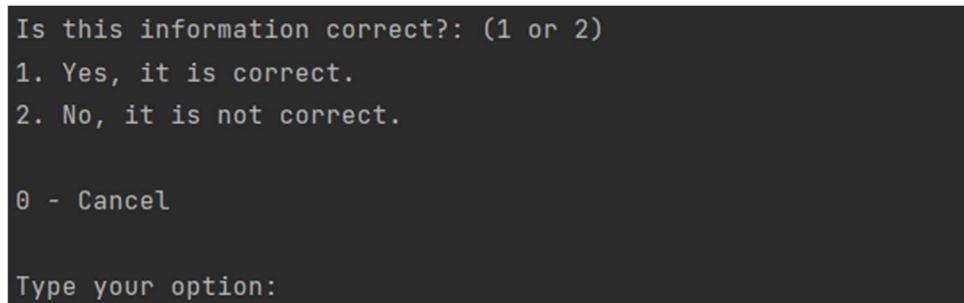
Picture 11 - Selection of the Employee Role

Next, enter all Coordinator's data in their respective fields: for each attribute, type the required information and then press Enter. The restrictions of each field are specified in the following table.

Field	Restrictions
Name	<b>(Required)</b> None.
Address	<b>(Required)</b> None.
Phone Number	<b>(Required)</b> Should start with "+351", followed by nine digits (E.g.: +351912345678).
Email	<b>(Required)</b> Should follow the email format (E.g.: example@example.com).
Citizen Card Number	<b>(Required)</b> Must be a valid Portuguese Citizen Card Number, with no spaces between the different sections (E.g.: 000000000).

Table 3 - Nurse attributes restrictions

After you typed all Nurse's information, the system will ask to confirm the data introduced.



Picture 12 – Confirmation of the introduced data

If there is any wrong information and you would like to abort the Nurse's register, type 2 and then press Enter. The system will inform you that the registration was cancelled.

## 5. Registering and Cataloguing Employees

Otherwise, if everything is correct, to confirm and proceed with the registration of the Nurse, type 1 and then press Enter. The system should inform you that the registration was successfully made.

If an error shows up, please check if you introduced any data that goes against the rules defined in the table above. You might need to repeat the process from the beginning.

### 5.3. Register a new Center Coordinator

To register a new Center Coordinator, you need to be logged in as an Administrator [\[Please see chapter 3, section 3.1\]](#).

After you log in, select the option “Register an Employee”, which appears in the Administrator Menu. A console-line interface will open.

The system will list the existing user roles. To select the third option (“COORDINATOR”), type 3 and then press Enter.



Picture 13 - Selection of the Employee role

Next, enter all Coordinator’s data in their respective fields: for each attribute, type the required information and then press Enter. The restrictions of each field are specified in the following table.

Field	Restrictions
Name	<b>(Required)</b> None.
Address	<b>(Required)</b> None.
Phone Number	<b>(Required)</b> Should start with “+351”, followed by nine digits (E.g.: +351912345678).
Email	<b>(Required)</b> Should follow the email format (E.g.: example@example.com).
Citizen Card Number	<b>(Required)</b> Must be a valid Portuguese Citizen Card Number, with no spaces between the different sections (E.g.: 000000000).

## 5. Registering and Cataloguing Employees

After you typed all Coordinator's information, the system will ask to confirm the data introduced.

```
Is this information correct?: (1 or 2)
1. Yes, it is correct.
2. No, it is not correct.

0 - Cancel

Type your option:
```

Picture 14 - Confirmation of the introduced data

If there is any wrong information and you would like to abort the Coordinator's register, type 2 and then press Enter. The system will inform you that the registration was cancelled.

Otherwise, if everything is correct, to confirm and proceed with the registration of the Coordinator, type 1 and then press Enter. The system should inform you that the registration was successfully made.

If an error shows up, please check if you introduced any data that goes against the rules defined in the table above. You might need to repeat the process from the beginning.

### 5.4. Consult Employees by Function

To consult every employee registered in the system by their role, you need to be logged as an Administrator [\[Please see chapter 3, section 3.1\]](#).

After you log in, select the option "List Employees By Role" which appears on the menu.

The first step is to select the type of role you want to consult. The system will request to choose between the roles registered in the system.

```
Employee Roles
1. RECEPTIONIST
2. NURSE
3. COORDINATOR

0 - Cancel

Type your option:
```

Picture 15 - Selection of the Employee Role to list.

## 5. Registering and Cataloguing Employees

After pressing the number that corresponds to the role pretended, press **Enter** to continue. The system will show a list of the employees of that role.

If an error shows up, please check if you entered the correct number. You might need to repeat the process from the beginning.

# 6. Registering Vaccination Centers



## Important

All features described in this chapter are only accessible by administrators.

### 6.1. Register a new Vaccination Center

To register a new Center Coordinator, you need to be logged in as an Administrator [\[Please see chapter 3, section 3.1\]](#).

After you log in, select the option “Register a new Vaccination Center” which appears in the Administrator Menu. A console-line interface will open.

In the first step, the system will request to choose the type of center to be registered.

```
Select the Vaccination Center type:  
1. Community Mass Vaccination Center  
2. Health Care Center  
0 - Cancel  
  
Type your option:
```

Picture 16 - Selection of the Vaccination Center's type

After entering the number that corresponds to the Vaccination Center type pretended press Enter to continue.

Next, enter all Vaccination Center's data in their respective fields: for each attribute, type the required information and then press Enter. The restrictions of each field are specified in the following table.

Field	Restrictions
Name	<b>(Required)</b> None.
Address	<b>(Required)</b> None.
Email	<b>(Required)</b> Should follow the email format (E.g.: example@example.com).
Phone Number	<b>(Required)</b> Should start with “+351”, followed by nine digits (E.g.: +351912345678).

## 6. Registering Vaccination Centers

Fax Number	<b>(Required)</b> Should start with “+351”, followed by nine digits (E.g.: +351912345678).
Website Address	<b>(Required)</b> Should start with “http(s)://”, (E.g.: https://domain.ext)
Opening Hours	<b>(Required)</b> Should follow the format HH:mm (E.g.: 20:00)
Closing Hours	<b>(Required)</b> Should follow the format HH:mm (E.g.: 23:00) and it must be after opening hours
Slot duration	<b>(Required)</b> Should be a positive number (E.g.: 5)
Maximum Vaccines Per Slot	<b>(Required)</b> Should be a positive number (E.g.: 5)

The next step is to select an available coordinator from the list that the system will show. After entering the corresponding number of the coordinator, press **Enter** to continue.

### 6.1.1. Register a Community Mass Vaccination Center

After completing all the steps above, if you have entered the option **1**, when selecting the type of center [\[Please see chapter 5, section 5.1\]](#), the system will show all data above, including the vaccine given on that center and ask to confirm the operation.

```
Is this information correct?: (1 or 2)
1. Yes, it is correct.
2. No, it is not correct.

0 - Cancel

Type your option:
```

Picture 17 - Confirmation of the inserted data

## 6. Registering Vaccination Centers

If there is any wrong information and you would like to abort the Vaccination Center's registration, type 2 and then press Enter. The system will inform you that the registration was cancelled.

Otherwise, if everything is correct, to confirm and proceed with the registration of the Vaccination Center, type 1 and then press Enter. The system should inform you that the registration was successfully made.

If an error shows up, please check if you introduced any data that goes against the rules defined in the table above. You might need to repeat the process from the beginning.

### 6.1.2. Register a Health Care Center

After completing all the steps above, if you have entered the option **2**, when selecting the type of center [\[Please see chapter 5, section 5.1\]](#), the system will request to enter two more required attributes. For each field type the required information and then press Enter. The restrictions of each field are specified in the following table.

Field	Restrictions
AGES	<b>(Required)</b> None.
ARS	<b>(Required)</b> None.

After you typed all the data, the system will ask to confirm the information.

```
Is this information correct?: (1 or 2)
1. Yes, it is correct.
2. No, it is not correct.

0 - Cancel

Type your option:
```

Picture 18 - Confirmation of the inserted data

If there is any wrong information and you would like to abort the Vaccination Center's register, type 2 and then press Enter. The system will inform you that the registration was cancelled.

Otherwise, if everything is correct, to confirm and proceed with the registration of the Vaccination Center, type 1 and then press Enter. The system should inform you that the registration was successfully made.

## 6. Registering Vaccination Centers

If an error shows up, please check if you introduced any data that goes against the rules defined in the table above. You might need to repeat the process from the beginning.

# 7. Registering SNS Users

## 7.1. Register a new SNS User



### Important

The feature described in this section is only accessible by Receptionists.

To register a new SNS User, you need to be logged in as a Receptionist [\[Please see chapter 3, section 3.2\]](#).

After you log in, select the option “Register a SNS User” which appears in the Receptionist Menu. A console-line interface will open.

Next, enter all SNS User’s data in their respective fields: for each attribute, type the required information and then press Enter. The restrictions of each field are specified in the following table.

Field	Restrictions
Citizen Card	<b>(Required)</b> Should follow the portuguese format (E.g.: 000000000LL4).
SNS Number	<b>(Required)</b> Should follow the portuguese format (E.g.: 123456789).
Name	<b>(Required)</b> None.
Birthday	<b>(Required)</b> Should follow the format dd/mm/yyyy (E.g.: 01/01/1970) and cannot be a future date
Phone Number	<b>(Required)</b> Should start with “+351”, followed by nine digits (E.g.: +351912345678).
Email	<b>(Required)</b> Should follow the email format (E.g.: example@example.com).
Address	<b>(Required)</b> None.

## 7. Registering SNS Users

After completing the previous steps, the system will request to choose the SNS User gender.



Picture 19 - Selection of the user's gender

After entering the number that corresponds to the type pretended, press **Enter** to continue.

### 7.2. Register Multiple SNS Users from a File



#### Important

The feature described in this section is only accessible by Administrators.

To register a new SNS User, you need to be logged in as an Administrator [\[Please see chapter 3, section 3.1\]](#).

After you log in, select the option “Upload SNS Users from a file” which appears in the Administrator Menu. A console-line interface will open.

The first step is to enter the file path that you want to upload to the system. Also, the file itself should follow a restrict format. The restrictions are shown on the table below.

Field	Restrictions
File Path	<b>(Required)</b> Should enter the full path file (E.g.: C:\Users\User\Desktop\File.csv).
File data	<b>(Required)</b> All data should be separated by “;” with all the following attributes: Name; Sex; Birth Date; Address; Phone Number; E-mail; SNS User Number; Citizen Card Number;

After that, the system will request to confirm the operation. If you want to proceed, press **S** or **s**, otherwise press **N** or **n** to cancel. After that press **Enter** to continue.

## 7. Registering SNS Users

The system will show on the console-line interface all the users registered in the system and operation is completed.

If an error shows up, please check if you introduced any data that goes against the rules defined in the table above. You might need to repeat the process from the beginning

## 8. Registering Vaccines



### Important

All features described in this chapter are only accessible by administrators.

### 8.1. Register a new Vaccine Type

To register a new Vaccine Type, you need to be logged in as an Administrator [[Please see chapter 3, section 3.1](#)].

After you log in, select the option “Register a new Vaccine Type”, which appears in the Administrator Menu. A console-line interface will open.

To register a new Vaccine Type, the first step is to introduce all the data necessary. For each attribute, type the required information and then press **Enter**. The restrictions of each field are specified in the following table.

Field	Restrictions
Code	<b>(Required)</b> Exact 5 digits (E.g.: 00000).
Designation	<b>(Required)</b> None.

On the next step, the system will show a list of Vaccine Technologies available. From the list, enter the number that corresponds to the technology. Then press **Enter** to continue.

```
Vaccine Type Technologies:  
1. LIVE_ATTENUATED TECHNOLOGY  
2. INACTIVATED TECHNOLOGY  
3. SUBUNIT TECHNOLOGY  
4. TOXOID TECHNOLOGY  
5. VIRAL_VECTOR TECHNOLOGY  
6. M_RNA TECHNOLOGY  
  
0 - Cancel  
  
Type your option:
```

Picture 20 - Selection of the Vaccine Type

After that the system will request to confirm the data introduced.

## 8. Registering Vaccines

```
Is this information correct?: (1 or 2)
1. Yes, it is correct.
2. No, it is not correct.

0 - Cancel

Type your option:
```

Picture 21 - Confirmation of the inserted data

If there is any wrong information and you would like to abort the Vaccine Type's registration, type 2 and then press Enter. The system will inform you that the registration was cancelled.

Otherwise, if everything is correct, to confirm and proceed with the registration of the Vaccine Type, type 1 and then press Enter. The system should inform you that the registration was successfully made.

If an error shows up, please check if you introduced any data that goes against the rules defined in the table above. You might need to repeat the process from the beginning.

### 8.2. Register a new Vaccine

To register a new Vaccine, you need to be logged in as an Administrator [\[Please see chapter 3, section 3.1\]](#).

After you log in, select the option "Register a new Vaccine", which appears in the Administrator Menu. A console-line interface will open.

To register a new Vaccine, it is needed to have at least one Vaccine Type registered in the system. If you try to register a new Vaccine and do not have a Vaccine Type registered, a message will appear to inform you what you need to do.

```
No vaccine type registered. Register a vaccine Type before registering a new Vaccine.
Press enter to go back to the menu.
```

Picture 22 - Error showed when ther is no vaccine type registered

If there is already one Vaccine Type registered in the system, the first thing that is required to register a vaccine is select its type. A list of Vaccine Types will appear in your console-line interface. All the Vaccine Types have an index before its information. To select the Vaccine Type you need to type the correspondent index.

## 8. Registering Vaccines

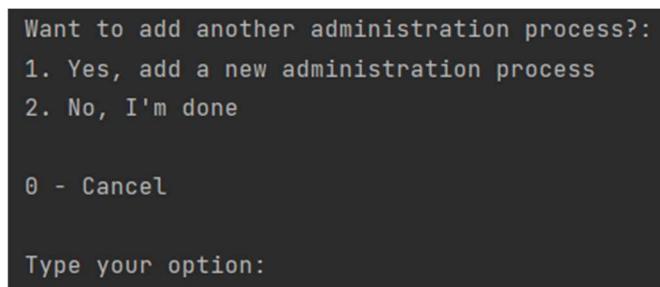
After the selection of the Vaccine Type, the system will request to introduce some data about the vaccine itself. For each attribute requested, type the required information, and then press Enter. The restrictions of each field are specified in the following table.

Field	Restrictions
Designation	<b>(Required)</b> None.
Id	<b>(Required)</b> None.
Brand	<b>(Required)</b> None.
Min age	<b>(Required)</b> Must be a positive number or 0.
Max age	<b>(Required)</b> Must be positive and bigger than min age.
Number of doses	<b>(Required)</b> Must be a positive number.

Depending on the number of doses you selected previously, you will need to repeat the next steps the number you entered. For each attribute requested, type the required information, and then press Enter. The restrictions of each field are specified in the following table.

Field	Restrictions
Dosage	<b>(Required)</b> Must be a positive number. Measured in ml.
Time since last dose	<b>(Required)</b> Must be a positive number. Counted in days.

After that the system will ask you if you want to add another administration process.



Picture 23 - Option to add another administration process

If you want to add another age group to the vaccine being registered press 1, if not press 2. After that press Enter to continue. When adding a new age group, the min age, max age and number of doses fields will be requested again. And for each dose specified in number of doses field we need to enter the dosage and time since last dose fields again.

# 9. Scheduling Vaccines

## 9.1. Schedule a Vaccine as an SNS User

To start the schedule of a vaccine, you need to be logged in as an SNS User [[Please see chapter 3, section 3.2](#)].

Once the login is complete, in the SNS User menu, select the option “Schedule a Vaccine”. A console-line interface will open.

To schedule a new Vaccination, the first step needed is to choose between accepting or declining the suggested vaccine type.

Enter the number that corresponds to the option pretended and press **Enter** to continue.

If you accepted the suggested Vaccine type, skip to this section [[Please see chapter 8, section 8.2.1](#)].

If declined the suggested Vaccine Type, skip to this section [[Please see chapter 8, section 8.2.2](#)].

## 9.2. Schedule a Vaccine as a Receptionist

To start the schedule of a vaccine, you need to be logged in as a Receptionist [[Please see chapter 3, section 3.2](#)].

After the login is complete, in the Receptionist menu, select the option “Schedule a Vaccine”. A console-line interface will open.

To schedule a new Vaccination, the first step needed is to introduce a valid SNS number. See the restrictions on the following table.



### Important

SNS Number needs to correspond to a SNS User registered already in the system.

Field	Restrictions
SNS Number	<b>(Required)</b> Should follow the Portuguese format, 9 digits (E.g.: 123456789).

After successfully introducing a SNS number, the system will request to choose between accepting the suggested vaccine type or not.

## 9. Scheduling Vaccines

Suggested Vaccine Type:

COVID-19

Select an option: (1 or 2)

1. Yes, accept suggestion.  
2. No, choose other vaccine type.

0 - Cancel

Type your option:

Picture 24 - Suggested vaccine type

If you accepted the suggested Vaccine type, skip to this section [\[Please see chapter 8, section 8.2.1\]](#).

If declined the suggested Vaccine Type, skip to this section [\[Please see chapter 9, section 9.3.2\]](#).

### 9.2.1. Schedule a Vaccine (accepting suggested vaccine type)

If the option was **1**, then the next step is to select the Vaccination Center available to issue the vaccine selected.

The system will show the list of the Vaccination Centers and request to choose one. After entering the corresponding number of the Center, press Enter to continue.

After that, the system will request to introduce the date and the hours pretended to schedule the vaccine. See the restrictions on the following table.



#### Important

Date needs to be in the future and Hours needs to be valid and between the timetable of the Center selected.

Field	Restrictions
Date	<b>(Required)</b> Should follow the Portuguese format, dd/mm/yyyy (E.g.: 01/01/2001) and should be a future date.
Hours	<b>(Required)</b> Should follow the Portuguese format, HH:mm (E.g.: 20:30) and the time should be between the opening and closing time of the center chosen.

The final step, the system will request to choose between accepting receiving a SMS about the scheduled vaccine or declining it.

## 9. Scheduling Vaccines

```
Do you want to receive an SMS with the appointment's info?  
Select an option: (1 or 2)  
1. Yes, send me an SMS.  
2. No, don't send me an SMS.  
0 - Cancel  
Type your option:
```

Picture 25 - Choose the SMS preferences

After entering **1** or **2**, the operation is completed, and the vaccine is scheduled.

If an error shows up, please check if you introduced any data that goes against the rules defined in the table above. You might need to repeat the process from the beginning.

### 9.2.2. Schedule a Vaccine (declining suggested vaccine type)

If the option was **2**, then the next step is to select the Vaccine Type pretended. The system will show the list and request to choose one.

The system will show the list of the Vaccination Centers and request to choose one. After entering the corresponding number of the Center, press Enter to continue.

After that, the system will request to introduce the date and the hours pretended to schedule the vaccine. See the restrictions on the following table.



#### Important

Date needs to be in the future and Hours needs to be valid and between the timetable of the Center selected.

Field	Restrictions
Date	<b>(Required)</b> Should follow the Portuguese format, dd/mm/yyyy (E.g.: 01/01/2001) and should be a future date.
Hours	<b>(Required)</b> Should follow the Portuguese format, HH:mm (E.g.: 20:30) and the time should be between the opening and closing time of the center chosen.

The final step, the system will request to choose between accepting receiving a SMS about the scheduled vaccine or declining it.

## 9. Scheduling Vaccines

```
Do you want to receive an SMS with the appointment's info?  
  
Select an option: (1 or 2)  
1. Yes, send me an SMS.  
2. No, don't send me an SMS.  
  
0 - Cancel  
  
Type your option:
```

Picture 26 - Choose the SMS preferences

After entering **1** or **2**, the operation is completed, and the vaccine is scheduled.

The system will show the appointment scheduled and ask to confirm it.

```
Is this information correct?: (1 or 2)  
1. Yes, it is correct.  
2. No, it is not correct.  
  
0 - Cancel  
  
Type your option:
```

Picture 27 - Confirmation of the inserted data

If there is any wrong information and you would like to abort the Vaccination registration, type 2 and then press Enter. The system will inform you that the registration was cancelled.

Otherwise, if everything is correct, to confirm and proceed with the registration of the Vaccination, type 1 and then press Enter. The system should inform you that the registration was successfully made.

If an error shows up, please check if you introduced any data that goes against the rules defined in the table above. You might need to repeat the process from the beginning.

# 10. Checking-in SNS Users for Vaccination

## 10.1. Register the Arrival of an SNS User



### Important

The feature described in this section is only accessible by Receptionists.

To register an arrival, you need to be logged in as a Receptionist [\[Please see chapter 3, section 3.2\]](#).

After you log in, select the option “Register an arrival”, which appears in the Receptionist Menu. A console-line interface will open.

Type the SNS User Number. Confirm the appointment that appears and press 1.

The SNS User appears now in the waiting room.

## 10.2. Consult SNS Users Waiting for Vaccination



### Important

All features described in this section and the following ones are only accessible by Nurses.

To consult SNS Users on the waiting room, you need to be logged in as a Nurse [\[Please see chapter 3, section 3.2\]](#).

After you log in, select the option “Get Users in Waiting Room”, which appears in the Nurse Menu. A console-line interface will open.

A list of users whose arrival was registered according to the previous section will appear in the screen.

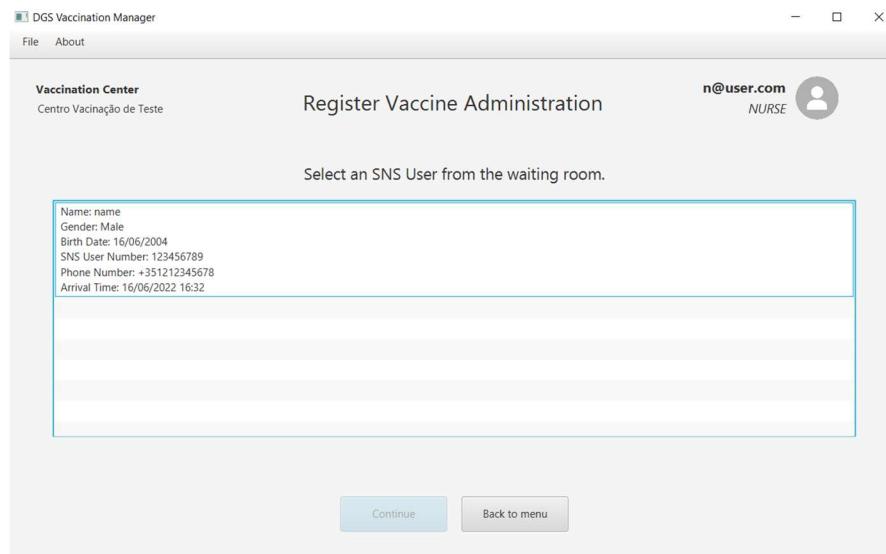
## 10.3. Register Vaccine Administration

To record a Vaccine Administration, you need to be logged in as a Nurse [\[Please see chapter 3, section 3.2\]](#).

After you log in, select the option “Register Vaccine Administration”, which appears in the Nurse Menu.

Then, you must select a user from the list that appears on the screen. This list contains all SNS users that are waiting in the waiting room.

## 10. Checking-in SNS Users for Vaccination



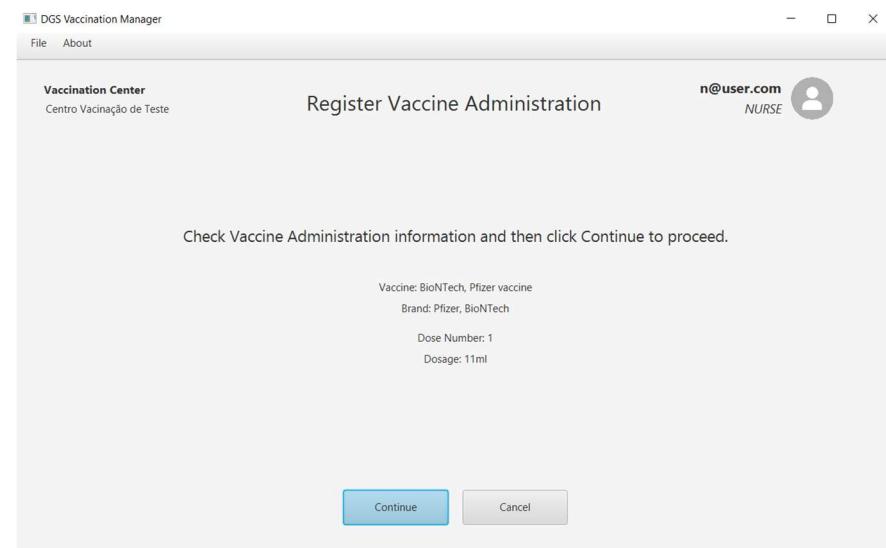
Picture 28 - Example of a list of users in the waiting room

After selecting a user, press the Continue button. It will show the user's name and age, as well as all previous adverse reactions recorded in the system. To continue the process, press the Continue button again.

If the user is taking his first dose, the system will show a list of possible vaccines to administer – it only lists vaccines that contain the vaccine type registered in the user appointment, and that contain an administration process for the user's age. Select a vaccine from the list, and then press Continue.

If the user is taking a second dose (or other than the first one), the system does not show any list, and automatically shows the dosage information.

Then, the dosage information will appear, in order to correctly administer the vaccine, according to the user's age.



Picture 29 - Dosage information of the selected vaccine

## 10. Checking-in SNS Users for Vaccination

After the administration of the vaccine, press the Continue button. The system will ask to type the lot number of the administered vaccine. The lot number follows the format defined in the following table.

Field	Restrictions
Lot number	<b>(Required)</b> Should contain five characters (letters or numbers), followed by a hyphen, and two numbers (E.g.: ABC12-34).

A popup will appear with the inserted vaccine administration data. If everything is correct, press Ok.

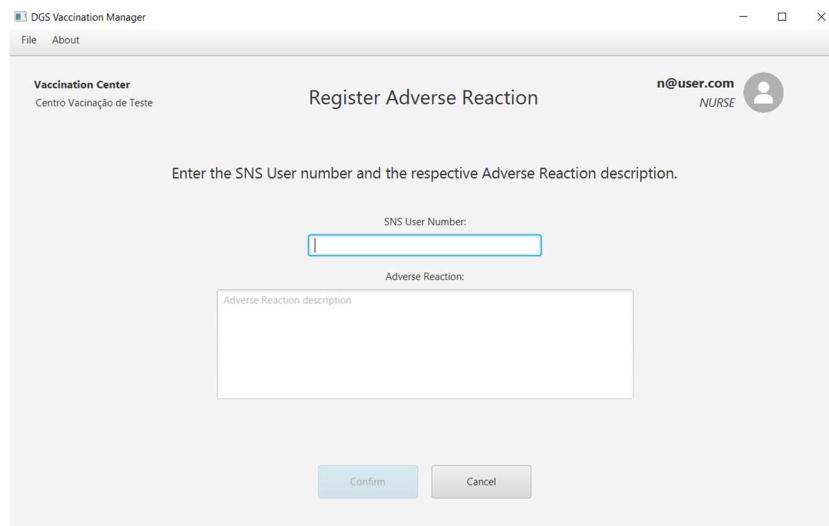
If you want to abort the record of the administration, press Cancel. The vaccine administration will not be registered.

### 10.4. Register Adverse Reactions

To record an Adverse Reactions, you need to be logged in as a Nurse [\[Please see chapter 3, section 3.2\]](#).

After you log in, select the option “Register Adverse Reaction”, which appears in the Nurse Menu.

In the screen that appears, enter the SNS User number of the person who suffered the adverse reaction, as well as the adverse reaction description.



Picture 30 - Register Adverse Reaction page

Then, click in the Confirm button. A popup to confirm the data inserted will show. Click Ok to register the Adverse Reaction or Cancel to abort the record.

# 11. Center Performance



## Important

All features described in this chapter are only accessible by Center Coordinators.

### 11.1. Export Vaccination Center Statistics

To export center statistics, you need to be logged in as a Center Coordinator [\[Please see chapter 3, section 3.2\]](#).

After you log in, select the option “Export Center Statistics”, which appears in the Coordinator Menu.

The system will show a different window, which contains 3 different spaces to fill with the data pretended.

Picture 31 - Screen for exporting Center Statistics

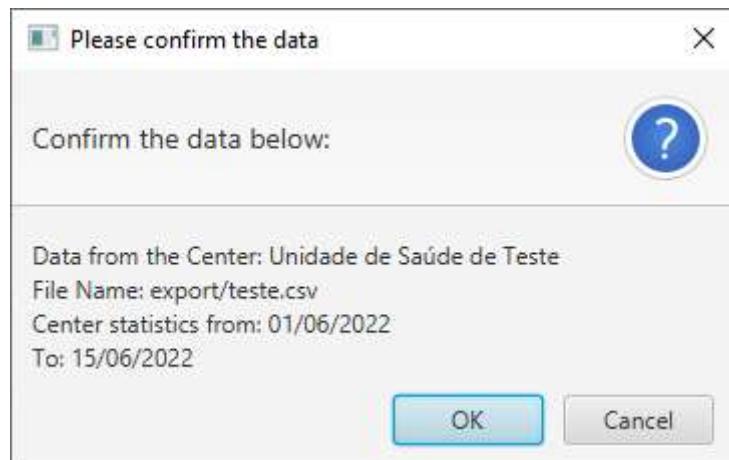
The first two ones are to select the interval of dates (the start date and end date, respectively). See the restriction below on the table.

Field	Restrictions
Date	<b>(Required)</b> Should select dates only from the past. The start date cannot be after the end date.

Next you need to select the file name. Write on the box “File name” the name you want to give to your file.

## 11. Center Performance

After completing all the steps above, click on the button “Export Statistics” and the system will request you to confirm the data you selected.



Picture 32 - Confirmation of the inserted data

After pressing the button Ok, a new window will show with the data you exported.



Picture 33 - Generated center statistics

If any alert shows up, please check if you introduced any data that goes against the rules defined above. You might need to repeat the process from the beginning. You can also click on the button “File”, on the menu bar, and select “Help” to get more information on how to export center statistics.

### 11.2. Analyse Center Performance

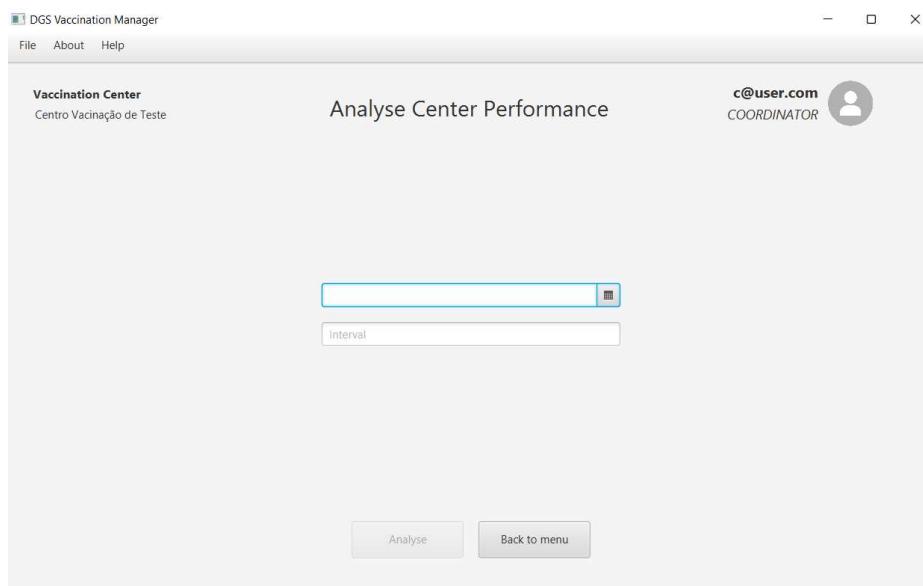
To analyse the center’s performance, you need to be logged in as a Center Coordinator [\[Please see chapter 3, section 3.2\]](#).

## 11. Center Performance

After you log in, select the option “Analyse Center Performance”, which appears in the Coordinator Menu.

The system will show a different window, which has two different fields, one date picker that lets you pick a date in a calendar easily, and a text field to insert the interval, in minutes, of the analysis that is pretended.

Field	Restrictions
Date	<b>(Required)</b> Should select dates only from the past.
Interval	<b>(Required)</b> Should be a positive integer and should not exceed the number of minutes that the center is open.



Picture 34 - Screen for analysing center performance

After this, press the “Analyse” button to process the center events for that time period.

A new window will be presented with the performance analysis containing the differences list of arriving and leaving people, the max contiguous sum sub list, the sum of that list and the beginning and end time of that interval.

To exit this screen simply click in the close button.

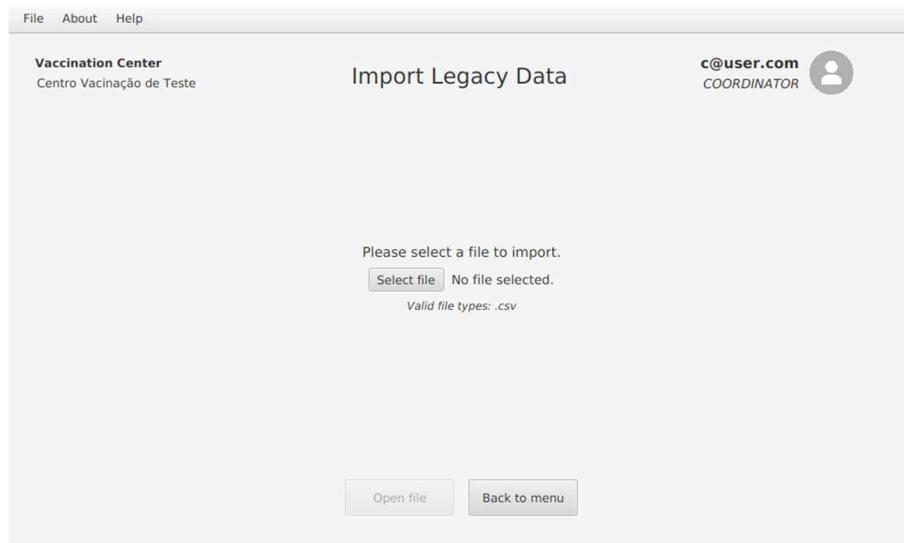
### 11.3. Import Data from a Legacy System

To import data from a legacy system, you need to be logged in as a Center Coordinator [\[Please see chapter 3, section 3.2\]](#).

## 11. Center Performance

After you log in, select the option “Import Data from Legacy System”, which appears in the Coordinator Menu.

The system will show a different scene with one field asking to select a file to import. The application will only accept valid file types (.csv).



Picture 35 - Screen for importing legacy data

After choosing a file, the user presses the “Open file” button, which will open a new window where he will be able to confirm the data. This data will be sorted by arrival time or by departure time; the sorting algorithm used is set in the configuration properties of the application.

### 11.4. Check Daily Vaccinated Per Center

The application exports automatically a CSV file with the daily total number of people vaccinated in each vaccination center. The file is exported at the time defined in the configuration properties that can only be accessed by the administrators. The separator and the file path are also defined in the configuration properties. The file path has the data's date is added in the file name.

To change the file path, execution time and file separator, you need to be logged in as an Administrator [\[Please see chapter 3, section 3.1\].](#)

After you are logged in as an Administrator, in the Menu Bar click in “File” and then click in “Preferences”. It will be opened a note pad with all the preferences.

## 12. Troubleshooting

### 12.1. I cannot login into the application.

Please check if you are inserting the right credentials, that were sent to you via SMS or Email [\[Please see chapter 3, section 3.1\]](#). If you still are having troubles, contact your administrator.

### 12.2. I'm a Coordinator and I'm not assigned to any center.

If you are not assigned to a vaccination center, please contact your administrator.

### 12.3. My app is not running.

Please restart your computer. If the problem persists, contact your administrator.

### 12.4. An error was thrown while the app initialized.

The problem might be caused by the file that holds the app data. Please contact your administrator.

### 12.5. I chose an option in the menu and nothing happened.

Due to technical reasons, some features are only accessible using a command-line interface. If you select an option that does not have a graphical interface, a terminal should open to use that feature. If the terminal does not appear, check if the terminal window is minimized. If you still can't find it, please restart the application.

### 12.6. My app is not responding when I'm running terminal options.

There are some features that are only available through a command-line interface. While you are using the terminal, the main graphical interface will be unavailable. Due to this, some operating systems show the app interface as "Not responding", which is completely normal.

### 12.7. The terminal and the app are not responding.

If none of them are working, go to the terminal and press CTRL + C. This will stop the current process, what can lead to loss of data. If this didn't solve the problem, restart the app.

### **12.8. I forgot my password.**

To recover your password, contact your administrator. It may be needed to create a new account.

### **12.9. I can't schedule an appointment.**

You can only schedule one appointment for the same vaccine type. If you need to schedule the second dose (or subsequent) of a certain vaccine, it's only possible to do it for a date when the recovery period has been past. [\[Please see chapter 9, section 9.2\]](#)

### **12.10. I cannot register the arrival of an SNS User.**

If the system does not show any appointment after typing the correct SNS user number, that means that the user does not have an appointment for that day. However, if the center is not full, you can schedule a vaccine for the user for the current day. [\[Please see chapter 9, section 9.2\]](#)

### **12.11. I cannot proceed after manually entering a date.**

Due to system limitations, the “Continue” button may not automatically activate after manually typing a date. Try to press “Enter” after entering the date. If that didn't solve the problem, please select the date using the calendar box.

### **12.12. I deleted *data.bin*. How do I restore it?**

Unfortunately, it is not possible to restore the data file. This file holds all the system information - once deleted, all the data is lost [\[Please see chapter 4, section 4.2\]](#).

### **12.13. I cannot exit the app.**

If you cannot exit the app, it means that the data file is corrupted. Some mechanisms are in place to prevent this from happening, and the file might be restored in the next app initialization. Therefore, if you are stuck in the app without a way to close it, go to the terminal and press CTRL + C, to shut down the app process.

## 13. FAQ

### 13.1. How do I create an account?

Only an administrator can create an account [\[Please see chapter 3, section 3.1\]](#). Contact your administrator in order to create an account and start using the application.

### 13.2. How do I login?

After having your credentials, use the login screen to access the application features [\[Please see chapter 3, section 3.1\]](#).

### 13.3. Can I access all the features of the application?

No. Depending on the role you were assigned to by the administrator, you will have a different main screen when loading the app [\[Please see chapter 3, section 3.2\]](#).

### 13.4. How do I navigate in the application?

When entering the application, and after you login, you are presented with a menu depending on the role you have. Use the menu to navigate the accessible features [\[Please see chapter 3, section 3.2\]](#).

### 13.5. How do I find my authentication credentials?

When registered in the system, you will receive a notification by SMS or email containing your credentials. If you were not notified, please contact your administrator [\[Please see chapter 3, section 3.1\]](#).

### 13.6. Can I delete my account?

No. Only the administrator has permissions to delete the created accounts. Please contact him in order to solve any problem related to your account.

### 13.7. Can I change my role?

No. The only way to change roles is to create a new account. Please contact your administrator to do so [\[Please see chapter 3, section 3.1\]](#).

### **13.8. How do I schedule a vaccine?**

To schedule a vaccine, you first need to login into your SNS User account [[Please see chapter 3, section 3.2](#)]. Then, on the main menu, select the “Schedule a Vaccine” option and follow the instructions in the screen [[Please see chapter 9, section 9.1](#)].

### **13.9. Can I cancel an appointment?**

No. It is not possible to cancel an appointment. If for some reason you cannot go in the scheduled time, you may want to contact the vaccination center directly.

### **13.10. Can I schedule two appointments for the same day?**

Yes. The system does not have any restriction for scheduling appointments for the same day. However, it is not recommended to do so.

### **13.11. Can I administer a vaccine to an SNS user that does not have an appointment for that day?**

No. The system only allows the record of vaccine administrations to users whose arrival has been previously registered by a nurse. For that, the user needs to have an appointment for the current day [[Please see chapter 9, section 9.2](#)].

### **13.12. Is it possible to register an adverse reaction after the user has left the center?**

Yes. An adverse reaction can be recorded whenever needed [[Please see chapter 9, section 9.4](#)].

# 14. Annexes

## A. MATCP Annex

### 1. Simple Linear Regression

#### a. Overview of Simple Linear Regression

In statistics, Simple Linear Regression is a type of linear regression model that only have one independent variable (which we know its behaviour), to predict the dependent variable. Through a set of points, it can attempt to predict continuous values, showing how they correlate between them. From this relationship it is possible to create a graph that tells us how precise the data is, using the correlation coefficient ( $R^2$ ) that goes from 0 to 1. If the ( $R^2$ ) is close to 1 ( $>0,90$ ), then the data is very precise.

#### b. Simple Linear Regression Model

*For the study of simple linear regression, we are going to use two examples and then how we can compare them. We used the file owid-covid-dataVF.xlsx as it has all necessary data to study SLR.*

*The goal was to make a daily and weekly analysis between all dependent variables and independent variables.*

*-The first one is the study between new\_cases and positive\_rate. (Case1\_#1).*

*-The second one is the study between new\_deaths and new\_tests. (Case1\_#10).*

#### c. Model significance

Anova Table is the total variability of the number of observations done by sum of squares of total deviations.

ANOVA					
	gl	SQ	MQ	F	F de significância
Regressão	1	2,45E+08	245236315	713,7307351	7,24041E-52
Residual	118	40544541	343597,81		
Total	119	2,86E+08			

As the example above shows, this table gives a few parameters, but the most important is the F, as we can conclude if this  $F > F_{critical}$  ( $F_{critical} = F_{\alpha,1,n-2}$ ) the model is significant.

## ***new\_cases* and *positive\_rate***

### **Daily Analysis**

To study the significance model, we had to find firstly the regression model between the two variables.

$$Y = \beta_0 + \beta_1 X_1$$

In this case, ***new\_cases*** is the dependent variable and ***positive\_rate*** is the independent variable.

$$Y = -37,059 + 30986X_1$$

(Regression model obtained with ***new\_cases*** and ***positive\_rate***)

After calculating all the necessary values, we generated the Anova Table and compared with our Anova Table values to see if it matched.

SE =	40544541,13	MSE =	343597,8062	F estatistica=	400,9275942
SR =	137757841,8	MSR =	137757841,8		
ST =	1,23691E-10				

As the Correlation Coefficient is concerned, we calculated that:

$R^2 = \frac{S_{xy}^2}{S_{xx} * S_{yy}} =$	0,858127162
$R = \frac{S_{xy}}{\sqrt{S_{xx}} * \sqrt{S_{yy}}} =$	0,926351533

This shows that, as the **R** is **0,926352** the SLR is very precise. This result is confirmed in the Anova Table as the values showed above are congruent with the LR calculated before.

## Weekly Analysis

To study the significance model, we had to find firstly the regression model between the two variables.

$$Y = -335,9647813 + 31261,74213X1$$

(Regression model obtained with **new\_cases** and **positive\_rate**)

In this case, **new\_cases** is the dependent variable and **positive\_rate** is the independent variable.

After calculating all the necessary values, we generated the Anova Table and compared with our Anova Table values to see if it matched.

Para confirmar os dados acima:			
SE =	110076873,6	MSE =	7338458,243
SR =	1699764595	MSR =	1699764595
ST =	1809841469	F estatística=	231,6242103

As the Correlation Coefficient is concerned, we calculated that:

$R^2 = \frac{S_{xy}^2}{S_{xx} * S_{yy}} =$	0,939178721
$R = \frac{S_{xy}}{\sqrt{S_{xx}} * \sqrt{S_{yy}}} =$	0,969112336

This shows that, as the **R** is **0,969112336** the SLR is very precise. This result is confirmed in the Anova Table as the values showed above are congruent with the LR calculated before.

## **new\_deaths** and **new\_tests**

### Daily Analysis

To study the significance model, we had to find firstly the regression model between the two variables.

$$Y = \beta_0 + \beta_1 X_1$$

In this case, **new\_deaths** is the dependent variable and **new\_tests** is the independent variable.

$$Y = 44,629 - 0,0002X1$$

(Regression model obtained with **new\_deaths** and **new\_tests**)

## 14. Annexes

After calculating all the necessary values, we generated the Anova Table and compared with our Anova Table to see if it matched.

Para confirmar os dados acima:		
SE =	523172,9209	MSE = 4433,668821
SR =	1261,670808	MSR = 1261,670808
ST =	524434,5917	F estatística= 0,284565866

As the Correlation Coefficient is concerned, we calculated that:

$R^2 = \frac{S_{xy}^2}{S_{xx} * S_{yy}} =$	0,002405773
$R = \frac{S_{xy}}{\sqrt{S_{xx}} * \sqrt{S_{yy}}} =$	0,049048684

This shows that, as the **R** is **0,049048684** the SLR is not precise at all. We can conclude that the variable **new\_deaths** has poor relationship with **new\_tests**. This result is confirmed in the Anova Table as the values showed above are congruent with the LR calculated before.

## Weekly Analysis

To study the significance model, we had to find firstly the regression model between the two variables.

$$Y = 423,3908246 - 0,000596544X1$$

(Regression model obtained with **new\_deaths** and **new\_tests**)

After calculating all the necessary values, we generated the Anova Table and compared with our Anova Table values to see if it matched.

Para confirmar os dados acima:		
SE =	3527254,296	MSE = 235150,2864
SR =	45601,46872	MSR = 45601,46872
ST =	3572855,765	F estatística= 0,193924785

As the Correlation Coefficient is concerned, we calculated that:

$R^2 = \frac{S_{xy}^2}{S_{xx} * S_{yy}} =$	0,012763311
$R = \frac{S_{xy}}{\sqrt{S_{xx}} * \sqrt{S_{yy}}} =$	0,112974824

This shows that, as the **R** is **0,112974824** the SLR is not precise at all. We can conclude that the variable **new\_deaths** has poor relationship with **new\_tests**. This result is confirmed in the Anova Table as the values showed above are congruent with the LR calculated before.

#### *d. Hypothesis tests for model coefficients*

##### **new\_cases** and **positive\_rate**

##### Daily Analysis

##### Hypothesis tests for significant level of 1%

The Hypothesis test are done for  $\hat{a}$  and for  $\hat{b}$ . Let's start with the  $\hat{a}$ :

$$H0: \hat{a} = 0 \text{ v.s. } H1: \hat{a} \neq 0$$

$T_a = \frac{\hat{a} - ao}{S \sqrt{\frac{1}{n} + \frac{\bar{x}^2}{S_{xx}}}} \sim t_{n-2} =$	6,683331528
---	-------------

Since  $t_{0,95,118}$  has the value of:

$$t_{0,95,118} = 1,657869522$$

We reject H0. The test is conclusive to say that at a significant level of 1%, H1 is true.

$$H0: \hat{b} = 0 \text{ v.s. } H1: \hat{b} \neq 0$$

$T_b = \frac{\hat{b} - bo}{S \sqrt{\frac{1}{n} + \frac{\bar{x}^2}{S_{xx}}}} \sim t_{n-2} =$	-4,747018168
---	--------------

We reject H0. The test is conclusive to say that at a significant level of 1%, H1 is true.

### Hypothesis tests for significant level of 5%

The Hypothesis test are done for  $\hat{a}$  and for  $\hat{b}$ . Let's start with the  $\hat{a}$ :

$$H0: \hat{a} = 0 \text{ v.s. } H1: \hat{a} \neq 0$$

$$T_a = \frac{\hat{a} - ao}{S \sqrt{\frac{1}{n} + \frac{\bar{x}^2}{S_{xx}}}} \sim t_{n-2} = 6,683331528$$

Since  $t_{0,975,118}$  has the value of:

$$t_{0,975,118} = 1,980272249$$

We reject H0. The test is conclusive to say that at a significant level of 1%, H1 is true.

$$H0: \hat{b} = 0 \text{ v.s. } H1: \hat{b} \neq 0$$

$$T_b = \frac{\hat{b} - bo}{S \sqrt{\frac{1}{n} + \frac{\bar{x}^2}{S_{xx}}}} \sim t_{n-2} = -4,747018168$$

We reject H0. The test is conclusive to say that at a significant level of 1%, H1 is true.

### new\_deaths and new\_tests

#### Daily Analysis

### Hypothesis tests for significant level of 1%

The Hypothesis test are done for  $\hat{a}$  and for  $\hat{b}$ . Let's start with the  $\hat{a}$ :

$$H0: \hat{a} = 0 \text{ v.s. } H1: \hat{a} \neq 0$$

$$T_a = \frac{\hat{a} - ao}{S \sqrt{\frac{1}{n} + \frac{\bar{x}^2}{S_{xx}}}} \sim t_{n-2} = 3,171409261$$

Since  $t_{0,95,118}$  has the value of:

$$t_{0,95,118} = 1,657869522$$

We reject H0. The test is conclusive to say that at a significant level of 1%, H1 is true.

$$H_0: \hat{b} = 0 \text{ v.s. } H_1: \hat{b} \neq 0$$

$T_a = \frac{\hat{a} - ao}{S \sqrt{\frac{1}{n} + \frac{\bar{x}^2}{S_{xx}}}} \sim t_{n-2} =$	1,132513655
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We reject H0. The test is conclusive to say that at a significant level of 1%, H1 is true.

### Hypothesis tests for significant level of 5%

The Hypothesis test are done for  $\hat{a}$  and for  $\hat{b}$ . Let's start with the  $\hat{a}$ :

$$H_0: \hat{a} = 0 \text{ v.s. } H_1: \hat{a} \neq 0$$

$T_a = \frac{\hat{a} - ao}{S \sqrt{\frac{1}{n} + \frac{\bar{x}^2}{S_{xx}}}} \sim t_{n-2} =$	3,171409261
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Since  $t_{0,975,118}$  has the value of:

$t_{0,975,118} =$	1,980272249
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We reject H0. The test is conclusive to say that at a significant level of 5%, H1 is true.

$$H_0: \hat{b} = 0 \text{ v.s. } H_1: \hat{b} \neq 0$$

$T_b = \frac{\hat{b} - bo}{S \sqrt{\frac{1}{n} + \frac{\bar{x}^2}{S_{xx}}}} \sim t_{n-2} =$	-0,533447154
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We can't reject H0. The test is not conclusive to say that at a significant level of 5%, H0 is false.

## Weekly Analysis

### Hypothesis tests for significant level of 1%

The Hypothesis test are done for  $\hat{a}$  and for  $\hat{b}$ . Let's start with the  $\hat{a}$ :

$$H_0: \hat{a} = 0 \text{ v.s. } H_1: \hat{a} \neq 0$$

$T_a = \frac{\hat{a} - ao}{S \sqrt{\frac{1}{n} + \frac{\bar{x}^2}{S_{xx}}}} \sim t_{n-2} =$	1,132513655
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Since  $t_{0,95,118}$  has the value of:

$t_{0,95,118} =$	1,753050356
------------------	-------------

We can't reject H0. The test is not conclusive to say that at a significant level of 1%, H0 is false, which means that the ordinate can be 0.

$$H0: \hat{b} = 0 \text{ v.s. } H1: \hat{b} \neq 0$$

$T_b = \frac{\hat{b} - bo}{\sqrt{S_{yy}}} \sim t_{n-2} =$	-0,440368919
---	--------------

We can't reject H0. The test is not conclusive to say that at a significant level of 1%, H0 is false.

### Hypothesis tests for significant level of 5%

The Hypothesis test are done for  $\hat{a}$  and for  $\hat{b}$ . Let's start with the  $\hat{a}$ :

$$H0: \hat{a} = 0 \text{ v.s. } H1: \hat{a} \neq 0$$

$T_a = \frac{\hat{a} - ao}{S \sqrt{\frac{1}{n} + \bar{x}^2}} \sim t_{n-2} =$	1,132513655
--	-------------

Since  $t_{0,975,118}$  has the value of:

$t_{0,975,118} =$	2,131449546
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We can't reject H0. The test is not conclusive to say that at a significant level of 5%, H0 is false, which means that the ordinate can be 0.

$$H0: \hat{b} = 0 \text{ v.s. } H1: \hat{b} \neq 0$$

$T_b = \frac{\hat{b} - bo}{\sqrt{S_{yy}}} \sim t_{n-2} =$	-0,440368919
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We can't reject H0. The test is not conclusive to say that at a significant level of 5%, H0 is false.

### e. Confidence intervals for prediction values

## ***new\_cases* and *positive\_rate***

### **Daily Analysis**

#### **Confidence interval of 90%**

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

$\hat{a}$	
CL =	0.9
$\alpha$ =	0.1
$t_{0.95,118}$ =	1.657869522
s =	586.1721643
$\sqrt{\frac{1}{n} + \frac{\bar{x}^2}{S_{xx}}}$ =	0.115517135
IC = ]	-149.3186318 75.19977173 [

Since  $\hat{a} = -37,0594$  and the IC contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

$$\left[ \hat{b} - t_{c}s\sqrt{\frac{1}{S_{xx}}}, \hat{b} + t_{c}s\sqrt{\frac{1}{S_{xx}}} \right]$$

$\hat{b}$	
$\sqrt{\frac{1}{S_{xx}}}$ =	1.978687241
IC = ]	29063.4051 32909.16961 [

Since  $\hat{b} = 30986,2$  and the IC contains that value, it is possible to conclude with 90% of confidence that this is an indicator inaccurate.

#### **Confidence interval of 95%**

## 14. Annexes

$\hat{a}$		
CL =	0.95	
$\alpha$ =	0.05	
$t_{0.975,118} =$	1.980272249	
s =	586.1721643	
$\sqrt{\frac{1}{n} + \frac{\bar{x}^2}{S_{xx}}} =$	0.115517135	
IC = ]	-171.1494649	97.030605 [

Since  $\hat{a} = -37,0594$  and the IC contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

$\hat{b}$		
$\sqrt{\frac{1}{S_{xx}}} =$	1.978687241	
IC = ]	28689.46585	33283.109 [

Since  $\hat{b} = 30986,2$  and the IC contains that value, it is possible to conclude with 90% of confidence that this is an indicator inaccurate.

## Weekly Analysis

### Confidence interval of 90%

$$\left[ \hat{a} - t_{cs} \sqrt{\frac{1}{n} + \frac{\bar{x}^2}{S_{xx}}}, \hat{a} + t_{cs} \sqrt{\frac{1}{n} + \frac{\bar{x}^2}{S_{xx}}} \right]$$

CL =	0.9	
$\alpha$ =	0.1	
$t_{0.95,118} =$	1.753050356	
s =	2708.958885	
$\sqrt{\frac{1}{n} + \frac{\bar{x}^2}{S_{xx}}} =$	0.308701457	
IC = ]	-1801.96989	1130.040328 [

Since  $\hat{a} = -355,964$  and the IC contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

$$\left[ \hat{b} - t_{cs} \sqrt{\frac{1}{S_{xx}}}, \hat{b} + t_{cs} \sqrt{\frac{1}{S_{xx}}} \right]$$

$\hat{b}$			
$\sqrt{\frac{1}{S_{xx}}} =$	0.758261118		
IC = ]	27660.80456	34862.6797	[

Since  $\hat{b} = 31261,742$  and the IC contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

### Confidence interval of 95%

$\hat{a}$			
CL =	0.95		
$\alpha =$	0.05		
$t_{0.975,118} =$	2.131449546		
$s =$	2708.958885		
$\sqrt{\frac{1}{n} + \frac{\bar{x}^2}{S_{xx}}} =$	0.308701457		
IC = ]	-2118.409828	1446.4803 [	

Since  $\hat{a} = -355,964$  and the IC contains that value, it is possible to conclude with 95% of confidence that this is an indicator accurate.

$\hat{b}$			
$\sqrt{\frac{1}{S_{xx}}} =$	0.758261118		
IC = ]	26883.53547	35639.949 [	

Since  $\hat{b} = 31261,742$  and the IC contains that value, it is possible to conclude with 95% of confidence that this is an indicator accurate.

### *new\_deaths* and *new\_tests*

#### Daily Analysis

##### Confidence interval of 90%

$$\left[ \hat{a} - t_{cs} \sqrt{\frac{1}{n} + \frac{\bar{x}^2}{S_{xx}}}, \hat{a} + t_{cs} \sqrt{\frac{1}{n} + \frac{\bar{x}^2}{S_{xx}}} \right]$$

## 14. Annexes

$\hat{a}$	
CL =	0.9
$\alpha$ =	0.1
$t_{0.95,118} =$	1.657869522
s =	66.58580044
$\sqrt{\frac{1}{n} + \frac{\bar{x}^2}{S_{xx}}} =$	0.211339272
IC = ]	21.29882569 67.95855064 [

Since  $\hat{a} = 44,63$  and the IC contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

$$\left[ \hat{b} - t_c s \sqrt{\frac{1}{S_{xx}}}, \hat{b} + t_c s \sqrt{\frac{1}{S_{xx}}} \right]$$

$\hat{b}$	
$\sqrt{\frac{1}{S_{xx}}} =$	5.07923E-06
IC = ]	-0.000741113 0.000380285 [

Since  $\hat{b} = -0,0002$  and the IC contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

### Confidence interval of 95%

$\hat{a}$	
CL =	0.95
$\alpha$ =	0.05
$t_{0.975,118} =$	2.131449546
s =	484.9229696
$\sqrt{\frac{1}{n} + \frac{\bar{x}^2}{S_{xx}}} =$	0.770948271
IC = ]	-373.4527071 1220.234356 [

Since  $\hat{a} = 442,391$  and the IC contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

$\hat{b}$			
$\sqrt{\frac{1}{S_{xx}}} =$	2.79353E-06		
IC = ]	-0.003483906	0.002290817 [	

Since  $\hat{b} = -0,0006$  and the IC contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

## 2. Multiple Linear Regression

### a. Overview of Multiple Linear Regression

In statistics, Multiple Linear Regression refers to a technique that uses two or more independent variables (which we know its behaviours), to estimate the outcome of a dependent variable. It is used to know how strong the relationship between the independent variables and the dependent variable is or even to get the value of the dependent at a certain point. From this relationship it is possible using the correlation coefficient ( $R^2_{ajust.}$ ) that goes from 0 to 1, to calculate how precise the data is. If the ( $R^2_{ajust.}$ ) is close to 1 ( $>0,90$ ), then the data is very precise.

### b. Multiple Linear Regression Model

*For the study of simple linear regression, we are going to use two examples and then how we can compare them. We used the file owid-covid-dataVF.xlsx as it has all necessary data to study MLR.*

*The goal was to make a daily and weekly analysis between all dependent variables and independent variables.*

*-The first one is the study between new\_cases and reproduction\_rate, icu\_patients, hosp\_patients, new\_tests, positive\_rate, people\_full\_vaccinated. (Case2\_#1)*

-The second one is the study between new\_deaths and reproduction\_rate, icu\_patients, hosp\_patients. (Case3\_#2).

### c. Model significance

**new\_cases** and **reproduction\_rate, icu\_patients, hosp\_patients, new\_tests, positive\_rate, people\_full\_vaccinated**

#### Daily Analysis

To study the significance model, we had to find firstly the regression model between the two variables.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6$$

In this case, **new\_cases** is the dependent variable and rest are the independent variables.

$$\hat{Y} = -989,6963 + 490,1287X_1 + 3,3670X_2 + -1,2745X_3 + 0,0075X_4 + 65851,5967X_5 + 3,18768E - 05 X_6$$

(Regression model obtained with **new\_cases** and **the independent variables**)

After calculating all the necessary values, we generated the Anova Table and compared with our Anova Table to see if it matched.

$SQ_T = Y^T * Y - n\bar{y}^2 =$	285780855,9
$SQ_R = \hat{B}^T X^T Y - n\bar{y}^2 =$	259118182,5
$SQ_E = Y^T * Y - \hat{B}^T X^T Y =$	26662673,45
$MQ_R = \frac{SQ_R}{k} =$	43186363,75
$MQ_E = \frac{SQ_E}{n - (k + 1)} =$	235952,8624
$F \text{ estatística} = \frac{MQ_R}{MQ_E} =$	183,0296243

As the Correlation Coefficient is concerned, we calculated that:

$R^2_{ajust.} = 1 - \left( \frac{n - 1}{n - (k + 1)} \right) (1 - R^2) =$	0,901748525	$R = \sqrt{R^2} =$	0,949604404
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This shows that, as the **R** is **0,949604404** the MLR is very precise. This result is confirmed in the Anova Table as the values showed above are congruent with the MLR calculated before.

## Weekly Analysis

To study the significance model, we had to find firstly the regression model between the two variables.

$$\hat{Y} = -4817,4992 + 258,7398X_1 + 1,0663X_2 - 0,8627X_3 + 0,0113X_4 + 61253,5137X_5 - 6,86513E - 05 X_6$$

(Regression model obtained with **new\_cases** and **the indepent variables**)

After calculating all the necessary values, we generated the Anova Table and compared with our Anova Table values to see if it matched.

$SQ_T = Y^T * Y - n\bar{y}^2 =$	1809841469
$SQ_R = \hat{B}^T X^T Y - n\bar{y}^2 =$	1792188214
$SQ_E = Y^T * Y - \hat{B}^T X^T Y =$	17653254,64
$MQ_R = \frac{SQ_R}{k} =$	298698035,7
$MQ_E = \frac{SQ_E}{n - (k + 1)} =$	1765325,464
$F estatistica = \frac{MQ_R}{MQ_E} =$	169,2028138

As the Correlation Coefficient is concerned, we calculated that:

$$R^2_{ajust.} = 1 - \left( \frac{n - 1}{n - (k + 1)} \right) (1 - R^2) = 0,984393546 \quad R = \sqrt{R^2} = 0,992166088$$

This shows that, as the **R** is **0,992166088** the MLR is very precise. This result is confirmed in the Anova Table as the values showed above are congruent with the MLR calculated before.

**new\_deaths** and **reproduction\_rate, icu\_patients, hosp\_patients**

## Daily Analysis

To study the significance model, we had to find firstly the regression model between the two variables.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3$$

In this case, ***new\_deaths*** is the dependent variable and ***new\_tests*** is the independent variable. 1

$$\hat{Y} = -4,5643 + 4,0417X_1 - 0,1968X_2 - 0,0616X_3$$

(Regression model obtained with ***new\_deaths*** and ***reproduction\_rate*, *icu\_patients*, *hosp\_patients***)

After calculating all the necessary values, we generated the Anova Table and compared with our Anova Table to see if it matched.

$SQ_T = Y^T * Y - n\bar{y}^2 =$	524434,5917
$SQ_R = \hat{B}^T X^T Y - n\bar{y}^2 =$	514125,899
$SQ_E = Y^T * Y - \hat{B}^T X^T Y =$	10308,69266
$MQ_R = \frac{SQ_R}{k} =$	171375,2997
$MQ_E = \frac{SQ_E}{n - (k + 1)} =$	88,86804021
$F \text{ estatística} = \frac{MQ_R}{MQ_E} =$	1928,424429

As the Correlation Coefficient is concerned, we calculated that:

$$R^2_{ajust.} = 1 - \left( \frac{n - 1}{n - (k + 1)} \right) (1 - R^2) = 0,97983486 \quad R = \sqrt{R^2} = 0,989866$$

This shows that, as the **R** is **0,989866** the MLR is very precise. This result is confirmed in the Anova Table as the values showed above are congruent with the MLR calculated before.

## Weekly Analysis

To study the significance model, we had to find firstly the regression model between the two variables.

$$Y = 423,3908246 - 0,000596544X1$$

(Regression model obtained with ***new\_deaths*** and ***reproduction\_rate*, *icu\_patients*, *hosp\_patients***)

## 14. Annexes

After calculating all the necessary values, we generated the Anova Table and compared with our Anova Table values to see if it matched.

$SQ_T = Y^T * Y - n\bar{y}^2 =$	3572855.765
$SQ_R = \hat{B}^T X^T Y - n\bar{y}^2 =$	3554731.642
$SQ_E = Y^T * Y - \hat{B}^T X^T Y =$	18124.12231
$MQ_R = \frac{SQ_R}{k} =$	1184910.547
$MQ_E = \frac{SQ_E}{n - (k + 1)} =$	1394.163255
$F \text{ estatística} = \frac{MQ_R}{MQ_E} =$	849.9080316

As the Correlation Coefficient is concerned, we calculated that:

$R^2 = \frac{SQ_R}{SQ_T} =$	0.994927273
$R^2_{ajust.} = 1 - \left( \frac{n - 1}{n - (k + 1)} \right) (1 - R^2) =$	0.993756644

This shows that, as the **R2** is **0,993756644** the MLR is very precise. This result is confirmed in the Anova Table as the values showed above are congruent with the MLR calculated before.

### d. Hypothesis tests for model coefficients

**new\_cases** and **reproduction\_rate, icu\_patients, hosp\_patients, new\_tests, positive\_rate, people\_full\_vaccinated**

#### Daily Analysis

#### Hypothesis tests for significant level of 1%

The Hypothesis test are done for each beta ( $\beta$ ).

Since  $t_{0,95}$  has the value of:

$$t_{0,95} = 1,658450216$$

Let's start with the  $\beta_0$ :

$H_0 : B_0 = 0$	$H_1 : B_0 \neq 0$
$T_0 = \frac{\hat{B}_0}{\sqrt{\hat{\sigma}^2 C_{00}}} =$	-0.185993896

We can't reject H0. The test is not conclusive to say that at a significant level of 1%, H0 is false.

$H_0 : B_1 = 0$	$H_1 : B_1 \neq 0$
$T_0 = \frac{\hat{B}_1}{\sqrt{\hat{\sigma}^2 C_{11}}} =$	0.784330886

We can't reject H0. The test is not conclusive to say that at a significant level of 1%, H0 is false.

$H_0 : B_2 = 0$	$H_1 : B_2 \neq 0$
$T_0 = \frac{\hat{B}_2}{\sqrt{\hat{\sigma}^2 C_{22}}} =$	1,889796535

We reject H0. The test is not conclusive to say that at a significant level of 1%, H0 is false.

$H_0 : B_3 = 0$	$H_1 : B_3 \neq 0$
$T_0 = \frac{\hat{B}_3}{\sqrt{\hat{\sigma}^2 C_{33}}} =$	-3.67049216

We reject H0. The test is not conclusive to say that at a significant level of 1%, H0 is false.

$H_0 : B_4 = 0$	$H_1 : B_4 \neq 0$
$T_0 = \frac{\hat{B}_4}{\sqrt{\hat{\sigma}^2 C_{44}}} =$	2.754003289

We reject H0. The test is not conclusive to say that at a significant level of 1%, H0 is false.

$H_0 : B_5 = 0$	$H_1 : B_5 \neq 0$
$T_0 = \frac{\hat{B}_5}{\sqrt{\hat{\sigma}^2 C_{55}}} =$	9.361896853

We reject H0. The test is not conclusive to say that at a significant level of 1%, H0 is false.

$H_0 : B_6 = 0$	$H_1 : B_6 \neq 0$
$T_0 = \frac{\hat{B}_6}{\sqrt{\hat{\sigma}^2 C_{66}}} =$	0.206460586

We can't reject H0. The test is not conclusive to say that at a significant level of 1%, H0 is false.

### Hypothesis tests for significant level of 5%

Since all of the values above are the same except the  $t_{0,975} = 1,9812$  we are going to show the decisions for each beta  $\beta$ .

Let's start with the  $\beta_0$ :

We can't reject H<sub>0</sub>. The test is not conclusive to say that at a significant level of 5%, H<sub>0</sub> is false.

β1:

We can't reject H<sub>0</sub>. The test is not conclusive to say that at a significant level of 5%, H<sub>0</sub> is false.

β2:

We can't reject H<sub>0</sub>. The test is not conclusive to say that at a significant level of 5%, H<sub>0</sub> is false.

β3:

We reject H<sub>0</sub>. The test is conclusive to say that at a significant level of 5%, H<sub>1</sub> is true.

β4:

We reject H<sub>0</sub>. The test is conclusive to say that at a significant level of 5%, H<sub>1</sub> is true.

β5:

We reject H<sub>0</sub>. The test is conclusive to say that at a significant level of 5%, H<sub>1</sub> is true.

β6:

We can't reject H<sub>0</sub>. The test is not conclusive to say that at a significant level of 5%, H<sub>0</sub> is false.

## **Weekly Analysis**

### **Hypothesis tests for significant level of 1%**

The Hypothesis test are done for each beta ( $\beta$ ).

Since  $t_{0,95}$  has the value of:

$t_{0,95} =$	1,812461123
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Let's start with the β0:

$H_0 : B_0 = 0$	$H_1 : B_0 \neq 0$
$T_0 = \frac{\hat{B}_0}{\sqrt{\hat{\sigma}^2 C_{00}}} =$	-0,954773508

## 14. Annexes

We can't reject H0. The test is not conclusive to say that at a significant level of 1%, H0 is false.

$H_0 : B_1 = 0$	$H_1 : B_1 \neq 0$
$T_0 = \frac{\hat{B}_1}{\sqrt{\hat{\sigma}^2 C_{11}}} =$	0,375636509

We can't reject H0. The test is not conclusive to say that at a significant level of 1%, H0 is false

$H_0 : B_2 = 0$	$H_1 : B_2 \neq 0$
$T_0 = \frac{\hat{B}_2}{\sqrt{\hat{\sigma}^2 C_{22}}} =$	0,475726602

We can't reject H0. The test is not conclusive to say that at a significant level of 1%, H0 is false

$H_0 : B_3 = 0$	$H_1 : B_3 \neq 0$
$T_0 = \frac{\hat{B}_3}{\sqrt{\hat{\sigma}^2 C_{33}}} =$	-1,889441515

We can't reject H0. The test is not conclusive to say that at a significant level of 1%, H0 is false

$H_0 : B_4 = 0$	$H_1 : B_4 \neq 0$
$T_0 = \frac{\hat{B}_4}{\sqrt{\hat{\sigma}^2 C_{44}}} =$	2,414775609

We reject H0. The test is conclusive to say that at a significant level of 5%, H1 is true.

$H_0 : B_5 = 0$	$H_1 : B_5 \neq 0$
$T_0 = \frac{\hat{B}_5}{\sqrt{\hat{\sigma}^2 C_{55}}} =$	6,831012918

We reject H0. The test is conclusive to say that at a significant level of 5%, H1 is true.

$H_0 : B_6 = 0$	$H_1 : B_6 \neq 0$
$T_0 = \frac{\hat{B}_6}{\sqrt{\hat{\sigma}^2 C_{66}}} =$	-0,410170262

We can't reject H0. The test is not conclusive to say that at a significant level of 5%, H0 is false.

*new\_deaths* and *reproduction\_rate, icu\_patients, hosp\_patients*

### Daily Analysis

#### Hypothesis tests for significant level of 1%

The Hypothesis test are done for each beta ( $\beta$ ).

Since  $t_{0,95}$  has the value of:

$$t_{0,95} = 1,658095744$$

Let's start with the  $\beta_0$ :

$H_0 : B_0 = 0$	$H_1 : B_0 \neq 0$
$T_0 = \frac{\hat{B}_0}{\sqrt{\hat{\sigma}^2 C_{00}}} =$	-0,377192315

We can't reject H0. The test is not conclusive to say that at a significant level of 1%, H0 is false.

$H_0 : B_1 = 0$	$H_1 : B_1 \neq 0$
$T_0 = \frac{\hat{B}_1}{\sqrt{\hat{\sigma}^2 C_{11}}} =$	0,372969984

We can't reject H0. The test is not conclusive to say that at a significant level of 1%, H0 is false.

$H_0 : B_2 = 0$	$H_1 : B_2 \neq 0$
$T_0 = \frac{\hat{B}_2}{\sqrt{\hat{\sigma}^2 C_{22}}} =$	-6,729776989

We reject H0. The test is conclusive to say that at a significant level of 1%, H1 is true.

$H_0 : B_3 = 0$	$H_1 : B_3 \neq 0$
$T_0 = \frac{\hat{B}_3}{\sqrt{\hat{\sigma}^2 C_{33}}} =$	18,02389558

We reject H0. The test is conclusive to say that at a significant level of 1%, H1 is true.

### Hypothesis tests for significant level of 5%

Since all of the values above are the same except the  $t_{0,975} = 1,9812$  we are going to show the decisions for each beta  $\beta$ .

$\beta_0$ :

We can't reject H0. The test is not conclusive to say that at a significant level of 5%, H0 is false.

$\beta_1$ :

We can't reject H0. The test is not conclusive to say that at a significant level of 5%, H0 is false.

$\beta_2$ :

We can't reject H<sub>0</sub>. The test is not conclusive to say that at a significant level of 5%, H<sub>0</sub> is false.

$\beta_3$ :

We can't reject H<sub>0</sub>. The test is not conclusive to say that at a significant level of 5%, H<sub>0</sub> is false.

## Weekly Analysis

### Hypothesis tests for significant level of 1%

The Hypothesis test are done for each beta ( $\beta$ ).

Since  $t_{0,95}$  has the value of:

$$t_{0,95} = 1,658095744$$

Let's start with the  $\beta_0$ :

$H_0 : \beta_0 = 0$	$H_1 : \beta_0 \neq 0$
$T_0 = \frac{\hat{\beta}_0}{\sqrt{\hat{\sigma}^2 C_{00}}} =$	0,585646

We can't reject H<sub>0</sub>. The test is not conclusive to say that at a significant level of 1%, H<sub>0</sub> is false.

$H_0 : \beta_1 = 0$	$H_1 : \beta_1 \neq 0$
$T_0 = \frac{\hat{\beta}_1}{\sqrt{\hat{\sigma}^2 C_{11}}} =$	-0,54434

We can't reject H<sub>0</sub>. The test is not conclusive to say that at a significant level of 1%, H<sub>0</sub> is false.

$H_0 : \beta_2 = 0$	$H_1 : \beta_2 \neq 0$
$T_0 = \frac{\hat{\beta}_2}{\sqrt{\hat{\sigma}^2 C_{22}}} =$	-5,12529

We reject H<sub>0</sub>. The test is conclusive to say that at a significant level of 1%, H<sub>1</sub> is true.

$H_0 : B_3 = 0$	$H_1 : B_3 \neq 0$
$T_0 = \frac{\hat{B}_3}{\sqrt{\hat{\sigma}^2 C_{33}}} =$	11,96093

We reject H0. The test is conclusive to say that at a significant level of 1%, H1 is true.

### Hypothesis tests for significant level of 5%

Since all the values above are the same except the  $t_{0,975} = 1,9812$  we are going to show the decisions for each beta  $\beta$ .

$\beta_0$ :

We can't reject H0. The test is not conclusive to say that at a significant level of 5%, H0 is false.

$\beta_1$ :

We can't reject H0. The test is not conclusive to say that at a significant level of 5%, H0 is false.

$\beta_2$ :

We can't reject H0. The test is not conclusive to say that at a significant level of 5%, H0 is false.

$\beta_3$ :

We can't reject H0. The test is not conclusive to say that at a significant level of 5%, H0 is false.

### e. Confidence intervals for prediction values

***new\_cases and reproduction\_rate, icu\_patients, hosp\_patients,  
new\_tests, positive\_rate, people\_full\_vaccinated***

## Daily Analysis

### Confidence interval of 90%

	$\hat{B}_0 =$	-989,6962818
	$\hat{\sigma}^2 =$	235952,8624
	$C_{00} =$	1,710469988
	$t_{0,95} =$	1,658450216
	$I.C.90\% (\hat{B}_0) =$	] -2043,289081 ; 63,89651697 [

Since  $\widehat{B}_0 = -989,6963$  and the CI do not contains that value, it is possible to conclude with 90% of confidence that this is an indicator inaccurate.

	$\hat{B}_1 =$	490,1286839
	$\hat{\sigma}^2 =$	235952,8624
	$C_{11} =$	1,654993736
	$t_{0,95} =$	1,658450216
	$I.C.90\% (\hat{B}_1) =$	] -546,2375186 ; 1526,494886 [

Since  $\widehat{B}_1 = 490,1287$  and the CI contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

	$\hat{B}_2 =$	3,367032143
	$\hat{\sigma}^2 =$	235952,8624
	$C_{22} =$	1,34536E-05
	$t_{0,95} =$	1,658450216
	$I.C.90\% (\hat{B}_2) =$	] 0,41218749 ; 6,321876795 [

Since  $\widehat{B}_2 = 3,3670$  and the CI contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

## 14. Annexes

	$\hat{B}_3 =$	-1,274467731	
	$\hat{\sigma}^2 =$	235952,8624	
	$C_{33} =$	5,10956E-07	
	$t_{0,95} =$	1,658450216	
	$I.C.90\% (\hat{B}_3) =$	] -1,850314564 ; -0,698620899 [	

Since  $\hat{B}_3 = -1,2745$  and the CI contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

	$\hat{B}_4 =$	0,007518522	
	$\hat{\sigma}^2 =$	235952,8624	
	$C_{44} =$	3,15872E-11	
	$t_{0,95} =$	1,658450216	
	$I.C.90\% (\hat{B}_4) =$	] 0,002990897 ; 0,012046147 [	

Since  $\hat{B}_4 = 0,0075$  and the CI contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

	$\hat{B}_5 =$	65851,59666	
	$\hat{\sigma}^2 =$	235952,8624	
	$C_{55} =$	209,6909392	
	$t_{0,95} =$	1,658450216	
	$I.C.90\% (\hat{B}_5) =$	] 54186,05532 ; 77517,13799 [	

Since  $\hat{B}_5 = 65851,6$  and the IC contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

	$\hat{B}_6 =$	3,18768E-05	
	$\hat{\sigma}^2 =$	235952,8624	
	$C_{66} =$	1,0103E-13	
	$t_{0,95} =$	1,658450216	
	$I.C.90\% (\hat{B}_6) =$	] -0,000224182 ; 0,000287936 [	

Since  $\hat{B}_6 = 3,187E-05$  and the CI do not contain that value, it is possible to conclude with 90% of confidence that this is an indicator inaccurate.

### Confidence interval of 95%

	$\hat{B}_0 =$	-989,6962818	
	$\hat{\sigma}^2 =$	235952,8624	
	$C_{00} =$	1,710469988	
	$t_{0,975} =$	1,981180359	
$I.C.95\%(\hat{B}_0) =$	]	-2248,315527 ;	268,9229636 [

Since  $\widehat{B}_0 = -989,6963$  and the CI contains that value, it is possible to conclude with 95% of confidence that this is an accurate indicator.

	$\hat{B}_1 =$	490,1286839	
	$\hat{\sigma}^2 =$	235952,8624	
	$C_{11} =$	1,654993736	
	$t_{0,975} =$	1,981180359	
$I.C.95\%(\hat{B}_1) =$	]	-747,9117139 ;	1728,169082 [

Since  $\widehat{B}_1 = 490,1287$  and the CI contains that value, it is possible to conclude with 95% of confidence that this is an accurate indicator.

	$\hat{B}_2 =$	3,367032143	
	$\hat{\sigma}^2 =$	235952,8624	
	$C_{22} =$	1,34536E-05	
	$t_{0,975} =$	1,981180359	
$I.C.95\%(\hat{B}_2) =$	]	-0,162817673 ;	6,896881958 [

Since  $\widehat{B}_2 = 3,3670$  and the CI contains that value, it is possible to conclude with 95% of confidence that this is an accurate indicator.

	$\hat{B}_3 =$	-1,274467731	
	$\hat{\sigma}^2 =$	235952,8624	
	$C_{33} =$	5,10956E-07	
	$t_{0,975} =$	1,981180359	
$I.C.95\%(\hat{B}_3) =$	]	-1,962372875 ;	-0,586562587 [

Since  $\widehat{B}_3 = -1,2745$  and the CI contains that value, it is possible to conclude with 95% of confidence that this is an accurate indicator.

## 14. Annexes

	$\hat{B}_4 =$	0,007518522	
	$\delta^2 =$	235952,8624	
	$C_{44} =$	3,15872E-11	
	$t_{0,975} =$	1,981180359	
$I.C.95\% (\hat{B}_4) =$	]	0,002109833 ;	0,012927212 [

Since  $\widehat{B}_4 = 0,0075$  and the CI contains that value, it is possible to conclude with 95% of confidence that this is an accurate indicator.

	$\hat{B}_5 =$	65851,59666	
	$\delta^2 =$	235952,8624	
	$C_{55} =$	209,6909392	
	$t_{0,975} =$	1,981180359	
$I.C.95\% (\hat{B}_5) =$	]	51915,97101 ;	79787,22231 [

Since  $\widehat{B}_5 = 65851,6$  and the CI contains that value, it is possible to conclude with 95% of confidence that this is an accurate indicator .

	$\hat{B}_6 =$	3,18768E-05	
	$\delta^2 =$	235952,8624	
	$C_{66} =$	1,0103E-13	
	$t_{0,975} =$	1,981180359	
$I.C.95\% (\hat{B}_6) =$	]	-0,00027401 ;	0,000337764 [

Since  $\widehat{B}_6 = 3,187E-05$  and the CI contains that value, it is possible to conclude with 95% of confidence that this is an accurate indicator.

## Weekly Analysis

### Confidence interval of 90%

## 14. Annexes

	$\hat{B}_0 =$	-4817,499213		
	$\hat{\sigma}^2 =$	1765325,464		
	$C_{00} =$	14,42174454		
	$t_{0,95} =$	1,812461123		
$I.C.90\% (\hat{B}_0) =$	] -13962,63149 ; 4327,633068 [			

Since  $\hat{B}_0 = -4817,4992$  and the CI contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

	$\hat{B}_1 =$	258,7397942		
	$\hat{\sigma}^2 =$	235952,8624		
	$C_{11} =$	0,268760896		
	$t_{0,95} =$	1,812461123		
$I.C.90\% (\hat{B}_1) =$	] -197,6798889 ; 715,1594774 [			

Since  $\hat{B}_1 = 258,7398$  and the CI contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

	$\hat{B}_2 =$	1,066314974		
	$\hat{\sigma}^2 =$	235952,8624		
	$C_{22} =$	2,84598E-06		
	$t_{0,95} =$	1,812461123		
$I.C.90\% (\hat{B}_2) =$	] -0,418926276 ; 2,551556224 [			

Since  $\hat{B}_2 = 1,0663$  and the CI contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

## 14. Annexes

$\hat{B}_3 =$	-0,862654804		
$\hat{\sigma}^2 =$	235952,8624		
$C_{33} =$	1,18082E-07		
$t_{0,95} =$	1,812461123		
$I.C.90\% (\hat{B}_3) =$	] -1,165187644	;	-0,560121965 [

Since  $\widehat{B}_3 = -0,8627$  and the CI contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

$\hat{B}_4 =$	0,011267698		
$\hat{\sigma}^2 =$	235952,8624		
$C_{44} =$	1,23337E-11		
$t_{0,95} =$	1,812461123		
$I.C.90\% (\hat{B}_4) =$	] 0,008175785	;	0,014359612 [

Since  $\widehat{B}_4 = 0,0113$  and the CI contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

$\hat{B}_5 =$	61253,51373		
$\hat{\sigma}^2 =$	235952,8624		
$C_{55} =$	45,54775899		
$t_{0,95} =$	1,812461123		
$I.C.90\% (\hat{B}_5) =$	] 55311,75747	;	67195,26998 [

## 14. Annexes

Since  $\widehat{B}_5 = 61253,5137$  and the CI contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

$\widehat{B}_6 =$	-6,86513E-05	
$\widehat{\sigma}^2 =$	235952,8624	
$C_{66} =$	1,58688E-14	
$t_{0,95} =$	1,812461123	
$I.C.90\% (\widehat{B}_6) =$	]	-0,000179557 ; 4,22543E-05 [

Since  $\widehat{B}_6 = -6,86513E-05$  and the CI contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

### Confidence interval of 95%

$\widehat{B}_0 =$	-4817,499213	
$\widehat{\sigma}^2 =$	1765325,464	
$C_{00} =$	14,42174454	
$t_{0,975} =$	2,228138852	
$I.C.95\% (\widehat{B}_0) =$	]	-16060,01597 ; 6425,017543 [

Since  $\widehat{B}_0 = -4817,499$  and the CI contains that value, it is possible to conclude with 95% of confidence that this is an indicator accurate.

$\widehat{B}_1 =$	258,7397942	
$\widehat{\sigma}^2 =$	1765325,464	
$C_{11} =$	0,268760896	
$t_{0,975} =$	2,228138852	
$I.C.95\% (\widehat{B}_1) =$	]	-1276,010356 ; 1793,489945 [

Since  $\widehat{B}_1 = 258,7398$  and the CI contains that value, it is possible to conclude with 95% of confidence that this is an indicator accurate.

## 14. Annexes

$\hat{B}_2 =$	1,066314974		
$\hat{\sigma}^2 =$	235952,8624		
$C_{22} =$	2,84598E-06		
$t_{0,975} =$	2,228138852		
$I.C_{.95\%}(\hat{B}_2) =$	]	-0,759557974 ; 2,892187922 [	

Since  $\hat{B}_2 = 1,0663$  and the CI contains that value, it is possible to conclude with 95% of confidence that this is an indicator accurate.

$\hat{B}_3 =$	-0,862654804		
$\hat{\sigma}^2 =$	235952,8624		
$C_{33} =$	1,18082E-07		
$t_{0,975} =$	2,228138852		
$I.C_{.95\%}(\hat{B}_3) =$	]	-1,234571843 ; -0,490737765 [	

Since  $\hat{B}_3 = -0,8626$  and the CI contains that value, it is possible to conclude with 95% of confidence that this is an indicator accurate.

$\hat{B}_4 =$	0,011267698		
$\hat{\sigma}^2 =$	235952,8624		
$C_{44} =$	1,23337E-11		
$t_{0,975} =$	2,228138852		
$I.C_{.95\%}(\hat{B}_4) =$	]	0,007466672 ; 0,015068725 [	

Since  $\hat{B}_4 = 0,0113$  and the CI contains that value, it is possible to conclude with 95% of confidence that this is an indicator accurate.

$\hat{B}_5 =$	61253,51373		
$\hat{\sigma}^2 =$	235952,8624		
$C_{55} =$	45,54775899		
$t_{0,975} =$	2,228138852		
$I.C_{.95\%}(\hat{B}_5) =$	]	53949,04921 ; 68557,97824 [	

Since  $\hat{B}_5 = 61253,51$  and the CI contains that value, it is possible to conclude with 95% of confidence that this is an indicator accurate.

## 14. Annexes

$\hat{B}_6 =$	-6,86513E-05		
$\hat{\sigma}^2 =$	235952,8624		
$C_{66} =$	1,58688E-14		
$t_{0,975} =$	2,228138852		
$I.C_{.95\%}(\hat{B}_6) =$	]	-0,000204992	;
			6,76899E-05 [

Since  $\widehat{B}_6 = -6,86513E-05$  and the CI contains that value, it is possible to conclude with 95% of confidence that this is an indicator accurate.

***new\_deaths* and *reproduction\_rate, icu\_patients, hosp\_patients***

### Daily Analysis

#### Confidence interval of 90%

$\hat{B}_0 =$	-4,564284849		
$\hat{\sigma}^2 =$	88,86804021		
$C_{00} =$	1,647685068		
$t_{0,95} =$	1,658095744		
$I.C_{.90\%}(\hat{B}_0) =$	]	-24,62837678	;
			15,49980708 [

Since  $\widehat{B}_0 = -4,564$  and the CI contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

$\hat{B}_1 =$	4,041702663		
$\hat{\sigma}^2 =$	88,86804021		
$C_{11} =$	1,321403204		
$t_{0,95} =$	1,658095744		
$I.C_{.90\%}(\hat{B}_1) =$	]	-13,92631161	;
			22,00971693 [

Since  $\widehat{B}_1 = 4,0417$  and the CI contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

## 14. Annexes

	$\hat{B}_2 =$	-0,196828969
	$\hat{\sigma}^2 =$	88,86804021
	$C_{22} =$	9,62567E-06
	$t_{0,95} =$	1,658095744
$I.C_{.90\%}(\hat{B}_2) =$	]	-0,24532408 ; -0,148333859 [

Since  $\widehat{B}_2 = -0,1968$  and the CI contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

	$\hat{B}_3 =$	0,061584934
	$\hat{\sigma}^2 =$	88,86804021
	$C_{33} =$	1,31373E-07
	$t_{0,95} =$	1,658095744
$I.C_{.90\%}(\hat{B}_3) =$	]	0,055919471 ; 0,067250397 [

Since  $\widehat{B}_3 = 0,0615$  and the CI contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

## Confidence interval of 95%

	$\hat{B}_0 =$	-4,56428485
	$\hat{\sigma}^2 =$	88,86804021
	$C_{00} =$	1,647685068
	$t_{0,975} =$	1,980626002
$I.C_{.95\%}(\hat{B}_0) =$	]	-28,5312134 ; 19,40264 [

Since  $\widehat{B}_0 = -4,564$  and the CI contains that value, it is possible to conclude with 95% of confidence that this is an indicator accurate.

## 14. Annexes

$\hat{B}_1 =$	4,041702663		
$\hat{\sigma}^2 =$	88,86804021		
$C_{11} =$	1,321403204		
$t_{0,975} =$	1,980626002		
$I.C_{.95\%}(\hat{B}_1) =$	]	-17,4214224 ; 25,50483 [	

Since  $\widehat{B}_1 = 4,0417$  and the CI contains that value, it is possible to conclude with 95% of confidence that this is an indicator accurate.

$\hat{B}_2 =$	-0,19682897		
$\hat{\sigma}^2 =$	88,86804021		
$C_{22} =$	9,62567E-06		
$t_{0,975} =$	1,980626002		
$I.C_{.95\%}(\hat{B}_2) =$	]	-0,25475727 ; -0,1389 [	

c

$\hat{B}_3 =$	0,061584934		
$\hat{\sigma}^2 =$	88,86804021		
$C_{33} =$	1,31373E-07		
$t_{0,975} =$	1,980626002		
$I.C_{.95\%}(\hat{B}_3) =$	]	0,054817434 ; 0,068352 [	

Since  $\widehat{B}_3 = 0,0618$  and the CI contains that value, it is possible to conclude with 95% of confidence that this is an indicator accurate.

## Weekly Analysis

### Confidence interval of 90%

## 14. Annexes

	$\hat{B}_0 =$	-4,564284849		
	$\hat{\sigma}^2 =$	88,86804021		
	$C_{00} =$	1,647685068		
	$t_{0,95} =$	1,658095744		
$I.C_{.90\%}(\hat{B}_0) =$	]	-24,62837678	;	15,49980708 [

Since  $\widehat{B}_0 = -4,5643$  and the CI contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

	$\hat{B}_1 =$	4,041702663		
	$\hat{\sigma}^2 =$	88,86804021		
	$C_{11} =$	1,321403204		
	$t_{0,95} =$	1,658095744		
$I.C_{.90\%}(\hat{B}_1) =$	]	-13,92631161	;	22,00971693 [

Since  $\widehat{B}_1 = 4,042$  and the CI contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

	$\hat{B}_2 =$	-0,196828969		
	$\hat{\sigma}^2 =$	88,86804021		
	$C_{22} =$	9,62567E-06		
	$t_{0,95} =$	1,658095744		
$I.C_{.90\%}(\hat{B}_2) =$	]	-0,24532408	;	-0,148333859 [

Since  $\widehat{B}_2 = -0,1968$  and the CI contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

	$\hat{B}_3 =$	0,061584934		
	$\hat{\sigma}^2 =$	88,86804021		
	$C_{33} =$	1,31373E-07		
	$t_{0,95} =$	1,658095744		
$I.C_{.90\%}(\hat{B}_3) =$	]	0,055919471	;	0,067250397 [

## 14. Annexes

Since  $\widehat{B}_3 = 0,0616$  and the CI contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

### Confidence interval of 95%

$\widehat{B}_0 =$	-4,56428485	
$\widehat{\sigma}^2 =$	88,86804021	
$C_{00} =$	1,647685068	
$t_{0,975} =$	1,980626002	
$I.C_{.95\%}(\widehat{B}_0) =$	]	-28,5312134 ; 19,40264 [

Since  $\widehat{B}_0 = -4,5643$  and the CI contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

$\widehat{B}_1 =$	4,041702663	
$\widehat{\sigma}^2 =$	88,86804021	
$C_{11} =$	1,321403204	
$t_{0,975} =$	1,980626002	
$I.C_{.95\%}(\widehat{B}_1) =$	]	-17,4214224 ; 25,50483 [

Since  $\widehat{B}_1 = 4,042$  and the CI contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

$\widehat{B}_2 =$	-0,19682897	
$\widehat{\sigma}^2 =$	88,86804021	
$C_{22} =$	9,62567E-06	
$t_{0,975} =$	1,980626002	
$I.C_{.95\%}(\widehat{B}_2) =$	]	-0,25475727 ; -0,1389 [

Since  $\widehat{B}_2 = -0,1968$  and the CI contains that value, it is possible to conclude with 90% of confidence that this is an indicator accurate.

## 14. Annexes

$\hat{B}_3 =$	0,061584934
$\hat{\sigma}^2 =$	88,86804021
$C_{33} =$	1,31373E-07
$t_{0,975} =$	1,980626002
$I.C.95\% (\hat{B}_3) =$	]
	0,054817434 ; 0,068352 [

Since  $\widehat{B}_3 = 0,0616$  and the CI contains that value, it is possible to conclude with 95% of confidence that this is an indicator accurate.

## B. MDSIC Annex

### 1. Sorting clients by arrival time, or by leaving time

#### a. *Introduction*

The development team initially implemented two sorting algorithms for the legacy data presentation: bubble sort and merge sort.

The bubble sort is a simple sorting algorithm that works by repeatedly swapping the adjacent elements if they are in the wrong order. It is recommended to use this algorithm for small to medium data sets as its average and worst-case time complexity is a bit high.

```
procedure bubble_sort(a[1],a[2],...,a[n]):
    for let i:= 0 to n:
        for j:= 0 to n - i - 1:
            if a[i] < a[j]:
                let aux:= a[j]
                a[j]:= arr[i]
                a[i]:= aux
    return a
```

One way of optimising this algorithm is to whenever an array is determined to be already sorted, halt further passes. For that, we can add a flag to whenever there is a swipe in a pass from the outer loop. If there are no swaps in a pass, it is determined that the array is sorted:

```
procedure bubble_sort(a[1],a[2],...,a[n]):
    for i:= 0 to n:
        flag:= false
        for j:= 0 to n - i - 1:
            if a[i] < a[j]:
                flag:= true
                let aux:= a[j]
                a[j]:= a[i]
                a[i]:= aux
            if flag is false then return a
    return a
```

This way we can skip loop iterations if, during the sorting, we determine that there were no swaps in that iteration, reducing the time the algorithm takes to complete, although this may be more noticeable in larger datasets.

The merge sort is a “Divide and Conquer” sorting algorithm. It is a technique that works by dividing a problem into smaller sub-problems, solves the sub-problems

recursively and finally combines these sub-problems to get the final solution. In this case, the merge sort algorithm divides an array into two halves, calls itself for the two halves and finally merges the two sorted halves. The latter is recommended for larger data sets.

```

procedure merge_sort(a[1],...,a[n]):
    if n > 1:
        mid:= n / 2

        left:= a[0 to mid]
        right:= a[mid to n]

        merge_sort(left)
        merge_sort(right)

    return merge(left, right)

procedure merge(left[1],...,left[x], right[1],...,right[y]):
    let result be an empty array with length x+y
    i:= 0
    j:= 0

    while i < x and j < y:
        if left[i] < right[j]:
            result[]:= left[i]
            i:= i+1
        else:
            result[]:= right[j]
            j:= j+1

    while i < x:
        result[]:= left[i]
        i:= i+1

    while j < y:
        result[]:= right[j]
        j:= j+1

    return result

```

### *b. Runtime tests for inputs of varying sizes*

The runtime of the algorithms depends on the size of the dataset given to it. Before looking at the results of the algorithms it is important to note that these measurements were made using the *Java* built-in package to track the execution

time of both the algorithms. This measurement is not 100% accurate and can have flaws due to *hardware* and other related runtime issues that can influence the result of the experiment. In order to minimize these external problems, five measurements were made for every dataset and algorithm; the next presented values are the average of those results.

Runtimes for a dataset with 7050 entries:

- Merge Sort: 4,84002 ms
- Bubble Sort: 337,91888 ms
- Bubble Sort (optimized): 183,72037 ms

Runtime for a dataset with 5 entries:

- Merge Sort: 0,03278 ms
- Bubble Sort: 0,00328 ms
- Bubble Sort (optimized): 0,02124 ms

### **Long story short:**

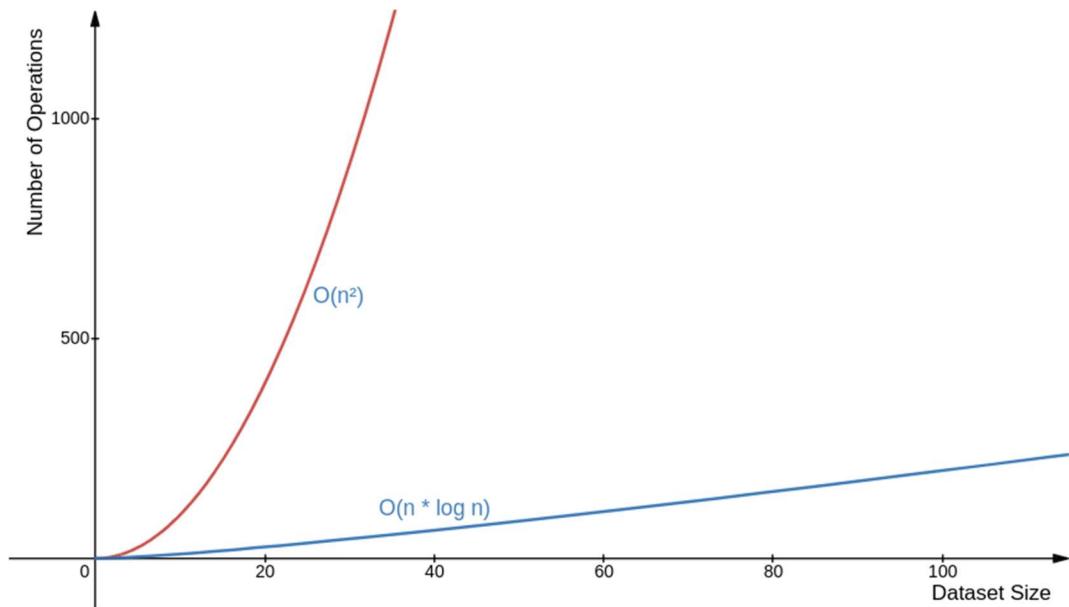
- Use the Bubble Sort algorithm if you have a small to medium dataset;
- Use the Optimized Bubble Sort algorithm if you know your dataset is “almost sorted” (you know there may be some out of order elements);
- Use the Merge Sort algorithm if you have a large, randomly ordered dataset.

#### *c. Worst-case time complexity analysis*

The bubble sort algorithm requires two loops: an inner loop and outer loop. In the worst-case scenario, the inner and outer loops perform  $O(n)$  comparisons, which in result makes the worst-case time complexity of the algorithm  $O(n \cdot n) = O(n^2)$ .

The merge sort algorithm requires to divide the array recursively into two halves. When we divide a number into half in every step, it can be represented in a logarithmic function. Then, we perform a single step operation to find the middle of a subarray, which corresponds to  $O(1)$ . And finally, for merging the arrays, it can be comprised in a time complexity of  $O(n)$ . In result, we get  $O(n(\log n + 1)) = O(n \log n)$ .

## 14. Annexes



Picture 1 - Asymptotic behaviour of algorithms

## 2. Evaluation of effectiveness of the vaccination center's response

### a. *Introduction*

One of the most useful applications of having all the center events registered in a single place or system is the capability of analysing all the data later and take decisions based on the conclusions that the possible to extract from the data.

In the presented application, this feature is implemented using a differences vector of people in the center. Every time someone arrives or leaves the center, the event is registered in the system. This way, it is possible to analyse the performance of the center on a certain interval of a given day.

Given a day and an interval,  $m > 0$  (in minutes), the application creates a differences vector,  $\nu$ , of size  $\frac{n}{m}$ , where  $n$  is the number of minutes that the center is open, and the  $i$ -th element is the difference between the number of people that arrived and the number of people that left the center in the  $i$ -th interval of time.

In order to start this process, it is important to be able to calculate  $n$ , the number of minutes that a center is open every day. This is done by converting both the opening and the closing hours of the center in minutes and subtracting them, as we can express as:

```
procedure to_min(hours:integer,minutes:integer)
  return hours * 60 + minutes
```

Let “hour” be an abstract structure of format  $HH:mm$  where it is possible to split the time in hours and minutes, we can do:

```
procedure center_work_min(start_time:hour,end_time:hour)
  start_hour:= get start time hours
  start_min:= get start time minutes
  end_hour:= get end time hours
  end_min:= get end time minutes

  return to_min(end_hour,end_min)-
    to_min(start_hour,start_min)
```

The output of this procedure is  $n$ , so, we can obtain the number of intervals of the analysis simply calculating  $c = \frac{n}{m}$ .

Now, to calculate the center performance, we need to consider that there are many structures to store the center events. For starters, we will use two distinct vectors, where each position has the data about an arrive or a departure of a SNS User in the center.

For now, we will consider that each position of the vectors only holds the time (in minutes) of the action, in order to simplify the pseudo code and avoid using object-like notations that would make the code harder to understand.

If we consider that both vectors are ordered for time of the event, we can do:

```

procedure arrives_vec(c:integer, a[1],a[2],...,a[n]:integers,
open_minutes:integer, interval:integer)
    (open_minutes represent the opening time of the center in
minutes)

    (the output will be recorder in a vector v of size c,
consider this vector has all it's position initialized with
value 0)

    end_interval:= open_minutes + interval
    j:= 1
    for i:= 1 to n
        if a[i] < end_interval then v[j]:= v[j] + 1
        else
            j:= j + 1
            end_interval:= end_interval + interval
    return v

```

Then, we can do the opposite process for users leaving the center:

```

procedure departures_vec(c:integer, a[1],a[2],...,a[n]:integers,
open_minutes:integer, interval:integer)
    end_interval:= open_minutes + interval

```

## 14. Annexes

```
j:=1
for i:=1 to n
    if a[i] < end_interval then v[j]:= v[j] - 1
    else
        j:= j + 1
        end_interval:= end_interval + interval
return v
```

The only line that really changes is the line 4 of the code, where instead of incrementing the value of the result vector, we decrement.

With both vectors in hands, we only need to make the difference between them.

```
procedure dif_vec(arrives[0 to c], departures[0 to c]
    (let dif be the result vector of size c)

    for i:=1 to c
        dif[i]:= arrives[i]-departures[i]

    return dif
```

But we can consider that the vectors had no precondition in terms of sorting, given so, the algorithm would be a little more complex.

```
procedure arrives_vec(c:integer, a[1],a[2],...,a[n]:integers,
open_minutes:integer, interval:integer)
beg_interval:=open_minutes
end_interval:= open_minutes + interval
k:=1
for i:=1 to n
    for j:=1 to n
```

```

        if a[i] >= beg_interval and a[i] < end_interval then
            v[j]:= v[k] + 1

            k:= k + 1

            beg_interval:= beg_interval + interval
            end_interval:= end_interval + interval

        return v

procedure departures_vec(c:integer, a[1],a[2],...,a[n]:integers,
open_minutes:integer, interval:integer)
begin
    beg_interval:=open_minutes
    end_interval:= open_minutes + interval
    k:=1
    for i:=1 to n
        for j:=1 to n
            if a[i] >= beg_interval and a[i] < end_interval then
                v[j]:= v[k] - 1
                k:= k + 1
            beg_interval:= beg_interval + interval
            end_interval:= end_interval + interval
    return v
end.

```

And then use the above procedure dif\_vec to obtain the differences vector.

In this case, to consider that no order is imposed, it is needed to run through the vector for each position and search for events that are between the pretended time interval.

We can consider a final adaptation, using a new data structure for holding the center events. We can consider a structure that holds, among other data, the event, and the event type. This way, and considering the data has no precondition in terms of sorting, we can do:

```

procedure dif_vec(c:integer, a[1],a[2],...,a[n]:event,
open_minutes:integer, interval:integer)
begin
    ...
end.

```

## 14. Annexes

(We may consider the event to hold the time of the event in minutes and the event type ‘arrive’/‘departure’)

```
beg_interval:=open_minutes
end_interval:= open_minutes + interval
k:=1
for i:=1 to n
    for j:=1 to n
        if a[i] minutes >= beg_interval and a[i] minutes <
end_interval then
            if(a[i] type is arrive) v[k]:= v[k] + 1
            if(a[i] type is departure) v[k]:= v[k] - 1
        k:= k + 1
        beg_interval:= beg_interval + interval
        end_interval:= end_interval + interval
return v
```

With this vector in hands, we can take some conclusions over the processed data. For example, we can determine the maximum sum contiguous sub list of  $v$ . This way, it is possible for a center coordinator to conclude what is the most critical time of the day in the center and can take some decisions accordingly.

To determine this sub list, we can have many approaches, one of the simplest is a brute force one that computes all the possible sub lists, and its sums in order to determine the max sum sub list.

Given so, we can do:

```
procedure max(v[1],v[2],...v[n]:integers)
    start_index:= 0
    end_index:= n
    sum:= v[1]
    for i:= 1 to n
        for j:= i to n
```

```

current:= 0
for k:= i to j
    current:= current + v[k]
if current > sum then
    sum:= current
    start_index:= i
    end_index:= j

```

In this case we compute the sum of each sub list and then compare it to the current max sum, this brute force is a bit *naïve*, approach. We can improve it by comparing the sum inside the second loop.

```

procedure max(v[1],v[2],...,v[n]:integers)
    start_max:= 0
    end_index:= n
    sum:= v[1]
    for left:= 1 to n
        current_sum:= 0
        for right:= left to n
            current_sum:= current_sum + v[right]
            if current_sum > sum then
                sum:= current_sum
                start_index:= left
                end_index:= right
    return v[left to right]

```

This way we improve the efficiency of the algorithm.

The maximum sum sub list of  $v$  represents the time window in  $v$  that the center has the most people inside.

Obviously, this brute force method is not the most efficient one. As we will analyse in the following points, the benchmark algorithm that was given to us is much more efficient by using a linear approach to the problem.

### *b. Runtime tests for inputs of varying sizes*

The runtime of the algorithm depends on the size of the list  $v$ . This size, is, as seen before, depends in two factors:  $n$ , the number of minutes that the center is open, and  $m$ , the time interval defined by the user.

Considering a center that works from 8A.M. until 8P.M. we can establish

$$n = 60 \cdot (20 - 8) \Leftrightarrow n = 60 \cdot 12 \Leftrightarrow n = 720$$

With this, we can establish a relation of inverse proportionality with  $m$ . As  $m$  grows, the size of  $v$  gets smaller.

We can compare both the brute force algorithm and the benchmark presented. For comparison we will use the second brute force present previously.

Before looking at the results of the algorithms it is important to note that these measurements were made using the *Java* built-in package to track the execution time of both the algorithms, we save the current time, in nanoseconds, when the algorithm starts, and then we save the end time aswell. After this, we subtract them and parse it back to milliseconds in order to have accuracy with decimal places. It is important to notice that this measurement is not 100% accurate and can have flaws due to *hardware* and other related runtime issues that can influence the result of the experiment. In order to minimize these external problems, three measurements were made for every  $m$  value and the next presented values are the average of those results.

For  $m = 24$ :

Benchmark = 0.0125ms | BruteForce = 0.0233ms

For  $m = 36$ :

Benchmark = 0.0088ms | BruteForce = 0.0161ms

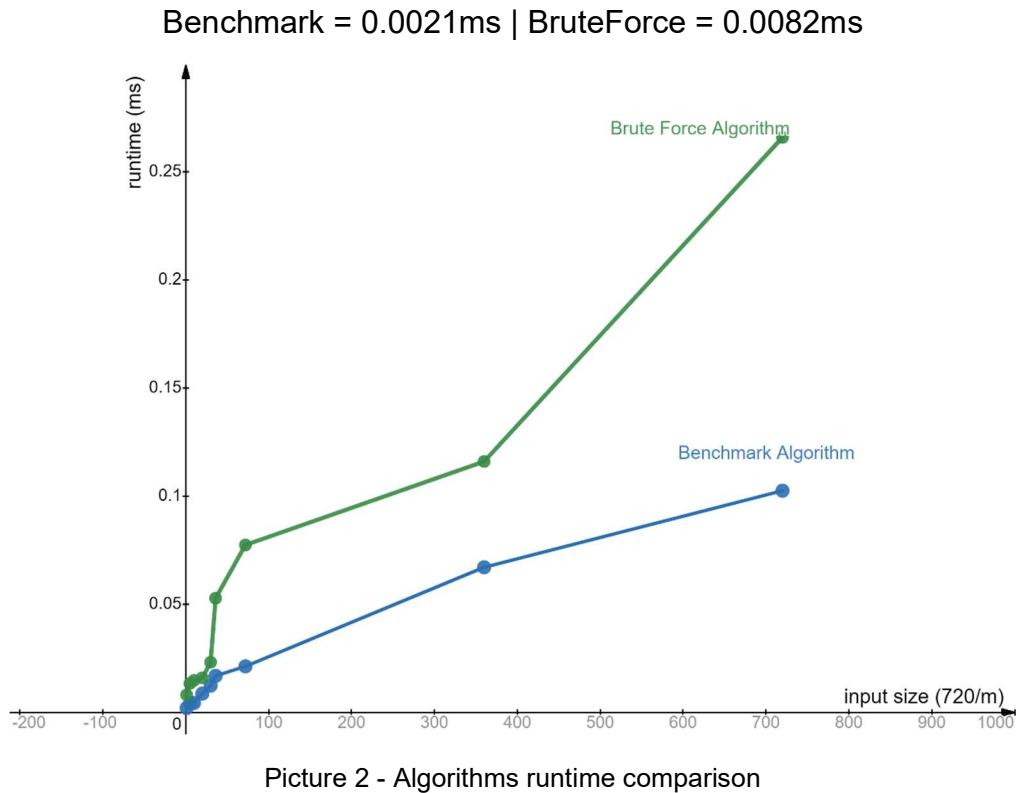
For  $m = 72$ :

Benchmark = 0.0045ms | BruteForce = 0.0149ms

For  $m = 144$ :

Benchmark = 0.0042ms | BruteForce = 0.0135ms

For  $m = 720$ :



To make the graphical differences between the two algorithms runtime graphs three more  $m$  values were added:  $m = 1, 10, 20$ .

As we can see, near the origin of the graphic, as the size of  $v$  is very small (or  $m$  is very large) the difference is barely noticeable, but as the size of the vector gets large enough, the benchmark algorithm is about 1.9x faster than the brute force one.

### c. Worst-case time complexity analysis

As we have seen before, the algorithms are very distinct in terms of runtime performance. Let's take a closer look at the previously shown pseudo-code and analyse it in terms of worst-case time complexity.

In this analysis we will not have a distinction between primitive operations, every line will be analysed in terms of worst-case scenario for all operations, nonetheless it will not impact the conclusion in terms of worst-case scenario.

```

procedure max(v[1],v[2],...,v[n]:integers)
    start_max:= 0
    end_index:= n
    sum:= v[1]

```

## 14. Annexes

for left:= 1 to n	2(n + 1)
current_sum:= 0	n
for right:= left to n	(n + 1)n
current_sum:= current_sum + v[right]	2n(n + 1)
if current_sum > sum then	n(n + 1)
sum:= current_sum	n(n + 1)
start_index:= left sum	n(n + 1)
end_index:= right sum	n(n + 1)
return v[left to right]	1

Thus, the number of operations performed in this algorithm is given by the expression:

$$2(n + 1) + n + (n + 1)n + 2n(n + 1) + 4n(n + 1) + 4$$

We can conclude that, in terms of asymptotic behavior, this algorithm is  $O(n^2)$ .

## C. Application Diagram

