**University of Bahrain**

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| **College of Science** | **Department of Mathematics** |



**Assessing Bahrain Bed Capacity during the COVID-19 Pandemic**

This report is submitted in partial fulfilment of the requirements for the Research Methods course in pursuit of a master’s degree in Big Data Science and Analytics

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تقييم سعة المستشفيات في مملكة البحرين أثناء فترة الوباء كوفيد-19

**يُسلم هذا التقرير كمطلب جزئي لمقرر طرق البحث العلمي استكمالًا لبرنامج الماجستير في علم البيانات الضخمة وتحليلها**

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ديسمبر 2020

Abstract

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Chapter One

Introduction to the Study

‎‎1.1 Introduction

‎1.2 Research Problem

‎1.3 Research Questions

‎1.4 Research Objectives

‎1.5 Research Significance

‎1.6 Research Setting

‎1.7 Definition of Terms

Chapter One

Introduction to the Study

Introduction

This section introduces the research and report.

Research Problem

This section describes the research problem addressed by this research.

Research Questions

This section describes the questions that this research aimed to answer.

Research Objectives

This section describes the objectives that this research aimed to achieve.

Research Significance

This section describes the importance of this research.

Research Setting

This section describes the context of how this research was conducted, including scope.

Definition of Terms

This section lists all the terms and their abbreviations used within the report.

Chapter Two

Theoretical Framework and Literature Review

‎‎1.1 Introduction

‎2.1 Literature Review

‎2.2 Theoretical Framework

‎2.3 Research Hypothesis

Chapter Two

Theoretical Framework and Literature Review

Literature Review

This section goes through similar research topics conducted and compares between previous relevant works related to this research.

Theoretical Framework

This section describes the how this research will be implemented and carried out.

Research Hypothesis

This section defines and describes the hypothesis assumed by the researchers.

Chapter Three

Methods and Procedures

‎3.1 Research Study’s Methodology

‎3.2 Research Study’s Population and Sample

‎3.3 Research Study’s Tools

‎3.4 Data Collection and Procedures

‎3.5 Statistical Approaches

Chapter Three

Methods and Procedures

Methodology

This research has adopted an exploratory scenario-based research design in which will assess the capability, in terms of bed capacity, of the Kingdom of Bahrain to respond to the sudden increase of COVID-19 cases that will require hospitalization. Based on quantitative historical data (for COVID-19 cases), a statistical growth model will be used to project the increase in the number of cases for the upcoming three months (90 days). Thus, with the projected number of hospitalized cases and based on the current capacity of the health system, it will assess the health system’s ability to respond to the increase of infections and avoid reaching saturation of bed capacity (i.e., over-exceeded).

The below figure, **Fig. 1**, illustrates the scenario-based design template, which is developed for this research, highlighting the variables that can be altered across different scenarios.

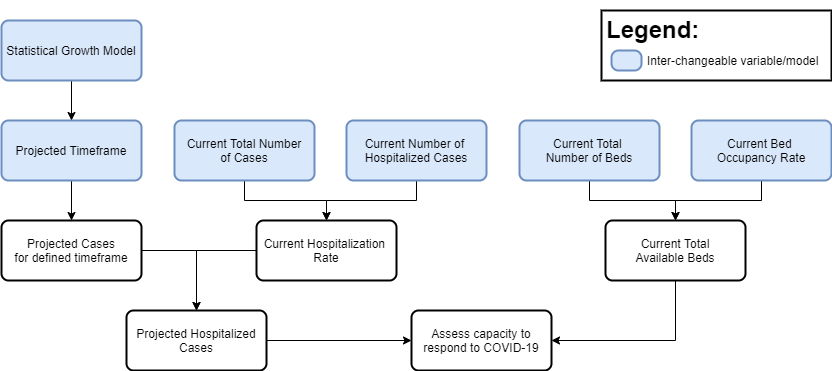


Fig. : Scenario-Based Design Template

The table below, **Table (1)**, illustrates the assumptions and definitions that will be used to define the context of our scenario (based on the scenario-based design template).

Table (): Adopted Scenario Variables

|  |  |
| --- | --- |
| **Variable** | **Adaptation in this research scenario** |
| Statistical Growth Model | The Logistic Growth Model will be used to project the number of cases in the scenario, as a different model would project a different number and hence change the applied scenario. |
| Projected Timeframe | This research will project the cases for three months (90 days). |
| Current Total Number of Cases | This research will use the total number of cases and hospitalized cases as published by the Ministry of Health (2020) on the 1st of August, 2020. These values play an important role as they determine the hospitalization rate for the chosen scenario. |
| Current Number of Hospitalized Cases |
| Current Total Number of Beds | This value will be calculated based on publicly available data. |
| Current Bed Occupancy Rate (BOR) | The current hospital BOR was assumed at 80% as per conversation with a health worker in the Kingdom of Bahrain (Hilal, 2020) and the Field Intensive Care Units (FICU) BOR was obtained (0.38%) from publicly reported figures by Naar (2020). |

In summary, this research aims to assess the total bed capacity of the Kingdom of Bahrain in the scenario that the COVID-19 infections follow a logistic growth pattern and based on 80% of hospital beds being occupied and 0.38% FICU beds are occupied. The scenario will be projecting cases for the upcoming 90 days relative to the current available total bed capacity.

Population

The population considered in this study will be all hospitals (public and private) in the Kingdom of Bahrain. This study will also include Field Intensive Care Units, which are ad-hoc centers; isolation centers (IC) and quarantine centers (QC), that were built to increase total bed capacity in the Kingdom of Bahrain (Naar, 2020). As the COVID-19 epidemic will impact the country, the entire health system will need to work together, under the direction of the National Taskforce for Combating the Coronavirus (COVID-19) and the Ministry of Health, to ensure a rapid response to the epidemic.

Research Study Tools

This section illustrates how the data will be extracted and the tools that will be used to conduct the statistical analysis for this research.

Data and Variable Extraction

To extract historical data related to COVID-19 cases in Bahrain, including the total number of cases and deaths, the publicly reliable dataset provided by Our World in Data (Roser et al., 2020) will be extracted in comma separated values (CSV) format. This public dataset includes the following attributes which will be used in our study:

1. Date
2. Total Cases – the cumulative total number of COVID-19 cases as of the given date
3. Total Deaths – the cumulative total number of deaths caused by COVID-19 as of the given date
4. Population – the population of the country as of 2020
5. Hospital Beds per Thousand – the number of hospital beds per 1,000 people

The following variables, in **Table (2)**, will be extracted from various sources as they will play an important role in the statistical analysis to produce factors related to this study. The equations will be further detailed in section ‎3.5 of this report.

Table (): Extracted Variables used in calculation of Research Factors

|  |  |
| --- | --- |
| **Extracted Variables** | **Source** |
| Total Field Intensive Care Units’ Beds (including Isolation Centers and Quarantine Centers) | This variable will be extracted and calculated from publicly reported figures by Naar (2020). |
| Hospital Beds Occupancy Rate (BOR) | This variable is assumed as per conversation with a health worker in the Kingdom of Bahrain. |

Other Study Tools

To execute the statistical analysis in this research, the reliable and data analysis feature-heavy “R” programming language and environment will be utilized.

Data Collection and Procedures

All data that will be collected in this research is secondary data as it has not been gathered directly by the authors, however, the data sources are globally (Roser et al., 2020) and governmentally (Ministry of Health, 2020) reliable sources. The data is quantitative, and time-series based, and extracted into CSV format and loaded into the data analysis tool used (R) for cleaning, processing, and modeling. The below figure, **Fig. 2**, illustrates, on a high-level, the data collection and procedure that will be carried out in this research.

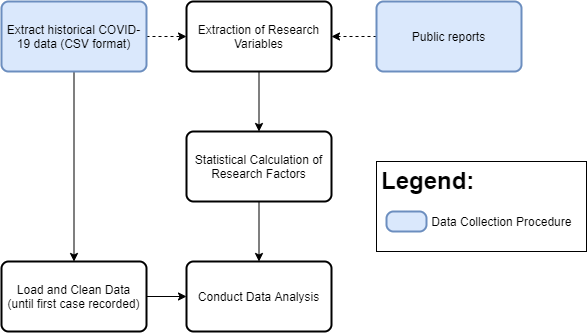


Fig. 2: High-Level Data Collection Procedure

Statistical Analysis Approach

This section illustrates the statistical analysis that will be implemented in this research, including the research factors considered.

COVID-19 Prediction Model

Historical quantitative data related to the number of COVID-19 cases will be extracted and used within our COVID-19 prediction model. The timeframe of the historical data will start from the first recorded case, the 24th of February 2020, until the 29th of July 2020. This data will be used as training data to generate a prediction model and then project the total number of cases for the next three months (90 days) – hence the projection timeframe will start and include the 30th of July 2020 until (and including) the 27th of October 2020. The data will be sorted chronologically as time-series data and formatted into the following structure to generate the model:

1. Day Counter – indicator for the day number since the first case occurrence (i.e., 10 will be the tenth day after the first case was reported, while 1 is the first day the first case was reported).
2. Total Cases – the cumulative number of cases on the given day (i.e., the total number of cumulative cases as of the 10th day).

After extraction and preparation of COVID-19 data, the Logistic Growth Model will be used, as defined in the scenario, to generate a prediction model to predict and forecast the cumulative number of COVID-19 cases the Kingdom of Bahrain.

The Logistic Growth Model is widely used to model population growth and besides its simplicity, has the advantage of setting a limit for the increase in population growth. In the case of COVID-19 infections, the number of cases cannot surpass the population of the country, which is realistic in comparison to an Exponential Growth Model which would increase (the number of cases) infinitely. The logistic growth model was also used to predict the 2015 Ebola epidemic (Chowell et al., 2014; Pell et al., 2018) and was used to predict COVID-19 cases in the neighboring Kingdom of Saudi Arabia (Alboaneen et al., 2020).

The Logistic Growth Model that will be used in this research can be expressed in the following equation, **Equation 1**, where is the cumulative number of cases on a given day number , is the maximum value for number of cases , and represents the daily growth rate, and the values of will be automatically estimated by the data analysis tool used; to fit the model with the data presented:

Equation : Adopted Logistic Growth Model

Statistical Calculation of Study Factors

Several research factors are not publicly available for direct use and for this reason, the statistical approaches in this research are devised to calculate their values. While others, such as Beds per Thousand People (BPTP) and Population were publicly available and were used to calculate other factors.

Given that the total number of hospital beds in the Kingdom of Bahrain could not be extracted from previous studies or reports, it will be calculated based on the variable *Beds per Thousand People (BPTP)* and *Population*. From the public dataset provided by Our World in Data (Roser et al., 2020), the variables are reported as and . To calculate the total hospital beds (), these variables will be used in the following equation, **Equation 2**:

Equation : Calculation of Total Hospital Beds

With the total hospital beds calculated along with the assumption that the hospital beds occupancy rate () currently stands at 80% (Hilal, 2020), the available hospital beds () that can actually be utilized in the treatment of COVID-19 cases, will be calculated using the below equation, **Equation 3**:

Equation : Calculation of Available Hospital Beds

Furthermore, the total number of Field Intensive Care Units’ (FICU) beds and their occupancy rate, including both Isolation Centers and Quarantine Centers (IQC), will also be calculated based on publicly reported figures by Naar (2020) – which reported 4,257 and 5,489 beds in Isolation Centers () and Quarantine Centers () respectively. The report also stated that 3,218 IC beds and 533 QC beds were occupied at the time of publishing, denoted as and respectively. Using these variables, the total beds in isolation and quarantine centers () will be calculated as per the below equation, **Equation 4**:

Equation : Calculation of Total IQC Beds

The bed occupancy rate (BOR) in isolation and quarantine centers (denoted by ) will be calculated as follows, **Equation 5**:

Equation : Calculation of IQC BOR

To obtain the available isolation and quarantine centers beds () that can actually be utilized in the treatment of COVID-19 cases, the total IQC beds and their occupancy rate will then be used in the below equation, **Equation 6**:

Equation : Calculation of Available Hospital Beds

To conclude on the total available beds () in the Kingdom of Bahrain, a simple addition of the available hospital beds and the available IQC beds will be performed, **Equation 7**:

Equation : Calculation of Total Available Beds

As of the 1st of August 2020, the current number of active cases () and hospitalized cases () will be extracted from Bahrain’s Ministry of Health (2020) public daily report and calculate the current hospitalization rate (), using the following equation, **Equation 8**:

Equation : Calculation of Current Hospitalization Rate

Lastly, using the current hospitalization rate (), and the projected total number of cases, the projected hospitalized cases on a given day () will be calculated by multiplying the with the projected hospitalized cases on that given day () as per the below, **Equation 9**:

Equation : Calculation of Projected Hospitalized Cases

The figure below, **Fig. 3**, illustrates the detailed process flow diagram of the statistical analysis approach that was adopted in this research.

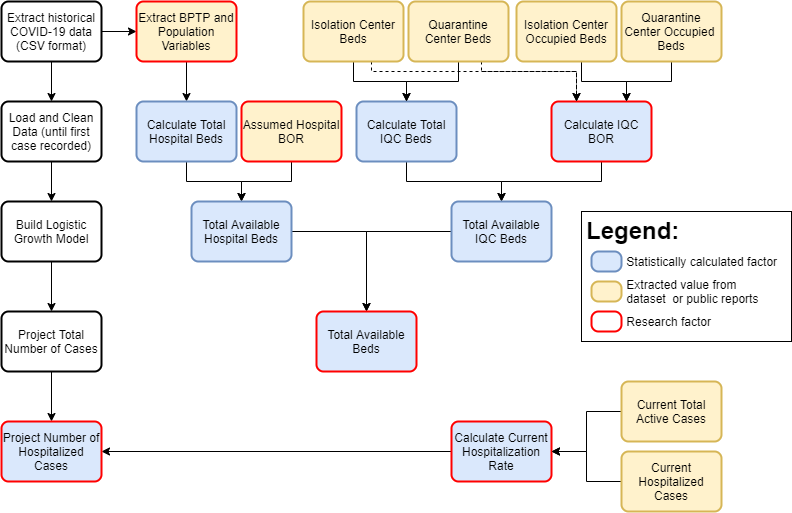


Fig. : Detailed Statistical Analysis Process Flow Diagram

Chapter Four

Results, Discussion, Conclusion and Recommendations

‎4.1 Results

‎4.2 Discussion

‎4.3 Conclusion

‎4.4 Recommendations and Limitations

Chapter Four

Results, Discussion, Conclusion and Recommendations

Results

This section presents the results obtained from the statistical analysis implemented in this research to assess the bed capacity in Kingdom of Bahrain.

Initial Data Observations

As per the data source, Our World in Data (Roser et al., 2020), the first case in Bahrain was reported on the 24th of February 2020. For the scope of this research, the data extracted and considered will encompass the first case reported until the 29th of July 2020 (a timeframe of 156 days), where the total number of cases reached 39,921. While the first death recorded in Bahrain was on the 17th of March 2020, the total deaths by end of the studied period was 141.

The total COVID-19 cases and deaths were plotted in the following figure, **Fig. 4**, to visualize and verify the trend taken by COVID-19 cases and deaths (represented on the y-axis) in Bahrain over the studied time-period; from the first case occurrence, until the 156th day (final day of the studied period corresponding to the 29th of July 2020) represented on the x-axis. As it can be observed, within the study timeframe of 156 days, the total number of COVID-19 cases seems to be growing exponentially since the first case was reported. Though the first COVID-19 related death was reported later, the deaths also seems to be growing exponentially, which is usually the case for such novel epidemics.

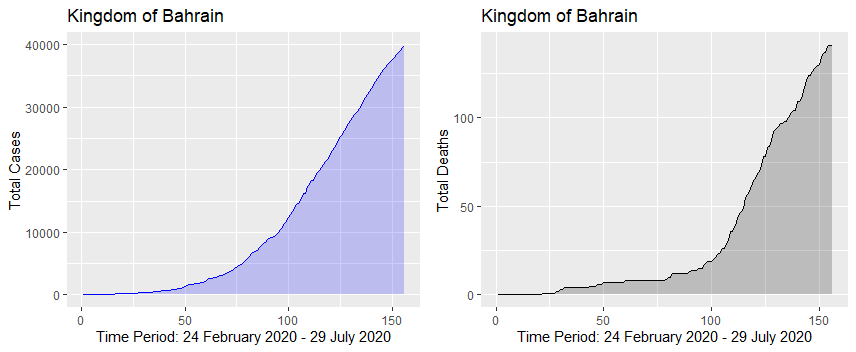


Fig. : Data Trend Observation Plots of COVID-19 Total Cases and Deaths in Bahrain

Logistic Growth Model Predictions

Based on the provided training data of total cases over the study timeframe (156 days), the best model generated by R can be presented by the substituting the estimated values in the following equation, **Equation 10**:

Equation : Logistic Growth Model - Fitted Model

Based on the fitted model, the Daily Growth Rate for our study timeframe was calculated as .

As of the nature of the data growth (growing exponentially), the model was chosen is the logistic model which is fitting the data better than exponential model because the logistic model has a limit of growth unlike the exponential model, and this is a major feature for choosing a model used for kind of pandemic growth studies. Fitting the models confirms its effectiveness for this study as it is showing on Fig 2 how the model fits the actual data very closely for (no# days) then used it to project the total cases on the next three months (90 days).

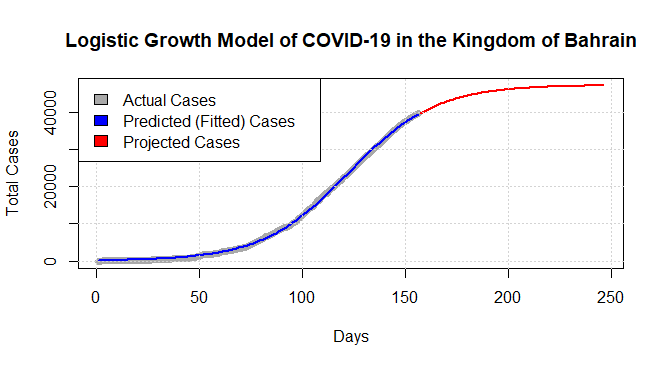


Fig 2. Logistic Growth Model of COVID-19 in the Kingdom of Bahrain

Based on the model obtained, the total projected cases are approximately 47277 on October 27, 2020. This result has been achieved by the calculated daily growth rate (0.038) based on the generated logistic growth model:

*Showing the formula*

|  |
| --- |
| # Extract Model Coefficients  LogisticGrowthModel.CoEf = coef(LogisticGrowthModel)  # Display Model Coefficients  for (CoefficientName in names(LogisticGrowthModel.CoEf)) {  print(paste("The coefficient of", CoefficientName, "is equal to =", round(LogisticGrowthModel.CoEf[CoefficientName], 3)))  }  # Calculate Daily Growth Rate  DailyGrowthRate = (1/LogisticGrowthModel.CoEf[3])  DailyGrowthRate.Rounded = round(DailyGrowthRate, 3)  print(paste("Based on the generated logistic growth model, the Daily Growth Rate of cases is", DailyGrowthRate.Rounded)) |

Consideration Other Factors Affecting Bed Capacity

In this study, there are more than one factor to consider as explained in Table (1). The factors are number of hospitalized cases, total number of beds and total number of available beds which are detailed here.

Total Number of Beds, Hospitalized Bed and Available Beds Calculation

The total number of hospital beds is 3403 where calculated based on **Equation** no# and substituting the values of the Beds per Thousand People (BPTP) and population and the as reported in Our World in Data (Roser et al., 2020) where and . While the total number of both Isolation Centers and Quarantine Centers (IQC) is calculated by **Equation** no# which is 9746. By this number and the reported number of occupied beds in IQC figures by Naar (2020), the bed occupancy rate (BOR) in isolation and quarantine centers is 0.38 by substituting the **Equation** no#. Finally, the current hospitalization rate is 0.8 obtained by using **Equation** no#.

Hospitalized Cases Calculation

The hospitalized cases are calculated based on **Equation** no# and substituting the values of …

Discussion

Text comes here

Text comes here

Text comes here

Conclusion

In conclusion, the Logistic Growth Model had a good fit with the data related to the COVID-19 total cases, and

Recommendations and Limitations

This research was conducted to forecast the number of COVID-19 cases in the Kingdom of Bahrain over a three months (90 days) time-period. Though it has implemented a commonly used population growth model, Logistic Growth Model, it is always recommended to run multiple simulations and predictions using multiple models, such as the several variations of the Susceptible, Infected, Removed or Recovered (SIR) model, to compare between model outcomes and a decide on which is most accurate.

It is highly recommended that further research is conducted to publicly avail and maintain records with regards to the overall health system capacity in Bahrain (including but not limited to the inventory and classification of general beds, ICU beds, and ventilators). Such metrics are vital in understanding the overall preparedness of the health system to respond to the COVID-19 epidemic (Barasa et al., 2020). As implemented in Kenya, maintenance of a nation-wide assets inventory list and regular nation-wide surveys to document and obtain these metrics, could prove helpful in the planning and execution of the response to the COVID-19 epidemic.

Furthermore, as COVID-19 is relatively novel and with limited, though growing, information on the disease and how it spreads, further investigations can be conducted to assess the impact of governmental restrictions on the spread of the disease. Such governmental policies and restrictions are not taken into consideration with models such as the Logistic Growth Model, which for a country such as Bahrain, could have played an important role in controlling and reducing the spread of the diseases.

Holidays and occasions can also be considered as variables of interest in the modeling of infection spread, as it has been observed with latest data that there seems to a spike in infections surrounding these occasions (Abueish, 2020). Such spikes would mean that the curve (a line that represents the number of infections on a give day) will be fluctuating rapidly around those occasions (i.e., a sudden increase while the trend would be decreasing) and hence a model such as the Logistic Growth Model would not accurately capture these fluctuations as it deals with the total cumulative number of cases instead.

Limitations

Though this research intended to implement a simplified forecast model and assessment, due to the limited time frame available to conduct this research, the authors had to oversimplify the research which resulted with several limitations and drawbacks.

The most prominent limitation was the exclusion of the Average Length of Stay (ALOS) research factor, which indicates the number of days that a patient will occupy a bed once hospitalized due to COVID-19. This measure is important because it accurately reflects and adjusts the available beds that can be utilized to respond to COVID-19 cases that require hospitalization. With its absence, the available bed capacity is overestimated which means that there might be an occurrence where the bed capacity might reach saturation. For example, if the ALOS is defined at 7 days, then once the hospitalized cases increase by 1 unit (person) this means that the available beds will decrease by 1 unit (bed) and remain out of service for 7 days until it is re-usable to serve another patient. In this research, since ALOS is excluded, this means the patient is admitted and released on the same day, and the bed is available to serve new cases immediately the next day – which is not the case.

Due to the lack of publicly available data related to the Bahraini health system, such as the total number of beds in the Kingdom or a real-time indicator on the bed occupancy rate, such variables were assumed or calculated from other sources which may not resemble the reality of the situation.

Furthermore, due to not implementing different growth prediction models, drawing conclusions on the accuracy of the selected model cannot be done and hence the findings (number of cases) maybe be underestimated.

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