**SAFEPASS:**

**AN IMPLEMENTATION OF AUTOREGRESSIVE INTEGRATED MOVING AVERAGE (ARIMA) FOR CROWD FORECASTING APPLIED IN QUARANTINE PASS**

A Capstone Project Presented to the Graduate Program

College of Engineering and Technology

Pamantasan ng Lungsod ng Maynila

In Partial Fulfillment of the Requirements for the Degree

Master’s in Information Technology

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August 2021

**APPROVAL SHEET**

The capstone project hereto titled

**SAFEPASS:**

**AN IMPLEMENTATION OF AUTOREGRESSIVE INTEGRATED MOVING AVERAGE (ARIMA) FOR CROWD FORECASTING APPLIED IN QUARANTINE PASS**

prepared and submitted by Joane Marie F. Llamera in partial fulfilment of the requirements for the degree of Master’s in Information Technology has been examined and is recommended for acceptance and approval for **Oral Examination**.

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**ACKNOWLEDGEMENTS**

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**Chapter One**

**INTRODUCTION**

* 1. **Background of the Study**

It has been more than a year since the novel coronavirus disease (COVID-19) outbreak was first reported in Wuhan, China, yet it remains a global issue. Although several vaccines are already available to help prevent people from getting seriously ill or dying from the virus, most countries are still struggling to battle the pandemic as the virus mutations continue to surface.

In the study entitled "Indirect Virus Transmission in Cluster of COVID-19 Cases, Wenzhou, China, 2020" by Cai, Jing et al. (2020), researchers had performed data analysis on COVID-19 cases associated with a shopping mall in Wenzhou. The results have indicated indirect transmission of the Covid-19 virus resulting from contamination of common objects, virus aerosolization in confined spaces, or spread of virus from asymptomatic infected individual.

In another study entitled "Association between mobility patterns and COVID-19 transmission in the USA: a mathematical modelling study" by Badr et al. (2020), results had shown a strong and statistically significant correlation between social distancing, quantified by mobility patterns, and reduction of COVID-19 case growth. With this, the researchers have emphasized the role of social distancing as an effective way to mitigate COVID-19 transmission and should remain part of personal and institutional response to the pandemic.

The World Health Organization have recommended maintaining an inter-personal distance of 1.5 or 2 m (about 6 feet) from each other to minimize the risk of contagion through the droplets that an individual usually disseminate through their nose and mouth.

Forecasting plays an important role during the pandemic and is highly important for effective governmental decision making, for managing supply chain resources, and for informing very difficult political decisions as, for example, imposing a lockdown or curfews.

The Inter-Agency Task Force for the Management of Emerging Infectious Diseases (IATF – EID) acts as the Philippine government's instrument to assess, monitor, contain, control, and prevent the spread and local transmission of COVID-19. They perform risk-level classifications of Provinces, Highly Urbanized Cities (HUCs), and Independent Component Cities (ICCs) upon which they implement localized lockdowns for identified critical areas.

Enhanced Community Quarantine is the most restrictive quarantine classification where strict home quarantine shall be observed in all households. People mobility will be limited to accessing essential goods, services and for work in offices or industries permitted to operate such as public and private hospitals, health, emergency and frontline services, essential goods manufacturers, and the likes. Localities under an Enhanced Community Quarantine (ECQ) are issued with quarantine pass allowing one person per household to buy essential goods or services.

The current implementation of quarantine pass is done manually on which several issues had been observed. An advisory from DILG Region V has been released on March 20, 2020, advising Provincial Directors to instruct Local Officials that the issuance of quarantine pass slips must be distributed on house-to-house basis in their areas of responsibility as releasing of Barangay pass in Barangay Halls defeats the intent of the Enhance Community Quarantine and Social Distancing. On a news article from Inquirer.net released on 23 March 2020, a barangay captain in Lanao del Sur has been arrested for “selling” passes that would allow people to leave their homes during the quarantine period.

By developing a mobile responsive application, these issues and the manual effort spent in generating and validating quarantine passes can be resolved. Augmented with decision support system, the proposed application will enable the government and residents to reduce make informed decisions aiming to reduce the transmission of COVID-19 virus.

* 1. **Statement of the Problem**

The current process of generating, issuing, and validating quarantine passes mostly involves face to face interaction defeating the purpose of the Enhanced Community Quarantine. Not only that it requires a lot of time and effort, but it is also prone to exploitations by those who wanted to get pass the quarantine guidelines.

The manual process does not have proper means to validate and authenticate the quarantine pass, thus, authorities are unable to apprehend any offenders. These loopholes may eventually result to an increase in the number of unauthorized persons outside of residence that forfeits the effectiveness of the quarantine guidelines.

Although one person per household is only allowed to go outside of residence to acquire essential goods, a high probability of having crowded establishment is also an issue of concern.

The policies alone set by IATF during Enhanced Community Quarantine is deemed to be less efficient if not implemented with appropriate tools and risks are not managed.

* 1. **Objective of the Study**

The main objective of this capstone project is to develop a mobile responsive web application that would automate the process of generating and validating quarantine pass and display statistical information for decision support system.

Specifically, this capstone project seeks to achieve the following objectives:

1. To provide digital quarantine passes for residents that will be validated at essential establishments by using Quick Response Code scheme.
2. To provide information to residents about the current crowd count of essential establishments.
3. To provide users with crowd forecast on essential establishments for upcoming days by using Autoregressive Integrated Moving Average (ARIMA) model.
   1. **Scope and Limitations**

To set boundaries on this capstone project, the proponent would focus on developing a mobile responsive web application which would automate the manual process of generation and validation of quarantine pass and embed a crowd forecasting functionality available to its users.

This capstone project will use dummy data for information of residents, households per barangay, barangay officials and essential establishments to give emphasize on how the automated system can provide usable crowd forecasts during the implementation of Enhanced Community Quarantine for better decision making and even risk management.

To limit the scope, the system to be developed will not cover other types of quarantine passes such as Special Quarantine Pass, Self-Employed Pass, 1 Week Transit Pass, 1 Day Transit Pass and the likes but only on Quarantine Pass intended for access to essential establishments.

* 1. **Significance of the Study**

Results obtained from this capstone project will benefit the following stakeholders:

**Local Government Officials.** This tool will remove the manual process of generating, issuing, and validating of quarantine passes during the implementation of Enhance Community Quarantine, enabling them to focus on other important activities. The application can act as an additional support system in ensuring that the guidelines of Enhanced Community Quarantine are implemented accordingly by providing crowd forecasts for decision support system.

**Residents.**  By having a mobile accessible application, individuals can easily obtain a quarantine pass without requiring face to face interaction. Using the application within their reach, they are provided with insightful data which allows them to decide on when is the best time to procure essentials goods minimizing their risk of exposure to congested areas.

**Future Proponents.**  This capstone project could serve as a good reference material for students who are to conduct study of the same nature.

* 1. **Definition of Terms**

**COVID-19**

Refers to the Coronavirus Disease 2019 which is caused by the virus known as the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).

**Community Quarantine**

Refers to the restriction of movement within, into, or out of the area of quarantine of individuals, large groups of people, or communities, designed to reduce the likelihood of transmission of an infectious disease among persons in and to persons outside the affected area.

**Enhanced Community Quarantine (ECQ)**

The enhanced community quarantine in Luzon is a series of stay-at-home orders and cordon sanitaire measures implemented by the Inter-Agency Task Force for the Management of Emerging Infectious Diseases (IATF-EID) on the island of Luzon and its associated islands. It is part of the COVID-19 community quarantines in the Philippines, a larger scale of COVID-19 containment measures with varying degrees of strictness. The "enhanced community quarantine" (ECQ) is the strictest of these measures and is effectively a total lockdown.

**Quarantine Pass**

A quarantine pass designates a household member as the representative of his or her household in procuring necessities. This disallows other family members to buy goods and conduct transactions outside their homes.

**Essential goods and services**

Covers health and social services to secure the safety and well-being of persons, such as but not limited to, food, water, medicine, medical devices, public utilities, energy, and others as may be determined by the IATF.

**Forecasting**

Forecasting is about predicting the future as accurately as possible, given all the information available, including historical data and knowledge of any future events that might impact the forecasts.

Forecasting should be an integral part of the decision-making activities of management, as it can play an important role in many areas of a company. Modern organizations require short-term, medium-term, and long-term forecasts, depending on the specific application.

**Time Series**

A time series is a sequence of data points that occur in successive order over some period of time. This can be contrasted with cross-sectional data, which captures a point-in-time.

**Time Series Forecasting**

Time series forecasting uses information regarding historical values and associated patterns to predict future activity. Most often, this relates to trend analysis, cyclical fluctuation analysis, and issues of seasonality. As with all forecasting methods, success is not guaranteed.

**Mean**

The arithmetic mean, more commonly known as “the average,” is the sum of a list of numbers divided by the number of items on the list. The mean is useful in determining the overall trend of a data set or providing a rapid snapshot of your data. Another advantage of the mean is that it’s very easy and quick to calculate.

**Regression**

Regression models the relationships between dependent and explanatory variables, which are usually charted on a scatterplot. The regression line also designates whether those relationships are strong or weak. Regression is commonly taught in high school or college statistics courses with applications for science or business in determining trends over time.

**Chapter Two**

**REVIEW OF RELATED LITERATURE**

This chapter presents the different research and other literatures form both foreign and local researchers, which have significant bearings on the variables included in the research. It focuses on several aspects that will help in the development of this study. The literatures of this study come from books, journals, articles, electronic materials such as PDF or E-Book, and other existing thesis and dissertations, foreign and local which are believed to be useful in the advancement of awareness concerning the study.

* 1. **Related Literature**

**Covid 19 and Social Distancing**

Insert related literature and studies

**Quick Response Code**

The acronym QR Code refers to a machine-readable optical label that contains information about the related item or product. When compared to 1-D Codes, 2-D Codes can store more data in a less amount of area. Unlike in Bar Codes on which information is only coded in one direction, QR code information is encoded in two directions: horizontally and vertically

|  |  |  |
| --- | --- | --- |
| **Features** | **QR Code** | **Bar Code** |
| High Capacity | Upto 7089 numeric digits | 10-20 digits |
| Durability against damage | Reading is possible (upto 30% damaged) | Reading is impossible |
| Reduced Space | 40 digits numeric | 10 digits numeric |
| 360◦ degree | Supports 360◦ | Horizontal reading |
| Language Supported | Numeric, Alphanumeric, Kanji, Kana etc. | Numeric, Alphanumeric |

**Table 2.1 Comparison of QR Code and Bar Code**

Denso Wave, a Toyota subsidiary firm in Japan, was the first to deploy QR codes in 1994. Other industries attempted to embrace this technology after its successful adoption at Denso Wave. The QR code is patented by Denso Wave, although it can be used elsewhere in the world. In 2011, the telecoms industry was the first to commercialize the QR code.

The popularity of these codes is primarily due to the following features, according to an article titled “Two-Level QR Code for Private Message Sharing and Document Authentication” (Tkachenko et al, 2016): they are robust to the copying process, easy to read by any device and any user, they have a high encoding capacity enhanced by error correction facilities, they have a small size and a low cost.

Those evident advantages, however, are not without their drawbacks:

1) Even though the information encoded in a QR code is ciphered and hence only legible to authorized users (the distinction between "see" and "understand"), it is always accessible to everyone.

2) Due to its insensitivity to the Print-and-Scan (P&S) procedure, it is impossible to identify an original printed QR code from a copy.

This machine-readable matrix code is made up of black and white squares. It can hold URL (Uniform Resource Locator) information, contact information, links to videos or photographs, plain text, and other sorts of material (ISO/IEC 18004, 2000).

The QR code architecture is discussed in a study titled "QR Code Analysis" (Singh, 2016). Each QR code symbol has a square pattern to it. There are two regions in this square pattern: the encoding region and the function patterns. The location where the encoding region indicates the data encoding is the focus of the function patterns. Finder patterns, timing patterns, and alignment patterns are all part of the function pattern. Finder patterns are three frequent structures found on the three corners of a QR code symbol. The Finder pattern is used to determine the symbol's proper orientation. The decoder software uses timing patterns to determine which side of the pattern to use. In the case of image distortion, alignment patterns are utilized to ensure that decoder software accurately decodes the symbol. Other than the function pattern, the rest of the region is the encoded region, which stores data code words and error correcting code words.

Error correction level and mask pattern are also included in the format information regions. The version information regions store the code version and error correcting bits. Information encoding utilizing the Reed-Solomon error correction code, information division on codewords, application of the mask pattern, and placement of codewords and function patterns into the QR code are all part of the QR code generating algorithm. The scanning process, picture binarization, geometrical correction, and decoding algorithm are all part of the QR code recognition method (Tkachenko et. al, 2016).

The following are the main characteristics of QR codes (according to Singh, 2016):

1) High Storage Capacity

When compared to a 1-D barcode, a QR code symbol can store up to 7,089 characters of data, which is a tremendous number.

2) Encodable Character Set

* Numeric data (Digits 0-9)
* Alphanumeric data (upper case letters A-Z; Digits 0 - 9; nine other characters: space, : % \* + - / \_ $)
* Kanji characters

3) Small Printout Size

The information in a QR code is stored in two directions: horizontally and vertically. Because of this feature, QR codes take up a fourth of the area that a 1-D barcode takes up for the same amount of data.

4) 360 Degree Reading

The QR code may be read from any angle. The finder patterns found in three corners of the symbol provides this feature. The finder pattern aids in the detection of the QR code.

5) Capability of Restoring and Error Correction

Data can be recovered if a component of the code symbol is destroyed or unclean. The error-detection procedure can concentrate on the proper information region. L, M, Q, and H are the four layers of error correction for QR codes. Level L has the least error correction capabilities, whereas level H has the strongest.

QR codes are employed in the majority of commercial market items in several nations. In essence, QR codes are a practical way to combine the virtual and physical worlds to give useful information at a moment's notice. QR codes are a low-cost technology that is simple to use and implement. QR codes have a wide range of uses in a variety of disciplines. The speed and convenience with which information is given is the true value of QR code access.

In a study conducted by Uzun (2016), a healthcare application was created consisting of QR-codes and QR-code reader applications, installed on smartphones or tablets, were placed in various locations of the hospital, which scans the QR codes to obtain vast amount of information. In the same study, they implemented a QR Code Identity Tag which allows for quick access to important medical information. The general information about the patient, including name, address, and emergency point of contact, will be displayed after the QR code is scanned by the reader, such as a smartphone or any other electronic device capable of scanning.

An article entitled “The Usefulness of the QR Code in Orthotic Applications after Orthopedic Surgery” (Cho et al., 2021), they pointed out the significance of QR code, in the orthotic field due to its advantages of repeatability and convenience. The usage of QR code prevented the dissemination of false orthosis information to the patients, because it provided audiovisual information in an easy way via a smart phone. They emphasized that QR code can be used more effectively by repeated patient education and accessibility than conventional oral training in an outpatient clinic.

During the current COVID-19 pandemic and previous pandemics, a variety of digital health initiatives were used to control disease spread. These control strategies have been shown to be effective in decreasing COVID-19's effect in a number of nations.

A study conducted by Nakamoto et al. (2020), proposed a pandemic management paradigm based on symptom-based quick reaction (QR) codes to contain the spread of

COVID-19. QR codes were designated as electronic certificates of an individual's health state under this framework, and they can be utilized for contact tracking, exposure risk self-triage, self-update of health status, health care appointments, and contact-free psychiatric consultations. Since the first case was officially reported in January 2020, the framework outlined in this paper has effectively restricted the spread of COVID-19 in Fujian Province, which has a population of about 40 million people. As of July 12, 2020, 361 (99.4%) of the 363 reported cumulative cases had been recovered, 1 patient had died (mortality rate 0.3%), and one patient had remained positive for COVID-19 (0.3%). Due to the approach's early deployment and strict application, it was able to successfully transition the GDP from –6.8% to a positive figure by July. Firms have been able to progressively resume normal operations while maintaining efficient containment. The technology has aided government agencies in achieving successful containment and travel control.

In an article entitled “Usefulness of an Online Preliminary Questionnaire under the COVID-19 Pandemic” by Hur and Chang (2020), it has been discussed how a mobile self-report questionnaire with quick response (QR) codes can help prevent hospital-acquired secondary infections by reducing contact between patients with COVID-19 and hospital personnel or other patients inside the hospital. The authors have emphasized how the method will save time and human resources needed for investigation, as well as minimize any potential turmoil in the hospital as a result of such screening activity.

**Time Series Forecasting**

Forecasting future values of an observed time series is useful in almost every aspect of research and engineering, including economics, finance, business intelligence, meteorology, and telecommunications (Palit and Popovic, 2005).

A forecasting method is a method for calculating forecasts based on current and historical data. As a result, it might just be an algorithmic rule with no need for an underlying probability model. Alternatively, it could result from establishing a specific model for the provided data and determining the best forecasts based on that model. As a result, the terms "method" and "model" should be maintained separate. Unfortunately, the word "forecasting model" is thrown around in the literature with a lot of looseness, and it's occasionally used incorrectly to define a forecasting strategy (Chatfield, 2000).

In his book "Time-series Forecasting," Chatfield (2000) divided forecasting methodologies into three categories:

(a) Predictions based on subjective judgment, intuition, "inside" commercial knowledge, and any other relevant data.

(b) Univariate approaches, in which forecasts are based solely on the current and previous values of a single series, potentially supplemented by a time function such as a linear trend.

(c) Multivariate approaches, in which the forecasts of one or more extra time series variables, referred to as predictor or explanatory variables, are based, at least in part, on the values of one or more additional time series variables.

Authors reviewed how different intervals were employed in diverse literature in an article titled "Financial time series forecasting with machine learning techniques: A survey" (Krollner et al, 2010). The varied predicting intervals utilized in the literature are depicted in Figure 2.1. The prediction periods are divided into three categories: one day, one week, and one month ahead. 'Several / Others' lists publications that use multiple or distinct time frames. The majority of periodicals make one-day forecasts, such as projecting the next day's closing price. However, being able to anticipate the stock index one day ahead of time does not always imply that an investor may profit from this information in terms of trading, especially because the index is not traded.

Text

Description automatically generated with medium confidence

**Figure 2.1 Sample Time Series Data**

A time series is denoted by Y = y1, y2..., . The technique of estimating future values of Y, , where h specifies the forecasting horizon, is known as forecasting. There are two types of quantitative approaches to time series forecasting: univariate and multivariate. Univariate methods are procedures that use previous observations to model future observations of a time series. Multivariate techniques build on univariate approaches by taking into account additional time series as explanatory variables. In this paper, we'll concentrate on univariate techniques. When dealing with time series prediction difficulties, another factor to consider is the forecasting horizon. One step ahead forecasting, or the prediction of the next value of a time series (yn+1), is usually the focus of forecasting methodologies. Occasionally, one is intrigued by the prospect of foreseeing many steps into the future. Multi-step forecasting is a term used to describe these jobs (Taieb et al., 2012).

The authors reviewed typical time series models in a study titled “Machine Learning vs Statistical Methods for Time Series Forecasting: Size Matters” (Cerqueira et al, 2019).

1. Naive method, also known as the random walk forecast, predicts the future values of the time series according to the last known observation:
2. The seasonal naïve model functions in the same way as the naive technique. The seasonal naïve technique differs in that it employs a previously known value from the same season as the intended forecast:

where *m* denotes the seasonal period.

1. One of the most often used approaches for modeling univariate time series is ARMA (Auto-Regressive Moving Average). ARMA(*p*, *q*) combines two components: AR(*p*), and MA(*q*). According to the AR(*p*) model, the value of a given time series, , can be estimated using a linear combination of the *p* past observations, together with an error term and a constant term *c*.
2. Exponential smoothing model is similar to the AR(p) model in the sense that it models the future values of time series using a linear combination of its past observations. Exponential smoothing methods produce weighted averages of the past values, where the weight decays exponentially as the observations are older.

Recursive, Direct, and DirRec are the three basic techniques for Multi-step Time Series Forecasting. In the Recursive strategy (Weigend and Gershenfeld, 1994), a one-step model is first trained. *F*

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with *t* ∈ {*n*, . . . , *N* − 1} and then uses it recursively for returning a multistep prediction. The recursive method's sensitivity to estimation error is well-known, as estimated values, rather than actual ones, are increasingly used as we move further into the future.

The Direct strategy (Cheng et.al, 2006) learns independently *H* models *fh*

,

with *t* ∈ {*n*, . . . , *N* − *H*} and *h* ∈ {1,...,*H*} and returns a multi-step forecast by concatenating the H predictions. The Direct method is immune to accumulation of errors because it does not employ any approximated data to produce forecasts. Despite this, there are certain flaws. First, since the *H* models are learned independently no statistical dependencies between the predictions is considered. To model the stochastic dependency between two series values at two distant instants, second direct approaches sometimes require more functional complexity than iterated methods. Finally, because the number of models to learn is equal to the size of the horizon, this technique necessitates a lengthy processing time.

Sorjamaa and Lendasse (2006) proposed the DirRec approach, which combines the designs and ideas of the Direct and Recursive techniques. DirRec computes forecasts using several models for each horizon (similar to the Direct technique) and expands the set of inputs at each time step by adding variables according to the previous step's forecasts (like the Recursive strategy). However, unlike the previous two solutions, the embedding size n is not uniform across all horizons. To put it another way, the DirRec strategy learns *H* models *fh* from the time series where

, …, ,

with *t* ∈ {*n*, . . . , *N* − *H*} and *h* ∈ {1,...,*H*}.

To stop COVID-19 from spreading further, governments around the world have implemented some of the most comprehensive non-pharmaceutical measures in history. These treatments, particularly the more severe ones, come at a high cost in terms of both money and lives.

A study conducted by Li et al. (2021), DELPHI, a unique epidemiological model, was created to model the impact of under-detection and government action on COVID 19 transmission. If the limits were applied one week sooner, the DELPHI model estimates a 75 percent drop in both cases and deaths for several countries around the world. If limits had been enforced sooner, Western European countries like as Switzerland, Spain, and Italy would have benefited the most. This supports the theory that these areas saw some of the greatest outbreaks outside of Asia, and hence did not have as much time to respond as nations like Romania and Iceland, which experienced an outbreak later. DELPHI estimates that if every country in the world enforced its limits one week sooner, nearly 280,000 deaths, or 68 percent of the world's total mortality count, could have been prevented by May 17th of 2021. This reveals that extreme actions taken by governments and communities around the world preserved a considerable section of the global population.

**ARIMA**

A family of stochastic processes known as auto regressive integrated moving average (ARIMA) processes is used to evaluate time series (Box and Jenkins, 1994). The following is the general plan:

Step 0) Certain hypotheses are assumed in the formulation of a class of models.

Step 1) For the observed data, a model is found.

Step 2) The parameters of the model are estimated.

Step 3) If the model's hypotheses are confirmed, proceed to Step 4, otherwise, return to Step 1 to revise the model.

Step 4) Forecasting is now possible with the model.

A straightforward type of an AR model of order p, i.e., *AR(p)*, can be written as a linear process given by:

Where is the stationary variable, *c* is constant, the terms in are autocorrelation coefficients at lags 1, 2,,*p* and *t* , the residuals, are the Gaussian white noise series with mean zero and variance *σ*2. An MA model of order q, i.e., *MA(q)*, can be written in the form:

Where *μ* is the expectation of (usually assumed equal to zero), the terms are the weights applied to the current and prior values of a stochastic term in the time series, and *θ*0 = 1. We assume that *t* is a Gaussian white noise series with mean zero and variance *σ2*. We can combine these two models by adding them together and form an ARIMA model of order (*p, q*):

Where *φi* = 0, = 0, and *σ*2 > 0. The parameters p and q are called the AR and MA orders, respectively. Because of its "integrate" stage, ARIMA forecasting, also known as Box and Jenkins forecasting, can deal with non-stationary time series data. In fact, the "integrate" component entails differencing the time series in order to convert a non-stationary one into a stationary one. ARIMA(p, d, q) is the general form of an ARIMA model (Siami-Namini et.al, 2018).

Insert Related Studies about ARIMA

**Chapter Three**

**THEORETICAL FRAMEWORK**

**Quarantine Pass Manual Process**

Upon issuance of IATF resolution declaring high-risk Provinces, Highly Urbanized Cities (HUCs), and Independent Component Cities (ICCs) under localized Enhanced Community Quarantine, the Local Government Units (LGUs) are advised to implement lockdown procedures limiting people mobility for essential activities only such as buying of food, groceries, medicines etc.

To ensure the public’s access to essential goods quarantine passes are issued by respective LGUs to residents within their jurisdiction. Only one quarantine pass will be given per household.

The generation and issuance of quarantine pass is purely manual process done by LGU officials. Quarantine pass templates are printed out on a piece of paper and distributed either in the Barangay halls or delivered on house-to-house basis in their areas of responsibility.

At checkpoints/essential establishment, the quarantine pass will need to be presented to the checkpoint/barangay officials for manual verification.

**Quick Response Code**

QR Code is a two-dimensional symbol. Denso, a significant Toyota group company, designed it in 1994, and it was accepted as an ISO international standard (ISO/IEC18004) in June 2000. This two-dimensional sign was created with the intention of being used in the production control of automotive parts, but it has since extended to other industries.

They encode either an e-mail address or a specific Web site URL, allowing smartphone users to directly access Web sites encoded by QR codes without having to type, copy, or memorize the Web site address.

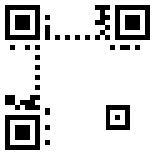
QR codes can hold a variety of information in addition to being used to transmit links:

* A business card can have a QR code that contains an electronic version of the contact information. When you scan the code, the reader app adds the contact to your address book.
* Event details can be stored as a QR code. Scanning the code on a concert poster prompts the software to add the event's name, date, and location to your smartphone or computer's calendar.
* An SMS with a phone number and text can be stored in a QR code. Scan the code, and the scanning software will immediately enter you into a contest where you can win fantastic prizes.
* An e-mail message with a topic and message text can be stored in a QR code. That message could be a request for information, and you might receive a response email with additional information and files attached.
* A geographical location can be encoded in a QR code. Scanning the code on a restaurant poster makes the location of the restaurant available to your navigation program, which will tell you how to get there.
* WIFI configuration data can be stored in a QR code. After scanning the code, your Android device will immediately set itself to use the hotel's wireless network.

## **Description of Quick Response bar codes**

In 1994, Denso-Wave, a Japanese company, invented the QR matrix code. It is an open standard that does not need the payment of a license fee. Various standards bodies, such as JIS and ISO (for example, the ISO/IEC 18004:2006 standard), are currently in charge of the physical encoding of QR codes. NTT DoCoMo, a Japanese telecom firm, devised the standard for encoding URLs.

Both the horizontal and vertical axes of QR codes carry information. When compared to ‘traditional' barcodes, this allows for significantly more raw data to be inserted. These can be numeric, alphanumeric, or binary data, with a maximum storage size of 2953 bytes. Actual data, including mistake correction information, is only found in a portion of each QR bar code. The URL data from the above QR code has been removed in the image below. As you can see, a significant portion of the bar code is dedicated to describing the data format and version, as well as positioning, alignment, and timing.

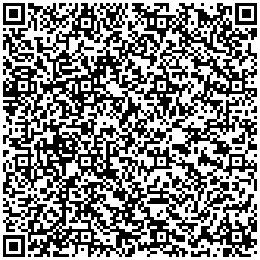
**[](https://www.prepressure.com/images/dict_qrcode_base.png)**

**Figure 3.1 Positioning, alignment, data in a QR code**

The larger the barcode, the more data that must be encoded. This page's QR code may be found below. Because the URL is longer than the home page, the bar code has grown as well. The following barcode does not include a URL, but rather the first five sentences of this page.

**[](https://www.prepressure.com/images/dict_qrcode_prepressure_qrpage.png)**

**Figure 3.2 QR barcode pointing to a web page**

**[](https://www.prepressure.com/images/dict_qrcode_prepressure_text.png)**

**Figure 3.3 QR barcode with five lines of text in it**

A module is the smallest square dot or pixel element in a QR code. An empty region around the graphic, as with other forms of bar codes, is encouraged to make it easier for devices to read the bar code. This peaceful region should be at least four modules wide.

The resolving power of the cameras used to scan the code determines the minimum dimensions of a QR code. For QR codes that contain a URL, a minimum size of 32 32 mm or 1.25 1.25 inches, excluding a silent zone, is recommended, according to a Kaywa white paper. This ensures that all camera phones on the market can read the bar code correctly. Changing the size to 26 mm in width and height (approximately 1 square inch) still covers 90% of the phones on the market. However, newer camera models with increased macro capabilities can already handle QR codes that are less than 10 mm (0.4′′) broad and high.

The preceding rule applies to codes that are perfectly printed and to which the user has direct access. When QR codes are used on a poster or billboard, things change. The common belief is that the physical dimensions of a QR code and its scanning distance are directly proportional. That ratio is about 1/10, thus if the reader is 50 centimeters away from the code, the QR code should be at least 5 centimeters in size. The height of the code should be at least 1 meter for a billboard that can be seen from a distance of 10 meters.

A good contrast between the background and the bar color itself is critical for reading accuracy. A dark color should be used on a bright background for the bar code. It is typically printed black on white background. If a colored background is required, it should be a solid color rather than a screening tint. Cyan or magenta should be avoided, but a solid yellow backdrop should suffice. If the contrast with the bar code is high enough, very light Pantone colors would also work.

**Autoregressive Integrated Moving Average (ARIMA) Model**

To understand the data and make future forecasts, the Autoregressive Integrated Moving Average (ARIMA) model employs time-series data and statistical analysis. The ARIMA model seeks to explain data by using time series data on previous values and making predictions using linear regression.

Each of the components of an ARIMA model can be understood by outlining them as follows:

* Autoregression (AR): a model in which a changing variable regresses on its own lagged (or prior) values.
* Integrated (I): denotes the differencing of raw observations to allow the time series to stabilize (i.e., data values are replaced by the difference between the data values and the previous values).
* Moving average (MA): A moving average model applied to lagged observations incorporates the dependency between an observation and a residual error.

**ARIMA Parameters**

ARIMA treats each component as a parameter with a consistent nomenclature. ARIMA with p, d, and q is a standard notation for ARIMA models, where integer values replace the parameters to denote the kind of ARIMA model utilized. The parameters are as follows:

* **p**: also called the lag order which refers to the number of lag observations in the model.
* **d**: The degree of differencing refers to the number of times the raw observations are differed.
* **q**: The order of the moving average is the size of the moving average window.

The parameters are integers that must be defined in order for the model to work. They can also be set to 0, indicating that they would be ignored in the model. The ARIMA model can then be transformed into:

* ARMA model (no stationary data, d = 0)
* AR model (no moving averages or stationary data, just an autoregression on past values, d = 0, q = 0)
* MA model (a moving average model with no autoregression or stationary data, p = 0, d = 0)

Therefore, ARIMA models may be defined as:

* ARIMA (1, 0, 0) – known as the first-order autoregressive model
* ARIMA (0, 1, 0) – known as the random walk model
* ARIMA (1, 1, 0) – known as the differenced first-order autoregressive model, and so on.

The ARIMA model seeks to estimate the coefficients α and θ, which is the outcome of using prior data points to anticipate values, once the parameters (p, d, q) have been set.

**Limitations of the ARIMA Model**

Although ARIMA models can be highly accurate and dependable under the right conditions and with enough data, one of the model's major drawbacks is that the parameters (p, d, and q) must be manually specified, making obtaining the best fit a lengthy trial-and-error process.

Similarly, the model is heavily reliant on the consistency and differencing of previous data. To ensure that the model offers reliable results and forecasts, it is critical to ensure that data was collected accurately and over a lengthy period of time.

**Box- Jenkins Methodology**

In 1970, statisticians George Box and Gwilym Jenkins published a book that described the Box-Jenkins technique to modeling ARIMA dynamics. An ARIMA process is a forecasting mathematical model. Identifying a suitable ARIMA process, fitting it to the data, and then utilizing the fitted model for forecasting are all part of Box-Jenkins modeling. One of the appealing aspects of the Box-Jenkins approach to forecasting is that ARIMA processes are a large class of models from which to choose, and it is usually possible to find one that adequately describes the data.

Model selection, parameter estimation, and model checking were all iterative three-stage processes in the original Box-Jenkins modeling approach. Makridakis, Wheelwright, and Hyndman (1998) added a preliminary stage of data preparation and a final stage of model application to their explanations of the process (or forecasting).

1. Data transformations and differencing are involved in data preparation. Data transformations (such as square roots or logarithms) can aid in the stabilization of variance in a series where variation varies with level. When it comes to business and economic data, this is a common occurrence. The data is then differentiated until no clear patterns, such as trend or seasonality, remain. The term "differencing" refers to calculating the difference between two consecutive observations or two observations separated by a year. Modeling the differenced data is frequently easier than modeling the original data.
2. In the Box-Jenkins framework, model selection employs a variety of graphs based on converted and differenced data to try to discover probable ARIMA processes that might provide a good match to the data. Other model selection criteria, such as Akaike's Information Criterion, have emerged as a result of later advances.
3. Finding the values of the model coefficients that provide the best fit to the data is known as parameter estimation. This can be accomplished using powerful computational methods.
4. Model checking is putting the model's assumptions to the test in order to identify any flaws. If the model is judged to be insufficient, you must return to Step 2 and try to find a better model.
5. The entire technique is intended to accomplish forecasting. It is usually a simple operation to compute forecasts once the model has been chosen, estimated, and validated. Of course, this is accomplished through the use of a computer.

Although Box and Jenkins' fundamental technique was developed for modeling time series with ARIMA processes, it can be used to a wide range of statistical modeling applications. It gives a useful framework for an analyst to think about data and find a statistical model that can be utilized to answer relevant data questions.

**Conceptual Framework**

This section aims to demonstrate the overview of the final product of this capstone project. An I-P-O (Input-Process-Output) model will be used as the conceptual schema of the system It identifies relevant variables, inputs, mappings, and other components and how they will interact with each other. This includes all the underlying concepts and their associated mappings based on the system’s use.

Diagram

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**Figure 3.4 IPO Diagram of Quarantine Pass Generation**

Diagram

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**Figure 3.5 IPO Diagram of Quarantine Pass Validation**

Diagram

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**Figure 3.6 IPO Diagram for Decision Support System**

The users of the proposed application are the residents who need to acquire a quarantine pass for access and procurement of essential goods or services identified by the IATF guidelines, local government officials implementing the quarantine policy, and essential establishments personnel allowed to operate during the quarantine period. They will have access to the same mobile responsive web application but will have role segregation to define their level of access.

The diagram on figure 3.4 and figure 3.5 illustrates the first component of the system where the system provides an automated process of generating and validating quarantine passes. Once a resident has been granted with quarantine pass, they will be able to download the generated QR code and present it to checkpoints/essential establishments whenever they go outside of residence. On the other end, when an essential establishment personnel scans the QR code, the system will display the information of the authorized quarantine pass holder along with the status of the quarantine pass. This action will then record the timestamp of scan in/scan out of the quarantine pass holder.

Diagram on figure 3.6 demonstrates how the data captured from quarantine pass holder’s mobility history can be utilized in generating insightful data regarding the current crowd count on a specific essential establishment and generate a one week forecast.

**Chapter Four**

**METHODOLOGY**

This proponent of this capstone project used prototype method in delivering the objectives of this project.

Diagram

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**Figure 4.1 Prototype Model**

Figure 4.1 shows the Prototype Model used by the proponent as a guide in developing the project entitled “SafePass: An Implementation of Autoregressive Integrated Moving Average (ARIMA) for Crowd Forecasting Applied in Quarantine Pass” which is a Systems Development Methodology (SDM) within which a paradigm output (or an early approximation of a final system or product) is constructed, tested, and then reworked.

Using this model, it will enhance the usability, design quality of the proposed application and it will also make the development process more cost-efficient since the development cycle becomes shorter.

The phases of the prototype model involve the following steps:

* 1. **Requirements Modeling**

This first step involves understanding the basics product requirements. The proponent of this capstone project possess firsthand experience on how the Quarantine Pass is obtained and utilized when going outside of residence. Apart from the proponent’s personal knowledge, it is also in this stage that the proponent had requested permission from local government authorities and other parties to conduct the study and where all relevant data and information were examined.

To build a logical model of the application, preliminary investigation was conducted via interviews with the involved parties. With these interviews, the researcher was able to identify the transactions involved and analyzed them against the proposed solution. This collected information had enabled the researcher to identify critical decisions geared toward implementing the proposed application.

In Molino IV, a barangay in the city of Bacoor, Cavite, the process of implementing home quarantine passes is done manually by designated LGU or barangay officials. Quarantine Pass templates are printed on a paper with the details of their barangay and some blank fields to be manually populated by the individual who will utilize it. The dissemination process of quarantine pass is for the barangay officials to deliver on house-to-house basis. In case the issued quarantine pass was lost, the resident should request for a replacement from their respective Barangay Hall.

In the 2015 census done by Philippine Statistics Authority, the estimated population in Barangay Molino IV, Bacoor Cavite is 51, 362 and the average number of people per household is 4. Given this data, there would be around 12,841 quarantine passes to be issued to each household on a manual basis requiring a lot of time and effort.

At each designated checkpoints or basic commodity establishments, residents are then required to present their quarantine pass allowing them access to the establishment. The probability of having crowd congestion in a specific establishment is high since the residents do not have visibility on the actual number of quarantine pass holders that are inside an essential establishment on a specific period. Additionally, instances of long queue in grocery stores are mostly observed as only 50% capacity is allowed inside the establishments.

It is for these reasons that the researcher opted to design and develop an application that would not only automate the manual and time-consuming processes but also to expand in utilizing the gathered data on quarantine pass holder’s mobility activity to display useful information and statistics for decision making and risk management.

Graphical user interface, application

Description automatically generated

**Figure 4.2 Sample Quarantine Pass**

In compliance with the Data Privacy Act of 2021, the data to be used in the study such as the Resident Personal Information, Household Demographics, and Essential Establishment details will be dummy data.

Below are the functional requirements grouped by specific role:

* Resident
* Register and Login – Register to gain access to the system.
* Generate Quarantine Pass – Generate a digital quarantine pass by providing personal information to be validated by the system.
* View Statistical Information – Access to the dashboard on actual crowd count and forecast per registered essential establishment.
* Essential Establishment Personnel
* Register and Login – Register to gain access to the system.
* Scan Quarantine Pass – Scan quarantine passes for individuals entering and leaving the essential establishment premises.
* View Statistical Information - Access to the dashboard on the establishment’s actual crowd count and forecast.

In generating the digital quarantine pass, QR code scheme will be implemented to help to speed up the flow of information. This would allow residents to download the QR code that will be scanned at essential establishment premises upon entry and exit.

Date time stamps of the entry and exit activity will be logged in the system and will be analyzed to generate crowd demographics. ARIMA model will be used to analyze the time series data on SafePass.

**Forecasting using Auto Regressive Integrated Moving Average (ARIMA) Model**

A time series is a collection of measurements taken at regular intervals. A time series can be yearly (for example, an annual budget), quarterly (for example, expenses), monthly (for example, air traffic), weekly (for example, sales quantity), daily (for example, weather), hourly (for example, stock price), minutes (for example, inbound calls in a call center), or even seconds in length, depending on the frequency (ex: web traffic).

The ARIMA model is a famous and commonly used statistical approach for time series forecasting.

**ARIMA model in words:**

Predicted Yt = Constant + Linear combination Lags of Y (upto p lags) + Linear Combination of Lagged forecast errors (upto q lags)

The first step is to look at the autocorrelations and partial autocorrelations shown on the Mobility Time Series data. An autocorrelation pattern like in figure 4.3 will appear in a series with a trend:

Chart

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**Figure 4.3 Sample of Non- Series Plot**

If the data series in the system has substantial autocorrelations, the system will need to execute differencing, which involves transforming the original series, xt, to become stationary around its mean and variance. The autocorrelation plots could look like in figure 4.4:

Chart

Description automatically generated

**Figure 4.4 Sample Stationary Series Plot**

Differencing usually significantly reduces the number of large autocorrelations. We'd have to difference the differenced series again if it didn't appear stationary.

The magnitude of a large autocorrelation and partial autocorrelation coefficient is frequently useful. To be statistically significant, an autocorrelation must be at least 2 / N in absolute value. The table below shows some frequent significant autocorrelation values for various sample sizes. Even though an autocorrelation is statistically significant, it may not be large enough to be a cause for concern.

|  |  |
| --- | --- |
| **N** | **Large Autocorrelation** |
| 25 | 0.40 |
| 50 | 0.28 |
| 75 | 0.23 |
| 100 | 0.23 |
| 200 | 0.14 |
| 500 | 0.09 |
| 1000 | 0.06 |

If the data series is steady in the first place, no differencing is required, and d=0.

In the ARIMA(p,d,q) model, the next step is to choose values for d, then p and q.

The partial autocorrelations of the correctly differenced series are used to calculate the value of p. The projected value of p would be the last lag with a big value if the partial autocorrelations broke off after a few lags. You have a moving average model (p=0) or an ARIMA model with positive p and q if the partial autocorrelations do not cut off.

The autocorrelations of the correctly differenced series are used to calculate the value of q. If the autocorrelations stop after a few lags, the predicted value of q would be the last lag with a big value. You either have an autoregressive model (i=0) or an ARIMA model with positive p and q if the autocorrelations do not cut off.

The diagnostic examination of a model is the final stage after it has been fitted. The checking is done by looking at the autocorrelation plots of the residuals to determine whether there is any additional structure (high correlation values). The model is deemed acceptable, and forecasts are created if all autocorrelations and partial autocorrelations are modest.

The values of p and/or q are modified, and the model is re-estimated, if some of the autocorrelations are high.

This procedure of reviewing the residuals and modifying the p and q values continues until the residuals have no more structure. The application can be used to generate forecasts and related probability limitations once an appropriate model has been chosen.

* 1. **Quick Design**

At this stage the initial prototype is developed, where the very basic requirements are showcased, and user interfaces are provided. This stage would provide a high-level view of the application to the client.

* + 1. **Context Diagram**

Diagram, venn diagram

Description automatically generated

**Figure 4.5 Context Diagram**

The context diagram in Figure 4.5 illustrates the authorized users input to the system and the expected output information. The target users are the residents and essential establishment personnel. The expected output of the proposed application is: Digital Quarantine Pass (QR Code), Quarantine Holder Information and Quarantine Pass Status, Crowd Count per Establishment and Crowd Forecast per Establishment.

* + 1. **Data Flow Diagram**

Diagram

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**Figure 4.6 Data Flow Diagram**

The researcher used the Data Flow Diagram, which is a dramatic representation of the information flow within a system that shows how information enters the system and leaves the system, what changes the information and where it is stored (Kendall, 2005).

* + 1. **Use Case Diagram**

Diagram

Description automatically generated

**Figure 4.7 Use Case Diagram**

The development of the proposed application does not solely depend on how the current system is manually implemented. It also contains a workflow process that was identified by the proponent as a necessary step to improve the system flow and accomplish the target results. The components of the proposed application “SafePass: An Implementation of Autoregressive Integrated Moving Average (ARIMA) for Crowd Forecasting Applied in Quarantine Pass”, is illustrated in Figure 4.7 with the use of Use Case Diagram. It describes its user, processes, and the relations between the system components that give the overall behavior of the application.

* + 1. **System Flowcharts**

Diagram

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**Figure 4.8 Resident System Registration Flow**

Figure 4.8 shows the flow of resident registration wherein they need to provide their personal information, residency information and attach a valid ID for verification purposes. Personal information includes First Name, Middle Name, Last Name, Date of Birth and Contact Number. Residency information such as Barangay Name and Street/Subdivision/Purok/Zone are needed to validate if the user belongs to the correct Barangay base on the resident’s database in the system. Lastly, the user must provide an identification card and upload an image for further system validation.

Diagram

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**Figure 4.9 Essential Establishment System Registration Flow**

The illustration on Figure 4.9 defines the process flow when an essential establishment registers in the application. Information such as Registered Business Name, Registered Business Owner Name, Registered Business Address/Barangay, number of people allowed in the premises shall be provided together with Business Registration Certificate and will be validated against the essential establishment’s database which contains a list of permitted establishments to operate during Enhanced Community Quarantine.

A picture containing text, hanger

Description automatically generated

**Figure 4.10 Generate Quarantine Pass Flow**

The process flow for the generation of quarantine pass is illustrated in Figure 4.10 wherein the system will check on what household the user belongs to and validate if the quarantine pass allotted for their household was already granted. If no other member of the same household has not requested for a quarantine pass, then the system will generate a QR Code and update the database that a quarantine pass was already granted. The user will have the ability to download the QR Code or view it on the system every time they login.

Diagram

Description automatically generated

**Figure 4.11 Scan Quarantine Pass Flow**

Figure 4.11 displays the system flow when a QR Code is scanned in an establishment. Resident with valid QR Code should present the QR code to the essential establishment personnel using SafePass application upon entry/exit. The system will then validate the QR code validity and should display the quarantine pass holder’s Full Name, Barangay, and the uploaded Image. This action will record the entry/exit date and time stamp of the holder and the establishment name in the system database.

Diagram

Description automatically generated

**Figure 4.12 Generate Statistical Information Flow**

In the process flow presented in Figure 4.12, a user will have the ability to view the current crowd count in an essential establishment registered in SafePass application. The crowd count information will provide details if a certain establishment is already reaching their allowed capacity which will help the residents decide whether to proceed or not. By using the historical data in the system, a weeklong crowd forecast can be generated which will aid the residents in planning when is the best time and day of the week should they go to the establishment to avoid crowd exposure. The same statistical information can also be utilized by the establishment in risk management and planning.

* 1. **Building Prototype**

At this stage, system requirements and other components necessary to develop the proposed application will be identified.

* 1. **User Evaluation**

This is the stage where a application users would evaluate the application based on its required features. The capstone project will utilize a checklist type of survey questionnaire in which the respondents will be able to answer faster and easier at their convenience.

**4.5 Refining Prototype**

In this stage, any dissatisfaction with the prototype at this level will result to a revision based on the given requirements. The new prototype will be re-evaluated, and the process continued until such time that the requirements identified by the end-user were met. Revisions will be done based on the user’s comments and suggestions during the evaluation of the developed application.

**4.6 Engineer Product**

The last stage of this approach will conclude with the confirmation and approval of the application by the end-users. This will also be referred to as the user acceptance phase. It is also in this phase that the proponent will be able to appraise the overall performance of the final system, using the predetermined indices or indicators such as functionality, efficiency, reliability, usability, and portability.

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**APPENDIX A:**