Modelling Effectiveness Of Lockdown Measures During The COVID-19 Pandemic – Europe and Asia
Interim Report

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Supervised by Dr. Adam Barrett

Contents

Abstract

This paper presents an introduction to the process of how modelling the effectiveness of lockdown measures during the COVID-19 pandemic will be achieved. This paper will first briefly introduce the two main concepts of this paper, COVID-19 and the SIR model. This paper will then outline the aims and objectives of this project. Further on, this paper will then describe possible professional and ethical issues. Furthermore, we then move into the literature review and background research area, this will give the reader a better idea of important concepts that are required to understand the paper as a whole. This section will introduce the SIR model and its component that partake the concept. Moreover, it will look over different works related to my topic and more importantly look into a research paper conducted by Vishaal R and Laura P, *A Modified Age-Structured SIR Model for COVID-19 Type Viruses*, which take a very interesting age-scaling approach to modelling the COVID pandemic. In this research paper they take a matrix-based approach to the SIR model which gives it an age-scaling factor, which from an outsider's point of view seems to be a very plausible approach, as the symptoms of COVID are crucial to the upper aged group whilst the lower aged group spread it easily. Lastly this paper will create an analysis plan which will cement the requirements needed for the final paper, a project plan which will set deadlines in which achievements are to be achieved and finally the interim log, where interactions with my supervisor, *Dr. Adam Barrett*, will be noted.

Introduction

SARS-CoV-2 more notably recognized as COVID-19, an ongoing contagious, fast spreading disease impacting how the world would live. After failing to quarantine the disease when it was first discovered in Wuhan, China, December 2019, COVID-19 spread the world amassing havoc.[1] Governing powers tried to shutdown the disease by implementing lockdown measures, hence why this report will aim to model the effectiveness of lockdown measures implemented by governing powers in Europe and Asia to draw a comparison between them.

The process of evaluating the effectiveness of lockdown measures can be achieved by using the SIR (susceptible, infected and removed) model. The SIR model is considered to be a relatively simple model due to the number and nature of its components, **S**usceptible, **I**nfected and **R**emoved. In the model, the susceptible group is defined as the group of people who are vulnerable to the disease, and hence is the default group for individuals in the population who aren't infected yet, haven't recovered or haven't died. On the other hand, the infected group is defined as the group of people within the population who are currently carrying the pathogen and will spread and infect it upon contact with the susceptible group. Lastly, the removed group is defined by the individuals who have either been recovered from the disease or have died from the disease, effectively removing them from the interests of the model.

Some researchers claim that the SIR model is too overly simplified to model such complex diseases, whilst some state the SIR model to be a very effective efficient model to model a disease, putting this dilemma aside, the paper will attempt to take an abbreviated approach to the model making changes where necessary to best suit the evaluation of the topic, modelling effectiveness of lockdown measures during the COVID-19 pandemic.

Aims, Objectives and Relevance

Aims and Objectives

This project mainly aims to explore and research lockdown measures implemented by countries in Europe and Asia. This will require myself to gather data from Worldometer[2] at three different stages of the COVID pandemic to be used in a modified SIR model. Worldometer is a source that manually validates data by cross-referencing primary sources made publicly available from governing bodies, and hence is trusted by many sources such as the UK Government, the Government of Thailand, Government of Pakistan, and many others.[3]The first time era required to be researched are COVID figures before lockdown measures were implemented to have a base comparison. Second, it is required to find the era in which COVID figures were at its peak to have them compared to the era in which lockdown measures weren't implemented yet, this will allow evaluation to whether peak COVID figures occurred during lockdown measures. As a result, this will give surface level knowledge and an outline to whether lockdown measures were significant or not.

Furthermore, the writer believes it is important to analyse the possible differences in culture which may or may not cause outliers in results. In a research paper by authors, Naoki Y and George B, *Apparent difference in fatalities between Central Europe and East Asia due to SARS-COV-2 and COVID-19: Four hypothesis for possible explanation*, the authors outline 4 hypotheses, 2 of which the writer thinks could cause the greatest potential to cause an outlier in the results that are to be found.[4] In hypothesis 1, the authors discuss differences in *socio-behavioural aspects determine the observed differences*. The authors explain the difference in greeting between individuals which likely cause a higher probability of spreading COVID in the west. The authors claim that in Asia, bowing is the mainstream form of greetings, where as in the West individuals tend to shake hands, kiss and hug instead of bowing creating physical contact between two individuals leading to an increase in the probability of which COVID can be transmitted. Furthermore, the authors also claim some cultural habits that cause an increase in the probability in which COVID is spread. The main cultural habit outlined by the authors are the use of masks. The authors claim that the use of face-covering in case of the influenza or fear of diseases is a common feature in Asian culture and not common in Western culture. And hence, the authors believe this social factor play an important role in which the spread of infection.[5]

Moreover, hypothesis 3 the authors claim that in East Asia, specifically China, agriculture developed much earlier compared to the West, and with this abundance of food, this led to an *explosive increase in population density*, and hence, under this *over-crowded and chaotic conditions*, individuals in East Asia may have possibly experienced more plagues including several zoonoses, *a disease that can be transmitted between animals and humans*.[6][7] Hence it is natural to believe that East Asians *may have evolved to become more resistant against infectious agents*.[8]

In addition, it is important to synthesize the data collected mentioned beforehand, this will be able achieved once the collected data is organized and sorted. By synthesizing the data collected through explanation and evaluation, this will allow me to first:

1. Make quantitative estimations about the effectiveness of lockdown measures through analysis of deaths and hospitalizations during lockdown
2. How Europe or Asia could have done an objectively better job in implementing lockdown measures to best interest the health of the population
3. And mentioned beforehand, how cultural differences are able to impact a disease such as COVID-19

Lastly, if time permits it would be ideal to use Python to create an interactive figure to show how the infected group in the SIR model is able to infect the susceptible group. This will require knowledge the writer has acquired in the module Natural Language Engineering which gave a good outlook of the Python language.

Relevance

Over and above, as this is project is heavily reliant upon researching figures and facts related to COVID, the writer is able to apply essential research skills developed throughout the Computer Science degree starting with the Professional Skills module. The writer is confident with the research skills developed such that the writer will be able to find appropriate sources and come to a conclusion whether this source is reliable or not. Furthermore, given that this project requires a good grasp of mathematics, more specifically modelling, graphing and calculus, the writer will be able to apply some of the knowledge learnt in the Mathematical Concepts module to good use. Lastly, as the writer intends to create interactive figures and diagrams, the writer can apply my Python skills or MATLAB skills to achieve my primary objective.

By the time the reader has gone through the final paper, it is expected that the reader will have a deeper understanding of the fundamental possibilities of whether the lockdown measures were effective or not and the improvements that could be made to them. Furthermore, it is also expected that the reader is able to grasp the foundations of the SIR model and the possible modifications that can be made to it to best suit the needs of the disease in question.

Professional and Ethical Considerations

Professional Considerations

This project involves the collection of data already surveyed and made public from official governing powers, hence not breaking any BCS Code of Conduct by *The Chartered Institute For IT*.[9] However, it is to the writer's concern that governing powers are also in line with the BCS Code of Conduct. The following section will discuss how this project is in line with the BCS Code of Conduct:

1. Public Interest
You shall:

a) *have due regard for public health, privacy, security and wellbeing of others and the environment.*
b) *have due regard for the legitimate rights of Third Parties*.*
c) *conduct your professional activities without discrimination on the grounds of sex, sexual orientation, marital status, nationality, colour, race, ethnic origin, religion, age or disability, or of any other condition or requirement*
d) *promote equal access to the benefits of IT and seek to promote the inclusion of all sectors in society wherever opportunities arise.*[10]

As the nature of this project requires the use of data that is made publicly available by governing bodies in an anonymous fashion, any analysis done on this data set does not impact public health, privacy security and wellbeing of others and the environment, nor does this break any legal laws as this dataset is made public. Furthermore, as the sex, sexual orientation, martial status, nationality, colour, race, ethnic origin, religion, age or disability does not impact the data set it is not within the interests of governing bodies to discriminate against them, hence in line with clauses 1.a, 1.b, 1.c and 1.d.

2. Professional Competence and Integrity
You shall:

a) *only undertake to do work or provide a service that is within your professional competence.*
b) *NOT claim any level of competence that you do not possess.*
c) *develop your professional knowledge, skills and competence on a continuing basis, maintaining awareness of technological developments, procedures, and standards that are relevant to your field.*
d) *ensure that you have the knowledge and understanding of Legislation* and that you comply with such Legislation, in carrying out your professional responsibilities.*
e) *respect and value alternative viewpoints and, seek, accept and offer honest criticisms of work.*
f) *avoid injuring others, their property, reputation, or employment by false or malicious or negligent action or inaction.*
g) *reject and will not make any offer of bribery or unethical inducement.*[11]

It is only within the writer's interest to further develop his knowledge within the field, specifically due to the fact how this the writer's first interaction with the SIR model, and does not claim any knowledge that is out of reach, whilst, at the same time keeping an open mind to criticism. Lastly, as this is paper is written under a scholarly environment, clauses 2.a, 2.b, 2.c, 2.d, 2.e, 2.f and 2.g are in accordance.

3. Duty to Relevant Authority
You shall:

a) *carry out your professional responsibilities with due care and diligence in accordance with the Relevant Authority's requirements whilst exercising your professional judgement at all times.*
b) *seek to avoid any situation that may give rise to a conflict of interest between you and your Relevant Authority.*
c) *accept professional responsibility for your work and for the work of colleagues who are defined in a given context as working under your supervision.*
d) *NOT disclose or authorise to be disclosed, or use for personal gain or to benefit a third party, confidential information except with the permission of your Relevant Authority, or as required by Legislation. Authority, or as required by Legislation.*
e) *NOT misrepresent or withhold information on the performance of products, systems or services (unless lawfully bound by a duty of confidentiality not to disclose such information), or take advantage of the lack of relevant knowledge or inexperience of others.*[12]

As this paper is conducted under a scholarly environment it is within the writer's interests to claim full professional responsibilities of this paper whilst being line with the Relevant Authority's, in this case, the University of Sussex, interests. Given that this data set is made public by governing bodies, this paper will be in line with clauses 3.a, 3.b, 3.c, 3.d and 3.e.

4. Duty to the Profession
You shall:

a) *accept your personal duty to uphold the reputation of the profession and not take any action which could bring the profession into disrepute.*
b) *seek to improve professional standards through participation in their development, use and enforcement.*
c) *uphold the reputation and good standing of BCS, the Chartered Institute for IT.*
d) *act with integrity and respect in your professional relationships with all members of BCS and with members of other professions with whom you work in a professional capacity.*
e) *encourage and support fellow members in their professional development.*[13]

Given that the writer is currently partaking in a university course accredited by the BCS, The Chartered Institute of IT, it is within the writer's interests to follow, and will follow, clauses 4.a, 4.b, 4.c, 4.d and 4.e.

Ethical Considerations

Lastly it is important for the reader to understand that anomalies may arise in this paper on a natural basis due to uncertainties of the data, with the writer being unable to impact the anomaly. Worldometer claims they encounter reporting issues from governing powers on a daily basis, which will impact the results of my findings.[14] On the 29th of April Worldometer claimed that the French Government reported a decrease of 1417 confirmed cases compared to the 28th of April, this was a different figure that appeared in a city-wide report released by the French Ministry of Health. As a result of these reporting issues, analysis on this paper can possibly be skewed and biased towards certain countries.[15] However the writer is confident that the impact will be minimized as Worldometer cross-references nation-wide reports released by Governing Powers to its state/city reports counterpart.

Literature Review and Background Research

The SIR Model

The SIR model is a model created by William O.K and Anderson G.M in 1972, that consists of three groups, the Susceptible, the Infected and the Removed.[16]

According to Tolles J and Luong T, authors of *Modelling Epidemics With Compartmental Models*, during a pandemic it is assumed that a population is to be placed in one of the three components of the SIR model, susceptible, infected and removed.[17] Firstly, it is assumed that the entire population starts off as susceptible and are expected to be infected through contact with another infected individual.[18] This suggests that no herd immunity, defined as *when a large portion of the population becomes immune to a disease*, is developed yet, hence causing many deaths in the upper age brackets.[19] Secondly, after a period of time in which the individual is considered to be infectious, the infected individual passes on the removed stage, either through recovery or death.[20] The period of time mentioned beforehand will depend on the nature of the pandemic, for example, in the context of COVID, the British government recommends self-isolating for 10 days, meaning that under normal circumstances it will take 10 days for an individual to move from the infected stage to the recovered stage through recovery.[21]

Further on, a function can be given to define the number of Susceptible (S) at any given time t, S(t). The same can be done for the Infected(I) and Removed(R) group, I(t), R(t). Whilst the change of susceptible, infected and removed with respect to time can be given by the following set of differential equations.[22]

$$\frac{dS}{dt} = -\beta \times I \times \frac{S}{N}$$

$$\frac{dI}{dt} = \beta \times I \times \frac{S}{N} - \gamma \times I$$

$$\frac{dR}{dt} = \gamma \times I$$

Through differentiation and integration, we can also follow that:

$$S(t) = S(0)e^{\frac{-R_0(R(t)-R(0))}{N}}$$

Where:

β defined as the transmission rate

γ defined as the removal rate

N defined as the total population

R_0defined as the reproduction number $= \frac{\beta}{\gamma}$

Furthermore, it is important to note that a value of $R_0 > 1$ suggests that the disease will begin to spread if no form of quarantining the infected group is introduced to the formula, hence meaning that the bigger the R_0 value is, the faster the disease will exponentially grow.[23] For example, measles is a relatively fast spreading disease with $12 \leq R_0 \leq 18$, meaning that a measles infected individual may spread the disease to 12-18 individuals in the susceptible group under vacuum circumstances.[24] This also means that due to the nature of which COVID spreads, the rate of susceptible individuals moving into the infected group is highly dependent on the number of infected people. As diseases spread exponentially, it can be determined that the more infected individuals there are, the faster it is expected for the disease to spread.

Assumptions of the SIR Model and It's Flaws

In order for the SIR model to be considered as a very simple model, the SIR model makes a number of assumptions.

1. First, the SIR model assumes that in a population of size N, each individual of the population N, has an equal chance of getting into contact with an infected individual.[25] This has been criticized by many researchers as this is not a realistic view of the probabilities of how diseases spread. Consider the fictional example between person A and B. The new outlet has just released a statement introducing COVID into the daily lives of A and B. Person A takes precaution by starting social distancing measures, whilst person B discards the news and continues to live its daily life. It is a fundamental flaw to say that person A and B have the same probability of getting into contact with an infected individual. Furthermore, this is made under the assumption that person A and B are of the same age. This assumption becomes even more flawed when the question of age is input into the question, individuals of higher age tend to have weaker immune systems, hence it is safe to claim that individuals of older age are more susceptible to diseases effecting immune systems. Thus, this generalization questions the reliability of this model as it is unrealistic.
2. Second, it is assumed that the individuals from the Removed group of the SIR model are unable to become infected again bringing them back into the Infected group. In the context of COVID, this proven false as on the 13th of October 2020, BBC reported that an individual that was able to get re-infected by COVID a second time.[26]
3. Lastly, the SIR model assumes a constant population of size N. In a world where travelling has never been cheaper than before, it is also a mistake to assume that a population will remain constant. However, this can be considered negligible in the case of COVID as governing bodies imposed travelling restrictions relatively fast.

However, one must take a step back to consider that the SIR model is a simulation of what is expected to happen and not a specific case by case scenario, hence why researchers consider the SIR model to be effective.

Solving the Age Flaw of the SIR Model

As mentioned in the abstract a research paper conducted by authors Vishaal R and Laura P, *A Modified Age-Structured SIR Model for COVID-19 Type Viruses*, takes a very intelligent method to bring the variable age into the formula.

First, the authors claim that for diseases such as COVID-19, the variable age, plays a big part in the components of the SIR model, this could possibly be due to how individuals of higher age tend to have weaker immune systems, suggesting that individuals of older age are more vulnerable to diseases such as COVID-19, as mentioned before.[27]

Age	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80+
0-9	19.2	4.8	3.0	7.1	3.7	3.1	2.3	1.4	1.4
10-19	4.8	42.4	6.4	5.4	7.5	5.0	1.8	1.7	1.7
20-29	3.0	6.4	20.7	9.2	7.1	6.3	2.0	0.9	0.9
30-39	7.1	5.4	9.2	16.9	10.1	6.8	3.4	1.5	1.5
40-49	3.7	7.5	7.1	10.1	13.1	7.4	2.6	2.1	2.1
50-59	3.1	5.0	6.3	6.8	7.4	10.4	3.5	1.8	1.8
60-69	2.3	1.8	2.0	3.4	2.6	3.5	7.5	3.2	3.2
70-79	1.4	1.7	0.9	1.5	2.1	1.8	3.2	7.2	7.2
80+	1.4	1.7	0.9	1.5	2.1	1.8	3.2	7.2	7.2

Figure 1. Age-Contact Matrix Implementation by Vishaal R and Laura P [28]

Second, the authors decide to separate age groups into 9 intervals, 0-9, 10-19, 20-29, 30-39, 40-49, 50-59, 60-69, 70-79 and 80+ to impose a matrix, M, which describes the rates of contact between each age bracket. The values of which describe the rates of contact between different age groups is based upon two different research papers conducted by first, Chikina M and Pegden W, second Prem K and Cook A.R.[29][30][31] The values that take place in the cells within the matrix are *proportional to the total number of contacts per time between age groups, divided by the product of their population size*.[32] The authors then further elaborate how if individuals from different age brackets had equal total number of contacts then this would be a constant matrix, which is one of the assumptions the SIR model assumes.

Following the age-contact matrix, the differential equations now become:[33]

$$\frac{dS_i}{dt} = -\beta \times \frac{S_i}{N} \times \sum_{j=1}^{n} M_{ij} \times I_j$$

$$\frac{dI_i}{dt} = \beta \times \frac{S_i}{N} \times \sum_{j=1}^{n} M_{ij} \times I_j - \gamma \times I_j$$

$$\frac{dR_i}{dt} = \gamma \times I_j$$

By implementing Vishaal R and Laura P approach to the SIR model, this partially solves assumption number 1 above as this now factors in the variable, age. The writer believes that if this approach is taken to the SIR model, the social behaviour of individuals becomes negligible, this is because with a disease such as COVID-19, age is one of the main factors effecting the three components of the SIR model, susceptible, infected and removed.

Requirement Analysis

A further goal of this project is to make the concept of the SIR model and how it was used to discuss the effectiveness of lockdown measures during COVID-19 understandable such that it can cater to all target audiences. The younger audiences may not be able to understand the analysis and evaluation of the topic through the figures in the SIR model, but the writer hopes to communicate with the younger audience through the conclusion, the section in which the writer summarizes the findings and more. Whereas, for audiences that are able to understand the SIR model and the figures behind it, the writer hopes to communicate cemented evidence supporting the writer's arguments communicating the importance of lockdown measures.

Requirement	Mandatory/Desirable?	Description
Gather data from Worldometer for relevant countries and have them cross-refernced	Mandatory	As mentioned beforehand, Worldometer reported that governing bodies had issues in reporting consistent figures, resulting in possible skewed data. By cross-referencing figures the writer will be able to provide the most accurate figures.
Research and explore different cultures throughout Europe and Asia regarding social behaviours that may involve physical contact of some sort	Mandatory	Given the greeting example in the Aims, Objectives and Relevance section, it is rather crucial to look for other possible social behaviours expressed by nations throughout Europe and Asia.
Synthesize data by looking at possible outliers and anomalies	Mandatory	By reviewing the data to look out for possible outliers and anomalies will allow the writer to make a decision to whether the anomalous data set should be included in the analysis or not, as possible outliers and anomalies could skew the results.
Read through first, Chikina M and Pegden W, second Prem K and Cook A.R's work on how an age-contact matrix can be produced for the relevant nations in question	Mandatory	The example matrix provided was in a case study conducted in the US, as this nation is not within the interests of the writer, the writer will still need to have a look at how an age-contact matrix can be produced for relevant nations in question.
The age-scaling factor proposed must be thoroughly researched and well explained and detailed	Mandatory	This is one of the main aspects of the paper and will require the most time.
Graphs must be well labelled and explained	Desirable	In order to meet my objective of making this paper being able to cater all target audiences, graphs must be labelled well in order to assist in the understanding of the graphs
Create interactive figures with Python/MATLAB	Desirable	If time permits, this will aid the reader by giving a better visual representation of findings which achieve the goal of making the paper cater to all target audiences.

Project Plan

Extensive research has already been achieved by the writer through the process of reading other researcher's work. By reading and noting the work of other researcher's the writer has grasped a good understanding of

1. Possible cultural factors that may explain differences in effectiveness of lockdown measures
2. What partakes the SIR model and it's relevant formulae
3. Understood the age-scaling modification applied to the SIR model to circumvent a fundamental flaw of the SIR model

However it is important that the writer looks into the production of an age-contact matrix explained in two separate research papers by author's first, Chikina M and Pegden W, second Prem K and Cook A.R.

Activity	Start Date	Duration (estimation in days)	End Date
Selection of project	26/08/2021	25	20/09/2021
Background research for project proposal	26/08/2021	51	17/10/2021
Project proposal	20/09/2021	27	17/10/2021
Further background reading	08/10/2021	34	05/11/2021
Interim Report	17/10/2021	25	11/11/2021
Gathering and cross-referncing data from Worldometer	12/11/2021	6	18/11/2021
Synthesisation of data	18/11/2021	21	09/12/2021
Look for possible outliers in data	09/12/2021	3	12/12/2021
Analysis of data	10/01/2022	14	24/01/2022
Application of age-scaling factor in the SIR model and production of age-contact matrix for relevant nations in question	24/01/2022	24	17/02/2022
Draft report	17/02/2022	61	19/04/2022
Feedback evaluation	TBA	N/A	TBA
Poster preparation and presentation	TBA	N/A	TBA
Final report	-	-	10/05/2022

Interim Log

Email #1 – 02/09/2021

Emailed Dr. Adam Barrett regarding selection of project

Meeting #1 - 04/10/2021

Introductory meeting, discussed possibilities of project and useful resources

Meeting #2 - 18/10/2021

Discussed what should be included in a proposal and examples of good proposals for shown. Proposal had not been completed by then as the writer was questioning scope of project.

Email #2 – 26/10/2021

Proposal submitted

Email #3 – 28/10/2021

Feedback for proposal received

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Appendix A: Proposal

Modelling Effectiveness of Lockdown Measures – Europe and Asia

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Introduction

SARS-CoV-2, more notably recognized as COVID-19, an ongoing contagious, fast spreading disease impacting how the world would live. After failing to quarantine the disease when it was first discovered in Wuhan, China December 2019, COVID-19 spread the world amassing havoc.[1] Governing powers tried to shutdown this disease by implementing lockdown measures, hence why this report will aim to model the effectiveness of lockdown measures implemented by governing powers in Europe and Asia to draw a comparison between them.

Aims

- Explore and research lockdown measures implemented by countries in Europe and Asia
- Gather data from Worldometer[2] at three different stages of the COVID pandemic to be used in a modified SIR model
    - 1. COVID figures before lockdown measures were implemented to have a base comparison
    - 2. Peak COVID figures to draw comparisons if they happened during lockdown or not
    - 3. COVID figures after lockdown measures
- Identify how differences in cultures may lead to differences in the effectiveness of lockdowns
- Create figures and diagrams using tools such as Python or MATLAB to aid in the understanding of my comparisons

Objectives

Primary Objectives:

- Research lockdown measures implemented throughout countries in Europe and Asia
- Collect and process COVID 19 figures to be used in a modified SIR model adapted to the COVID pandemic
- Use technology to create interactive figures/diagrams to support claims made
- Compare and contrast Europe's relaxed lockdown measures to Asia's strict lockdown measures
- Explore possible cultural reasons to why there may be differences in the effectiveness of lockdowns and use data to support such claims
- Explore possible outliers which may lead to inconsistencies in analysis

Extension Objectives:

- Explore the effectiveness of facial covering to identify its importance in slowing down the rate of spread
    - Compare covid figures between times where facial covering were mandatory and where facial covering were optional, whilst keeping in mind that facial covering was made optional once vaccine programs were made available nation wide

Relevance

As this is project is heavily reliant upon researching figures and facts related to COVID, I am able to apply my essential research skills developed throughout my Computer Science degree starting with the Professional Skills module. I am confident with my research skills developed such that I will be able to find appropriate sources and come to a conclusion whether this source is reliable or not. Furthermore, given that this project requires a good grasp of mathematics, more specifically modelling, graphing and calculus, I will be able to apply some of the knowledge learnt in my Mathematical Concepts module to good use. Lastly, as I intend to create interactive figures and diagrams, I can apply my Python skills or MATLAB skills to achieve my primary objective.

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