A Year of Work in Covid-19 Statistical Modeling

Jorge Luis Romeu, Ph.D.
Emeritus SUNY; Adjunct Prof., Dpt. MAE, 263 Link Hall, Syracuse University, NY 13224

Abstract
We overview a year of statistical work developing tutorials, models and analysis applications to Covid-19 issues to illustrate our methods and persuade researchers from other professions to include statistics and statisticians in their work. Section 2 describes the web page created, and its background material. Section 3 overviews Quality Control and Design of Experiments papers that, using Covid-19 data, assess whether state counties or regions should be opened or locked-down. Section 4 overviews Reliability and Logistics papers that, using patient data, help take Triage decisions. Section 5 summarizes Principal Components and Discriminant Analysis papers that, using patient data, assess the results of Covid-19 vaccine and treatment clinical trials. Section 6 overviews Stochastic Process papers that implement Markov Chain models to evaluate decisions on opening colleges and assess Covid-19 hospital and ICU needs to avoid being overwhelmed. Section 7 presents Socio-economic analyses of problems derived from the Covid-19 pandemic. Section 8 presents Quality Engineering approaches to the Design and Improvement of Covid-19 vaccine distribution systems. Section 9 summarizes our work.

Keywords: public health, DOE, multivariate, discrimination, survival analysis, Markov chains.

1. Introduction

In this article we summarize one year of pro-bono work on statistical modeling of Covid-19 topics. It all started on March 4th, when we wrote a communication to the Grand Lodge of New York, raising our concerns about continuing Lodge meetings, given the speed with which the Coronavirus was spreading from China, to Europe, to New York, California, Washington, etc.

We stated how, in Washington State, 10 deaths were attributed to the virus. Assuming that if the death rate was in fact 2%, as in China, there could be up to 10/0.02 = 500+ infections. Authorities had identified only 100+. Thence, there existed the possibility of having 400+ cases, still remaining undetected, potentially infecting others. In addition, we provided a numerical example describing how the infection process worked, that made its way to the media and became a video tutorial.

Shortly after, we proposed to the American Statistical Association and American Society for Quality[1] to organize a group of retired members to volunteer with Covid-19 statistical efforts. In April, we wrote the proposal https://web.cortland.edu/matresearch/Covid-19Proposal2020.pdf and started distributing and hanging our papers in ResearchGate, LinkedIn and other Internet forums.

We started developing statistical models and applications of methods that could illustrate statistics usage, persuade researchers and practitioners from other professions to include statistics in their work, as well as to invite more statisticians to collaborate with them. These tutorials would also help educate political

[1] GLNY, the ASA, and ASQ are three Civil Society organizations we belong to, and work with.

leaders (https://web.cortland.edu/matresearch/CORONAVARUSListEngNov2020.pdf) as well as the general public. The research material was well-received, according to its LinkedIn and ResearchGate hits: https://web.cortland.edu/matresearch/SELECTEDREADINGSRESEARCHGATE.pdf

In the rest of this paper we summarize the contents and uses of the statistics papers written. In Section 2 we describe the web page we created, and its introductory section. In Section 3 we deal with papers on Design of Experiments and Quality Control Applications. In Section 4, we deal with Reliability and Logistics Applications. In Section 5 we summarize the papers using Multivariate Analysis (Principal Components and Discriminant). In Section 6 we overview Stochastic Process papers that implement Markov Chain models. In Section 7, we present Socio-economic analyses of some problems derived from dealing with Covid-19. In Section 8, we conclude.

2.0 History and basic information:

In this section we present some Basic Information regarding the Study of the Coronavirus Pandemic and its outbreak, from both historical and sociological, and numerical and medical perspectives.

First, this Pandemic has been ill-named the *Chinese or Kung-Fu virus*, just as the 1918 Flu Pandemic: https://web.cortland.edu/matresearch/HISTORY%201918%20FLU%20PANDEMIC.pdf *was* named the *Spanish Flu,* and perhaps with a similar objective.

The Economist article: https://web.cortland.edu/matresearch/CoronavarusEconomist.pdf appearing at the beginning of the Pandemic, analyzes its origin and implications.

We developed an illustrative Numerical Example of the transmission process of the virus:

https://www.researchgate.net/publication/339936386_A_simple_numerical_example_that_illustrates_the_dangesrs_of_the_Coronavarus_epidemic

Said numerical example made its way to the Syracuse newspapers, which adapted it into a U-Tube video for educational use: https://www.syracuse.com/coronavirus/2020/03/how-fast-can-coronavirus-spread-statistics-professor-explains-why-we-need-to-act-now-video.html

We wrote a formal Proposal, asking the retired community of statisticians, academics and researchers, to contribute their time and experience, pro-bono, to help fight the Covid-19 Pandemic. It is found in: https://www.researchgate.net/publication/341282217_A_Proposal_for_Fighting_Covid-19_and_its_Economic_Fallout

The Johns Hopkins University global map, illustrating the world-wide expansion of the Coronavirus https://gisanddata.maps.arcgis.com/apps/opsdashboard/index.html#/bda7594740fd40299423467b48e9ecf6 was included in the web page, for general information.

Similar Information ,about the spread of Coronavirus infection in the State of New York, is found in: https://www.syracuse.com/coronavirus-ny/

In Syracuse University's MFE634, a graduate Quality Engineering course, students applied Quality tools to analyze several Covid-19 issues: https://web.cortland.edu/matresearch/Covid-19COPQGrp1.pdf, and

https://web.cortland.edu/matresearch/Coronavirus_Assess_Grp2.pdf,
https://web.cortland.edu/matresearch/Covid-19FTAGrp5.pdf

Prior MFE634Quality Engineering students also had Experiences with Epidemiology (Ebola & Zika): https://web.cortland.edu/matresearch/EbolaGageR&R2016.pdf
https://web.cortland.edu/matresearch/2017ZikaVirusFinPres.pdf

The Section ends with a list of our Covid-19 papers, including *hits* from LinkedIn and ResearchGate: https://web.cortland.edu/matresearch/SELECTEDREADINGSRESEARCHGATE.pdf that provide some indication about how often and how much these papers were read, and about the readers' institutions.

3.0 Design of Experiments (DOE) and Quality Control (SPC) Applications:

In this section we present tutorials on specialized statistical methods such as DOE and SPC that can be successfully applied to the Study of the Coronavirus Pandemic issues. We give the title of the papers, the link where it can be found, and a short description of its contents:

Monitoring Community Infection Levels of Covid-19 Virus using Quality Control Techniques

https://web.cortland.edu/matresearch/AplicatSPCtoCovid19MFE2020.pdf

This short paper illustrates some practical aspects in the implementation of *Control Charts* for proportions and mean/range, *to assess and monitor* community infection levels of Covid-19.

Design of Experiments in Identification of Factors impacting Community Spread of Covid-19

https://www.researchgate.net/publication/341532612_Example_of_a_DOE_Application_to_Coronavarius_Data_Analysis

This paper walks the reader through the *detailed implementation of a DOE*, *to assess* the Effect on *Community Infection Spread*, of Factors Social Distancing, Face Masks and Day Schedule. The data set used was created by the author, using his experience and readings of Covid-19.

Fractional Factorial DOEs in Identification of medical treatments that reduce Covid19 infection

https://www.researchgate.net/publication/344924536_Design_of_Experiments_DOE_in_Covid-19_Factor_Screening_and_Assessment

This paper is *a tutorial on Fractional Factorial DOEs* used *to screen and identify* experimental treatments and characteristics that may affect Covid-19 patients. Designs used include *Plackett-Burnam*, which helps to *reduce the number of experiments* done, saving valuable researcher time and effort. The Covid-19 data was also created by the author, using his experience and readings.

4.0 Reliability and Logistics Applications:

In this section we present, as above, tutorials on some specialized statistical methods such as *Reliability and Logistics*, which can be successfully applied to *Triage, and to ICU* overcapacity problems.

Design and performance evaluation of ICU units, using Reliability

https://www.researchgate.net/publication/342449617_Example_of_the_Design_and_Operation_of_an_ICU_using_Reliability_Principles

Health care facilities require implementing *efficient and effective Logistics* (e.g. ensuring PPEs, support equipment and workers are available). *Failure Modes and Effects Analysis* (FMEAs) and *Fault Tree Analysis* (FTAs) are two valuable *reliability techniques*. Finally, a reliability analysis example illustrates how to establish *efficient replacement schedules* for key ICU equipment.

A summary of Fault Tree Analysis (FTA) and Failure Mode and Effects Analysis (FMEA)

https://web.cortland.edu/matresearch/FMEA&FTASumaryS2017.pdf

This *Power Point presentation* provides a quick and simple *introduction to* the techniques of *Fault Tree Analysis* (FTA) and *Failure Mode and Effect Analyses* (FMEA). It includes real examples and the corresponding icons used to build FTAs.

An Example of Survival Analysis of Covid-19 using ICU & Patients Ventilator data

https://www.researchgate.net/publication/342583500_An_Example_of_Survival_Analysis_Data_Applied_to_Covid-19

First, we consider patient Ventilator *Time to Death or to Recovery*. We then include patient *covariate information* (e.g. age, number of *Comorbidities*, and if termination was due to death, or to recovery). We analyze the probability of *patient survival*, given Ventilator Time, age, Co-morbidities; and strength and direction of covariates effects in patient's Ventilator sojourn. We also implement *Discriminant and Regression Analyses* between recovering and dying Patients, *to assess* which *factors* impact them. The purpose of these procedures is *to help evaluate Triage* in the unfortunate case its application is required, *due to ICU overcapacity*.

Statistical Methods to Accelerate Covid-19 Vaccine Clinical Trials using sequential analysis

https://www.researchgate.net/publication/344193195_Some_Statistical_Methods_to_Accelerate_Covid-19_Vaccine_Testing

Clinical Trials are about assessing the success or failure *of a treatment or a vaccine*. In this paper, *industrial sampling plans* are used to help shorten Clinical Trials. We discuss *testing methods* and their *sample size requirements*, then, sampling *plans for attributes* (pass or fail) that follow the Binomial Distribution. We then explore *double and sequential sampling plans*, the Expected *Sample Number*, that assesses the efficiency of multi-stage sampling plans. We conclude with a *detailed tutorial on sequential probability ratio tests*. We illustrate these plan discussions via *numerical and practical examples*. All these methods can *help accelerate clinical trials* without affecting their quality or reliability.

Survival Methods to Establish Covid-19 Vaccine Life (Length of its Effectiveness)

https://www.researchgate.net/publication/344495955_Survival_Analysis_Methods_Applied_to_Establishing_Covid-19_Vaccine_Life

This paper provides a *detailed three-step tutorial on Survival Analysis*, applied to the study and assessment of *Life Length of Covid-19 Vaccines*. First, survival analysis was implemented to assess *rate of decay of Vaccine Life Length*, in time, to establish its *Useful Life*. Secondly, we studied how Life may be modified by *population factors* such as *age, socioeconomic conditions*, *gender*, number of *co-morbidities*, etc. Then, *Discriminant Analysis* between the two vaccinated groups (those later infected with Covid-19, and those that were not) was implemented *to identify* which *factors impacted Vaccine Life and Efficacy*. Finally, a *multiple regression* analysis was implemented *to quantify* such impact. It was determined that, as patient Age and Number of Co-morbidities increases, the length of time (Life Length) and efficacy of the Vaccine diminishes. Such *results* are used to *determine* the *number of Vaccine doses* required *for immunization*.

Covid-19 ICU Staff and Equipment Requirements using the Negative Binomial

https://www.researchgate.net/publication/345914205_Covid-19_ICU_Staff_and_Equipment_Requirements_using_the_Negative_Binomial

In this article we *estimate a health care system* (e.g. hospital, ward, ICU) *load and operating requirements* (number of beds, of doctors, nurses, ventilators, etc.) to successfully cope with a possible system overload, during a given Covid-19 wave. We implement *Poisson and Negative Binomial Distributions* to assess *ICU overflow*, and estimate *Staff and Equipment requirements*. We *simulate patient admissions* using these distribution parameters, obtaining *average, best or worst cases*, evaluating these results using *survival analysis*. We *compare* and discuss *ICU staff and equipment requirements*, estimated under patient overflows, obtaining *Confidence Intervals* with different probabilities of admission. *Probabilities of survival on an ICU*, given patient age and co-morbidities, are estimated, including *expected times to death*. All this *information* may be *used to determine patient allocation* to an ICU and ventilator facility, *in case of Triage*.

5.0 Multivariate Analysis (Principal Components; Discriminant Analysis):

In this section we present, in the same format as done above, *Principal Components and Discriminant Analysis* statistical *tutorials*. These methods can be successfully *applied to Triage, and ICU overcapacity* problems.

Principal Components and Discriminant Analysis of Covid-19 data: Part I

https://www.researchgate.net/publication/341385856_Multivariate_Stats_PC_Discrimination_in_the_Analysis_of_Covid-19

The *analysis* below *uses real data taken from New York State Regions*, released on V/13/20 by NYS authorities. It illustrates the power of *multivariate analysis* in the Coronavirus Pandemic struggle. *A Principal Components* analysis was implemented *to assess* variable *impact* on each Region's infection rate. Principal Components *reduces the number of analysis variables* to a *smaller set of highly significant* ones. A *Discriminant Analysis* was then used to assess which of these variables does a better job of *separating* the *Regions into* those that can *safely open* their economy, and *those that should wait*. Using such variables within *Fisher Discriminant equation*, NYS *regions* can be *periodically re-evaluated*, using subsequently obtained NYS data. This is a preliminary study, subject to further data validation and verification. We encourage other researchers to substitute our data in the tutorial and input theirs, and get similar results for their regions.

More on Principal Components and Discriminant Analysis of Covid-19 data: Part II

https://www.researchgate.net/publication/342154667_More_on_Applying_Principal_Components_Discrimination_Analysis_to_Covid-19

This *paper is a continuation of* the above *Multivariate Statistics in the Analysis of Covid19.* We use the 62 New York state counties to (1) assess *which metrics* better *separate* them, and (2) obtain an *equation to classify* regions into *high and low risk* groups, according to said metrics. Variables used are: (1) *percent positives* per 10K (of county population) and (2) *deaths* per 10K. Since we don't' have county *population and thence, can't obtain county density*, we use, (3) subjective *Urban v. Rural* status. We implement *Principal Components* to identify (1) which *variables* most significantly help us *differentiate* between *high and low infection counties*. Then, using identified variables, we develop (2) *Discrimination Functions to classify NYS counties* into high and low risk groups, according to their Covid-19 metrics. We *use the Principal Component scores to* plot the different counties and *assess how* counties are *similar* (*clustered*), or *different*, *according to* the Axes: *Positives and Deaths*.

Principal Components and Discriminant Analysis of Covid-19 data: Power Point

https://web.cortland.edu/matresearch/ApplyPrincCompDSCC-Cov19.pdf

This *Power Point* was used *to present* the two above *Multivariate Analysis papers* to the *Data Science Conference on COVID-19* August 28, 2020. It will help better understand their content.

Logistic Regression/Discriminant Analysis Identifying key Covid Vaccine Clinical Trial Factors

https://www.researchgate.net/publication/346956247_Logistic_Regression_in_Factor_Identification_of_Covid-19_Vaccine_Clinical_Trials

A *tutorial on* the use *of Logistic Regression* to *identify key factors* in Covid-19 *Clinical Trials*. The data analyzed was produced by this researcher using his experience and information. *We compare Logistics Regression with Discriminant Analysis methods* by analyzing same clinical trial data to identify Covid-19 factors that affect vaccine effects. By either method *we detect the same factors* that differentiate between both infected groups (vaccinated and placebo). This *approach* can be *reproduced by substituting, as responses*, placebo v. vaccinated; by infected v. not infected; by deceased v. surviving; by Vaccine A v. Vaccine B, etc. Researchers *may also use, as factors, other patient characteristics* such as weight, age, gender, occupation, number (or types) of co-morbidities and levels of interaction. We conclude that both Logistics Regression and Discriminant Analysis *results are equivalent*. *Logistics provides* the *probability of* a data *element belonging to* one or the other *group under consideration*. Statistically significant factors identify the *key model components* on which researchers should undertake further research.

6.0 Stochastic Processes Applications (Markov Chains):

In this section we present, following the same manner as done in the sections above, several *tutorials on modeling* the trajectories of Covid-19 processes as *Markov Chains*. Through their movement between the different Markov states, we can obtain transition probabilities and sojourn times, useful to assess logistics, compare rates, triage, etc. By running different infection rates and facility logistics, we can compare the relative efficiency of different solutions, and select the best one.

A Markov Chain model to study the spread of the Covid-19 virus https://www.researchgate.net/publication/343021113_A_Markov_Chain_Model_for_Covid-19_Survival_Analysis

This Markov Chain illustrates the power that Markov modeling offers to Covid-19 studies. This article *models the trajectory of Covid-19 infected patients into an ICU*, and up to their death through a Markov Chain. We *first* consider a *simple three-state, recurrent model*. Its *steady state probabilities* are obtained *for efficient and inefficient system* comparisons. We *then include* additional *absorbing states*, to account for more complex situations. Using TPM we obtain the (1) *probability of death* of a Patient; and using their sojourns in the different states, (2) their *expected time to death*. The results are useful in establishing (1) *logistic requirements* of health care units, to provide excellent patient care, and (2) some *objective Triage procedures*, if ever such extremes are required. *This Markov Chain* tutorial has been, *by* the number of hits in its LinkedIn and ResearchGate web pages, *our most read Covid-19 report*.

A Two-Absorbing-States Markov Chain to study the problem of Covid-19 Herd Immunization

https://www.researchgate.net/publication/343345908_A_Markov_Model_to_Study_Covid-19_Herd_Immunization

This *second Markov model* assumes that the *virus will infect* a large part of the *population*, thus preventing further community spread and *yielding Herd Immunization*. Our *previous Markov Chain assumed* there was *neither a vaccine nor a treatment* for Covid-19. Also that, if current infection rates remained unchecked, everyone would eventually die. *This paper assumes* that Covid-19 *survivors become immune*, thence, cannot become re-infected. There is much debate about employing *Herd Immunity* as an alternative *solution for combating Covid-19*. Our *Markov Chain* quantitatively *analyzes such situation*. The model obtains (1) the *probability of* a Patient *death or immunization*. Also, the (2) *expected times to death* (or to immunization) when starting *from different states* in the Space (which can be *used in Triage* situations). Transition rates can help *compare efficient and inefficient medical strategies*, as well as help *establish* an *acceptable infection rate*. Times spent in a State (Sojourn) help *estimate the required size of health care facilities* that will treat patients. *Statistics* models *help answer* many *health questions*, as well as *compare the performance* of different public health strategies, in a *more objective, non-partisan way*. As George Box, a well-known statistician, once said: *all models are wrong; some models are useful.*

A Markov Chain to study the problem of Re-opening Colleges under Covid-19

https://www.researchgate.net/publication/343825461_A_Markov_Model_to_Study_College_Re-opening_Under_Covid-19

This *Markov Model* studies the dilemma of *Re-opening Colleges under Covid-19*. We analyze the situation using a Markov Chain defined over *a nine element state space* that moves through a set of Transient states, eventually leading *to two Absorbing States*: *Expulsion or Coursework Completion*. The *model*, due to its specific State Spaces and transition probabilities is very *useful to compare reopening plans*. Through the infection (transition) rates we study their impact on the *probabilities of Expulsion and Course Completion*. Differing infection rates depend on student *compliance with community public health measures* such as face covering, social distancing, etc. By assigning different values to these rates, *their impact can be assessed and compared*. Once updated and fine tuned (or rebuilt) Markov *models can be used by college authorities* to re-assess and improve their reopening plans, *by faculty and students*, to assess their risks in such openings, *and by government authorities*, to assess the validity and safety of such plans, thus allowing or proscribing them. This *model* can *also* be *modified to assess* re-opening the *public school system*.

GSS/ASA Workshop (U-Tube) on Covid-19 (our Markov Chain presentation is *the last one)*

https://www.youtube.com/watch?v=ByGEUGbU_JU&feature=youtu.be

U-Tube recording of the *Applications in Using Blended Data Workshop*, sponsored by the *ASA Government and Social Statistics Sections*. Our *Markov Chain presentation* is the last one.

A Markov Model to Assess Covid-19 Vaccine Herd Immunization Patterns

https://www.researchgate.net/publication/347441411_A_Markov_Model_to_Assess_Covid-19_Vacine_Herd_Inmunization_Patterns

This *Markov model* assesses different *patterns of vaccination*, which may *affect* achieving (or not) *Herd Immunity*. The urgency of this paper stems *from polls suggesting* a significant number of *people are not willing to become vaccinated*. Herd Immunity can be acquired by (a) letting the virus infect most of the population. Weaker ones (the elderly, those with co-morbidities etc.) will die) and those surviving will become immunized; alternatively, (b) by vaccinating a large part of the general population. In either case, *the majority of the population must be actively involved*. Vaccination entails two aspects: one is individual and the other social. First, the *vaccine protects the individua*l. Secondly, if enough individuals in the general population are vaccinated, the *activity has an effect over the Pandemic*. With few new customers to infect, the virus starves and disappears. If insufficient persons become vaccinated, this latter benefit is lost. By *changing* the *vaccination parameters* (e.g., infection rates, participation, and immunization percentages), model results will differ, allowing the *comparison of different public health strategies*.

7.0 Socio-economic Analyses of Problems derived from Covid-19:

In this section we present four papers that discuss *conceptual issues affecting* the results or the interpretation of the statistical analysis *of Covid-19 problems*. Format is similar to that of previous ones.

Fallouts of Off-Shoring (outsourcing) and Tax payers' contributions, to the Coronavirus Pandemic

https://www.researchgate.net/publication/341685776_Off-Shoring_Taxpayers_and_the_Coronavarus_Pandemic

This paper discusses how the *Off-shoring American jobs* during a quarter of a century, was one of the main causes that *prompted the election of President Donald Trump*. His *initial handling* of Coronavirus Pandemic was *not efficient -his handling of Covid-19 vaccine research and production, was*. In addition, extended *Off-shoring affected* many industries that could have provided *essential* resources to help in the fight against Covid-19. The *result* of these factors was that, the *number of Covid-19 infections and deaths* occurred was *possibly larger* than it should have been.

A Digression on the Interaction between Race, Ethnicity, Class and Coronavirus.

https://www.researchgate.net/publication/343700072_A_Digression_About_Race_Ethnicity_Class_and_Covid-19

This paper discusses the *allegation that, if African-Americans and Hispanics* were *impacted by Covid-19 above their population representation,* it was *because genetic* factors were involved. We indicate how *it* *may not be race or ethnicity, but poverty* and other negative socio-economic conditions such as insufficient or no health care, poor living environments, working in high risk jobs, living in overcrowded quarters, perhaps over more than one generation, what causes these populations to become infected in larger percentages. Notice and *compare how, middle and upper class African-American and Hispanic households* (e.g., President Obama, Secretary Condoleezza Rice, Professor Romeu) are affected in *equivalent numbers*, as *their middle- and upper-class peers, in mainstream and white America*.

A Digression about Aspects of Clinical Trials for the new Vaccine against Covid-19.

https://www.researchgate.net/publication/346305686_A_Digression_on_Covid-19_Vaccine_Clinical_Trials_and_its_Consequences

We digress about *Covid-19 vaccine accelerated Clinical Trials* and the early release, by CDC, of several candidate vaccines made possible by the application of new techniques. We wrote two previous papers:

https://www.researchgate.net/publication/344495955_Survival_Analysis_Methods_Applied_to_Establishing_Covid-19_Vaccine_Life about the use of survival analysis for assessing vaccine life length, and https://www.researchgate.net/publication/344193195_Some_Statistical_Methods_to_Accelerate_Covid-19_Vaccine_Testing about efficiently assessing vaccine test results.

Some drawbacks on vaccine early release stems from limited testing time: failure to identify some *side-effects*, especially long-term ones; failure to determine *the time length* of immunization provided, or the *particular cohorts* (e.g. elderly) that each of the vaccines will benefit (or hurt). The world needs *a working vaccine*, even with potentially minor problems. After a few years of world-wide vaccination, *heard immunity will* be *achieved*. Meanwhile, we have to make-do with what we now have.

A Digression on Covid-19 Vaccine Rollout.

https://www.researchgate.net/publication/348607971_A_Digression_on_Covid-19_Vaccine_Rollout

Research for a Covid-19 vaccine was a complete *success*! However, the *US rollout* of such vaccines has proven *a failure*. Such poor rollout suggests the *need to re-examine its approach*, and *redefine some of its methods*. For comparison, *in June of 1944* the Allied army successfully landed in *Normandy*. Over 1,200 aircraft and more than 5,000 vessels carrying 160,000 troops, medical supplies, water, food, ammunition, etc. were moved in a few days. *Operations Research, the technique* that made possible the invasion's *essential Logistics, was born*. The *political and military leaders* had the brilliance of *establishing the key goals* of the military operation, while *letting OR people* take care of *the technical details of its logistics implementation*. This article provides *examples of proven OR, logistics and quality engineering techniques* that have been *successfully applied to improve many situations*. Some of the *methodology presented* in this paper, may also *help improve* the current *Vaccine rollout performance*.

8.0 Additional Work

After completing the initial series of papers, we continued expanding their scope. Several months later (Fall of 2021) we wrote a paper on the use of *Quality Engineering Methodology in the Study, Assessment and Development of Covid-19 Systems*, either already deployed or to be soon released.

https://www.researchgate.net/publication/352998703_Quality_Engineering_Methodology_in_Covid-19_Systems_Design_and_Improvement

In the Spring 2022 we developed, with our MFE634 Quality Engineering graduate students, a project on using *Quality Engineering Methodology for Improving the Distribution of Covid Vaccines Worldwide*, especially in Third World Countries, through the World Health Organization:

https://web.cortland.edu/matresearch/WorldwideCovidDistrFinalGrp3.pdf

9.0 Discussion & Conclusions

Most work reported here was undertaken between March of 2020 and February of 2021. In those twelve months, this researcher wrote *over two dozen papers, reports and tutorials*, on Covid19. After Spring 2021, we continued working on Covid19 issues, individually, and with our Quality Engineering students.

We followed *Eight Steps in developing* our Covid-19 oriented, *statistical papers*:

1. Select a current Covid-19 topic of interest
2. Research the topic from a Public Health perspective
3. Select a statistical method to deal with this topic
4. Review the theory of the statistical method to be used
5. Find/develop an appropriate data set for the analysis
6. Analyze the data using the stated method
7. Obtain/interpret the Results, and Conclude
8. Distribute the papers (via web, institutions etc)

The reader may estimate the *number of hours invested in this effort*. Certainly, we have put in several hundred hours of pro-bono work to help defeat Covid-19. We hope it has contributed.

Combining the results from the Markov Chains, Survival, and Multivariate Analyses, as well as other methods used in this series, *may provide tools* for public health and other professionals to *help establish rules for Triage* procedures, if such situation ever becomes necessary.

In our work we want to *reach four audiences*: (1) *public health* professionals and researchers, (2) *medical doctors*, (3) *statisticians* and (4) *the public* in general.

We want to *encourage public health and medical professionals to* use more statistical procedures and *do more joint work with statisticians* -not only after the data have been collected, but also at the time that the experiments are being designed.

We want to encourage statisticians, especially those retired, who have the experience, financial support (their pension), and the free time to provide such assistance, *to contribute in helping with the planning, implementation and analysis* of statistical procedures –or with writing about them.

We want to provide illustrative examples to doctors, public health researchers, government, and general public, to help them better understand what statisticians do, *fostering greater collaboration*.

Finally, *this series of papers on statistical analysis of Covid-19* problems can *also be used as part of a biostatistics course* in a public health or medical curriculum, or in an *applied modeling and data analysis graduate course, in a statistics department*.

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