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Charlie L. Sy

Kathleen Aviso

Christina D. Cayamanda

Anthony F. Chiu

Rochelle Irene Lucas

*See next page for additional authors*

Authors
Charlie L. Sy, Kathleen Aviso, Christina D. Cayamanda, Anthony F. Chiu, Rochelle Irene Lucas, Michael Angelo Promentilla, Luis F. Razon, Raymond R. Tan, John Frederick Tapia, Ador Torneo, Aristotle T. Ubando, and Derrick Ethelbhert C. Yu

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# Preparing for Shortages of Future Covid-19 Drugs: A Data-Based Model for Optimal Allocation

Written by:

*Charlle L. Sy* [a]
*Kathleen B. Aviso* [a]
*Christina D. Cayamanda* [b]
*Anthony S. F. Chiu* [a]
*Rochelle Irene G. Lucas* [c]
*Michael Angelo B. Promentilla* [a]
*Luis F. Razon* [a]
*Raymond R. Tan* [a]
*John Frederick D. Tapia* [a]
*Ador R. Torneo* [d]
*Aristotle T. Ubando* [a]
*Derrick Ethelbhert C. Yu* [e]

[a] Center for Engineering and Sustainable Development Research, De La Salle University
[b] AnimoLabs Foundation, Inc.
[c] Lasallian Institute for Development and Educational Research, De La Salle University
[d] Jesse M. Robredo Institute for Governance, De La Salle University
[e] Center for Natural Sciences and Environmental Research, De La Salle University

Drugs for the treatment of Covid-19 are currently being tested, and those that are approved for use are likely to be in short supply due to the global scale of the pandemic. This policy brief proposes a model for optimally allocating future Covid-19 drugs to patients to minimize deaths under conditions of resource scarcity. A linear programming model is developed that estimates the potential number of deaths that may result from Covid-19 under two scenarios: with antivirals and without antivirals. It takes into account patient risk level, the severity of their symptoms, resource availability in hospitals (i.e. hospital beds, critical care units, ventilators), observed mortality rates, and share of the Philippine population. Based on simulations, the model can make actionable recommendations on how to prioritize the allocation of the drugs.

Optimal allocation models will be necessary in the anticipated scenario where health administrators do not have enough supply of Covid-19 drugs to treat all patients in accordance with their risk levels or severity of symptoms. The rapid spread of Covid-19 in many countries; the current problems in the global pharmaceutical supply chains due to the lockdown policies adopted by many governments; and competition for both finished drugs and raw materials however makes this scenario highly likely. A simulated scenario illustrates how the model can be used for decision support. In this scenario, the priority is given to medium-risk patients because of their numbers. Projections based on the model, however, show diminishing returns in terms of number of lives saved when more than 60% of patients receive Covid-19 drugs. The implication is that the optimal allocation model is most useful in guiding Covid-19 drug allocation when supplies are scarce. The proposed drug allocation model becomes less useful when drug supplies are enough to be administered to the majority of patients.

Future approved Covid-19 drugs will be in short supply until global production capacity is built up to meet the demand. It is imperative for health administrators to exercise sound judgment in allocating a very scarce resource so that it will deliver in the words of the eminent philosopher Jeremy Bentham "the greatest good to the greatest number of people." It is in this spirit that this model is proposed to inform decision-makers of the most likely outcomes of different scenarios. It is meant to serve as a rational guide for resource allocation and decision-making because data-driven medical allocation will save more lives than random allocation or a simplistic first-come, first-served policy.

## Summary of Recommendations:

- It is imperative that health administrators anticipate and prepare for a supply shortage of future Covid-19 drugs; they must be capable of rationally allocating scarce supplies when they come.
- Health administrators will benefit from forecasting models that can give them foresight of the likely outcomes of different ways of allocating Covid-19 drugs under different scenarios.
- Health administrators should strongly consider using data driven models to determine the optimal allocation of scarce Covid-19 drugs to patients where they can save the most number of lives.
- Computer models like the one proposed in this study can guide decision-making in prioritizing allocation of Covid-19 drugs during a shortage.

## Introduction

The large-scale, multi-country SOLIDARITY trials being run by the World Health Organization (WHO) raises global hopes of finding an immediate cure for Covid-19 even before a vaccine can be made available. The drugs being tested include: remdesivir, chloroquine/hydroxychloroquine, ritonavir/lopinavir and ritonavir/lopinavir-interferon-beta. – which have been previously developed to treat other diseases. SOLIDARITY offers the promise of repurposing these drugs within a shorter-than-normal timeframe to minimize the impact of Covid-19 (Kupferschmidt and Cohen, 2020).

If SOLIDARITY succeeds, it is likely to create a large demand for these drugs due to the spike in the number of Covid-19 cases worldwide. Dealing with such shortages during a pandemic is a major policy issue that needs to be addressed (Musazzi et al., 2020). Optimization models have been shown to be valuable for supporting such resource allocation decisions in past outbreaks (Arora et al., 2010; Koyuncu and Erol, 2010). We apply this approach to the anticipated problem of optimally allocating future Covid-19 drugs when demand exceeds the supply.

This policy brief proposes a model for optimally allocating future Covid-19 drugs to patients to minimize deaths. It takes into account patient risk level, the severity of their symptoms, resource availability in hospitals (i.e. hospital beds, critical care units, and ventilators), observed mortality rates, and share of the Philippine population in two scenarios: with antivirals and without antivirals. It is meant to inform policy decision-makers and hospital administrators of the options available when allocating Covid-19 drugs to patients, taking into consideration patient characteristics and existing resource constraints.

## Model Overview and Results for a Simulated Scenario

We have developed a linear programming model to determine how antivirals can be allocated to minimize mortality. An editable copy of the model is available free of charge upon request. We assume based on existing developments that the elderly and the immunocompromised patients have higher risks of contracting the infection, with the highest probability of manifesting the most severe symptoms, while the younger and healthier ones have lower risks and milder symptoms. Depending on infection severity, a sick person will require healthcare resources either in the form of hospital accommodation for less severe cases, or the need for intensive care units and ventilators for more severe ones. We then account for the current demographic profile of the population in the National Capital Region (NCR) and all available resources in healthcare facilities in the region.

The model is programmed to minimize the total number of deaths resulting from the infection subject to limitations in hospital healthcare facilities and antiviral availability. The model is illustrated here with a future scenario. As shown in Figure 1, the population of NCR has been divided into three categories (i.e., low risk, medium risk and high risk) while three levels of severity are considered (i.e., mild, moderate, critical). Sensitivity analysis was conducted by examining how different levels of antiviral availability impacts the total number of deaths.

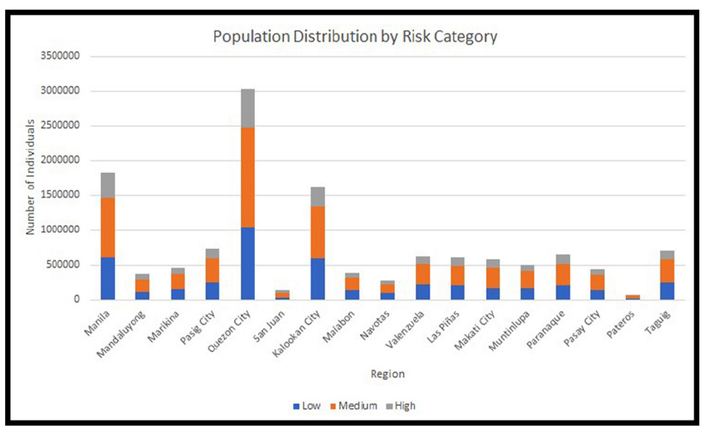


***Figure 1. Projected NCR Population Risk Levels***

The results of a simulated scenario are shown here. These scenarios are not intended to be taken at face value, since actual data of the efficacy of future Covid-19 drugs are not available yet. The scenario is intended only to demonstrate the capability to compute for the best allocation of scarce resources and thus give valuable insights for decision-making under duress. In particular, it can be seen that the drugs can be used to mitigate symptoms and simultaneously reduce unmet demand for scarce resources such as respirators and ICU beds. Further analysis can be done by looking at different scenarios resulting from variations in mortality rate, and infection rates.[f]

Sensitivity analysis is conducted by increasing the number of available antivirals as a proportion of the total number of those infected. Figure 2 illustrates how the total number of individuals who are able to receive the drug increases with respect to availability. Where drug supply is only sufficient to treat 40% (0.4) of patients or below, the least number of patient death occurs when the available supply of drugs are used primarily to treat "Medium Risk" patients – the group with the highest share of the population. This result is due partly to higher probabilities of reducing sickness severity when antivirals are administered to this group, subject to the assumptions we used regarding drug performance. By comparison, "Low Risk" patients are given last priority. Figure 3 illustrates the illness severity distribution for individuals given antivirals. The increase in available antivirals can reduce the proportion of individuals experiencing critical conditions. Finally, Figure 4 illustrates the decrease in number of deaths as the amount of available antivirals increases. In this case, it can be seen that mortalities plateau once drugs are available to at least 70% of Covid-19 patients.

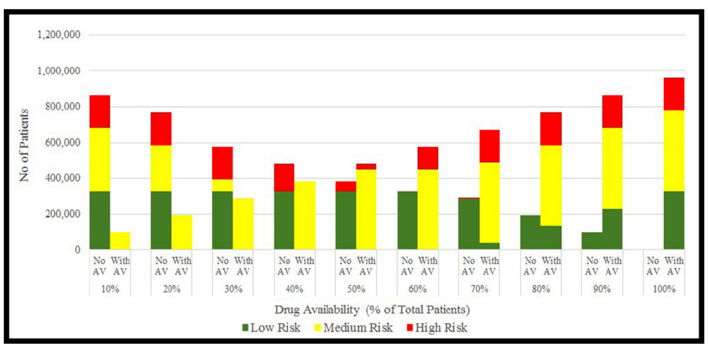


***Figure 2: Distribution of Patients According to Risk Levels***

[f] We implement the model in the software LINGO. This programming language can be acquired from Lindo Systems, Inc. (www.lindo.com), while the model itself along with the annotated data spreadsheets are available from the lead author upon request.

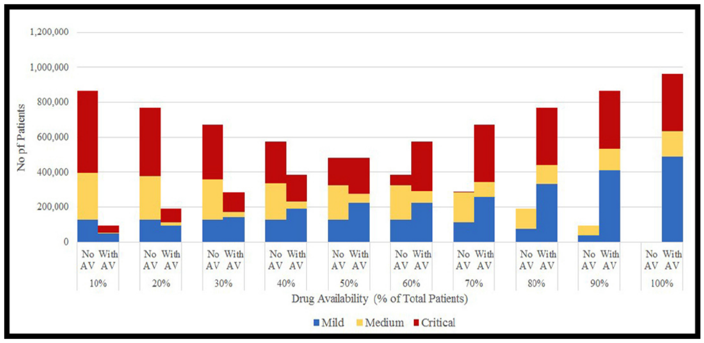


***Figure 3. Illness Severity Distribution***

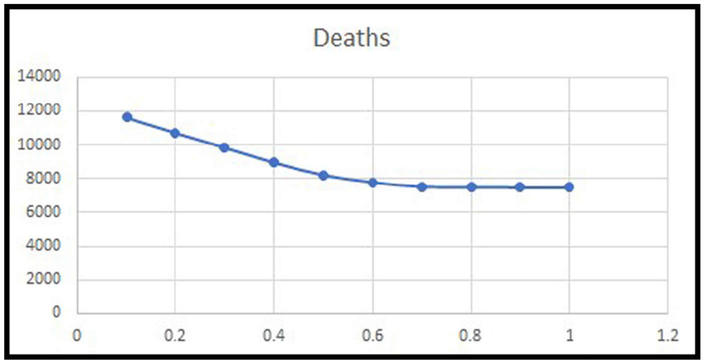


***Figure 4. Total number of deaths as a function of available antivirals***

## Conclusions and Recommendations

Due to the global scale of the pandemic, shortage of future Covid-19 drugs is inevitable. It is important for policy makers and medical professionals in the Philippines to be prepared for the lack of adequate supply of these pharmaceutical products. As illustrated in this policy brief, it is possible in principle to optimize the allocation of such drugs using our computer model. Data on the efficacy of the drugs undergoing trial is still unavailable, but once these are published, they can be fed into the model developed along with local data on demographics, Covid-19 case statistics, and hospital resources. This model is capable of generating data-driven guidelines for drug allocation which will save more lives than the use of an ad hoc allocation approach.

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**CONTACT INFORMATION**

**DLSU - Angelo King Institute for Economic and Business Studies (DLSU-AKI)**
Room 223, St. La Salle Hall
2401 Taft Avenue
1004 Manila

Angelo King International Center
Corner of Arellano Avenue and Estrada Street
1004 Manila

+63-2-8524-4611 loc. 287,
+63-2-8524-5333, +63-2-85245347 (Fax)
https://www.dlsu-aki.com