Proceedings of the 2015 Winter Simulation Conference
L. Yilmaz, W. K. V. Chan, I. Moon, T. M. K. Roeder, C. Macal, and M. D. Rossetti, eds.

MODELING A VACCINE DISTRIBUTION SUPPLY CHAIN

David Krahl

Kromite, LLC
243 N. Union Street
Suite 117
Lambertville, NJ 08530, USA

Joy Schwerzmann

Battelle
2987 Clairmont Road
Suite 450
Atlanta, GA 30329, USA

Sam Graitcer

CDC
1600 Clifton Road
Atlanta, GA 30333, USA

1 INTRODUCTION

The model examines the impact of using retail pharmacies as vaccinators in addition to traditional distribution by healthcare providers. It evaluates the time to reach 80% coverage for adults and children nationally and on a state-by-state basis. The model is also configured to evaluate ordering policies and quantities.

From 1976 to 2006 an estimated 2,000 to 49,000 people died each year in the United States from the seasonal influenza virus. During a severe influenza pandemic, such as the 1918 H1N1 pandemic, mortality could substantial increase unless a safe and effective pandemic vaccine can not only be developed but also rapidly distributed and administered in communities before disease peaks occur. Recent studies have shown that vaccination can reduce the risk of flu-related intensive care for children by 74% and flu-related hospitalization of adults by 71%. Providing efficient, timely, and convenient distribution of the vaccine, particularly when a virus with pandemic potential is identified, is critical to protecting the US population.

2 VACCINE DISTRIBUTION

The pandemic vaccine distribution process begins with manufacturers sending the vaccines to a central distribution point . Centers for Disease Control and Prevention (CDC) allocates the vaccines to states based on their population. Vaccines are shipped to the individual provider sites within the states and are allocated to adults and children. Ordering of new vaccines occurs weekly at the provider level. New vaccines are ordered to maintain a target inventory by state and by provider. Production for vaccines is ramped up over the first few weeks and ceased at the end of the pandemic response. For the purpose of this model, the vaccine production is assumed to be 30,000,000 doses each week. A table is used to model the initial ramp-up of production beginning at 20% for week one and rising to 100% by week five.

3 MODEL STRUCTURE

The model was built in ExtendSim, a block diagram oriented general purpose simulation software program. The model was constructed using a variety of modeling components to represent the stages in the process.

Entities that represent the production of vaccines are created on a daily basis. Vaccines are initially allocated to state providers or pharmacies. The production quantity ramps up over time. Once the vaccine has arrived from manufacturing to the central warehouse, those that are destined for state providers are earmarked for each specific state and age group based on an allocation percentage. The allocated number of vaccines for each provider is assigned to an attribute. The allocation is based on the quantity ordered

978-1-4673-9743-8/15/$31.00 ©2015 IEEE

and is prorated based on the number produced as there may be shortfalls particularly as production ramps up. The vaccines are then delayed by the shipping time for that state to the provider. Once the vaccines arrive, they are added to the available inventory for each provider and pharmacy in that state.

Each provider is assigned a daily demand calculated by an equation that evaluates the daily administration rate once per day. The equation evaluates the demand for all of the states. If demand exceeds available inventory, the shortfall is recorded as unmet demand. It is assumed that persons requesting the vaccine who do not receive it will return at a later date. A table of historical demand is created at the start of each run and a new record added recording the demand each day. The daily consumption was calculated based on historical information and professional information. Vaccines are ordered by the providers on a weekly basis. The current inventory, target inventory, and number of vaccines on order are used to calculate the number to order. This was based on the understanding that the individual providers would do their own ordering independent of any central inventory control system. A "clone" or live link to the database table was added to the model so that the analyst could view the changes in inventory over time.

4 DATA ORGANIZATION

An embedded database stores the model input data, working information, and results. Relations between the tables were created to ensure data integrity. Information provided by these tables includes distributions for demand, age category, provider type, and initial inventory for each provider. On a state-by-state basis, shipping delay by state and ramp up in production are assigned. Tracked during the course of the simulation is the current inventory, doses on order, unmet demand, and weekly log tables by state and by provider.

As each provider/location combination is represented solely by the database, providers and locations can be added or removed by changing the contents of the tables. A model that focuses on a particular region or state can be created by including only those providers within that area. Greater resolution can be obtained by adding additional records and subdividing the providers into smaller geographical areas. The model automatically takes into account any dimensional changes to the tables. If a provider is added or removed, only data changes are required to reflect this. Because it is a relational database, data integrity is preserved.

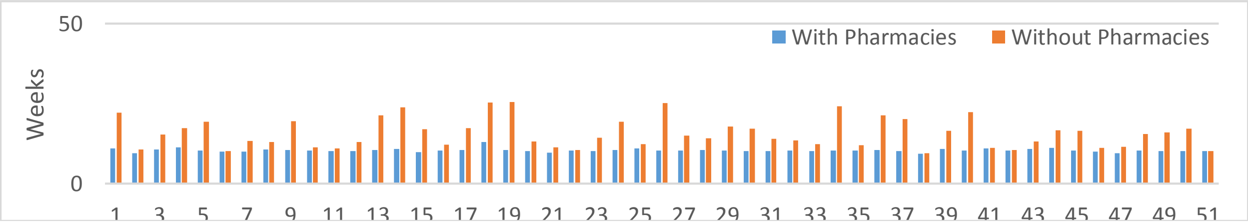
Because this model is database-driven, the same model can be used to analyze the impacts of pharmacy distribution on a national, regional, or state-by-state level just by changing the scope of the data. This is done by importing data sets appropriate to the geography to be studied. There are other advantages to this.

- It is very easy to add and remove providers and locations from the model.
- Data and results in tabular format can be imported and exported to external data sources.
- Because these tables update as the model runs, they are helpful for face validation and debugging.

5 MODEL RESULTS

Because this is based on an annual event, the winter flu season, it is a terminating model with a defined start and end point. This is defined by the months leading up to and into the beginning of the flu season.

The model indicated that the time to coverage for 80% of the population was reduced by an average of 8 weeks when retail pharmacies administered vaccine. This could be a critical reduction in the case of a pandemic. The bar chart below shows a reduction in nearly every state (and Washington DC) and a significant reduction in variability between the states when pharmacies are used to administer influenza vaccine. In no case did the time to coverage increase when pharmacies were used to administer vaccines.



Comparison of time to 80% coverage for states distributing vaccines with and without pharmacies.