Reacting to a pandemic influenza outbreak will require the mass distribution of vaccine, when available, which will require county health departments to set up and operate one or more mass vaccination clinics, also known as points of dispensing (PODs). Carefully planning these PODs before an event occurs is a difficult but important job. First, this article describes a tool—the Clinic Planning Model Generator computer program—designed to help public health agencies evaluate and make adjustments to their POD plans. The Clinic Planning Model Generator was built on data from a smallpox exercise and other biological agent POD exercises. Second, this article demonstrates the application of the Clinic Planning Model Generator through an example pandemic influenza scenario. This work is the result of an ongoing collaboration between Montgomery County, Maryland’s Advanced Practice Center for Public Health Emergency Preparedness and Response, and the Institute for Systems Research at the University of Maryland.

KEY WORDS: emergency preparedness, pandemic influenza, public health, technology

Planning for an influenza pandemic outbreak is one of the most challenging tasks in the field of public health emergency planning and response. Past influenza pandemics have caused significant death, disease, and economic and social disruption. Many scientists are in agreement that a worldwide influenza pandemic is imminent.

As public health agencies begin to adapt their point of dispensing (POD) plans to prepare for a pandemic influenza scenario, it continues to be difficult to test their plans using various influenza scenarios owing to lack of resources (eg, funding) and insufficient time to conduct exercises. For this reason, local public health agencies need tools, resources, and current research to adapt their POD models in a timely and succinct manner.

An important question for public health emergency planners—those persons within local public health agencies dedicated to creating POD plans—is how to allocate a limited number of staff to different workstations in a POD to maximize capacity. Research is limited, but some work has been done to answer this question. The authors thank the National Association of County and City Health Officials and the Centers for Disease Control and Prevention for their support in the development of the Clinic Planning Generator Model (Cooperative Agreement Number U50/CCU302718). Corresponding author: Katherine Aaby, MPH, RN, Montgomery County Advanced Practice Center, Public Health Emergency Preparedness and Response, and the Institute for Systems Research at the University of Maryland.

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*The authors recognize that there may not be a vaccine at the onset of the influenza pandemic; however, it is anticipated that a vaccine will become available.

1A POD is defined for the purposes of this article as a location where medication/vaccinations are distributed to patients.
question for mass smallpox vaccination PODs. Meltzer et al.\textsuperscript{3} describe the Maxi-Vac 1.0 software,\textsuperscript{3} which uses a database of results from a particular simulation model to find the answer. Averett\textsuperscript{5} describes work on RealOpt, which uses a simulation optimization model. Whitworth\textsuperscript{6} discusses the analysis of a specific plan for dispensing medication in response to an anthrax outbreak on a hypothetical island community. Researchers at Weill Medical College of Cornell University, under contract to the United States Department of Health and Human Services, Agency for Healthcare Research and Quality,\textsuperscript{7} created the Bioterrorism and Epidemic Outbreak Response Model, a capacity planning model.

Montgomery County, Maryland’s Advanced Practice Center (APC),\textsuperscript{8} in partnership with the Institute for Systems Research at the University of Maryland, has developed the Clinic Planning Model Generator (CPMG) to assist public health agencies in developing and evaluating their POD plans.

**Background and Development of the Model**

The creation of the CPMG began with an identified need from Montgomery County, Maryland, Public Health Services (PHS) to answer the following POD planning questions:

- How many patients can be vaccinated per hour?
- Is the size of the POD facility sufficient to accommodate the number of patients to be vaccinated?
- How much staff is needed?
- What is the most efficient flow pattern in a POD?

Researchers at the Institute for Systems Research at the University of Maryland partnered with Montgomery County PHS staff in 2003 by participating in a public health POD subcommittee. After learning the complexities of POD planning, the researchers proposed the development of a predictive computer model to help answer Montgomery County’s questions and to assist public health emergency planners in the development of vaccination and dispensing POD plans that are timely and efficient and fall within the CDC guidelines.\textsuperscript{2}

The development of the CPMG began with a POD exercise conducted by Montgomery County’s PHS on June 21, 2004.\textsuperscript{9} This exercise was created to simulate the procedures for mass vaccination in the event of a widespread outbreak of smallpox.

Researchers from the University of Maryland, along with student volunteers, conducted a time study to collect data on POD performance during the exercise. The average arrival rate was 213 patients per hour. Analysis of the data yielded estimates of how much time a patient spent at each station, the total time spent in the POD, and the average time a staff member was in contact with a patient at each station.

The research team designed and built a discrete-event simulation model of the POD using Rockwell Software’s Arena. For validation purposes, the initial model was designed to simulate the exercise that occurred. Patients arrived in batches that corresponded to actual bus arrivals. In the model, each patient was represented as an entity that progressed through different queues and processes. The model included animation for visualizing the movement of patients through the POD.

Discrete-event simulation models, although very useful, require specialized software, licensing, resources, and knowledge skills to operate. Thus, the University of Maryland, in close collaboration with Montgomery County PHS and input from other public health agencies, designed and built the CPMG, which can create planning models for PODs using a familiar spreadsheet software (Microsoft Excel). This allows users easier access and a clearer understanding of the CPMG. In addition, a User’s Guide was developed to direct the user through the process step-by-step on how to use the model.

As the development of the CPMG continued, data from other POD exercises and POD plans have been used and continue to be used to improve the model.\textsuperscript{8} The model was reviewed by other public health agencies, and their comments and suggestions were integrated. In August 2005, the CPMG was made available to local public health emergency planners via Montgomery County’s APC and the National Association of County and City Health Officials.

**Purpose and Use**

To improve flow patterns of patients through the POD, the CPMG allows public health emergency planners to quickly project the number of days needed to vaccinate/medicate patients, the number of employees needed to staff the PODs, the queue length and queue wait time (time in line at a station), and the total time in the POD. The results of the CPMG show where

\textsuperscript{9}The Centers for Disease Control and Prevention (CDC) and the National Association of County and City Health Officials (NACCHO) established seven APCs, of which Montgomery County, Maryland, is one, to develop cutting-edge tools and resources for local public health agencies nationwide to prepare for, respond to, and recover from major emergencies.

\textsuperscript{9}Montgomery County, Maryland: Dagwood Exercise. June 21, 2004; Burlington County, New Jersey: TOPOFF 3 Exercise. April 7, 2005; Montgomery County, Maryland: Annual Flu Clinic Exercise. November 2, 2005; POD plans from Collin County, Texas, and Burlington County, New Jersey.
congestion occurs and identify the maximum number of patients that can be vaccinated/medicated in the shortest amount of time. At the same time, public health planners can manipulate and make continuous adjustments either as part of the preplanning stage of POD development and/or for support during an actual event. In general, this model is designed to assist in planning a POD with improved efficiency and performance while projecting what might occur in the event of an outbreak.

Two key considerations need to be taken into account when using the model. They are the capacity of each POD (measured as the number of patients served per hour) and the time (in minutes) spent by patients in the POD (known as the time in system, flow time, or throughput time). The capacity of the POD determines the number of PODs that must be opened and the total time needed to vaccinate/medicate the affected population. The time in system influences the number of patients the POD can accommodate at a time. More patients require more space as they wait to receive treatment. If too many patients are in the POD, congestion, crowding, and confusion may result.

The CPMG is designed to allow public health emergency planners to input a known population size and set time constraints specific to their application (ie, days allotted for treatment, hours of operation, and number of open PODs). On the basis of these data inputs, immediate results show suggested staff levels and detailed POD information regarding waiting times, queue lengths, and time in system. Adjustments can easily be made to staffing levels and other inputs until the user is satisfied with the efficiency of the POD. The versatility of this program allows the user to accept default values if little information is available about their POD, or to input more detailed information such as routing probabilities and process times. Public health emergency planners must also take into account that core support functions and logistics (eg, data entry, translators, communications, food service, vaccine preparation, security, geographic location) are considered to be operational when using this model.

● **Pandemic Influenza Scenario Demonstration**

To illustrate the planning capabilities and versatility of the CPMG, Montgomery County APC staff and researchers from the University of Maryland created a POD planning model to assist in the creation of a vaccination plan for pandemic influenza. The results are based on data from an annual influenza clinic held in November 2005 and on the scenario discussed below. The scenario in this paper is one of many pandemic influenza scenarios and is used for demonstration purposes only. The CPMG has the flexibility to be used in various scenarios.

The following are the assumptions for the pandemic influenza scenario: human to human transmission; a vaccine is developed for this influenza strain; active surveillance is in place; staff are located at the Emergency Operations Center; communication pathways are established; security is in place; and two doses are needed for protection.* A transportation system is in place to transport staff and patients if necessary. Public information is dispersed through various local and regional outlets in various means of communication. Staff at the POD are provided with required personal protective equipment and receive vaccination. Schools and local businesses are temporarily closed and the POD is set up at a local school.

As the scenario continues, Montgomery County PHS is given 10,000 doses of vaccine each week for an unknown number of weeks (antiviral medications for POD distribution will not be discussed in this article but the clinic planning model is applicable for this scenario). The State of Maryland allocates to Montgomery County the vaccine doses according to an assumed attack rate of 25 percent of the population getting infected.† On the basis of the CDC’s FluAid 2.0 program, there are 230,490 cases in Montgomery County, 8,068 hospitalizations (3.5% of those ill), and 1,808 deaths (22.4% of hospitalizations).‡ To demonstrate the CPMG, the assumption is made that the vaccine is delivered in increments of 80,000 doses every 2 months. Only one POD site is demonstrated in this scenario; however, the user can input more than one POD site if necessary. The POD is open many times during a week, extending for several weeks to months, depending on the availability of the vaccine and the wave of the pandemic. Public health staff (N = 600) and volunteers are called on to fill the roles of the POD; however, 50% of the staff are unavailable owing to illness or for having to care for someone who is ill. Patients are selected and notified on the basis of a predetermined criteria set by the CDC and Montgomery County PHS. Patients arrive at the POD by private or public transportation.

● **Methods**

A number of different schemes for using the 10,000 available doses are possible. One scheme is to give 5,000 doses only. The CPMG has the flexibility to be used in various scenarios.

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first doses and 5,000 second doses each week, which seems simple but would require some complex planning to initialize the system. The following strategy was selected for further analysis to demonstrate the model.

For four consecutive weeks, the POD staff administers first doses only. For the next 4 weeks (the 5th, 6th, 7th, and 8th weeks), the POD staff administers second doses, only to the patients who were treated in the first 4 weeks. This 1-1-1-1-2-2-2-2 pattern, illustrated in Figure 1, will repeat every 8 weeks. Each week the POD staff administers 10,000 doses to patients. On the basis of previous POD data, it is expected that additional uninvited persons will arrive by mistake or with the hope of receiving their vaccinations early. Therefore, 10,100 patients (the 10,000 invited and an additional 100) are expected to arrive each week. Table 1 demonstrates the inputs of 10,100 patients, one open POD, and its operation of 4 days a week for 8 hours each day. The model calculates the demand as 316 patients per hour.

The decision was made to simplify the vaccination POD and have only two stations: triage and vaccination. The former includes registration and the latter limited education and screening. At the triage station, patients are greeted and assessed as they arrive at the POD. Patients who do not fall within the patient criteria and those showing symptoms of an illness (an estimated 2% of the number arriving) are not allowed to enter the POD. Patients symptomatic at triage are redirected to designated medical facilities. The remaining patients (98% of those that visit the triage station) receive a registration form at the triage station and proceed to the vaccination station, where they complete the form and wait for an available nurse or physician. The nurse or physician reviews the form to verify that the patient can safely receive the vaccine and then vaccinates the patient, who is also provided a fact sheet on influenza vaccine. The patient then leaves the POD. Figure 2 illustrates the routing of the patients.

### Results

Evaluating the capacity and queuing of this POD planning model required information about the processing times at each station. Table 2 reflects the average processing time at each station and the variance. These numbers were reviewed and validated by public health professionals. The appendix describes the mathematical equations used to estimate POD capacity and queuing. Aaby et al.12 present a more general formulation of the model.

In addition, the distances from the triage station to the vaccination station and from these stations to the exit were estimated on the basis of the planned layout of the POD (which is based on data from Montgomery County’s annual influenza clinic). The CPMG includes

### Table 1  Clinic planning model generator input demand interface

<table>
<thead>
<tr>
<th>Inputs</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of population to be treated</td>
<td>10,100</td>
</tr>
<tr>
<td>Time allotted for treatment (d)</td>
<td>4</td>
</tr>
<tr>
<td>Daily hours of operation</td>
<td>8</td>
</tr>
<tr>
<td>Number of clinic sites</td>
<td>1</td>
</tr>
<tr>
<td>Demand</td>
<td></td>
</tr>
<tr>
<td>Required throughput (patients per hour)</td>
<td>316</td>
</tr>
</tbody>
</table>
TABLE 2 ● Processing time data for the triage and vaccination stations

<table>
<thead>
<tr>
<th>Station</th>
<th>Mean processing time (min)</th>
<th>Processing time variance (min²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triage</td>
<td>0.26</td>
<td>0.07</td>
</tr>
<tr>
<td>Vaccination</td>
<td>3.26</td>
<td>1.31</td>
</tr>
</tbody>
</table>

the time needed to walk from one station to the next in its evaluation of the performance of the model.

The key decisions made were the number of PODs, the operating hours per day, and the staffing at each station. According to the POD planning model, the initial scheme was to operate the POD for two 6-hour days, which required at least 45 nurses to administer vaccinations (to meet a demand of 842 patients per hour). Since this number of nurses was considered unrealistic (if not impossible), a different scheme was considered. Operating the POD for 4 days, 8 hours per day, requires at least two staff for triage and 17 nurses to administer vaccinations (to meet a demand of 316 patients per hour). However, the POD planning model estimated that, at that staffing level, the average queue length (number of people in line) at the vaccination station would be 47 patients, and the average waiting time would be over 9 minutes. Adding just one nurse to the vaccination station (for a total of 18) reduces the queuing at the vaccination station significantly. The average queue length drops to six patients, and the average waiting time becomes just over 1 minute. The POD requires enough space at the vaccination station to accommodate the queue. Because the queue length varies, it is prudent to plan for a queue of up to 12 patients (twice the average), which requires at least 35 feet. The total number of staff needed to operate the POD each day would be 27, including support staff such as clinic manager, supply manager, float staff, triage/forms leader, and vaccination leader. The average time in system would be 5.45 minutes, with an average of 29 patients in the POD. Because this plan has a reasonable number of staff and minimal waiting time, it is considered the most efficient.

To validate the model, the results, obtained using the planning model, were compared to a simulation model of the proposed POD. Figure 3 shows the results from each model, along with error bars denoting the 95% confidence interval of the simulation results. The planning model output was within the confidence interval of the simulation model output for all measured performance criteria, including staff utilization (not shown in Figure 3).

As previously mentioned, the rate at which vaccine becomes available is not known for certain until the pandemic occurs and vaccine production begins. At that point, public health agencies can revise the planning model inputs and quickly determine the number of PODs needed, their operating hours, and the required staffing levels.

● Conclusion

Planning for an influenza pandemic requires that many decisions be made at the local level. The CPMG is a valuable tool to aid public health professionals in preplanning, as well as planning during an event that requires medication and/or vaccination. This tool gives public health emergency planners a mechanism to evaluate the capacity of POD plans in a cost-effective way, and to plan not only for emergencies but annual events such as a seasonal influenza clinic.

The CPMG does not meet every need of POD planning; rather, it is primarily designed to predict clinic flow, bottlenecks, and to help assess staffing in accordance with station utilization. Through the expertise of researchers at the University of Maryland and staff with Montgomery County PHS, the CPMG continues to evolve and improve as more and more

![Comparison of models](image-url)
local public health emergency planners use it to improve on their POD plans. Future versions of the model will explore other factors, including downtime in shift changes, staff breaks, staff illness, special populations, and processing families as a unit. To download the Clinic Planning Model Generator go to http://www.isr.umd.edu/Labs/CIM/projects/clinic/.

REFERENCES


### Appendix: The Clinic Queueing Network Model

The analysis of queueing networks is a well-known problem, and different approximations for the general case have been presented. The following model is a special case of the more general model presented in Aaby et al. The symbol \( i \) is used throughout to denote a station; \( i = 1 \) is the triage station, \( i = 2 \) is the vaccination station, and \( i = 3 \) is the exit.

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P ) = Size of population to be treated</td>
<td>( TH' = ) Required throughput</td>
</tr>
<tr>
<td>( L ) = Time allotted for treatment</td>
<td>( m'_i = ) Minimum staff at station ( i )</td>
</tr>
<tr>
<td>( h ) = Daily hours of operation</td>
<td>( TCT = ) Time in clinic</td>
</tr>
<tr>
<td>( N ) = Number of clinics</td>
<td>( r_s = ) Clinic capacity</td>
</tr>
<tr>
<td>( m_i = ) Number of staff at station ( i )</td>
<td>( M = ) Total staff across all clinics</td>
</tr>
<tr>
<td>( t_i = ) Mean process time at station ( i )</td>
<td>( w_i = ) Wait time at station ( i )</td>
</tr>
<tr>
<td>( \sigma^2_i = ) Process time variance at station ( i )</td>
<td>( W_i = ) Walking time from station ( i )</td>
</tr>
<tr>
<td>( d_{ij} = ) Distance from station ( i ) to station ( j )</td>
<td>( Q_i = ) Queue length at station ( i )</td>
</tr>
<tr>
<td>( v = ) Average walking speed</td>
<td>( u_i = ) Utilization at station ( i )</td>
</tr>
<tr>
<td>( P_{ij} = ) Routing probability from station ( i ) to station ( j )</td>
<td>( WIP = ) Average number of patients in clinic</td>
</tr>
<tr>
<td>( c^2_a = ) Arrival SCV</td>
<td></td>
</tr>
</tbody>
</table>

The throughput required to treat the population in the given time is \( TH' = \frac{P}{L \cdot h \cdot N \cdot 60} \).

Arrival variability to the clinic \( c^2_a \) is specified by the user.

Arrival rates for the clinic and for individual stations are calculated on the basis of the population and length of time for treatment:

\[
\begin{align*}
r_1 &= \frac{P}{L \cdot h \cdot N \cdot 60} \\
r_2 &= r_1 \cdot P_{12}
\end{align*}
\]

Station arrival rates are used to determine the minimum staff at each station: \( m'_i = r_j \cdot t_i \).

User-selected staff levels \( m_i \) are then used to calculate station utilization: \( u_i = \frac{m_i}{m_s} \).

The variability of arrivals, processes, and departures from each station must be calculated:

\[
\begin{align*}
c^2_{a2} &= (c^2_{a1} - 1) \cdot P_{12} + 1 \\
c^2_{ij} &= \frac{\sigma^2_i}{t^2_{ij}} \\
c^2_{di} &= 1 + (1 - u^2_i) (c^2_{ai} - 1) + \frac{u^2_i}{\sqrt{m_i}} (c^2_{ai} - 1)
\end{align*}
\]

The average time spent waiting at station \( i \) depends on the process and arrival variability as well as the utilization:

\[
w_i = \frac{1}{2} (c^2_{ai} + c^2_{ai}) \left( \frac{u_i^{2m_i+2-1}}{m_i (1 - u_i)} \right) t_i
\]

The average time spent traveling to the next station after station \( i \) depends on the routing probabilities and the average walking speed:

\[
W = \frac{1}{60v} \sum_{j=i+1}^{i+1} P_{ij} d_{ij}
\]
The cycle time at station i is $CT_i = w_i + t_i + W_i$.

The station cycle times are weighted by their arrival rates to calculate the total average time in clinic:

$$TCT = CT_1 + P_{12} CT_2$$

Other statistics calculated include clinic capacity, the average queue length at each station, and the average clinic WIP:

$$R = \min \left\{ \frac{m_1}{t_1}, \frac{m_2}{t_2 P_{12}} \right\}$$

$$Q_i = w_i r_i$$

$$WIP = r_1 \cdot TCT$$