Dynamic Simulation for

Smallpox Vaccination Clinic Planning

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Mark Whitworth
Center for Emergency Response Analytics
Cambridge, MA
www.response-analytics.org

John J. Shaw, DMD
Capitol Region MMRS
Hartford, CT

Abstract

Smallpox vaccination clinics must be tailored to meet the needs of the communities they serve. Fast service time will be a key measure of the success of a post-event vaccination program. Clinic operations are complex and difficult to plan. A complete plan must include effective client transportation and supply logistics. Static analysis techniques like spreadsheets and mathematical models cannot capture the complexities of clinic operations and cannot accurately predict clinic performance. The *Smallpox Vaccination Clinic Model* is a customizable, dynamic simulation model that can be used to help planners integrate logistical, clinical, and administrative operations effectively and make well informed tradeoffs among service level, cost, and safety concerns.

Introduction

Local planners are faced with the daunting task of preparing plans for effective, flexible mass vaccination or prophylaxis to be carried out in the event of a bioterrorist attack involving biological or chemical agents.

The Center for Disease Control has published a *Smallpox Vaccination Clinic Guide* that presents guidelines for siting, resourcing, and operating smallpox vaccination clinics. The *Guide* does an admirable job of highlighting the issues that planners must consider. It is not possible, however, for such a document to reflect local practices and needs, to include process knowledge gained at the local level, or to address critical local considerations (e.g., transportation constraints, likely travel conditions, population density, language requirements, etc.).

Most local planners are finding it necessary to modify the CDC's guidelines in order to meet the needs of the communities that they serve. Many planners are integrating transportation systems in their response plans. Some of these planners are also segmenting operations—performing some tasks at staging areas, shuttling clients to a central clinic where they undergo the remaining operations, and shuttling clients back to the staging areas.

It is likely that such changes will disrupt the balance between the CDC's resourcing recommendations and the locality's service level objectives. Disrupting the balance can translate into long lines of hungry, angry clients, overflowing parking lots, and clogged access roads.

Some planners have attempted to use static analysis tools to re-balance resource requirements against service level requirements. Many of them have concluded that these tools and techniques (which include spreadsheet software and mathematical models) can capture neither the complexity of operations inside the clinic, the logistics of moving clients to and from the clinic, nor the specialized requirements of individual localities.

An analysis of smallpox clinic operations submits far more easily to dynamic simulation, which addresses many of the limitations of other techniques including:

- Variations in clinic and transportation management strategies
- Surges and lulls in client arrivals
- "Batching effects" that some functions (like group orientation and bus arrivals) have on clinic operations
- Variability of task execution times
- "Family effects" resulting from the tendency of families to travel through the process together
- The "passenger effect" that some operations have on client and vehicle dwell times (e.g., if a group of clients come in the same car or chartered bus, none of them can leave until everybody is vaccinated. If one passenger requires counseling, then the dwell time for the entire group increases).

The Smallpox Vaccination Clinic Model

The *Smallpox Vaccination Clinic Model* is a dynamic simulation model that includes:

- Clinic processes described in the CDC's *Annex 3 Smallpox Vaccination Clinic Guide;*

- client transportation by foot, car, bus, and automobile; and

- local process variations including process segmentation and the use of staging areas.

The model is implemented in ReThink, a sophisticated modeling and simulation environment from Gensym Corporation (Burlington, MA). ReThink models have been used on hundreds of projects to design, analyze, improve, and manage work processes in industry, business, government, and defense.

The model includes a hierarchical, graphical representation of the clinic's workflow and resources.

The following three figures show a portion of the vaccination process hierarchy for a community that is planning to use staging areas and an integrated transportation system in order to control access to central clinic.

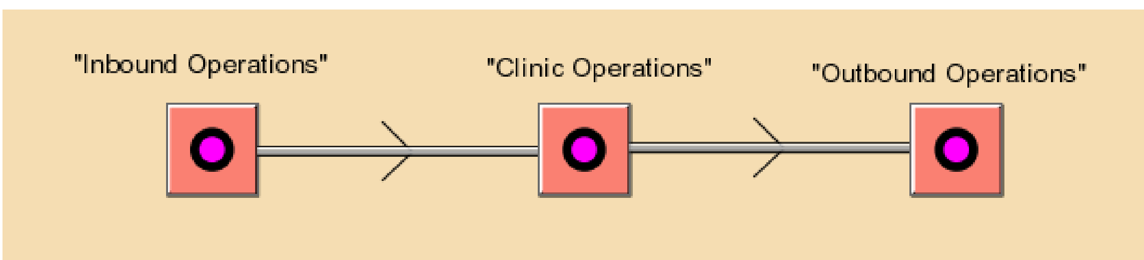

Figure 1. Level 1 Vaccination Response Plan

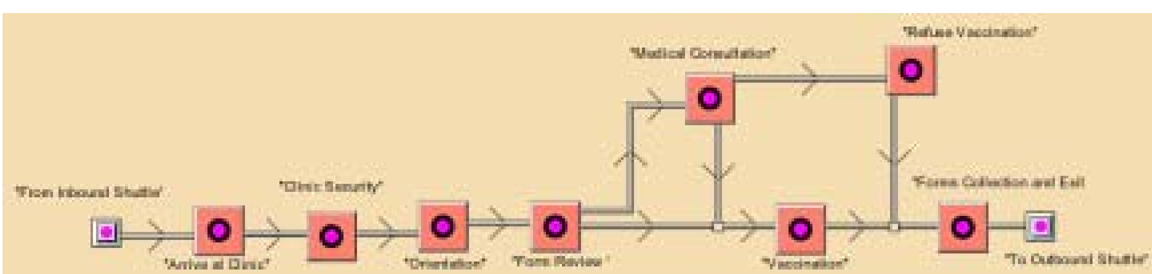

Figure 2. Level 2 Clinic Workflow

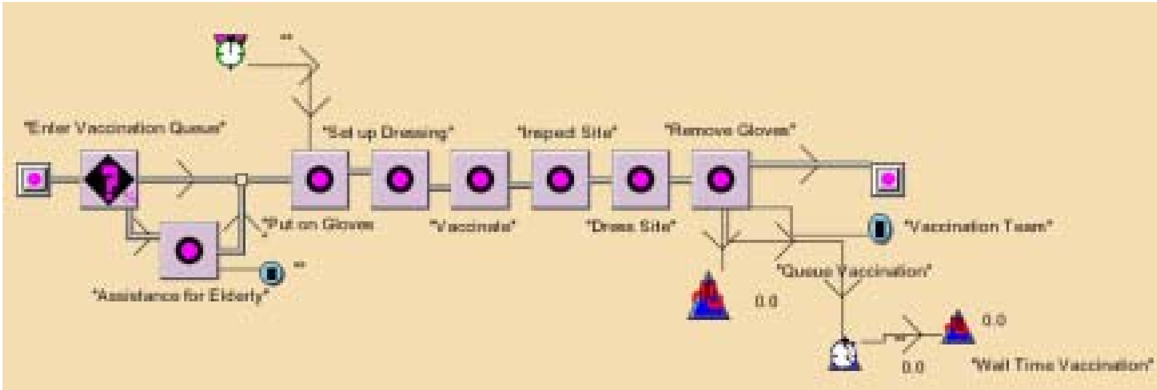

Figure 3. Level 3 Vaccination Detail

The model is highly tunable, allowing quick reconfiguration of process layouts and easy adjustment of a wide variety of inputs. Application of the model in Connecticut and New Hampshire has shown it to be easily adaptable to a wide range of clinic settings.

A discrete event simulator moves simulated families through the transportation system and clinic operations. The simulator tracks and reports on a wide variety of critical performance indicators like queue lengths, service times, population, and resource utilization.

The model can be extended to include SNS management (i.e., push package and vendor managed inventory) and other supply chain operations (non-SNS supplies, food, water, etc.).

The model's basic framework can support the analysis of types of emergency procedures other than smallpox vaccination.

Using the Model

A typical project using the model may run from 2 to 4 weeks and involves:

1. Interviewing planners to learn how they intend to operate their clinics and the settings in which they will operate them
2. Customizing the model to capture procedural details
3. Configuring the model to reflect operational details like hours of operation, client arrival rates, task execution times, and staffing levels
4. Simulating clinic operation
5. Interpreting and documenting the results.

Figures 4, 5, and 6 show sample model inputs that describe client population and arrival assumptions, task execution times, and staffing levels.

Input Parameters				
Number of Clients	50,000			
Days of Operation	10			
Hours per day	24			
Arrival Mode	Percentage	Group Size Min	Group Size Mode	Group Size Max
Pedestrian	10	1	3	10
Car	50	1	3	6
Bus	40	10	40	60

Figure 4. Defining how clients arrive at a clinic

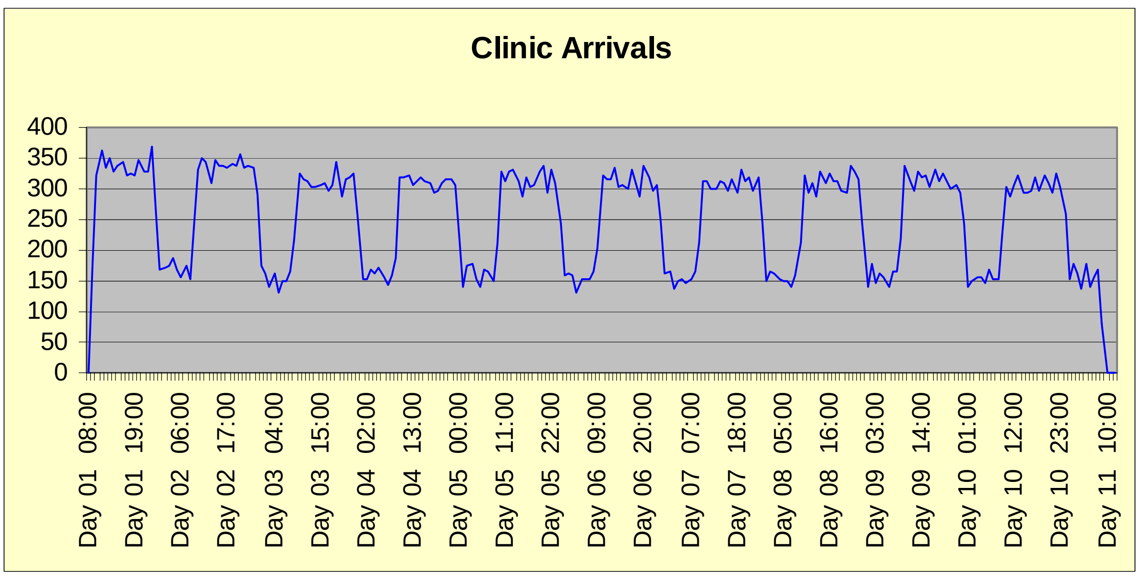

Figure 5. Defining when clients arrive at the clinic

Task	Task Times (Minutes)			Resources	
	Min	Mode	Max	Count	Capacity
Security	0.5	1	4	8	
Triage	0.5	1	2	6	
Contact Evaluation	5	10	15	2	
Sick Evaluation	5	10	15	2	
Form Distribution	0.5	0.5	2	6	
English Orientation	30	30	30	6	30
Spanish Orientation	30	30	30	2	25
Other Language Orientation	30	30	30	4	
Review Forms	0.5	1	2	7	
Medical Evaluation	4	7	10	4	
Vaccination	2.5	4.5	6.5	15	
Form Collection	1	2	3	14	

Figure 6. Defining clinic tasks and resources

The model is a very effective tool for balancing service level requirements against resource requirements. Planners can use the model to determine what service levels can be achieved with a given staffing level or conversely, what staffing levels are required to achieve a target service level target. The model clearly demonstrates the interdependencies among clinic operations and the interactions between client transportation and clinic operations.

Figures 7, 8, and 9, show “before and after” simulation outputs for a clinic. The *before* outputs show the performance of the clinic as the local planners designed it. Simulation identified and quantified flaws in the design. The *after* outputs show the performance of the clinic after the design flaws were corrected.

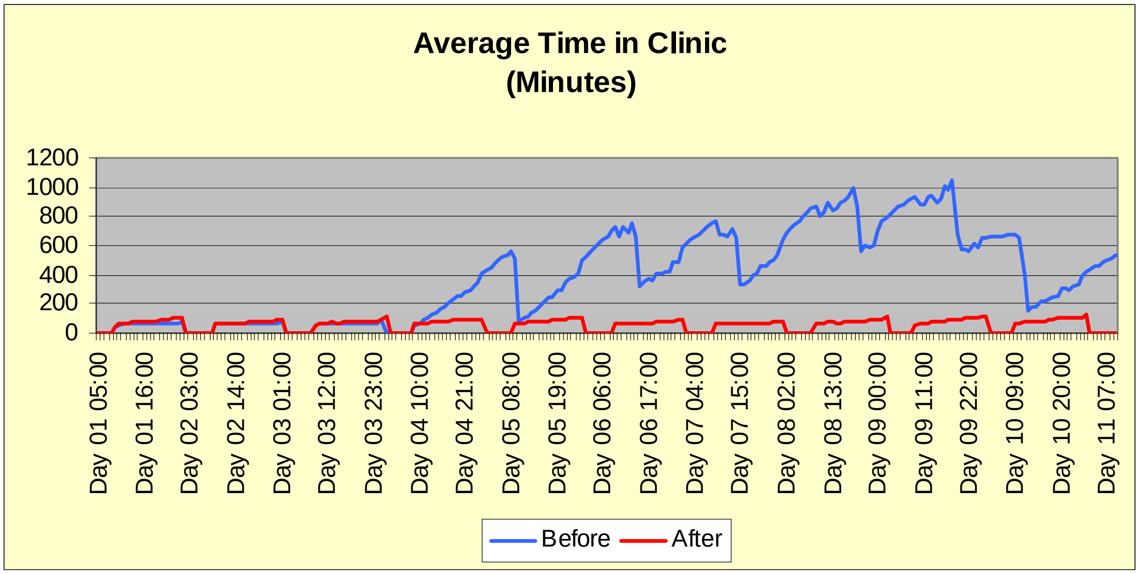

Figure 7. Average time clients spent in clinic

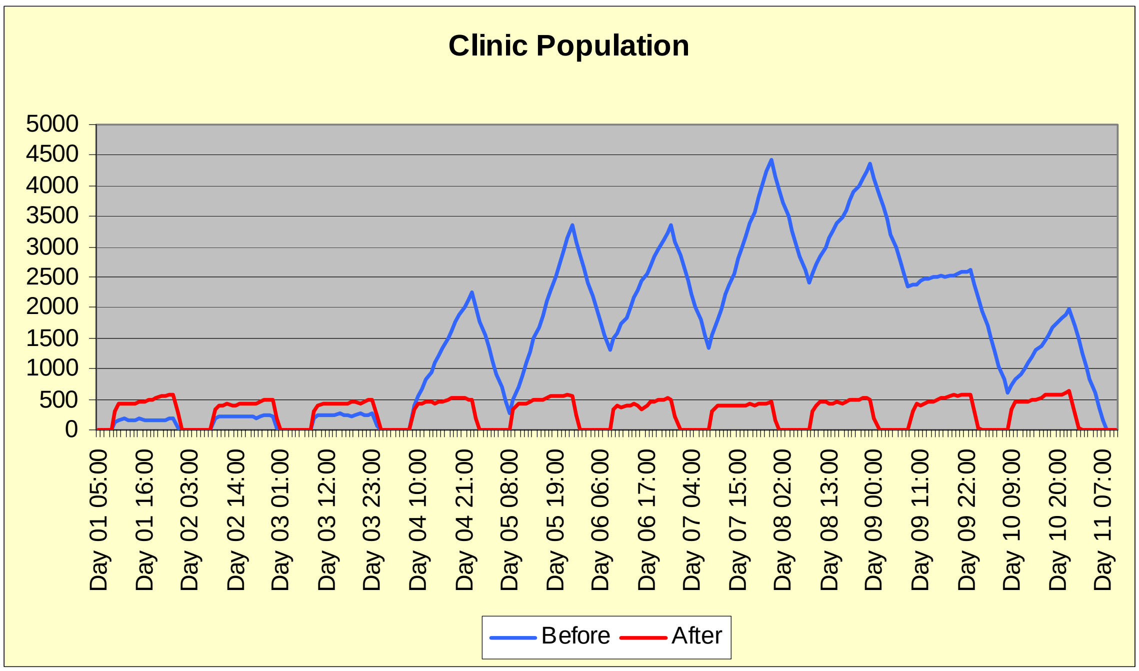

Figure 8. Client population in clinic

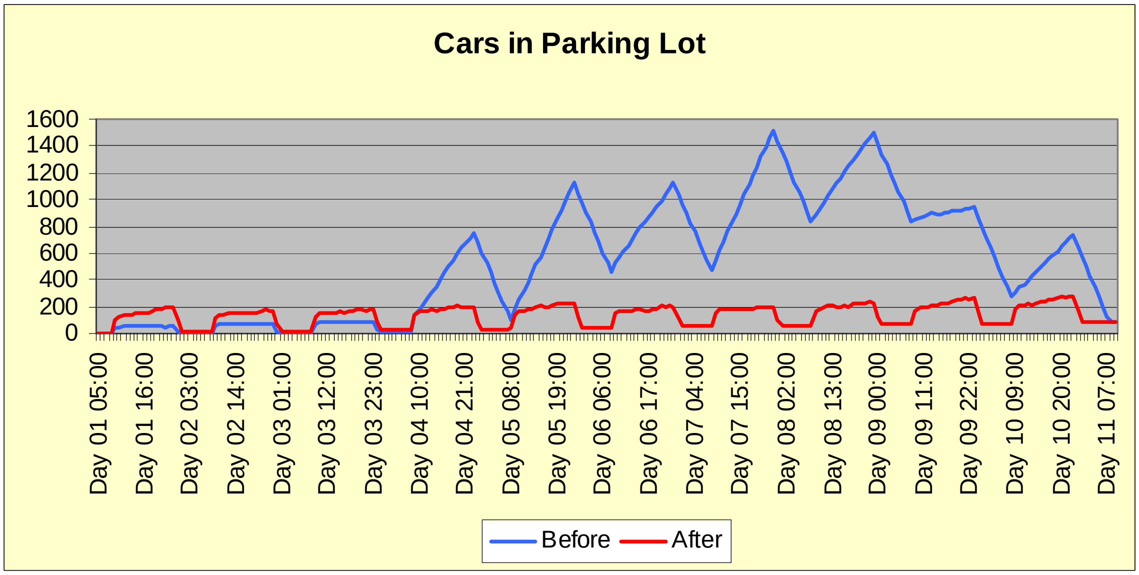

Figure 9. Parking lot utilization

Conclusion

Designing an effective and efficient smallpox vaccination clinic that meets the needs of individual communities is a difficult and complex task. Local planners need more help than one-size-fits all tools and static analysis techniques can give them.

The Smallpox Vaccination Clinic Model can provide local emergency planners with a better understanding of their clinic designs, help them to make the best possible use of their resources, enhance their credibility as they approach community leaders for resources and support, and give them more confidence that their clinics will operate smoothly and achieve the service levels that the community will demand.

Dynamic modeling and simulation is a valuable tool that should be considered by all planning agencies in the design of all emergency medical response plans.

References

Center for Disease Control, Smallpox Response Plan and Guidelines (Version 3.0), Annex 3—Smallpox Vaccination Clinic Guide, November 26, 2002