Software and Analytics Methods For Election Systems

White Paper
September 2014

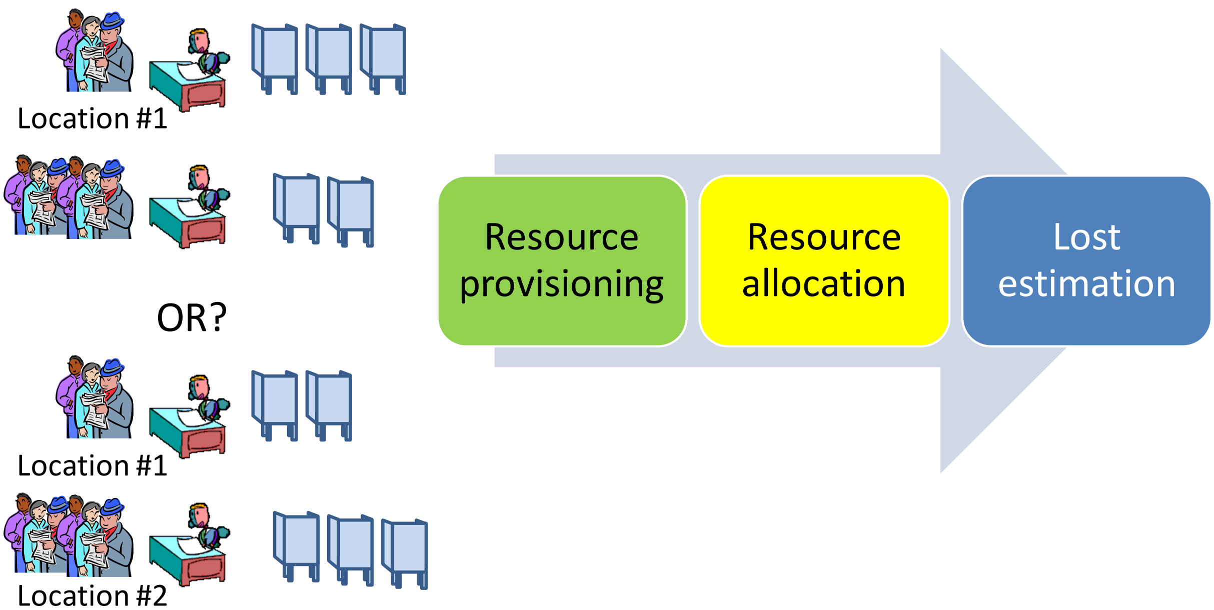

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Figure 1. Interacting concentration areas.

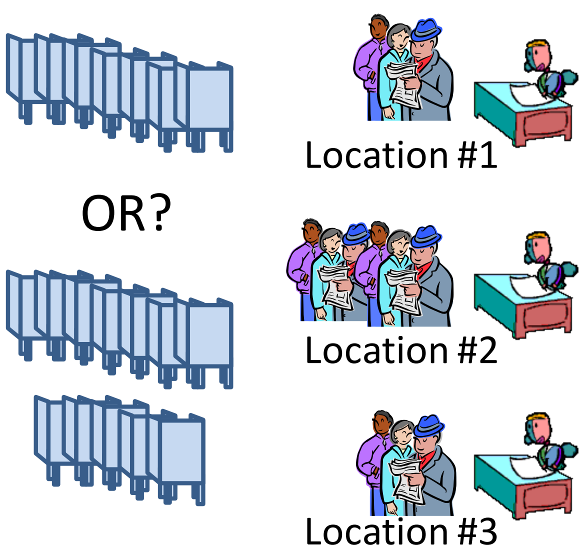

Figure 2. A provisioning decision problem.

1. Overview

Running elections involves standing up resources as needed and then standing them down. These challenging tasks have long been routinely handled by legislators, election officials and their consultants without the aid of Yet, analytical techniques such as discrete event simulation, queuing theory, and regression-based estimation. Yet these methods can be of considerable help in provisioning and resource allocation decisions, and already widely employed by manufacturers, retailers, restaurant owners, and even amusement park operators in making everyday decisions. To assist in election planning and operating, the SEAL laboratory is attempting to make truly useful software and methods that are field tested and approved by election system leaders. These efforts (Figure 1) are divides among support for resource provisioning (how many machines, booths, etc. are needed overall?), allocation (how many should be deployed in each location?), and loss estimation (how many were deterred from voting?). We also hope to make fundamental contributions that improve transparency and contribute to academic knowledge.

2. Resource Provisioning

Legislators and laws often apportion resources on a per voter basis. In some states and counties, this may be reasonable. Yet, in others it can lead to serious differences in voter access to the polls. The amount of resources needed at each polling station depends on how long each voter needs to be served by those resources. Details about the length of ballots in each location, how easy it is to undervote or cast a straight ticket vote, and the degree of voter preparation can cause critical differences in voter turnout and access. For example, we estimate that, at some locations the average time needed to cast a ballot when at a machine was 12.5 minutes, while at others, in the same county and on the same machines, it was 7.0 minutes. The difference related primarily to extra local issues on precinct ballots.

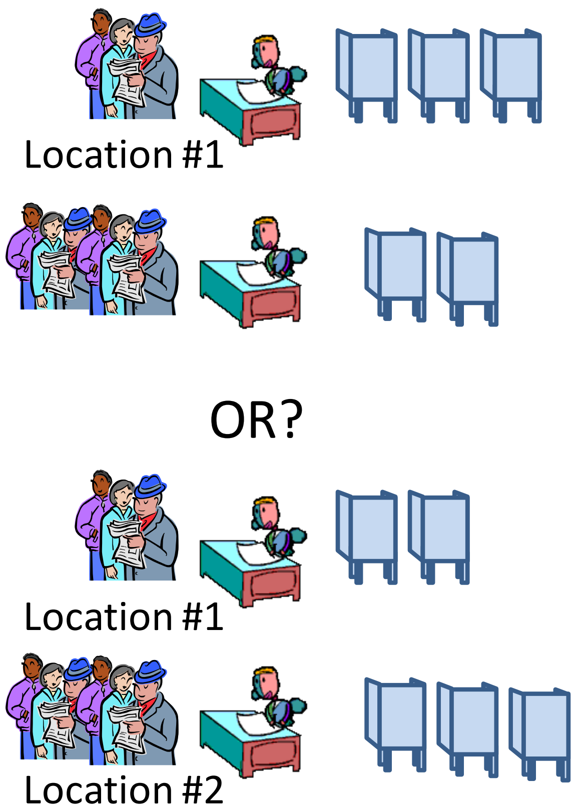

Figure 3. Rigorous guarantee of solution quality.

In our view, a more defensible, equitable approach is to assign a maximum expected waiting time (either for an average voter or for the one who waits longest). Then, specific counties would be required to use (hopefully free and trustworthy) simulation-based software to develop defensible estimates of the numbers of resources needed. Simulation is often critical because queuing theory may not be able to capture key problem elements such as a finite election period or voting convenience centers.

3. Resource Allocation

Once a resource amount or range of available resources is provided, election officials must next determine the specific amounts required for each location. In resource allocation not only an overall number of resources, but also amounts allocated to various locations must be specified. Our on-going research has already made fundamental contributions to simulation-based optimization relevant to election systems optimization and equity objectives. Figure 4 illustrates how the imposition of a threshold limit can lead to globally optimum solutions to minimax problems. Exploiting this structure is proving key to developing computational efficiency and solutions with guaranteed quality.

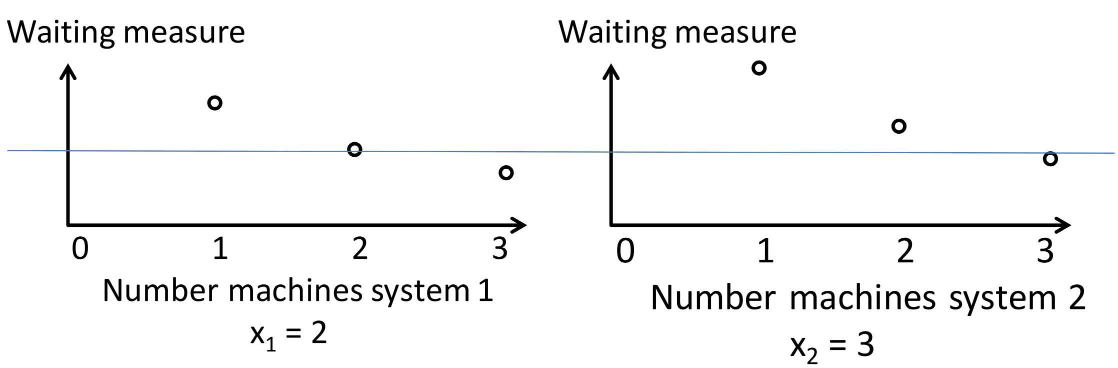

Figure 4. Illustration of the derivation of a minimax solution using a threshold.

THEOREM 3. *Assume A1 (that the samples* $Y_1(x_i), \ldots, Y_n(x_i)$ *are i.i.d. normal distributed with finite variance) and A2 (the sequence of true means,* $\mu_i(L_x), \mu_i(L_x+1), \ldots, \mu_i(U_x)$ *is nonincreasing). Further, assume that* $\mu_i(U_x) \le \mu_0 \le \mu_i(L_x)$. *Let* $\hat{k}_i$ *denote the derived number of resources from the SAS procedure applied with parameters* α *and* δ *satisfying* $0 < \alpha < 1$ *and* $\delta > 0$. *Then,*

$$Pr\{\mu_i(\hat{k}_i) - \delta \le \mu_0 \le \mu_i(\hat{k}_i - 1) + \delta\} \ge 1 - \alpha. \tag{6}$$

Figure 5. Theorem guaranteeing solution quality in resource allocation.

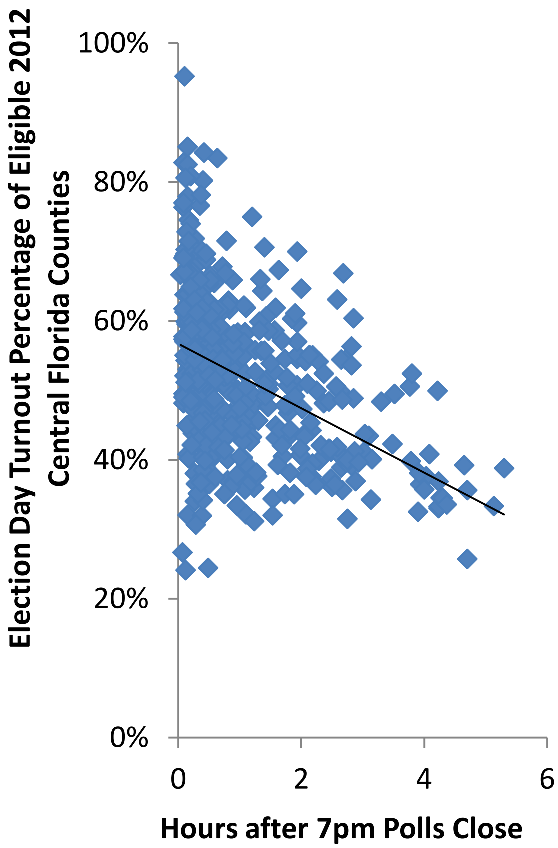

Figure 6. Turnout fractions and poll closing times for 2012 central Florida locations.

4. Rigorous and General Results

It is hoped that the procedures under development will have an enabling and major effect on a large class of simulation optimization methods. SEAL researchers appear to be the first to solve the following basic problem in resource decision making: How can one derive a rigorous and convergent simulation optimization method to determine the minimum number of resources needed to achieve a performance requirement (Figure 5)?

5. Loss Estimation

Estimating losses associated with a historical resource allocation is an important topic by itself. For example, in the 2012 presidential election, we estimate that over 200,000 people in Florida did not vote because they were deterred by long lines.

The derivation of this estimate is illustrated in Figure 5, which shows the closing times of precinct polling locations in central Florida locations. Closing times are a readily available way to measure the length of lines at the official poll-closing time, usually 7 pm in Florida. That means if the poll actually closes 6 hours later, that last voter waited approximately 6 hours. Surprisingly perhaps, the locations with the longest waits had some of the lowest turnout. This results in the approximate rule that 2% of the people drop out for every hour of waiting.

Developing more general and accepted ways to estimate such losses motivates some of our on-going research. Some of the methods may shed light on other waiting systems such as the allocation of medical care resources among veterans who now may face extended, and in some cases, life-threatening waiting times. Our election systems allocation work may well have fundamental and far reaching value.