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Mass Prophylaxis Dispensing Concerns: Traffic and Public Access to PODs

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The ability to quickly dispense postexposure prophylaxis (PEP) using multiple points of dispensing (PODs) following a bioterrorism event could potentially save a large proportion of those who were exposed, while failure in PEP dispensing could have dire public health consequences. A Monte Carlo simulation was developed to explore the traffic flow and parking around PODs under different arrival rates and how these factors might affect the utilization rate of POD workers. The results demonstrate that the public can reasonably access the PODs under ideal conditions assuming a stationary (uniform) arrival rate. For the 5 nonstationary arrival rates tested, however, the available parking spaces quickly become filled, causing long traffic queues and resulting in total processing times that range from 1 hour to over 6 hours. Basic planning considerations should include the use of physical barriers, signage, and traffic control officers to help direct vehicular and pedestrian access to the PODs. Furthermore, the parking and traffic surrounding PODs creates long queues of people waiting to access the PODs. Thus, POD staff are fully used approximately 90% of the time, which can lead to worker fatigue and burn out.

Over the past decade, policymakers have become increasingly concerned about the possibility of a terrorist attack using a biological agent on a civilian population. In response to this threat, the Cities Readiness Initiative (CRI) was created. This is a federally funded effort to prepare major U.S. cities and metropolitan areas to effectively respond to a large-scale bioterrorism event by dispensing antibiotics to their entire identified population within 48 hours of the decision to do so.[1] At the local level, plans typically include the use of points of dispensing (PODs) to distribute antimicrobial postexposure prophylaxis (PEP) to the public following a bioterrorism event. During a recent workshop sponsored by the Institute of Medicine, many different strategies for PEP dispensing were discussed and explored.[2] While multiple dispensing modalities will likely be required in response to a real incident, PEP dispensing through PODs is the cornerstone of current plans and is the focus of this study.

Several studies have shown that PEP dispensing can have great benefits by preventing development of inhalational anthrax if the PEP is administered within 2-3 days of exposure.[3-5] In order to complete the PEP dispensing in a timely manner, much of the planning focus has been on the internal POD processes, such as station layouts, throughput rates, and staffing requirements. Computer models have been developed to address these concerns and to examine ways to improve the efficiency of POD dispensing.[6-8] Less attention, however, has been placed on the processes and logistical challenges outside the PODs, including public access, traffic flow, and parking.

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Studies on PEP dispensing through PODs have primarily focused on obtaining the throughput needed inside the PODs to successfully complete the dispensing campaign in the desired amount of time. This approach has been a matter of identifying the target population requiring PEP and the desired duration of the dispensing campaign. For example, in order to reach a population of 24,000 people in 24 hours, a single POD would require a sustained throughput rate of 1,000 person-medication doses dispensed per hour (this dispensing rate has been observed in exercises[10]). This simplistic approach, however, is based on the underlying assumptions that the public arrives at the PODs at a uniform rate and that the PODs can dispense the prophylaxis in a rapid and consistent manner. Arrival of people to the PODs at a nonuniform rate is a concern, especially if it results in underuse of POD staff and lower throughput rates than planned.

This study explores the impact of nonuniform arrival rates in conjunction with the logistical challenges of public access, parking, and traffic flow in and around the PODs. Specifically, we examine the transportation challenges facing public officials during the siting, access, and operation of PODs in selected urban locations. Furthermore, we examine how nonuniform arrival rates to the PODs may affect the POD staff utilization and the expected impact on PEP dispensing throughput rates. A Monte Carlo simulation employing a queuing model was developed that examines how parking and transportation factors may affect the ease with which the public can access PODs and how service times in PODs may affect the parking and transportation around the PODs.

Methods

Case Study Locations

Many CRI cities have developed and exercised plans in order to meet the CRI objective for completing PEP dispensing within 48 hours of the decision to do so. Two such cities, Boston and Philadelphia, have detailed some of their POD dispensing plans.[9,10] Additionally, CRI drills involving delivery of PEP antibiotics to households by the United States Postal Service (USPS) have been carried out in several Boston and Philadelphia ZIP codes.[11,12] We chose these same ZIP codes as case study locations for our traffic analysis. They include 02132 (West Roxbury) and 02118 (South End) in Boston, and 19130 (central Philadelphia) and 19144 (Germantown) in Philadelphia. The objective of this study was to examine how arrival rates, parking, and traffic may affect prophylaxis dispensing via PODs in an urban setting. These ZIP codes were selected because the USPS drills had been conducted in these areas and would allow for comparison with the USPS drills, but the approach used in this study can be applied to other ZIP codes as well.

Published plans for dispensing PEP through PODs indicate that public schools, community centers, armories, and other large public buildings have been identified as potential facilities to serve as PODs.[9,13,14] In our analyses, the public schools in each ZIP code were identified, and 1 public school in each ZIP code was chosen as a potential POD location. Whenever possible, preference was given to larger schools (ie, high schools). The schools chosen for our analysis were based on our selection criteria and do not reflect actual plans from Boston or Philadelphia. The schools chosen for this analysis were Media Communications Technology High School (formerly West Roxbury High School in the 02132 ZIP code), Blackstone Elementary School (02118 ZIP code), Laura Waring Elementary School (19130 ZIP code), and Germantown High School (19144 ZIP code). The traffic access and parking limitations for the potential PODs in the South End, central Philadelphia, and Germantown ZIP codes are similar, so only the analysis of the potential POD in the South End ZIP code is shown in this report. The potential POD in West Roxbury has different traffic and parking characteristics than the other ZIP codes, so the analysis of West Roxbury is also described.

Model Overview

A Monte Carlo simulation employing a queuing model was developed to address the study questions. The model includes 4 compartments: a parking lot for vehicles arriving at the POD, a traffic queue for vehicles that need to wait to enter the parking lot, a POD queue for people waiting to be served in the POD, and the POD where people receive their PEP antibiotics (Figure 1). The model includes the number of parking spaces available at the POD, the rate at which people arrive at the POD (by either walking or driving), the staff utilization rate of POD workers, and the service time in the POD. All transitions between compartments are modeled using a first-in-first-out principle. Because the objective was to examine how factors external to the POD could affect a dispensing campaign, modeling of internal POD dispensing activities was simplified. For example, the individual stations in the POD were not modeled, so the POD throughput rate is modeled as a single rate rather than taking into account the interdependencies of multiple stations in the POD.

The maximum POD throughput is set prior to any simulation, but the actual throughput rate may vary during the simulation. A constant POD staffing level and service rate are assumed, and the actual throughput rate is a function of the arrival rate of the public to the POD—that is, are there enough people coming to the POD to keep the staff busy and allow for the maximal throughput rate? The service time, which represents the amount of time that each person spends in the POD, is assumed to be fixed in each simulation, but we also conduct a sensitivity analysis on the service time. The total time in process includes the time waiting to park, the time waiting to enter the POD, and the service time in the POD. We assume that transit time between parking and the POD queue is negligible.

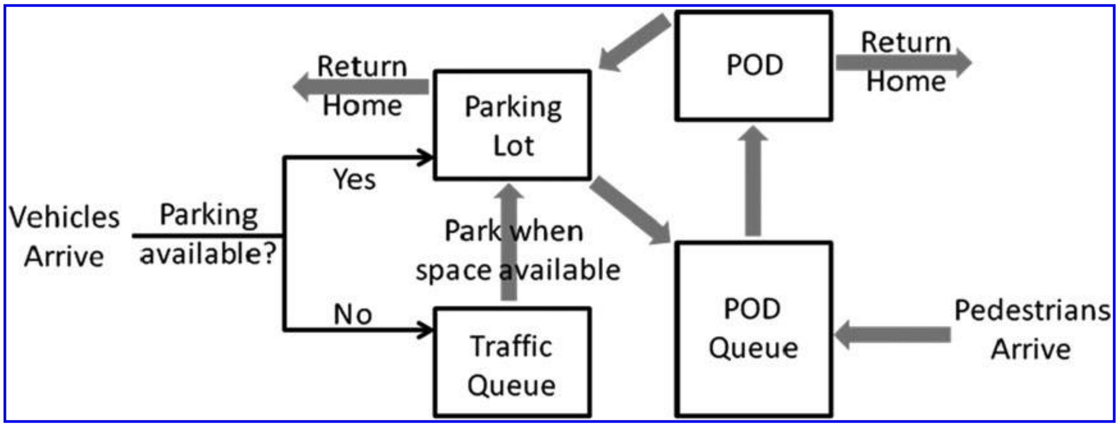

Figure 1. Components of the Queuing Model. The arrival of vehicles (left side of diagram) and pedestrians (right side of diagram) and how people proceed through the queues that lead to receiving PEP in the POD and returning home are shown.

The number of available parking spaces was estimated from aerial photos of the proposed POD locations (we used Google® maps and our geospatial information system [GIS] database, but other sources for aerial photos and maps can also be used). Additional analyses were conducted assuming that nearby athletic fields would be used to augment the number of parking spaces available. In the model runs, it was assumed that no parking spaces were used by POD workers in order to allow the general public access to these critical parking spaces.

Six different hourly arrival rates were used to simulate the demand of the general public seeking prophylaxis from the PODs. Within each hour, a Poisson process is used as a model for the arrival rate at the PODs. The arrival rates examined in this study are shown in Figure 2 and include:

- Uniform (stationary) arrival;
- An evacuation rate based on observations prior to Hurricane Ivan in 2004;[15]
- A Rayleigh distribution, which has been used to describe hurricane evacuation times;[16]

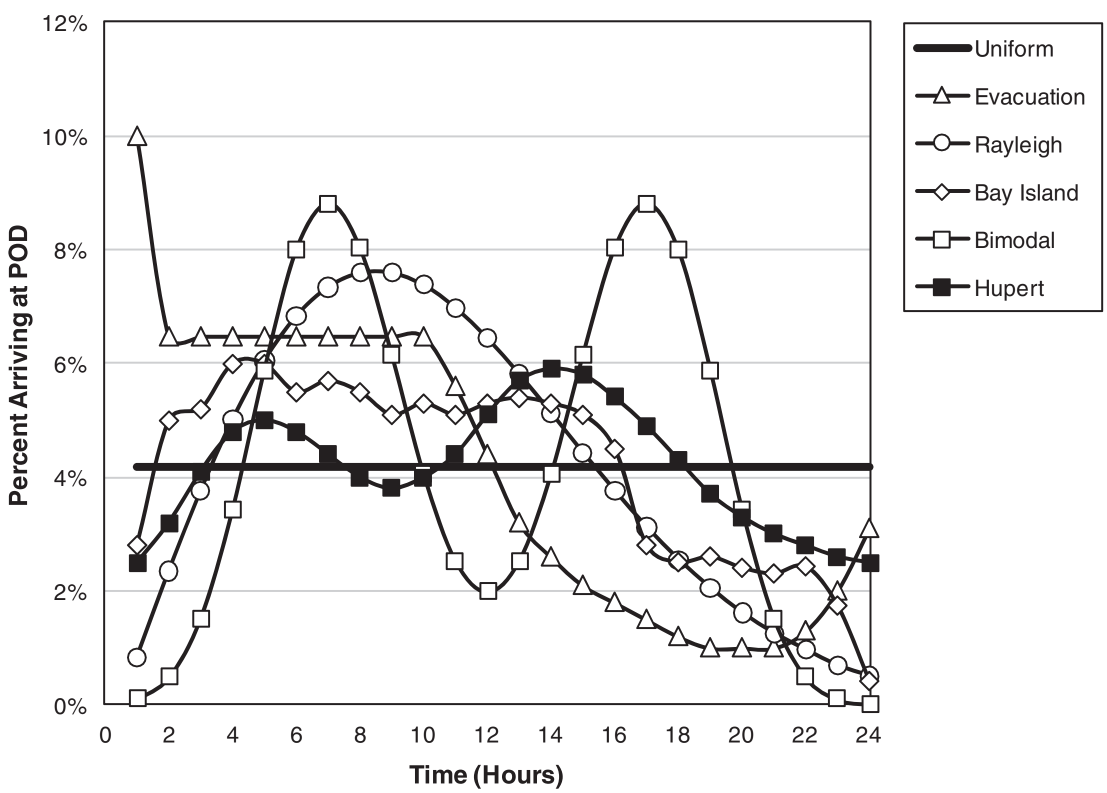

Figure 2. POD Arrival Rates Tested. Six different rates for the arrival of the general public to the POD were tested in this study. One stationary arrival rate assuming a uniform distribution was tested as well as 5 nonstationary arrival rates.

- A distribution approximation of arrival rates in a hypothetical "Bay Island" POD study;[17]
- A bimodal distribution based on a binomial function; and
- An approximation of a bimodal arrival rate used in a study by Hupert and colleagues.[18]

The size of the population seeking prophylaxis from the PODs was derived from census data for each of the ZIP codes examined in this report. For the West Roxbury ZIP code, we assume there are approximately 10,000 households and 24,000 people living in 4.6 square miles.[19] We assume that 1 person per household (ie, the head of household) goes to the POD to obtain prophylaxis for all members of the household, that all people get to the POD by vehicle, and that there is no pedestrian traffic to the POD. The South End ZIP code has approximately 11,000 households and 22,000 people living in 1.1 square mile.[20] The analysis of the potential POD in the South End also assumes head-of-household pickup, but it assumes that the POD is reached by both pedestrians and people arriving in vehicles.

We assume that head-of-household pickup of prophylaxis at the PODs, which has been field-tested in Philadelphia,[10] allows the PODs to dispense PEP to the target population in 24 hours, meeting the CRI objective. We assume that it takes 24 hours for distribution of the PEP antibiotics from the Strategic National Stockpile (SNS) and for local public health officials to prepare the PODs, leaving 24 hours for PEP dispensing. The maximal POD throughput rate was set at 420 heads-of-household per hour, which results in approximately 1,000 person-medication doses per hour (assuming 2.4 people per household) and matches the field tests executed in Philadelphia.[10] For ease of comparison, we assumed 10,000 households for both the West Roxbury and South End ZIP codes.

In addition to the POD throughput, the study models the service time in the POD. The model assumes that once people enter the POD, they complete the dispensing process, receive their prophylaxis, and exit the POD in 10 minutes (this has been observed in POD dispensing exercises and has been used in other models[18]). Sensitivity analyses were conducted to examine how variation in this service time (range of 10-30 minutes) in the POD affects the parking and traffic conditions outside the POD.

The outcome metrics used to evaluate the effectiveness of the parking and traffic around the POD location include:

- Number of vehicles parked in the POD parking lot;
- Number of vehicles in the traffic queue waiting to park;
- Number of people waiting to enter the POD (POD queue) after parking; and
- Total time in process.

The number of parked vehicles indicates whether and how often the parking capacity is exceeded due to the arrival rate of people to the POD and the POD throughput rate. When the parking capacity is exceeded, cars line up in the traffic queue and wait for an available parking space. The number of cars in the traffic queue indicates whether further traffic congestion could affect the immediate area surrounding the POD location. The number of people waiting to enter the POD indicates whether the POD throughput can keep pace with the demand from the general public. The total time in process is the combination of the time waiting to park, the time waiting to enter the POD, and the service time in the POD. Since the service time in the POD is constant in this model, the total time in process reflects the time people spend waiting to park and waiting to enter the POD. We assume that travel time between parking and entering the POD queue is negligible.

The arrival rate to the POD, available parking, and other factors surrounding the POD also have an impact on the performance of the POD dispensing. The effectiveness of PEP dispensing can be gauged by the utilization rate of the POD staff and how frequently the POD workers are working at full capacity and dispensing at their maximal throughput rate. These staff utilization outcome metrics allow us to evaluate whether the PODs may be under-used during the dispensing campaign.

POD Transportation Factors

POD arrival rates are expected to affect POD throughput, staff utilization, and overall POD performance. Factors affecting POD arrival rates include proximity to public transit, proportion arriving by vehicle or on foot, traffic access, and parking availability. These factors are expected to vary as a function of geographical location of the POD. In this study, we examine these transportation factors and show the simulation results for the proposed PODs in West Roxbury and the South End.

Implementation

A Monte Carlo simulation was developed in Visual Basic for Applications in a Microsoft Excel workbook. Each outcome described in this study represents 20 model iterations. For each set of 20 runs, the mean of the maximum, mean, and median values for each traffic and parking outcome metric are captured and reported. For the staff utilization outcome metrics, the maximum, median, and minimum values are reported for the set of 20 runs.

Results

West Roxbury Transportation Considerations

Parking

Automobile ownership in West Roxbury (02132 ZIP code) is approximately 90%, in contrast with the 55%-60% automobile ownership in the 3 other ZIP codes examined in this study.[19-22] The proposed POD location in West Roxbury is Media Communications Technology High School, which has approximately 200 parking spaces available on site.

Transit

The availability of public transportation is typically more limited as you move away from densely populated urban settings. West Roxbury is served by a commuter train but has no subway service and only limited bus service. The limited public transportation options underscore the reliance on personal automobiles in West Roxbury. In West Roxbury, approximately 80% drive alone or carpool to work, while 6% use the commuter rail and 4% use bus service.[19]

Pedestrian Access

In some urban settings, sidewalks are located on school property but are not always connected to nearby neighborhoods. In West Roxbury, a 4-lane road with a dividing median leads to a single access road to the high school (see Figure 3) and is not conducive to pedestrian access (unlike the grid-type road network in the three other ZIP codes

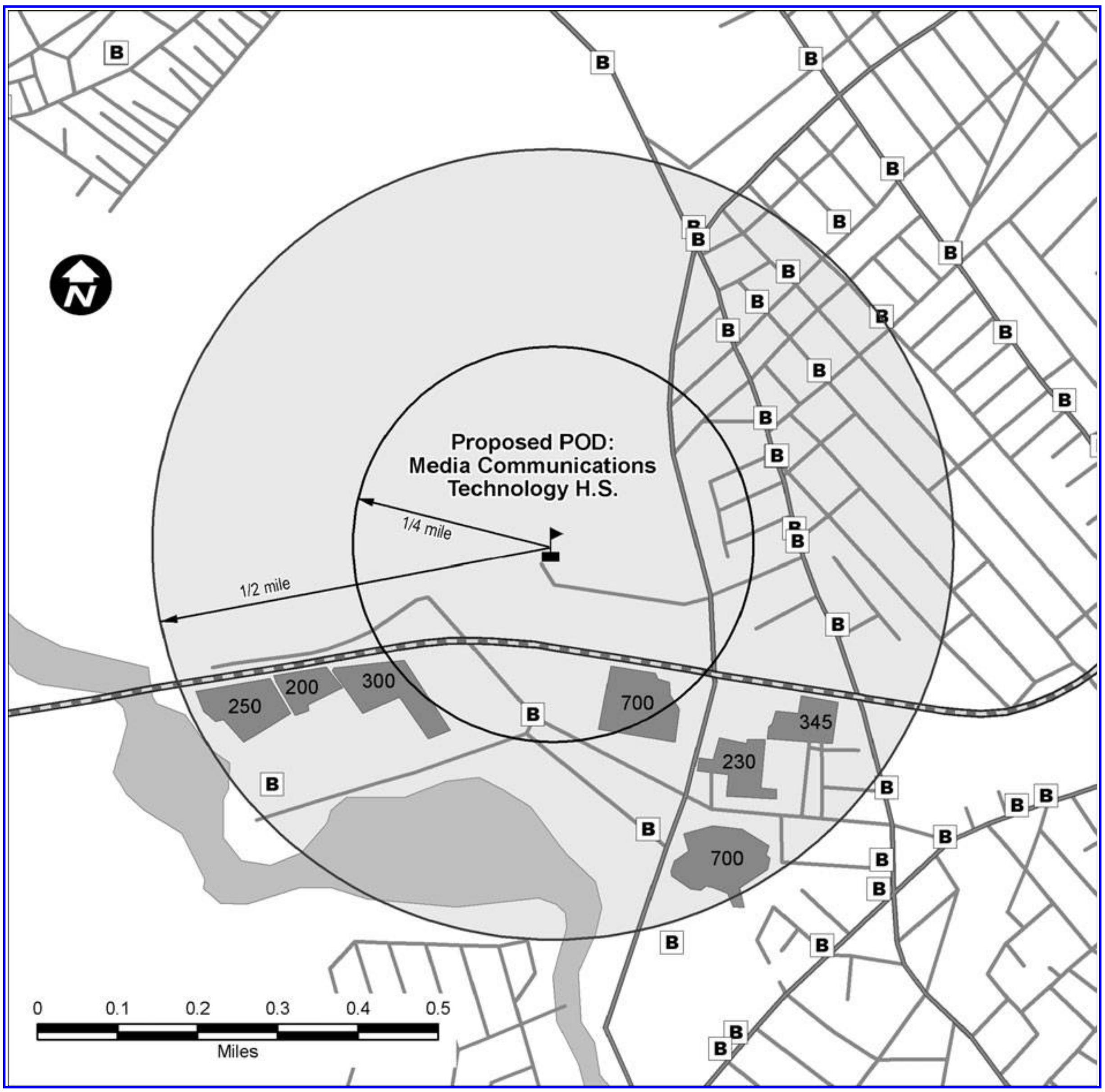

Figure 3. The Proposed POD Location for West Roxbury ZIP Code (02132). Media Communications Technology High School is the proposed POD site, and quarter-mile and half-mile radii are shown for the school. The number of parking spaces available at private parking lots within a half-mile of the school are shown.

examined). This single access to the schools is a design feature that helps provide added security for the school but may limit its accessibility during a PEP dispensing campaign.

POD Analysis

In light of public transit limitations in West Roxbury, we analyzed the vehicle arrivals and departures (no pedestrian access) during the 24-hour PEP dispensing operation period in the proposed POD location.

Table 1 shows the parking and traffic outcome metrics for the 6 different arrival rates, assuming 200 available parking spaces and a 10-minute service time in the proposed West Roxbury POD. Assuming a stationary arrival rate (ie, a uniform distribution of arrival times), the model predicts that the 200 parking spaces available at the school are adequate for the demand, with a maximum of 171 parking spaces filled and no traffic queue formed. The median number in the queue waiting to enter the POD is 41 people, and the median total time in process is 18 minutes. Figure 4 illustrates the 4 outcome metrics for a single Monte Carlo simulation of the proposed West Roxbury POD. In the case of a uniform arrival rate, the results in Table 1 and Figure 4 show that the available parking and POD throughput rate result in total processing times of less than half an hour.

Table 1 indicates that the total time in process is considerably longer under assumptions of nonstationary arrival rates. For all 5 nonstationary arrival rates we examined, the parking lot fills to capacity and causes a lengthy traffic queue. The bimodal arrival rate described by Hupert and colleagues[18] generates the lowest peak arrival rates (closest to the uniform arrival rate) and results in a median traffic queue of 89 cars. The traffic queues for the other nonstationary arrival rates have median values of 835 to 1,469 cars. For all of the nonstationary arrival rates, the median POD queue length is approximately 116 people, and the median total time in process ranges from 43 minutes to more than 4 hours. Figure 5 illustrates the 4 outcome metrics assuming Hupert's bimodal arrival rate over the course of a single Monte Carlo simulation for the proposed West Roxbury POD. Figure 5 shows that the available parking spaces become full approximately 4.5 hours after the POD is opened and that the resulting traffic queue has a

Table 1. Traffic and POD Processing Outcome Metrics for Different Arrival Rate Assumptions in the Proposed West Roxbury POD

Arrival Rate		*Parked Vehicle (vehicles)*	*Traffic Queue (vehicles)*	*POD Queue (people)*	*Total Time in Process (minutes)*
Uniform	Maximum	171	12	94	27
	Mean	116	2	42	18
	Median	118	1	41	18
Evacuation	Maximum	200	2,707	117	415
	Mean	181	1,412	107	240
	Median	200	1,469	116	251
Rayleigh	Maximum	200	2,505	116	386
	Mean	171	1,252	99	215
	Median	200	1,327	116	240
Bay Island	Maximum	200	1,588	116	255
	Mean	177	779	103	145
	Median	200	835	116	154
Bimodal	Maximum	200	2,490	116	377
	Mean	164	1,125	96	184
	Median	200	1,148	116	195
Hupert	Maximum	200	801	116	143
	Mean	165	261	92	64
	Median	200	89	116	43

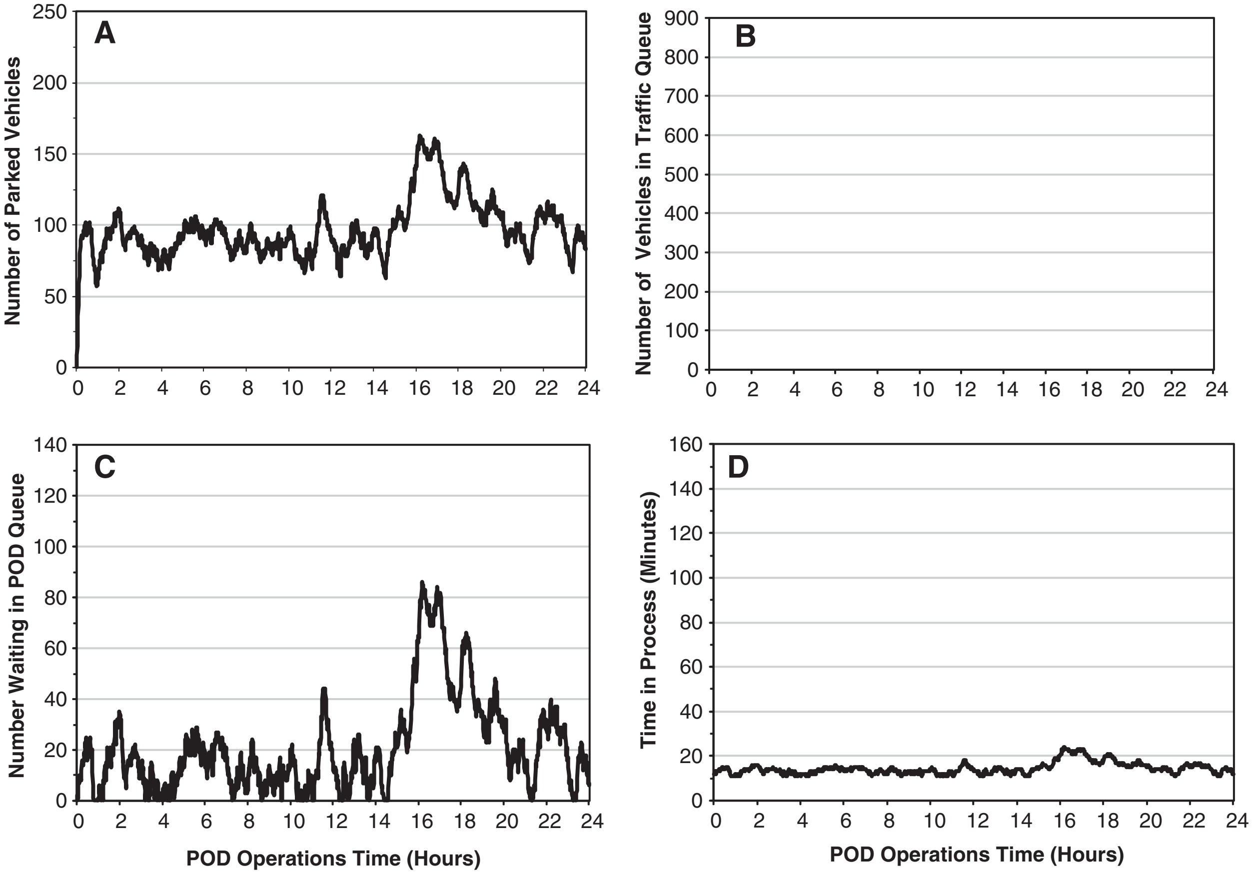

Figure 4. Output Metrics Assuming a Uniform Arrival Rate for the Proposed West Roxbury POD. The output metrics of interest are shown: (A) the number of parked vehicles in the POD parking lot, (B) the number of vehicles in the traffic queue waiting for a space in the POD parking lot, (C) the number of people who have parked and are waiting to enter the POD, and (D) the total time in process for people arriving at the POD.

median of 89 cars and reaches a maximum of more than 800 cars. This traffic queue exceeds the approximately 45 cars that the access road can accommodate and would cause congestion at the intersection of the access road.

The metrics for POD performance at the proposed West Roxbury POD are shown in Table 2 for each of the 6 different arrival rates, assuming 200 available parking spaces and a 10-minute service time in the POD. The minimum staff utilization rate for all 6 arrival rates was over 89%, indicating that the POD workers were quite busy throughout the 24 hours of dispensing. In fact, the simulations show that the POD workers were dispensing PEP at full capacity approximately 85% of the time (on average). This means that all POD staff are expected to be actively working at full capacity approximately 85% of the time. For the nonstationary arrival rates tested, the congestion in the parking lot causes a continuous supply of people waiting in the POD queue for service. Consequently, once the POD is dispensing at full capacity, it operates at full capacity until the end of the dispensing campaign (data not shown).

The impact of longer service times in the POD and increased parking capacity was examined, and select results are shown in Table 3. For the stationary arrival rate, increasing the service time in the POD from 10 minutes to 20 minutes (while maintaining the maximal throughput rate) causes the parking spaces to become full and the traffic queue to reach maximum values of more than 60 cars. A service time of 30 minutes in the POD fills the available parking spaces within the first hour of POD opening and could hypothetically cause a traffic queue that steadily increases to a maximum value of approximately 1,000 cars. The parking capacity at this POD could be increased by allowing the public to park on the athletic fields around the high school. An increase of parking capacity from 200 to 600 spaces alleviates traffic queues if the service time in the POD is 20 minutes, but the additional parking spaces cannot eliminate the traffic queue if the POD service time is 30 minutes (all assuming a stationary arrival rate).

Assuming the Hupert arrival rate (nonstationary), a POD service time of 10 minutes, and 600 parking spaces, parking spaces are available until approximately 13.3 hours after the POD has opened. After parking capacity is reached, the traffic queue grows to a maximum of approximately 425 cars. Under assumptions of a nonstationary arrival rate, additional parking spaces can help to reduce the traffic queue but cannot eliminate it.

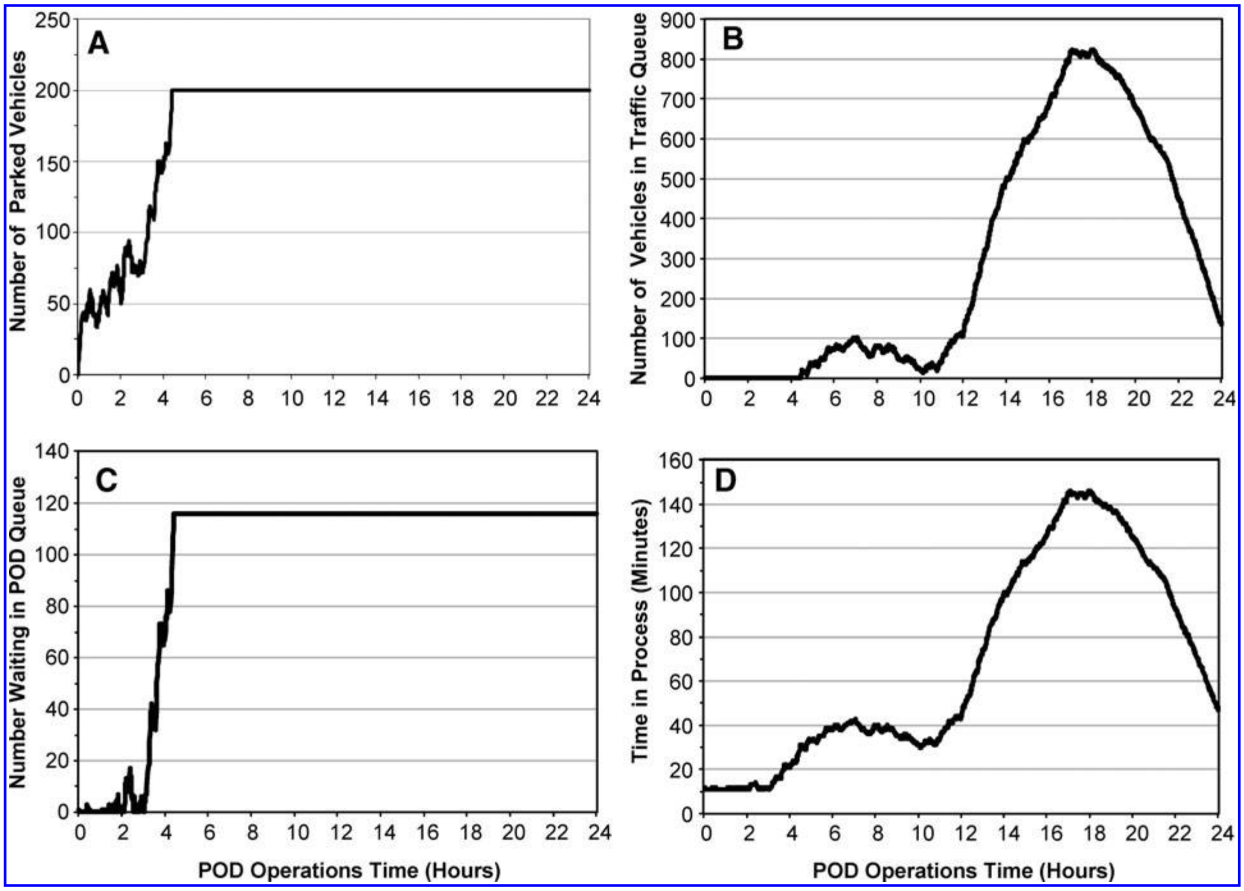

Figure 5. Output Metrics Assuming a Bimodal Arrival Rate for the Proposed West Roxbury POD, similar to one described by Hupert et al.[18] The output metrics of interest are shown: (A) the number of parked vehicles in the POD parking lot, (B) the number of vehicles in the traffic queue waiting for a space in the POD parking lot, (C) the number of people who have parked and are waiting to enter the POD, and (D) the total time in process for people arriving at the POD.

South End Transportation Considerations

Parking

Densely populated urban settings in the United States generally have limited parking. Likewise, schools in densely populated urban settings do not have many parking spaces available on site. The elementary schools we examined had approximately 15-35 parking spaces available on the school property. The high school identified in the Germantown neighborhood of Philadelphia had approximately 80 parking spaces available on site. These limited parking spaces are not adequate to accommodate the thousands of people who would seek prophylaxis at these potential POD locations.

Transit

Personal automobile ownership for people living in densely populated urban settings is typically low, and many people use public transportation. For 3 of the ZIP codes examined (excluding West Roxbury), approximately 36%-58% drive alone or carpool to work, while the remainder of the population use public transportation, walk, or bike to work.[20-22] Most densely populated urban settings have a well-developed public transportation system, and Boston and Philadelphia are no exceptions. Analysis of the Massachusetts Bay Transit Authority (MBTA) in Boston and the Southeastern Pennsylvania Transportation Authority (SEPTA) in Philadelphia indicate that the urban areas in this study are well supported by both bus transit and a subway system. The MBTA and SEPTA typically provide transportation for approximately 1.2 million people each day.[23] Figure 6 shows the available public transportation near the proposed South End POD location, which includes multiple bus routes and subway stations within walking distance (ie, within a quarter mile). The carrying capacity of these public transportation providers should be sufficient to get people to and from the proposed South End POD location.

Pedestrian Access

There are sidewalks on both sides of the streets, and pedestrian-activated signals are present at most major intersections near the proposed South End POD. The gridlike

Table 2. Staff Utilization Outcome Metrics for Different Arrival Rate Assumptions in the Proposed West Roxbury POD

Arrival Rate		*POD Staff Utilization (%)*	*POD Staff Dispensing at Full Capacity (%)*
Uniform	Maximum	99.0	94.6
	Mean	98.1	85.1
	Minimum	97.1	74.8
Evacuation	Maximum	99.4	98.8
	Mean	98.7	96.4
	Minimum	96.8	92.1
Rayleigh	Maximum	94.5	89.2
	Mean	94.0	87.4
	Minimum	93.2	86.3
Bay Island	Maximum	98.4	94.8
	Mean	98.0	94.4
	Minimum	96.9	93.6
Bimodal	Maximum	91.5	86.0
	Mean	90.0	84.6
	Minimum	89.2	83.6
Hupert	Maximum	97.3	90.4
	Mean	96.5	88.5
	Minimum	96.1	85.5

layout of roads present around the proposed South End POD allows access to the proposed POD from multiple directions.

POD Analysis

The simulations for the South End location use the same assumptions as the West Roxbury simulations, with the same target population size (10,000 heads-of-household) and maximal POD throughput rate (420 heads-of-household per hour). The key differences are the reduced number of parking spaces available at the POD location (40 in the proposed South End POD) and the proportion of people arriving at the POD on foot. Table 4 shows the traffic and parking outcomes of the proposed South End POD. Assuming a stationary arrival rate and 40% access to the POD by pedestrians, the model predicts that the 40 parking spaces are quickly filled, resulting in a traffic queue with a median of 522 cars, which will likely cause traffic congestion around the POD area. Although the traffic queue is quite large, the model predicts only a small number of people in the POD queue waiting to enter the POD. Because of the long traffic queues, the median total time in process is 87 minutes.

Based on a higher assumption of 70% pedestrian access (and a stationary arrival rate), the 40 spaces in the POD parking lot are sufficient to service the vehicle access. The median POD queue is 29 people, and the median total time in process is approximately 14 minutes. These results suggest that the POD may operate efficiently under a stationary arrival rate and when higher proportions of people access the urban POD on foot.

Similar to the results obtained in the West Roxbury simulations, the outcome of the model is quite different when nonstationary arrival rates are assumed. Under the assumption of 70% pedestrian access to the proposed South End POD and Hupert's bimodal arrival rate, the POD parking lot becomes full and causes traffic queues with a median of 52 cars and a maximum queue of 269 cars. The POD queue has a median of 176 people (maximum of 681 people), and the median total time in process is 45 minutes (maximum of 144 minutes). These results mirror those obtained for the proposed West Roxbury POD and demonstrate that nonstationary arrival rates to the PODs will likely cause traffic challenges outside the PODs and should receive increased attention from planners.

Discussion

The results of this study highlight potential deficiencies in PEP dispensing plans because of some underlying assumptions. Simplistic PEP dispensing plans implicitly assume that the public will arrive at the PODs in a uniform and steady rate. Under this ideal assumption, our simulations show that a PEP dispensing campaign can be efficiently completed as planned with minimal traffic queues. In a real-world situation, however, it is unrealistic to expect the public to arrive at the PODs in a uniform and steady rate. The evacuation prior to Hurricane Ivan, for example, exhibited a nonuniform distribution.[15] For all 5 nonstationary arrival rates tested, our simulations show that the parking spaces became filled, traffic queues of hundreds to thousands of cars developed, and the total time in process ranged from 1 hour to more than 6 hours.

Some PEP dispensing planners have considered nonuniform arrival rates to the PODs and are concerned that the nonuniform arrivals may cause the POD staff to be underutilized at times and thus prevent the POD from consistently reaching its planned maximal dispensing throughput rate. One study by Hupert and colleagues suggests that the POD staff may be underutilized, with an average staff utilization of 76% at the greeting station (the first station inside the POD),

Table 3. Traffic and POD Processing Outcome Metrics for Different Parking and POD Service Time Assumptions in the Proposed West Roxbury POD

Arrival Rate	*Parking Spaces Available*	*POD Service Time (minutes)*		*Parked Vehicle (vehicles)*	*Traffic Queue (vehicles)*	*POD Queue (people)*	*Total Time in Process (minutes)*
Uniform	200	10	Maximum	171	12	94	27
			Mean	116	2	42	18
			Median	118	1	41	18
Uniform	200	20	Maximum	200	63	46	37
			Mean	169	18	29	28
			Median	179	14	33	28
Uniform	200	30	Maximum	200	1,024	12	180
			Mean	192	511	0	106
			Median	193	523	0	106
Uniform	600	20	Maximum	250	0	103	36
			Mean	178	0	38	27
			Median	181	0	35	27
Uniform	600	30	Maximum	305	0	88	44
			Mean	236	0	30	36
			Median	242	0	26	35
Hupert	200	10	Maximum	200	801	116	143
			Mean	165	261	92	64
			Median	193	89	116	43
Hupert	600	10	Maximum	600	425	516	146
			Mean	357	90	284	67
			Median	311	0	234	47

when a simple ascending arrival rate was used.[18] Assuming a more extreme bimodal arrival rate than in our analysis, the Hupert study suggests that the queue at the greeting station drops to zero for 1-2 hours before increasing again (resulting in staff underutilization).

In our study, the POD queue never drops to zero for our mild bimodal arrival rate. As a result, our model suggests that staff utilization is high throughout the dispensing campaign (average staff utilization rate was over 95% for all 6 arrival rates, and the POD operated at its maximal capacity approximately 90% of the time). The key difference between our results and the results described in the Hupert study is the arrival rate. While the Hupert study assumes people arriving directly to the POD, our arrival rate applies to pedestrians and vehicles. The additional constraints of the limited parking spaces and the resulting traffic queue produce a backlog of people trying to access the POD. This backlog explains why the POD queue does not drop to zero in our simulations.

Contrary to some concerns of staff underutilization (and reduced average dispensing throughput), our simulations suggest that POD staff will be fully utilized approximately 90% of the time. This constant demand on POD staff can potentially lead to worker fatigue and burnout, and planners should consider strategies to mitigate these possible effects.

Our analyses showed that the performance in the POD can affect the parking and traffic outside the POD. If the service time in the POD increases from 10 minutes to 20 minutes, the added time in the POD can cause the

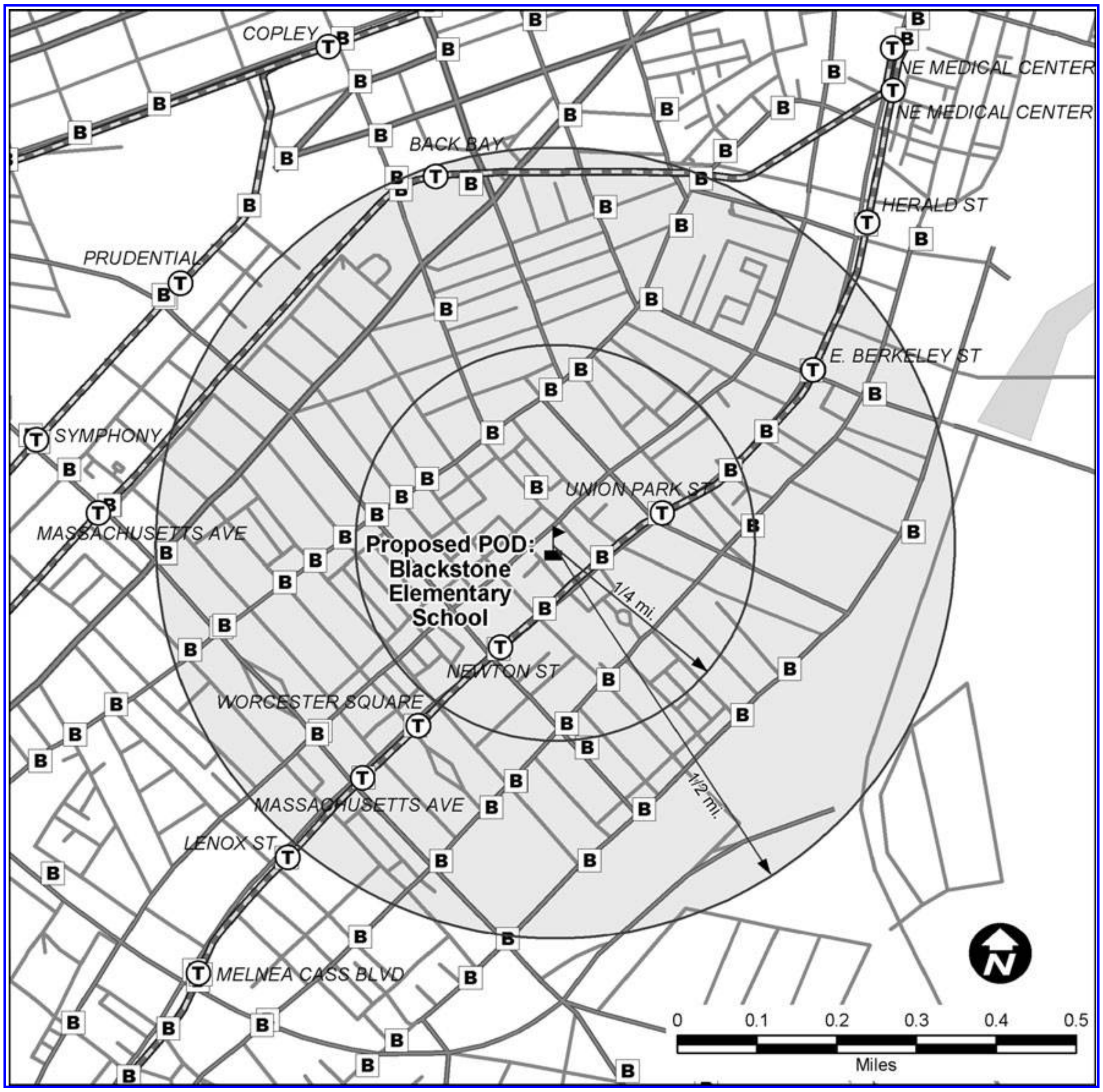

Figure 6. The Proposed POD Location for South End ZIP Code 02118. Blackstone Elementary School is the proposed POD site, and quarter-mile and half-mile radii are shown for the school. Subway transit stations are indicated by the circled Ts.

parking spaces to fill up and create a long traffic queue, even under an unrealistically optimistic uniform arrival rate assumption.

Our analyses suggest that planners need to more carefully consider traffic and parking surrounding the proposed POD locations in order to minimize potential problems that may be encountered as the public tries to access the PODs. The logistical challenges are different from POD to POD. For example, the limited parking capacity around schools, the accessibility by public transportation, and the extensive sidewalk system in densely populated urban settings lend themselves to a POD strategy that places a strong emphasis on pedestrian access to the PODs. Conversely, there are situations where the public relies heavily on personal automobiles or where public transportation may be lacking. This type of situation typically drives POD planning toward vehicle access. In both settings, POD planners need to consider

- Signage to direct vehicular and pedestrian traffic;
- Barriers to define vehicular access and pedestrian queuing near PODs; and
- Traffic control officers at intersections around the PODs.

These materiel and personnel are required to help minimize parking and traffic problems and to support more efficient access to the POD. Furthermore, access of POD workers to the PODs is also important. POD workers may need to use public transit to reach the PODs, since parking at the urban schools is very limited. Shuttle

Table 4. Traffic and POD Processing Outcome Metrics for the Proposed South End POD

Arrival Rate	*Pedestrian Access (%)*		*Parked Vehicle (vehicles)*	*Traffic Queue (vehicles)*	*POD Queue (people)*	*Total Time in Process (minutes)*
Uniform	40	Maximum	40	826	16	150
		Mean	36	481	2	82
		Median	37	522	1	87
Uniform	70	Maximum	40	16	86	23
		Mean	27	2	32	14
		Median	27	1	29	14
Hupert	70	Maximum	40	269	681	144
		Mean	34	95	274	66
		Median	37	52	176	45

service specifically for POD workers may be helpful in situations where public transit is limited. Strategies must be explored for getting POD workers to the PODs so that the available parking spaces are reserved for the general public.

Increasing the number of available parking spaces can help to reduce the traffic queue that is expected to occur. These additional parking spaces can be obtained by using adjacent athletic fields that are often associated with schools. Planning is required to identify additional parking spaces, and personnel would be required to help direct the public toward these spaces.

The impact of a limited number of parking spaces at PODs could be alleviated by the use of shuttle buses. For example, approximately 2,700 parking spaces are available in private parking lots within half a mile of the proposed POD location in West Roxbury (see Figure 3). Identifying these pickup points for the general public and using shuttle buses to transport people to the POD can help to alleviate some of the parking congestion at the POD location. Furthermore, the paperwork that is typically filled out upon entry at the POD could be distributed and filled out at these pickup points to facilitate timely processing in the POD. Agreements with the private businesses who own the parking lots might be necessary to enable this type of shuttle operation.

In a real-world incident, the expected arrival rate of the general public to PODs is highly uncertain. With the multiple PODs that would be operational, it is unclear which PODs may be targeted by the public. In this study, we assume that people within a single ZIP code go to the same POD location. There may be other strategies for how to direct the public to different PODs, but these strategies have not been published in the open literature.

There are limitations to the results described in this article. They are derived from a simple POD model and a simple traffic model. There are no dynamic interactions between the traffic congestion and the arrival of additional vehicles and pedestrians to the POD. Even with this simple model, however, our analyses should caution planners that parking and traffic concerns need to be considered to facilitate more efficient access to the PODs for the public. Local planners should consider these traffic and parking logistics when identifying potential POD locations as well as the materiel and personnel required outside the PODs to help manage traffic, parking, and pedestrians. Microsimulations, which model individual people, cars, roads, and buildings with realistic physical sizes, can be used for specific locations to identify potential traffic and parking challenges and explore plans that may be used to successfully address them.

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