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Dispensing Medical Countermeasures in Public Health Emergencies via Home Health Agencies and Points of Distribution

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Citation

Dispensing Medical Countermeasures in Public Health Emergencies via Home Health Agencies and Points of Distribution

An undergraduate honors thesis submitted in partial fulfillment of the requirements for the degree of Bachelors of Science in Industrial Engineering

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Abstract:

A major concern regarding emergency preparedness on the state government level involves the handling and dispensing of the Strategic National Stockpile (SNS) of medicinal supplies. Each state is required to update and maintain a plan of action for dispensing SNS materials that would effectively provide care to the state's population in times of distress. This research evaluates a state's ability to dispense an adequate amount of medicine to her population in a timely manner, specifically after it has been received by the state government. Although simulation modeling has previously been utilized to replicate the dispensing process at pre-designated points of distribution (PODs), the impact of including home health agencies (HHAs) as dispensing agents remains an open question.

This work utilizes traveling salesman heuristics and RealOpt simulation modeling software to determine if the use of HHAs would enable the provision of aid to impacted populations in a more timely fashion. Data for model input parameters is provided by a partner in the public health community and simulation results are utilized to compare the effectiveness of a dispensing operation that employs PODs to one that employs both PODs and HHAs. The inclusion of five home health agencies in the distribution of the Strategic National Stockpile in a case study area results in an increase in the population served by 2.4%, a decrease in personnel shortage (medical and non-medical) by 16 persons, and an increased access for the vulnerable homebound population. While this research illustrates a potential increase in access to the homebound population dependent on home health agencies, this growth is limited by the number of staffing levels and patient censuses of the home health agencies in question.

Acknowledgements:

First and foremost, none of this would be possible without God. I thank Him every day for His amazing blessings. I would also like to thank Dr. Milburn for her guidance, wisdom, and patience throughout this research process. She has been an amazing influence in my life and I will forever treasure our time working together. I would also like to thank the State of Arkansas for the financial support through the State Undergraduate Research Fellowship. Lastly, I would like to thank my family and friends for all the support they have shown in this adventure. I love you all to the moon and back!

"Don't cry because it's over, smile because it happened." -- Dr. Seuss

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Dispensing Medical Countermeasures in Public Health Emergencies via Home Health Agencies and Points of Distribution

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Background Information:

In the event of a national emergency, it is crucial the appropriate quantities and types of medical supplies be accessible to the public. Depending on the severity of the emergency, local supplies may not be adequate to provide protection during a public health threat. To prepare for and thwart a potential national health emergency, Congress charged the Department of Health and Human Services (DHS) and the Centers for Disease Control and Prevention (CDC) with the establishment of the National Pharmaceutical Stockpile in 1999. This program was later named the Strategic National Stockpile (SNS) in 2003 [19]. The goal is to maintain a reserve of drugs, vaccines, and other medical items in "Push Packages" which can be delivered to the United States and her territories within 12 hours of federal deployment [7]. After reaching their destinations, the materials become the responsibility of the states.

Emergencies resulting from crises such as major earthquakes, contagious disease outbreaks, or even terrorist attacks may require an overwhelming amount of supplies to medically aid potential victims. The SNS currently consists of items such as antibiotics, chemical antidotes, and other medical/surgical items [19]. To access this stockpile, utilization requests submitted by the state are evaluated by the DHS and the CDC before assets are released [19]. To provide timely support in moments of need, the Centers for Disease Control and Prevention administered the Cities Readiness Initiative (CRI) to provide technical expertise and funding to state public health departments to improve their ability to dispense medical supplies to their

entire populations within 48 hours [21]. This 48-hour limit is differentiated into the time required to request and transport SNS supplies from state receiving points to regional distribution points (also known as Points of Distribution or PODs) and the time allowed for the dispensing of these supplies to the public. PODs are strategically designated locations that the public must visit to access the supplies [3]. PODs can be distinguished as either open or closed. Open PODs are operated by the government and open to the entire public, while closed PODs are establishments, such as large churches or private businesses, that are limited in the clientele they serve [12]. Current dispensing plans for several states call for both open and closed PODs. The flow of these supplies from federal storage to the end-users is illustrated in Figure 1:
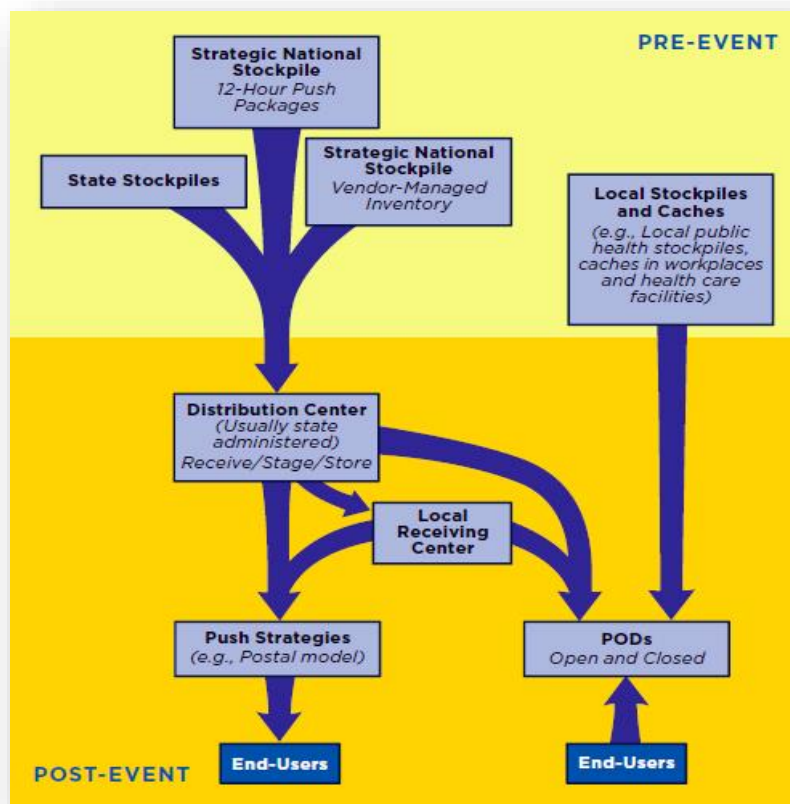

Figure 1: Distribution of SNS Supplies [21]

All states are required by the federal government to have a plan of emergency preparation for the dispensing of medicinal drugs. States' plans must be reviewed and updated annually to avoid deficiencies revealed during SNS Program Assessments and state and local training exercises [18, 16, 17, 20]. While the Cities Readiness Initiative has had a great effect on strengthening preparedness capacities [22], performance has proven to be somewhat lower in three critical areas of the distribution process: coordination and guidance for dispensing, security, and distribution [15]. Furthermore, the Cities Readiness Initiative is only applied in a few designated cities in the United States, leaving room for inadequacies in cities or counties who are not qualified for this government program. The case study area for this research is not located in a CRI certified area, making it vulnerable to failure for emergency response within the 48-hour time period. A lack of feasibility in a state's emergency readiness could lead to disaster and potential loss of life in times of trial. This research provides a model that states can use to analyze whether home health agencies can be used as resource multipliers in their states to achieve dispensing to their populations within required timeframes.

Research Questions:

In conjunction with the use of PODs in the distribution of the SNS, home health agencies have great potential to act as private dispensing entities. A home health agency (HHA) is an organization which is primarily engaged in providing skilled nursing services to patients in their homes and is licensed pursuant to state or local law [10]. In-home dispensing via HHAs would allow increased access to the homebound population of the state and extend the beneficial

reach of SNS. Citizens with restricted mobility represent a vulnerable population and may not be able to reach established PODs. Additionally, using HHAs to dispense to HHA nurses, patients, and their families can divert congestion away from the PODs other members of the public will use. This research establishes the comparative effectiveness of dispensing operations exclusive and inclusive of HHAs.

Objectives:

The purpose of this research is to analyze and evaluate current SNS distribution methods to determine if improvements are available and/or necessary to achieve complete SNS dispensation within the 48-hour target range. Emphasis is placed on dispensing activities that occur within open PODs, closed PODs, and HHAs rather than the logistics activities required to distribute supplies to all PODs. Simulation models of POD operations will be utilized to replicate the existing distribution methods as well as to create alternative SNS allocation strategies. These strategies will specifically consider one major modification to the current method in which supplies are dispensed at the local level: utilizing home health agencies (HHAs) as closed PODs. A comparison of the effectiveness of a dispensing operation that uses only PODs to one that utilizes both PODs and HHAs will be conducted based on simulation modeling results. A case study area will serve as the basis for all existing and potential models.

Literature Review:

Simulation modeling has been widely used in the study of population health and health care delivery problems. A 2003 review found 990 full text papers on the topic [8]. Each paper considers diverse aspects of simulation modeling and addresses various details concerning the multi-layered complexity involved in large scale dispensing of antibiotic treatments. Relevant findings on a select amount of papers are discussed below.

Hupert, Mushlin, and Callahan (2002) evaluate the effectiveness of utilizing computer simulation to predict staffing needs for the distribution of medical supplies and antibiotics in case of a medical emergency [11]. To conduct this analysis, authors used Arena discrete event simulation modeling to replicate a singular point of distribution and its average throughput of patients in a four-station model that included entry screenings, triage, medical evaluations, and drug dispensing. In addition, critically ill patients were to be transported to special care facilities. Special attention was placed on station queues and the bottlenecking tendencies of each in reference to available resources such as medical staff. It was concluded discrete event simulation modeling is indeed a useful tool to aid in preparedness measures such as predicting staffing needs for medical distribution sites for a multitude of emergency scenarios. Their simulation model flow can be found below in Figure 2.
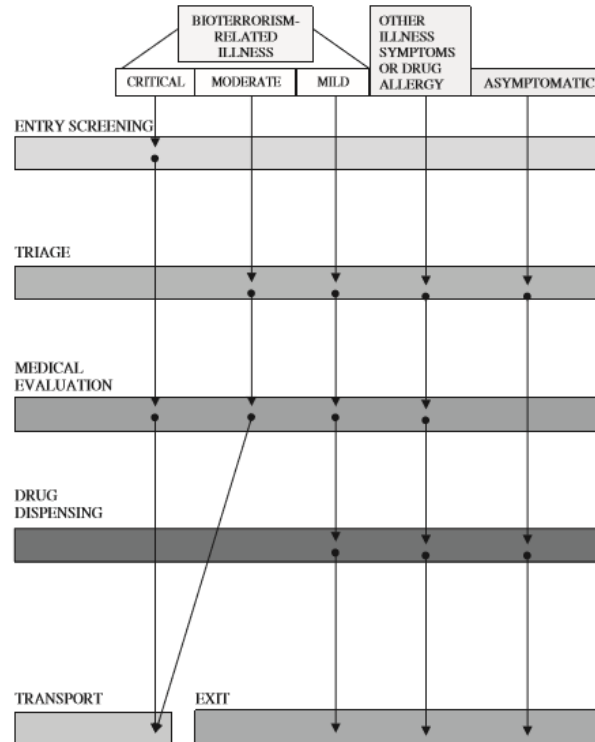
Figure 2. Antibiotic Distribution Center Patient Flow Diagram [11]

Further inquiry into mass distribution was taken by Lee, Chen, Pietz, and Benecke (2009) with their development and implementation of an emergency-response decision-support tool known as RealOpt [13]. Their analysis discussed the requirements and complexity of mass dispensing of medical countermeasures, such as the Strategic National Stockpile, in times of duress. Focus was placed on methodology implemented to construct a tool coupling simulation and optimization processes to determine locations for points of distributions (PODs), design their floorplans, determine their required labor resources, and conduct other statistical analyses based on the POD's simulated results. RealOpt has been distributed to "more than 1,000 public-health and emergency coordinators from tribal, local, state, and federal public-health departments, including the CDC and RAND Corporation" since 2003 to determine POD

layout and staffing needs [13]. A representation of their simulation model may be found below in Figure 3:
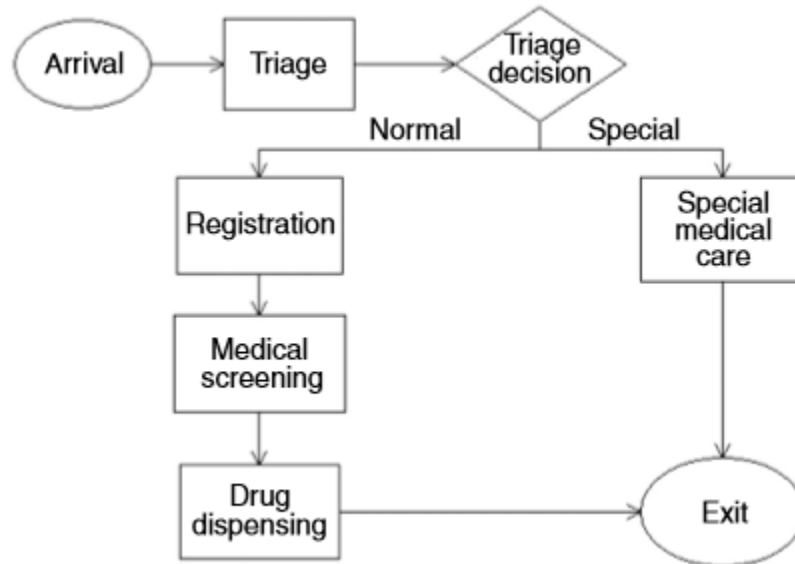
Figure 3. Anthrax Antibiotics Dispensing Flowchart [13]

Aaby, Herrmann, Jordan, Treadwell, and Wood (2006) developed and implemented Arena software to model a point of distribution of antibiotics in case of a medical emergency [1]. This model was validated with results pulled from the Montgomery County, Maryland mass-dispensing and vaccination exercise simulation conducted on June 21st, 2004. Authors approached the situation with a worst-case scenario in mind: a lethal virus such as smallpox is released into the general population, causing every person in the affected area to require a vaccination. To make simulation software more accessible to public health officials, the authors developed capacity-planning and queueing models using spreadsheet software which is commonly available. Authors also proposed clinic layouts and operational guidelines based on

general queuing principles and their simulation experiences. Their model layout may be found

below in Figure 4:
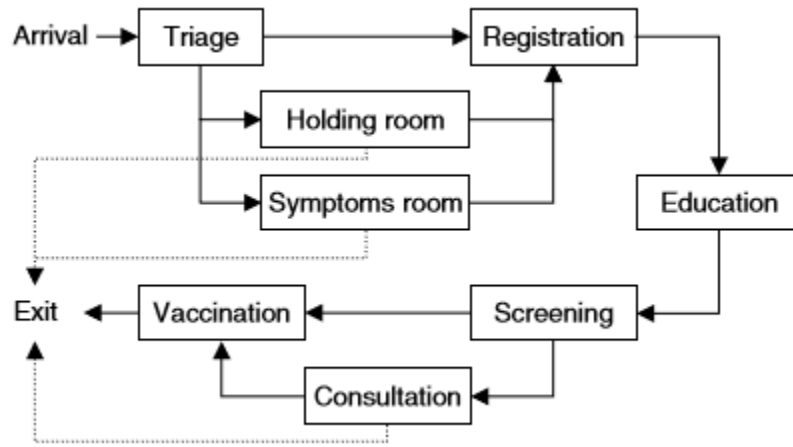
Figure 4. Patient Flow through the Point of Distribution [1]

Giovachino, Calhoun, Carey, Coleman, Gonzalez, Hardeman, and Mccue (2005) utilized a

Strategic National Stockpile exercise on the District of Columbia Department of Health on

October 4th, 2003 to maximize the throughput of the state's dispensing plan and find ways to

better the quality of their dispensing procedures [9]. Authors focused on "treating" citizens

who had been victimized by Yersinia pestis (bacteria that causes plague), considered to be only

a portion of the population represented in the exercise. Resource utilization and

minimalization of dispensing errors were the author's main concerns. The model addressed

decisions and assumptions made regarding the number of stations/processes within the

dispensing center, the number of personnel stationed at each process, and the number of mock

patients assigned with fictional identities chosen to exhibit symptoms of Yersinia pestis. After a

collection of exercise data, Microsoft Excel and its Visual Basic Programming package were

utilized to develop a queuing model simulating the point of distribution. Once validated,

authors utilized this model to recommend changes to the District of Columbia's dispensing plan. Recommendations were aimed to increase throughput of persons per minute through the dispensing center. A visual representation of their model may be found below in Figure 5:
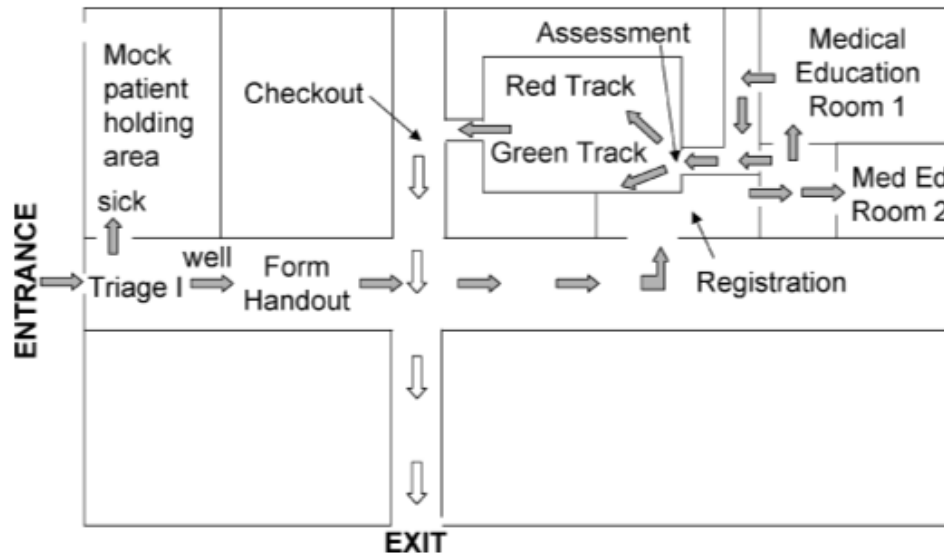
Figure 5. Site Layout of a Point of Distribution [9]

When analyzing the numerous studies completed over medical countermeasures in public health emergencies and comparing them to this research, both similarities and differences were identified. In congruence to this work, most studies simulated the mass dispensing operations within PODs, some even focusing on maximizing population throughput and appropriate resource allocation as are the metrics for this research. In contrast, many of these studies are focused on the design, layout, or process of each point of distribution that might serve the population more efficiently. This research, in comparison, focuses on the application of home health agency methods to the distribution of medicine. Additionally, there are differentiations in model constructions between this research and those housed in the

literature review (as seen in Figures 2 – 5). Many models contained separate tracks or paths

through the point of distribution based on severity of illness or treatment requirements, though

an assumption in this research concerns the equality of patient illness levels thereby including

only one path through the point of distribution. Additionally, other models include additional

steps in the distribution process such as education or screening, while the model in this

research is primarily focused on dispensing.

Methods:

<u>Overview</u>

In achieving the desired objectives for this research, an overview was constructed

outlining the deliverables required to analyze the effects of utilizing home health agencies in

public health emergencies:

1. Replicate the current state of PODs without the use of home health agencies

2. Identify the processes required of home health agencies in medical emergencies

    a. Establish the requirements and effects of the in-home demands faced by

        home health nurses distributing SNS supplies

    b. Establish the requirements and effects of the in-transit demands faced by

        home health nurses distributing SNS supplies

3. Analyze the impact of a proposed model incorporating in-home and in-transit pieces

    of home health on the current model

Models inclusive and exclusive of home health agency effects are analyzed respectively based on population of the general public served (throughput) as well as personnel shortages for complete population service (minimizing resource allocation).

<u>Replicating the Current State of a Point of Distribution</u>

As is standard for a state's SNS distribution plan, each POD consists of four stations: greeting, registration, dispensing, and form collection. Patients enter the system by first being greeted at the initial station and funneled into a registration station where they are required to fill out the appropriate medical forms to receive treatment. Though non-medical staff is permissible to man the greeting station, registered nurses are required to approve and sign the paperwork that must be completed in the registration station. This resource restriction generally results in a queue for registration, which after completion leads to an additional queue for the third station of the POD: dispensing. This station is operated by medical personnel that are qualified to vaccinate patients and authorized to handle the SNS supplies, each with enough space and equipment to distribute the drugs to a constant flow of patients. After receiving the vaccination, patients pass through to the form collection station. As the final event in the system, form collection workers consist of non-medical personnel responsible for approving and filing the final medical paperwork for the patient. To create a replica of the system to be simulated, users must first construct a model reflecting the flow of patients through the point of distribution. A graphical representation of the flow of a point of distribution may be found in Figure 6 below:
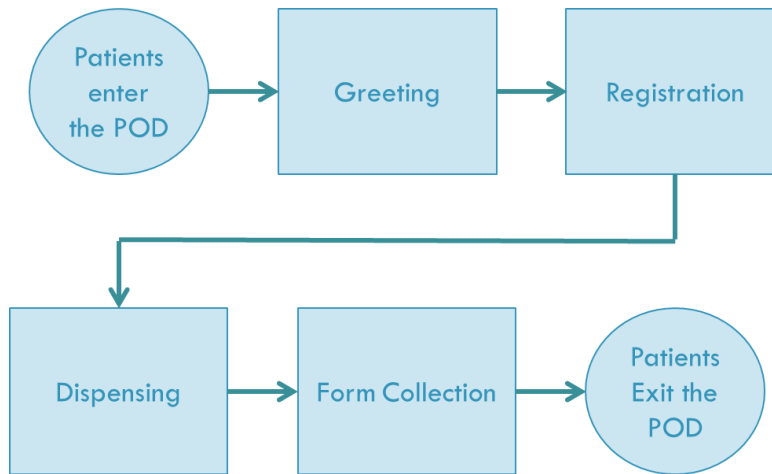
Figure 6: Process Flow of a SNS Point of Distribution

To fulfill state requirements regarding plans for the distribution of the Strategic National Stockpile, a partner in the public health community simulated its state's current model via a POD simulation support tool known as RealOpt. This software package enables decision makers to analyze "various decision support capabilities for modeling and optimizing the public health infrastructure for all hazard emergency response" [14]. The public health partner utilized an offshoot of the program, RealOpt-POD, to prepare a real-time resource allocation in congruence to the medical facilities available with its state. This specific branch of the RealOpt software "couples large-scale simulation and fast optimization routines into one decision support system" by "determining optimal labor resources required" to "maximize the number of individuals who can be treated and minimize the average time spent in the clinic" [14]. With appropriate inputs to the system, including a patient interarrival rate as well as resource levels and service times for a single shift of a point of distribution, RealOpt users are able to simulate an influx of patients needing to receive treatment in an event of a widespread vaccination.

For the purpose of this research, RealOpt software was utilized to construct a simulation reflecting the state of a POD for a particular case study area, aligning with the plans laid out in its states' emergency preparedness plan. A model of the system was constructed in the software, found in Figure 7 below. Each station was attributed a service time and a resource allocation (as seen in Table 1 below) as standards designated for normal points of distribution. Other model parameters pre-set by the department may be found in Table 2 below. Note the arrival rate to the system is uniform.
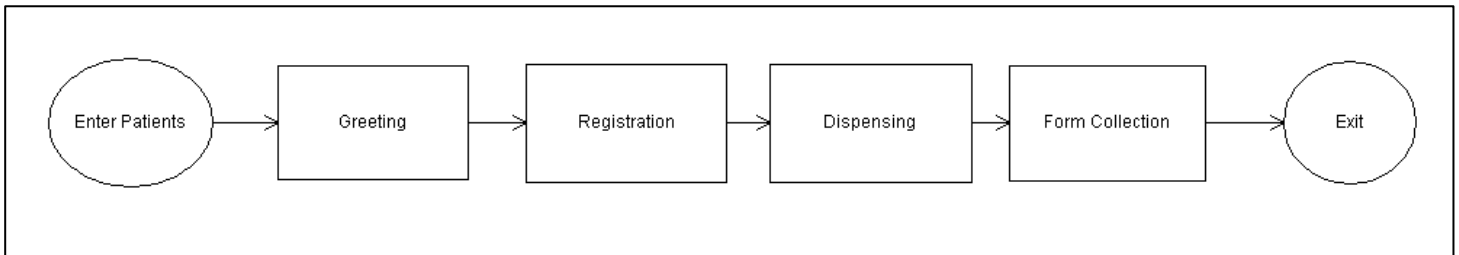

Figure 7: RealOpt Model of a POD

Table 1: Service Times and Resource Assignability for Each Station

Name	Service Time (sec)	Resource Assignability
Greeting	TRIA(5,10,15)	Non-Medical
Registration	TRIA(60,120,180)	Medical and Non-Medical
Dispensing	TRIA(60,120,180)	Medical
Form Collection	TRIA(3,5,10)	Non-Medical

Table 2: Simulation Parameters

Simulation Model Inputs	
Resource Availabilities	32 medical, 36 non-medical
Simulation Time	12 hours
Number of Shifts	2
Arrival Rate	Uniform
Maximum Operation Time After Simulation Completion Time	1 hour
Maximum Average Flow Time	8 minutes
Maximum Average Waiting at Any Service Station	2 minutes
Fatigue Factor	1 reserves per 10 assigned workers

RealOpt software has the potential to be utilized in two major analyses for effective points of distribution: maximizing throughput and minimizing resource allocation. These two functions are independent of one another, each yielding separate outputs aligned with their respective purposes. In its first functionality, RealOpt software has the ability (in the case of maximizing throughput) to statistically approximate the population served based on the parameters previously stated above. With these parameters, users may determine the largest number of patients which may be treated subject to a fixed number of personnel predetermined by system constraints. In its second functionality of minimizing resource allocation, users must additionally provide the minimum required total throughput per POD per shift. This additional input represents the target throughput of (or the population to be served by) the point of distribution. In providing this information, RealOpt allows for the determination of the number of personnel (and their allocation to the stations) required to achieve 100% throughput of patient population, repurposing previously required resource availabilities from Table 2 a suggestion rather than a system constraint. The minimum required total throughput for one POD in the case study area per shift is 23,761 patients.

Identifying the Processes Required of Home Health Agencies

In considering the use of home health agencies to ease the constraints on an open POD in the case study area, the requirements of a HHA nurse must be analyzed and replicated. In the case of an emergency situation, any one nurse from a registered case study area Home Health Agency may begin his or her day at the Home Health Agency's central office to pick up supplies for their assigned patients. After this initial stop, a nurse will begin a route consisting of patient homes acting as nodes, the amount of which is dependent on the home health agency. Such a route is similar to a traveling salesman problem in which the goal is to find the shortest route to visit a set of locations [23], and will be treated as such in the in-transit portion of the analysis. After completing this route, a nurse will return to the central office to drop off remaining medicinal supplies. See Figure 8 for a visual representation of this system description:
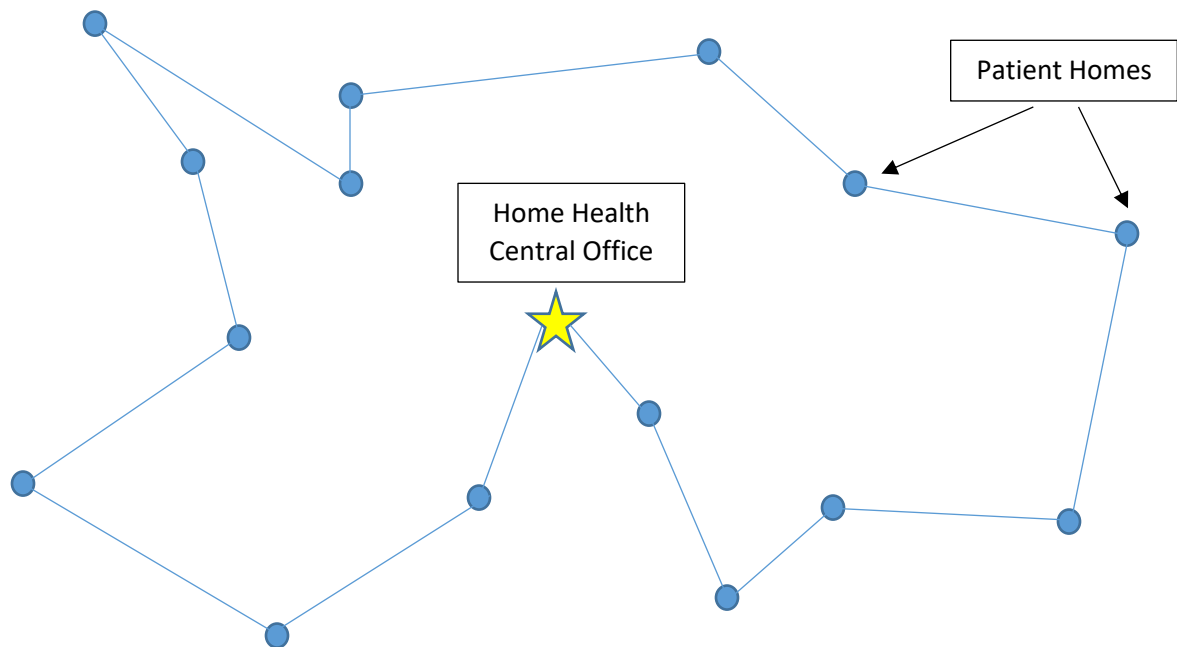

Figure 8. Example Route for a Single Home Health Agency Nurse

The responsibilities of a home health nurse may be broken down into two portions: in-home and in-transit. Note that due to the unprecedented nature of this research, expert advice, literature estimates, and simulated exercises were sought to determine the detailed responsibilities of each portion. In-home requirements of a HHA nurse in the distribution of SNS supplies encompass the actions completed by the nurse from the moment they enter a patient's driveway until they exit the patient's place of residence. In contrast, the in-transit portion of the HHA nurse's responsibilities include the time it takes to travel to a patient's house from his or her previous location.

In-Home Requirements

When nurses enter a home purposed with administering drugs in a public health emergency, there are certain precautions which must be taken to ensure all medicine is distributed responsibly. Due to the novelty of utilizing home health agencies for emergency readiness, a series of eight steps outlining the actions of nurses administering SNS supplies in a patient's home was constructed based on information provided by nursing faculty of the University of Arkansas Eleanor Mann School of Nursing led by Dr. Charleen McNeill. Each of these steps were replicated in time studies completed by University of Arkansas nursing students to gather per-patient estimates of each step in the in-home portion. After ridding the data set of any significant outliers (outside three standard deviations from the mean), input analyzer was employed to quantify a triangular distribution encompassing duration of these actions and can be referenced in Table 5. KS and Chi-Squared p-values showing the significance of each triangular distribution for its respective data sets were also included, demonstrating that a triangular fit is appropriate for steps 1 through 6. Though steps 7 and 8 did not result in

significant p-values for the triangular distribution, no other distribution fit showed significant improvement in its p-values, so the triangular distribution was adopted for simplicity.

An assumption of the system includes 2.5 head of household model, indicating that four of the eight steps outlined by nursing faculty must be replicated 2.5 times on average per household visited. Specifically, introduction to client, client education, pulling medication, and dispensing drugs must be completed by the nurse for every member of the patient's family that is receiving treatment at the time of dispensing. To better encompass a more appropriate estimation of average household size, this value was assigned a triangular distribution with a minimum of 1, a most likely value of 2.5, and a maximum of 10 persons per household. This distribution reflects the number of people per patients' household under the assumption every house has a minimum of 1 person and a maximum of 10 people receiving treatment, with a most likely value of 2.5 persons. A summary of all in-home distribution steps, their durations, associated p-values, and number of replications per home may be found in Table 3 below:

Table 3: In-Home Steps of Medicinal Distribution

Steps	Duration Distribution (sec)	KS P-Value	Chi-Squared P-Value	Number of Times Performed Per Home
1. Park and Enter	105	-	-	1
2. Organize Supplies	TRIA(14,15.9,29)	> 0.15	0.504	1
3. Gather Supplies	TRIA(14,27.5,32)	> 0.15	0.184	1
4. Intro to Client	TRIA(10,17.9,29)	> 0.15	0.334	TRIA(1,2.5,10)
5. Client Education	TRIA(15,25.1,44)	> 0.15	0.521	TRIA(1,2.5,10)
6. Pull Medication	TRIA(47,61,103)	> 0.15	0.447	TRIA(1,2.5,10)
7. Dispense Drug	TRIA(64,92.6,255)	0.0196	< 0.005	TRIA(1,2.5,10)
8. Pack and Exit	TRIA(17,37.3,62)	0.0844	< 0.005	1

With these estimates, Monte Carlo simulation via @Risk Excel software was employed to create an estimate for the entire process. By simulating the individual steps and multiplying their summed time estimate by an additionally simulated household size, @Risk was able to provide a single average value representing the nurse's entire visit to a single arbitrary home on their route. To gain a better approximation of this value, processes were simulated three times each for one hundred replications. Single values may be multiplied by the number of patient homes visited by a particular home health agency nurse to gather the full amount of time spent in patient homes by any single home health agency nurse.

In-Transit Requirements

As stated above, the approach to solving the in-transit portion of a HH nurses' duties focused on its similarities to the traveling salesman problem (TSP). In 1959, Beardwood, Halton, and Hammersley proposed an estimation of the length of a route subject to the number of nodes on the salesman's route and the area covered by that salesman [4]. Equation 1 below contains the route length estimator used to approximate nurse's travels with constant k taken as 0.7214 [5]:

$$Length\ of\ Tour\ through\ N\ Point\ in\ Area\ A = k * \sqrt{NA} \qquad (1)$$

A singular case study area Home Health Agency is assigned specific zip codes in which they can provide service, combining all zip codes to create a total area of service for said agency. Because information detailing the allocation of HHA staffing resources among patients within each agency's total area of service is not available to the public, the service area of a particular HH nurse, *A*, was calculated via two separate methods: optimistic and pessimistic approximations. In the pessimistic version of the system, *m* nurses from a particular home

health agency must serve an equal number of patients that may be located at any point amongst the HHA service region, making the maximum value of *A* equal to the total area of service for a particular home health agency. In the optimistic version of the system, *m* nurses from a particular home health agency serve equal partitions of the total HHA area with an equal number of patients. See Figure 9 for a visual representation of these systems:

For 2 nurses:

each serves area *A* [circle area is 2*A*]

each visits *N* stops [*N*-1 patients + own home]

patient location

HHA service region

[a]

[b]
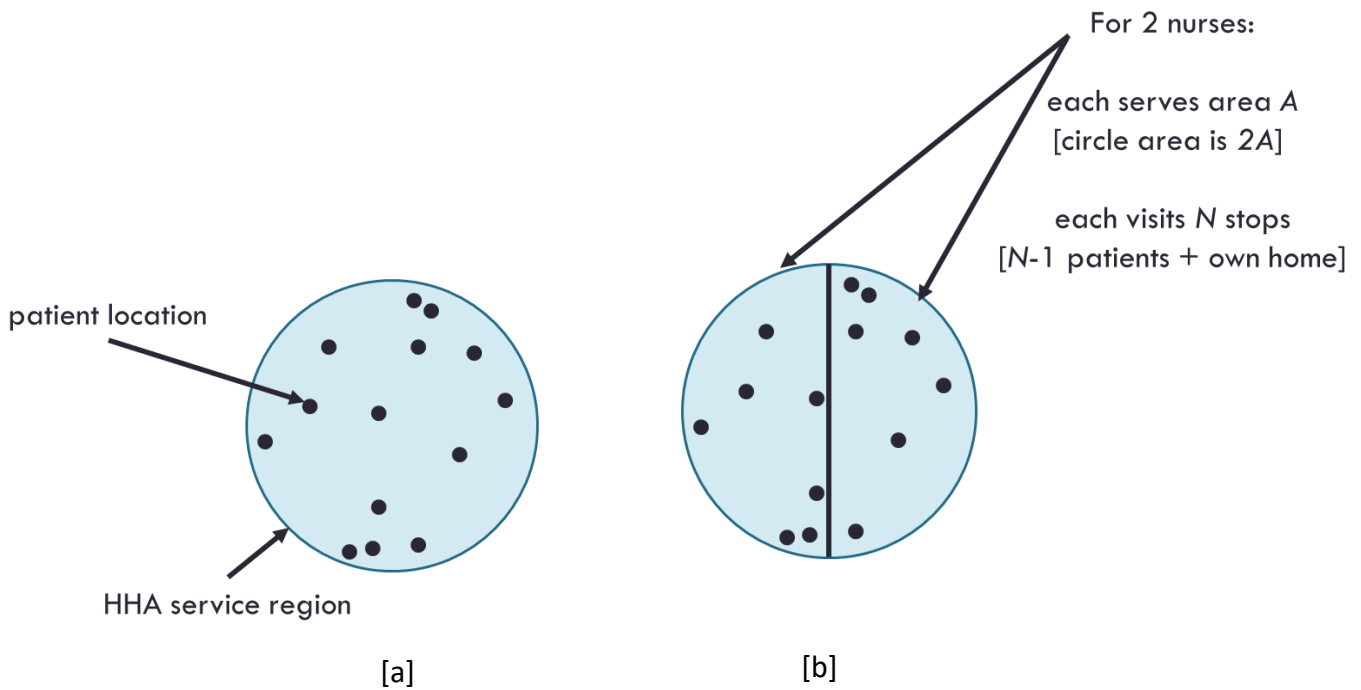
Figure 9. [a] Pessimistic and [b] Optimistic Allocation of Nurse Service Areas, *A*, With *N* stops

To apply this general in-transit knowledge for a particular home health agency, either the optimistic simulated length of route or pessimistic length of route (assuming a 30mph speed average) may be added to the total in-home time calculation of *N* homes on a nurse's tour to find the total optimistic time or total pessimistic time per HHA nurse. This individual time will determine if servicing home health patients with SNS supplies in emergency situations is even feasible for home health agencies in the case study area within a 24-hour time period.

This reasoning will either support or deny the inclusion of home health agencies in open model calculations.

<u>Analyze the Impact of a Proposed Model Incorporating Home Health Agency Support</u>

By validating the feasibility of incorporating home health agencies in a 24-hour period, the number of patients touched by utilizing these resources can be calculated and applied to the open POD model prepared for the case study area. Identifying this patient count requires a calculation encompassing five major home health agencies whose zip codes provide coverage for the case study area. This patient count may be eliminated from the required population throughput to be served by a single POD in the area, thereby increasing the count of patients receiving treatment as well as decreasing the personnel shortage to treat all citizens desiring medical vaccination. Incorporating the original model with slightly altered input parameters will quantify the impact of utilizing home health agencies in emergency situations.

Experimentation and Results:

<u>Current State of a Point of Distribution</u>

As explained in the Methods section of this paper, many of the current state parameters found in Tables 1 and 2 were provided by results obtained by a partner in the public community. In fact, to maximize throughput, all input required for the RealOpt software – such as hours per shift, max extension for completion, max average flow time, max average waiting time, and resources per shift - were previously provided. After simulation completion, average waiting times per event were identified (see Table 4). Flow time was found to be 11 minutes and 21 seconds per patient and actual throughput per shift was found to be 11,221 patients.

Table 4. Results of Maximizing Throughput an Open POD without HHA in RealOpt

Event	Duration Distribution (sec)	Average Wait Time (sec)
Greeting of Patients	TRIA (5, 10, 15)	16
Registration	TRIA (60, 120, 180)	336
Dispensing	TRIA (60, 120, 180)	66
Form Collection	TRIA (3, 5, 10)	4

In contrast, minimizing resources in RealOpt requires the knowledge of the minimum required total throughput per POD per shift. Unlike the previously specified parameters, this value was not provided by the public health partner and was, consequently, left to be calculated by the research team. Therefore, an equation considering the percentage of people desiring treatment (estimated at 90% of the population not already being serviced by closed PODs), the number of major open PODs designated for the area, and the number of shifts per POD distribution was created to establish this patient population for a single POD per shift in the case study area (see Equation 2 below).

$$Demand = \frac{\frac{(Population\ of\ Washington\ County*90\%)-Closed\ POD\ Population}{Number\ of\ Major\ Open\ PODs\ servicing\ case\ study\ area}}{Number\ of\ Shifts\ Per\ POD}$$

$$= \frac{\frac{(220{,}792*90\%)-8{,}628}{4}}{2} = 23{,}761\ people \tag{2}$$

With this population, a simulation of an open POD simulation minimizing resources resulted in average wait time found in Table 5, an average flow time of 7 minutes and 51 seconds per patient, and 512 medical and 80 non-medical required resources per shift.

Table 5. Results of Minimizing Resources in an Open POD without HHA in RealOpt

Event	Duration Distribution (sec)	Average Wait Time (sec)
Greeting of Patients	TRIA (5, 10, 15)	20
Registration	TRIA (60, 120, 180)	146
Dispensing	TRIA (60, 120, 180)	44
Form Collection	TRIA (3, 5, 10)	3

In combining these two analyses, the research team found that without the use of home health agencies, the state's current plan allows 47.22% of the population demand to be served with a personnel shortage (medical and non-medical) of 592 people. These are the measures that will be compared to after the incorporation of home health agencies.

Case Study Application: Five Major Home Health Agencies

To integrate in-home and in-transit experimentation with the case study completed for the case study area, the five major home health agencies must first be identified and assigned attributes relative to the calculations of this section. To uphold anonymity of these HHAs, each was assigned an identifying number from one to five. Each HHA possessed statistical data such as patient count, total number of staff members, total homes to visit, administering nurses, and number of houses per route. Note that both patients and staff will be treated with SNS supplies, so they act as additional "nodes" on an administering nurse's route. Out of all staff members, only a few can administer drugs, so these are the resources that will be utilized to distribute medicine. The number of houses per route is calculated by dividing the total homes to visit by the number of administering nurses and then subtracting one to exclude the household of the administering nurse on route (as to not count that household twice). A summary of these values may be found in Table 6 below:

Table 6. Major Home Health Agencies in the Case Study Area

HHA	Patients	Total Staff	Total Homes to Visit (Patients + Staff)	Administering Nurses	Number of Houses Per Route (N-1)
1	325	28	353	15.5	23
2	300	44.2	344.2	26	14
3	322	33.75	355.75	19	19
4	230	33.5	263.5	18	15
5	430	39.7	469.7	22.1	22

These values provide the N value for Beardwood's formula found in Equation 1.

However, the area covered per nurse, A, requires the optimistic and pessimistic areas to be

calculated per each nurse employed by each HHA under consideration. To find the total service

area of each HHA, the zip codes assigned to each HHA were collected from Medicare's Home

Health Agency data set [2].   From there, the squared area of each zip code was identified via

the 2010 Zip Code Demographic Profile Dataset [6] and then summed to a total service area for

each HHA. Pessimistic areas, A_p, for a single administering nurse was considered equal to the

total service area for a particular HHA. Optimistic areas, A_O, were calculated by dividing the

total service areas of HHAs by the number of their respective administering nurses. See Table 7

for a summary of this information:

Table 7. Area Calculations of Major Home Health Agencies in the Case Study Area

HHA	Area Covered (sq mi)	Pessimistic Area Covered	Optimistic Area Covered
1	2796	2796	180
2	1353	1353	52
3	3887	3887	205
4	2724	2724	151
5	3667	3667	166

In-Home Home Health Agency Calculations

In simulating the in-home estimation provided by the University of Arkansas nursing students, average times per task were estimated and shown in Table 8 below:

Table 8. In-Home Time Estimates Per Step

Steps	Duration Distribution (sec)	Avg. Time/Patient (sec)	Avg. Time/Home (sec)
1. Park and Enter	-	105	105
2. Organize Supplies	TRIA(14,15.9,29)	19.6	19.6
3. Gather Supplies	TRIA(14,27.5,32)	24.5	24.5
4. Intro to Client	TRIA(10,17.9,29)	12.3	85.7
5. Client Education	TRIA(15,25.1,44)	29.9	125.5
6. Pull Medication	TRIA(47,61,103)	66.8	317.7
7. Dispense Drug	TRIA(64,92.6,255)	137.9	620.6
8. Pack and Exit	TRIA(17,37.3,62)	38.8	38.8

These estimates result in an average of 1,337 seconds per patient house, or 22 minutes on average. The simulated values were then multiplied by the number of houses on a single nurses' tour for each HHA to find the average times spent on the in-home portion of the calculations. See Table 9 for a summary of these values:

Table 9. Simulated In-Home Time Per Nurse Per Home Health Agency

HHA	Average Times In-Home (hrs)
1	8.5
2	5.1
3	7.1
4	5.6
5	8.2

In-Transit Home Health Agency Calculations

In simulating the in-transit estimations optimistic and pessimistic route lengths for each major HHA in the case study area, Beardwood's formula in Equation 1 was utilized as demonstrated in Table 10 below. Note that *N* is used to incorporate the beginning and end point of a nurse's route). This table also consists of the optimistic and pessimistic transit times for each nurse, calculated by multiplying distance by an assumed 30mph average speed.

Table 10. Transit Times Per Nurse Per HHA

HHA	Optimistic Area, A_O	Pessimistic Area, A_p	N (homes visited + 1)	Optimistic Miles Driven Per Nurse	Pessimistic Miles Driven Per Nurse	Optimistic Time in Transit Per Nurse (hrs)	Pessimistic Time in Transit Per Nurse (hrs)
1	180	2796	24	47.5	186.9	1.6	6.2
2	52	1353	15	20.2	102.8	0.7	3.4
3	205	3887	20	46.1	201.1	1.5	6.7
4	151	2724	16	35.5	150.6	1.2	5.0
5	166	3667	23	44.6	209.5	1.5	7.0

Combining In-Home and In-Transit Home Health Agency Calculations

To find the total time commitments of each HHA in optimistic and pessimistic scenarios, the in-home and the in-transit portions of the research were summed and can be found in Table 11 below:

Table 11. Total Average Times Per Nurse Per Home Health Agency

HHA	Average Time In-Home (hrs)	Optimistic Time in Transit (hrs)	Pessimistic Time in Transit (hrs)	Optimistic Total Time, on Avg. (hrs)	Pessimistic Total Time on Avg. (hrs)
1	8.5	1.6	6.2	10.1	14.7
2	5.1	0.7	3.4	5.8	8.5
3	7.1	1.5	6.7	8.6	13.8
4	5.6	1.2	5.0	6.8	10.6
5	8.2	1.5	7.0	9.7	15.2

Incorporating HHAs into Open POD Simulation

To identify the impact of including home health agencies in emergency situations, the total amount people served by the five major HHAs was calculated from the patients and staff counts from Table 8 and is calculated in Equation 3:

$$Total\ People\ Served = (Patients + Total\ Staff) * 2.5\ household\ model \qquad (3)$$

$$= (1607 + 179) * 2.5 = 4,466\ people$$

To calculate the effects of the total population served by home health agencies, the open POD model was simulated again by keeping all other parameter static while subtracting 4,466 people from the service population and the throughput requirements. With the inclusion of HHAs, the proposed distribution plan allows 49.60% of the population demand to be served with a personnel shortage (medical and non-medical) of 576 people.

Conclusions and Future Research:

According to the results of this study, it can be concluded that in an optimistic situation, utilizing home health agency nurses to dispense SNS supplies to families of their staff and patient members is feasible for 100% of the case study HHAs in 12 hours. In a pessimistic situation, this statistic is lowered to 40%. This significant increase in total service times per nurse is attributed to the service areas assigned to each nurse. When the range of service widens to encompass the entirety of the HHA's service area, in-transit times per nurse increase dramatically per nurse, as the time required of the in-home portion of the nurses'

responsibilities will remain relatively static among average households. Demonstrations of these results are displayed graphically in Figures 10a and 10b below:
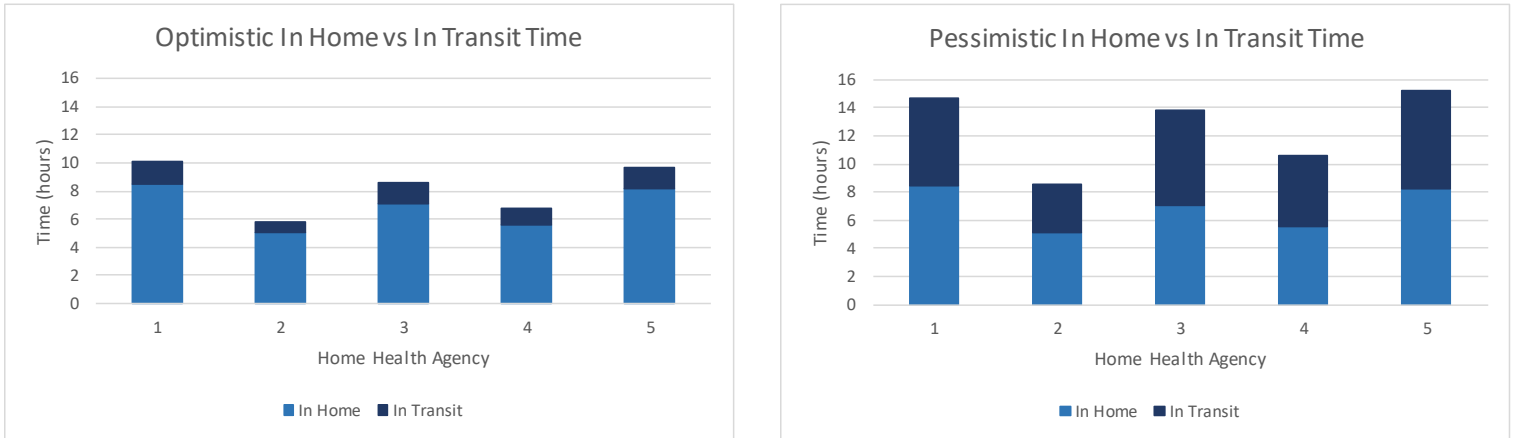

Figure 10. [a] Optimistic and [b] Pessimistic In-Home and In-Transit Times

To ensure the success of home health agency nurses within a normal shift time of 12 hours, collaboration between home health agencies within the specified service area should be pursued ahead of time. In fact, a recommended extension of this research concerns the optimization of this service area designation such that specific areas may be assigned to individual nurses as a part of the emergency preparation plan. In optimizing these service areas ahead of time, the in-transit times associated with each nurse may in turn be approximated, and nurses with completed routes may be reallocated as resources for the case study area's open PODs for the duration of their shifts, allowing for increased access to service for the population.

As mentioned earlier, two metrics were considered when determining the direct impact of this research on the area's emergency preparedness: population demand to be served and personnel shortage. By including home health agencies in the distribution of SNS supplies in

emergency situations, the population served increases by 2.4% from 47.2% to 49.6% and the

personnel shortage (both medical and non-medical) decreases by 16 people from 592 to 576.

An additional asset of this inclusion involves increasing access to medical aid for the vulnerable,

homebound population of the area in question. Therefore, it must be concluded that an

inclusion of home health agencies in the emergency preparedness of the state has the potential

to positively impact the effectiveness of its plan in times of emergency.

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