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COVID-19 Vaccination Clinic Success: An Interdisciplinary Application of Simulation and Modeling

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This paper shares a case study of a rapid cycle of process improvement, physical simulation, and simulation software development to stand up a mass COVID-19 vaccination site. The resulting standard work, clinic setup and simulation software tool were designed and implemented by an interdisciplinary team at a moderate size not-for-profit health system. This unique example of a simulation and modeling implementation led to a high throughput vaccination clinic with an outstanding patient experience.

Healthcare delivery presents many opportunities for real-time data to support rapid decision making, but the COVID-19 pandemic placed unparalleled pressure on health systems in the United States to make decisions with limited information. Safe, efficient, and high quality COVID-19 vaccination delivery presented our health system a unique challenge that we addressed with an interdisciplinary approach to design our mass vaccination clinic.

SIMULATION MODELING IN HEALTHCARE

Simulation modeling has been used for decades in healthcare to evaluate the efficiency of existing workflows and to innovate novel approaches to delivering care (Fone et al., 2003; Jacobson et al., 2006; Katsaliaki & Mustafee, 2011; Mohammadi et al., 2018; Turkcan et al., 2014). Despite a significant base of literature extolling the benefit of simulation modeling in healthcare (Salleh et al., 2017), its practical application is not routine practice, particularly in non-academic healthcare systems. In fact, few published works have documented actual implementation in the healthcare systems where simulation models were developed. Katsaliaki and Mustafee (2011) reported that only 11 out of 201 and Mohiuddin et al. (2017) found only three of 21 studies were implemented in the real-world. This was not the case for this project where we leveraged process improvement, simulation, and modeling to rapidly launch a COVID-19 vaccination clinic.

VACCINE CLINIC PROJECT

The COVID-19 pandemic has brought about one of the most pressing mass vaccination initiatives confronted in modern history. To decrease the effect of the virus on hospitalizations, lasting physical sequela, loss of jobs and mortality, a massive segment of the population must be vaccinated in a limited amount of time. Mass vaccination efforts have been used for over 200 years to rapidly increase population immunity, but there remain many challenges to quick and effective delivery of vaccines (Heymann & Aylward, 2006). As a primary mass vaccination site, we had to overcome these challenges and established three goals 1) maximize vaccine distribution with zero waste, 2) provide every clinic patient an excellent experience, and 3) maintain an excellent work environment for every staff member. To achieve these goals, we analyzed not only the work of our clinic volunteers but also the work performed by our patients visiting the clinic to build a patient-centered physical environment and realistic digital simulation tools (Cornet et al., 2019; Holden et al., 2013; Holden et al., 2020).

PHYSICAL SIMULATION

The development of the vaccine clinic was predicated on the delivery of 1000 shots in an 8-hour day. To achieve this target, along with the goal of providing an excellent patient experience with no lines or bottlenecks, we needed to get one patient in and one patient out of the clinic every 28.8 seconds.

The project kicked off with a two-day pre-simulation event to build standard work using value stream mapping, a Lean manufacturing technique. This required considering all the necessary roles, information, supplies, and processes for the vaccine clinic. Existing flu vaccine clinic standard work documents, door screening procedures for COVID-19, hospital registration requirements and COVID-19 vaccination guidelines from the Indiana State Department of Health were gathered and a team of key stakeholders from 12 departments was formed including: pharmacy, mass flu vaccine clinic,

Figure 1. Physical setup of the COVID-19 clinic.

Input	Sample values
General	
Shots available for the day	1,000 shots
Daily hours of operation	8 hours
Percentage of registered patients	80%
Patient Walk Times	
From screening to registration	80 seconds
From registration to vaccination	20 seconds
From vaccination to holding area	30 seconds
Staffing Numbers	
Screeners	3 people
Registration	10 people
Vaccinators	10 people
Task Times	
Screening	60 seconds
Registering pre-registered patients	3 minutes
Registering walk-ins	10 minutes
Vaccinating	3 minutes
Other values	
Seats in holding area	30 seats
Number of sections in holding area	4 sections

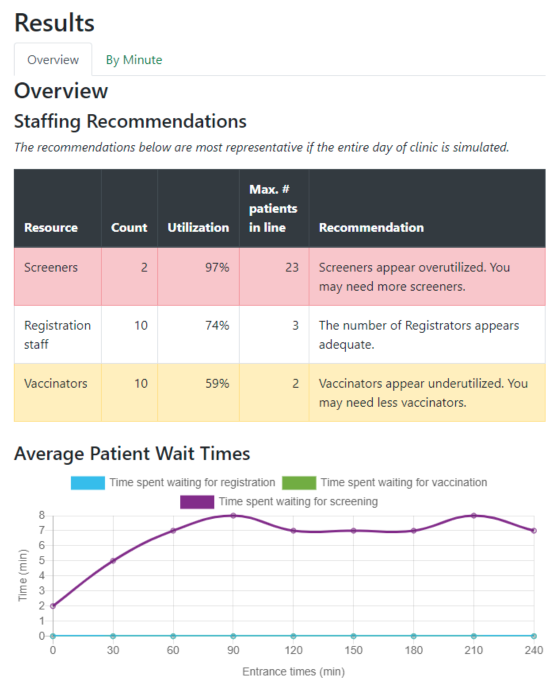

Figure 2. Simulation Model Input and Output Examples

registration, nursing informatics, information services, supply chain, environmental services, emergency medical service, continuous improvement, finance, innovation, and quality assurance. Additionally, a healthcare provider, hospital screener, event manager, and hospital registration specialist provided expert feedback.

The value stream mapping exercise afforded a definition of new standard work, roles, and responsibilities which were then used to create a physical simulation. The physical simulations were "staged rehearsals" with over 50 volunteers acting as mock patients and were utilized to collect average task and walk times between service touchpoints for a variety of scenarios. At the end of the simulation event, stakeholders were provided standard work for nine roles, process times for each area, and a functional physical clinic setup (Figure 1).

DIGITAL SIMULATION

The standard of work documents and on-site rehearsal sessions were utilized to collect key data feeding into a custom web-based simulation software built with programming language Dart. The COVID-19 vaccination clinic simulation tool (simulator) allows vaccination clinic managers to predict flows of patients going through the clinic on a given day based on various inputs (Figure 2), such as task times, walking times, supplies, and staffing numbers. The simulator models the action and movements of each individual patient and staff member throughout the hours of operation of the clinic, with a one-second granularity. The simulator distributes patients throughout the day in 15-minute "blocks" of time; to account for real-world "messiness," the software randomly simulates patients arriving a little earlier or slightly past their appointment time.

Once all the inputs are entered, the simulator computes and then displays an overview of staff utilization; the average patient wait times at registration, vaccination, and screening; and the average time it takes a patient from point of entry to exiting the clinic. This overview screen facilitates the quick identification of any major problem with the inputs, such as too many vaccinators leading in an underutilization of vaccinators, as seen in Figure 2. The simulator also allows the operator to view minute-by-minute visualizations of the lines forming in front of the different stations, the occupancy of the holding area, and the number of supplies left at each station before replenishing. The simulator was made public and is available at https://hsir.parkview.com/covidvaccine/.

CLINIC SUCCESS

In addition to finding light in the darkness of the pandemic, our health system also realized the power of combining Lean methods, simulation, and modeling that has been revealed in the literature (Ahmed et al., 2020; Antony et al., 2019). While simulation models of healthcare operations have been developed for decades (Salleh et al., 2017), including mass vaccination (Asgary et al., 2020; Wiggers et al., 2011), these models are often developed without stakeholder engagement and are rarely operationalized (Katsaliaki & Mustafee, 2011; Mohiuddin et al., 2017; Salleh et al., 2017). Trust between health system leaders and the simulation developer is an important element in successful implementation (Harper et al., 2021) and proved to be essential. Our interdisciplinary team worked closely with over

20 departments and applied process improvement and simulation techniques to build a digital model that continues to be used operationally to adapt clinic workflow to changes in patient population, vaccine delivery, and volunteer availability. With refinements projected by the model, the clinic exceeded the original target and can deliver 1300 vaccines in an 8-hour day. Most importantly, we have brought comfort to our community as depicted in this quote *"Many things in society are negative. Problems abound. However, the recent COVID-19 vaccine site for the elderly at Parkview's Mirro Center was an example of how things can be done well."* (McHugh, 2021).

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