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A Data-Driven Paradigm for Community-Based Outpatient Clinic Design and Decision-Making for the Department of Veterans Affairs

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Abstract: The healthcare field is undergoing transformative technological change outpacing decision makers. The Veterans Health Administration (VHA) operates a vast network of over 1,300 healthcare facilities, including Community Based Outpatient Clinics (CBOCs), aimed at providing exceptional care to 9.8 million enrolled veterans. As demands for services increase, optimizing facility layouts becomes imperative. This research explores the integration of advanced simulation and data-driven tools into the decision-making process for CBOC facility design within the VHA. By incorporating generative simulation tools such as ProModel, the VHA can model patient flow dynamics, resource utilization, and appointment scheduling, enabling evidence-based decision-making for facility design. Simulation methodologies, particularly ProModel, offer a robust framework to evaluate CBOC layouts dynamically. Through scenario analysis and optimization, stakeholders can identify bottlenecks, optimize workflows, and enhance overall operational efficiency. The research proposes leveraging ProModel to simulate and compare different CBOC models (One-PACT, Two-PACT, Three-PACT) to inform construction decisions effectively.

Keywords: Generative Design, Community-Based Outpatient Clinics (CBOCs), Discrete Event Simulation

1. Introduction

1.1 Background

Healthcare infrastructure and facility layouts hold a pivotal role in the overall well-being of physicians, patients, and their communities. At $2.8 trillion annually, healthcare represents just less than one fifth of the United States economic landscape. Annually, billions of dollars improve health care facilities emphasizing the imperative to allocate these funds intentionally and with informed decisions. Farouq Halawa, Senior Research Scientist of optimization, simulation, and health systems, brought to light how these designs are uniquely, simultaneously accountable to, “quadruple aims of enhancing patient experience, improving population health, reducing costs, and improving staff work life.” In reverence to this scene, an adaptive, forward-thinking approach is necessary in pulling together the evolutionary technological opportunities with hospital infrastructure. In tandem with intuitive decision making, generative simulation tools and methodologies are redefining the essence of hospital design and facility layout. The VA Asset and Infrastructure Review (AIR) Commission, conducted in 2021, outlines the updated priorities of the VA (Department of Veteran’s Affairs, 2021). These priorities include addressing risks inherent to veteran migration and environmental factors which could influence capital investment and divestment criteria. Additionally, it does not account for infrastructure capacity imbalances in relation to veteran migration. The Veterans Health Administration (VHA), the healthcare arm of the VA is the largest healthcare network in the United States (US) (Veteran’s Health Administration, 2022). The VHA is exploring generative design decision tools for making effective infrastructure investment and divestment decisions in the face of dynamic veteran migration patterns and environmental threats. As part of these efforts, facilities standardization handbooks are guiding generative technologies. While the analysis of alternatives provided by generative AI models can speed up the process, they stand to benefit from basic discrete event simulation approaches which measure site adapted efficacy of newly designed facilities, and that is the focus of this research paper.

1.2 Literature Review

The Veterans Health Administrations (VHA) is the leading integrated healthcare system nationally, operating in over 1,300 health care facilities derived of over 170 medical centers and over 1,130 outpatient sites (VA, 2024). In 1995, the VHA initiated the transition from inpatient care to outpatient care. This shift aimed to increase preventative care and early disease intervention for veterans by improving access to primary care (EBSCO, 2004) (VA, 2024). From this, Community Based Outpatient Clinics (CBOC) developed, enabling veterans living significant distances from VA hospitals to access primary care. Of the 16.5 million living veterans in the United States, the VHA currently serves 9.8 million and the number of enrolled veterans continue to increase (VA, 2024).

The priority of the Department of Veterans Affairs is "to care for those who shall have borne the battle and for their families, caregivers, and survivors." Their core values include focusing their, "minds on [the] mission of caring and thereby guide [their] actions toward service to others (VA. Gov, 2023)." Nested in this calling, the VHA's mission statement summarizes their aim to provide, "exceptional health care that improves [veterans] health and well-being (VA. Gov, 2023)." The focus of the VA and VHA's organization at large lies in prioritizing the well-being of patients, the families of patients, their staff, and the broader community at large (VA Performance Data, 2024).

Healthcare expenditure and the continuation and coordination of care for veterans through the VHA expects to surge in the coming decades. Of the veteran population, 49% are 65 years and older with one in four being above 70 years old and one in five above 50. The anticipation of an aging baby boomer population, broader health care coverage, and the full implementation of the Affordability Care Act produce an ever-needing patient population for healthcare at large (Vespa, 2021). The unique needs of the VHA's veteran patient clientele meet at the complex intersection of age-related illnesses, military service, and social barriers. These concepts only begin to underscore the escalating demand for expanding CBOC medical service capacity and optimizing operational utilization in their systems.

In accordance with the mission statements of the VA and VHA, it is crucial to prioritize the optimization of the healthcare operational systems within their Community-Based Outpatient Clinics (CBOCs) through a comprehensive array of means. This call to action encompasses aspects such as hospital facility and infrastructure design. In 2008, cognitive psychologists found there to be a significant impact on the safety and performance of both patients and physicians alike. Evidence from a review of 600 articles supports this conclusion identifying the strong correlation between the physical environment of healthcare settings and the outcome for all users (Reiling et al., 2008). A decrease in number of adverse events, an increase in healthcare quality for patients, an increase in effective care from physicians, and a reduction of stress and fatigue of physicians serve as a few of many evidential examples of the results stemming from a proper hospital facility layout (Ibid., 2008). A well-designed facility layout will provide assurance of adequate workflow efficiency.

Current facility design initiatives, prevalent in both the broader medical field and specifically within the Veterans Health Administration, are retrospective in nature. Designers continue to make decisions using stakeholder's intuitive input found from, "observations, surveys, post-occupancy studies," or, "space syntax analysis" (PubMed, 2021). There is a gap in utilizing quantitative evidence found from, "layout optimization frameworks, healthcare layout modeling, applications of artificial intelligence, and layout robustness" (Ibid., 2021). In healthcare facility design, there exists an underutilization of these data driven tools in informed decision-making. This deficiency presents a potential risk in the wake of a financially and health-oriented demanding field.

Furthermore, in designing the CBOC facility layout, there is an opportunity integrate the concepts of data-driven decision-making with the VHA's mission of providing exceptional care to patients and creating a successful workspace for physicians. Recognizing the facility layout is an integral part of creating environments that optimize patient outcomes and enhance the overall healthcare experience for veterans, their families, and communities, affirms the call to strengthen the design processes as much as possible.

The VA currently has standardized design objectives for CBOC layouts. These objectives answer to a variety of clinical activities, staffing, and operational needs adaptable to future demands. Specific to CBOC design, the VA aims, "to develop highly functional and efficient outpatient clinics" fiscally efficient to "reduce cost and overall project schedule" (CFM VA, 2024). The VA's current aim with CBOC design include the following three constraints:

1. Develop standard design for various functional areas within outpatient clinics, referred to herein as 'design modules.
2. Develop standard designs for three outpatient clinics of graduating size using the design modules. Projects representing multiple VISNs will be identified by VA prior to award of this task. Building areas will be approximately 20,000 NUSF, 50,000 NUSF, and 80,000 NUSF.
3. Ensure that standard designs enable and promote off-site construction methods such as volumetric "modular" construction, panelized construction, etc." (Ibid.,2024).

A project team, comprised of "VA subject matter experts, VA program officials, VA Medical Center staff" from three different VISNs, along with the "design consultant team," developed and designed candidate solutions for the CBOC facility layout (Ibid.,2024). The goal was to align these solutions with the three specified objectives. In working sessions, they exemplified an intuitive design approach as identified before, and generated candidate solutions, "while integrating the aptitudes and interests of [a] diverse group of participants" (Ibid.,2024) From these working sessions, the team developed three candidate solutions for facility design, including "layouts for the One, Two, and Three-PACT CBOCs" (Ibid.,2024). Regarding implementation of the candidate solutions, the testing conducted solely aimed at validating the flexibility and modularity of the layouts (Ibid.,2024).

Incorporating these intuitive approaches is valuable for generating potential solutions. However, the importance of data analysis and statistically informed decision-making becomes crucial when addressing a billion-dollar decision to determine the optimal facility layout for the VA's CBOC design. The incorporation of generative simulation offers the organization an opportunity to enhance its ability to make well-informed choices. In the context of hospital facility layouts, simulations can model and analyze complex scenarios, optimize resource utilization, and provide data-driven insights for informed and efficient design choices.

2. Simulation Integration

Simulation is the "imitation of a dynamic system using a computer model in order to evaluate and improve system performance" (Harrell et al., 2022). Simulation effectively substitutes trial and error approaches due to their time consuming, disruptive, and expensive nature. Simulations strength helps in understanding "complex systems" and "making decisions" (Ibid., 2022). Amongst their many uses, they can perform capacity or constraint analysis, configuration comparison, optimization, sensitivity analysis, or visualization (Ibid., 2022).

Within simulations, complexity is a summation of interdependencies and variability. Interdependencies cause behavior of one element to affect other elements (Ibid., 2022). Within medical care, an example of an interdependency is the Emergency Department's rely on diagnostic imaging, laboratory services, specialist consultations, pharmacy, nursing staff, and patient transportation. These all provide a comprehensive care for a critically ill patient that comes to the hospital, highlighting interdependence among various departments. Variability is uncertainty (Ibid., 2022). The unpredictability of a patient arrival times at the Emergency Department introduces variability, crating uncertainty in resource allocation and staffing schedules within the hospital.

For a community-based outpatient clinic, it may integrate primary care physicians, registered dietitians, pharmacy services, nursing staff, behavioral health services, community health educators, patient advocates, and health information management to collaboratively address diverse health needs within the community. This highlights interdependence in a comprehensive healthcare delivery. The CBOC experiences variability in patient appointment scheduling, creating uncertainty in resource allocation and staffing levels, as the demand for services fluctuates, impacting the clinic's ability to efficiently manage patient care.

Simulations are an appropriate and effective methodology as it meets the following criteria. First, when an operational, logical, or quantitative, decision is made. Second, when the process being analyzed is well defined and repetitive. Third, activities and events are interdependent and variable. Lastly, the cost to experiment on the actual system is greater than the cost of simulation (Ibid., 2022). The decision-making process for CBOC facility layouts aligns with the four prominent characteristics that make a situation most suitable for simulation.

Recognizing these challenges of interdependence and variability in a CBOC highlights the opportunity to utilize effective process system tools in decision-making to enhance overall healthcare delivery. Addressing these complexities will ensure the continuation to meet the VAs mission at large. A simulation approach is the use of a multi-criterion, generative design decision model in ProModel. ProModel simulation offers a tool for modeling and analyzing the dynamic nature of patient flow, resource utilization, and appointment scheduling within CBOCs. By simulating various scenarios, healthcare administrators can gain insights into optimizing processes, improving resource allocation, and enhancing overall efficiency. This transition to computer simulation opens the door to a new paradigm in decision making for CBOCs infrastructure layout, withholding a more effective and streamlined healthcare operations. Iterative simulation, including ProModel, may fill a human limitation to grasp real-world complexity.

Simulation of CBOC for the VA will be a dynamic, stochastic, discrete model. This means the model will be continuous overtime, one or more variables may be random, and state changes will occur at discrete periods triggered by events. Within ProModel, the dynamic characteristic of variables included in the model present a normal, uniform, or exponential distribution, adding to the validity of the model.

Process Systems process items through a series of activities. Prime examples include manufacturing systems and service systems. Within a hospital there are multitudes of processing systems all broken down into smaller processes. Process systems, such as CBOCs, can be built into the simulation once broken down into four main components: entities, activities, resources, and controls. Entities are, “items processed through the system” (Ibid., 2022). Activities are, “tasks performed that are directly or indirectly involved in processing entities” (Ibid., 2022). Resources are, “means by which activities are performed” (Ibid., 2022). Controls, “dictate how, when, and where activities are performed” (Ibid., 2022). In terms of these components, examples within a hospital or a CBOC include patients as entities, an activity being their check in process or blood work tests, resources include the physicians or arrival kiosks, and hours of operations are examples of controls. These components of the CBOC processing system will all be the inputs to ProModel. From these inputs, a user will be able to “run” the simulation and receive metrics able to be used in capacity or constraint analysis, configuration comparison, optimization, sensitivity analysis, or visual decision-making (Ibid., 2022).

Figure 1. The CBOC One-Pact Facility Layout, as Published in the VA’s Community Based Outpatient Clinic Prototype Proposed Layout, used in the proof of concept for ProModel Simulation Design (CFM VA, 2024)

3. Proof of Concept

To exemplify this application, displayed and explained below is a simplified proof of concept exemplifying the CBOC One-Pact Facility Layout simulated in ProModel. To simulate, inputs, outputs, and metrics were identified. For this simulation, the CBOC One-Pact Facility Layout produced by the VHA’s expert groups and published to the VA’s Community Based Outpatient Clinic Prototype Proposed Layout was used as the facility layout (CFM VA, 2024). The screenshot of the layout from the design manuals is shown in Figure 1.

Following the publication of the VA’s *Community Based Outpatient Clinic Prototype Proposed Layout*, the VA published the *Prototype for Standardized Design and Construction of Community Based Outpatient Clinics* (Ibid., 2024). Within this, an “Optimal Patient/Staff Flow Mapping” diagram, shown in Figure 2 below, that provides three main routes of patients attending services at a CBOC (Ibid., 2024). These three routes were simplified to use as a proof of concept in ProModel Simulation. From the three routes published by the VA, the routes utilized in our ProModel simulation are as follows:

1. Patients attending CBOC services for standardized examination and primary care.
    a. Patient arrives to CBOC, waits in queue for the receptionist, assisted at the receptionist desk, waits in queue in the lobby waiting room, receives height and weight measurements, attends an appointment in an examination room, exits the system.
2. Patients attending CBOC services for laboratory and blood testing.
    a. Patient arrives to CBOC, waits in queue for the receptionist, assisted at the receptionist desk, waits in queue in the lobby waiting room, is taken to the laboratory to be attended to, is seen by at minimum one physician before leaving, exits the system.
3. Patients attending CBOC services for group therapy or shared medical appointment.

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a. Patient arrives to CBOC, waits in the queue for the receptionist, assisted at the receptionist desk, waits in the queue in the lobby waiting room, attends group therapy or shared medical appointment, exits the system.

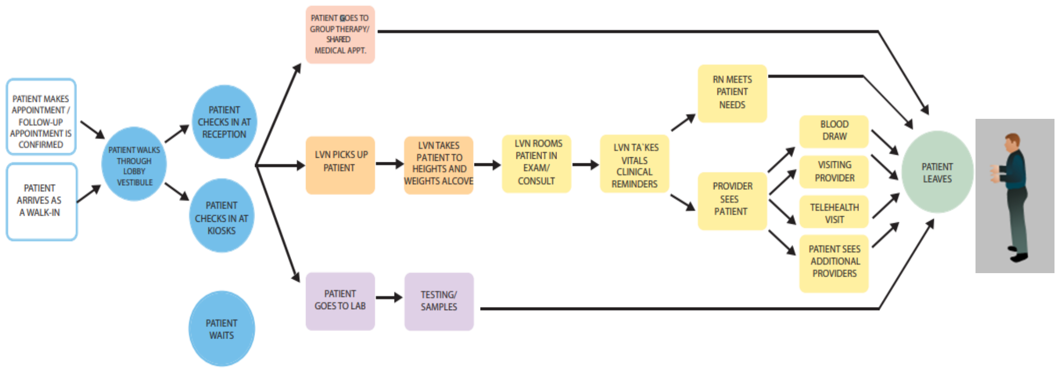

Figure 2. The Optimal Patient/Staff Flow Mapping Process as published in the VA's Prototype for Standardized Design and Construction of Community Based Outpatient Clinics (CFM VA, 2024)

Once the routes were identified, the next inputs into ProModel included the locations, entities, arrivals, processing, user distribution, and working hours.

<u>Entities</u>: Any being that may move through the hospital processing system, chosen by the user for simulation and analysis, will be categorized as an "entity." For the proof of concept, a single entity was designated as "patient," visually depicted as an individual wearing a green suit, as illustrated in Figure 3 below. In ProModel, one can curate multiple entities or multiple entity types. Within a medical setting, this may include ambulatory, inpatient, outpatient, emergency room, surgical, maternity, pediatric, geriatric, chronic, psychiatric, diagnostic, follow-up, or more.

<u>Locations</u>: A location will be any area or point in time the entity needs to move to or from along its' processing system. For the proof of concept, locations used include Service Queue to Receptionist, Reception, Waiting Room Queue, Height and Weight Room, Group Appointment Services, Examination Rooms, Laboratory, and Consult/ Telehealth Room. Each location is depicted using varying icons a user my choose from the ProModel program or upload. These icons assist in visualizing the processing system accurately. In ProModel, a user can curate multiple locations or multiple location types. A "queue" refers to a waiting line where entities wait for processing or service. Within a medical setting this may include admission/registration area, emergency room, outpatient clinic, inpatient ward/room, surgical suite, labor and delivery units, maternity ward, intensive care unit, diagnostic imaging, pharmacy, laboratory, radiology, cafeteria/waiting area, or more. Depending on the complexity of the simulation and specific focus of analysis, additional locations or units may be included to accurately represent the hospital's processes and workflow.

<u>Arrivals</u>: Arrivals within ProModel are used to model the entries of entities into the simulation over time, representing patterns or distributions. Arrivals as an input provides an opportunity for the user to analyze and optimize the process system's performance by simulating different arrival patterns and processes. For arrivals, the user may also utilize the 'user distribution' feature that offers a statistical representation of entity arrival's characteristics. One can customize the probability distribution within user distribution to simulate a realistic variability in arrival patterns or processing times. For the proof of concept, we simplified arrivals to a "patient" of which come one at a time, have an infinite capacity, arrive at a frequency of once every twenty minutes exponentially distributed, and are constrained to a user distribution. The user distribution for the proof of concept allocates 50% of patients that arrive in the system come to receive general examination services, 30% arrive to receive laboratory services, and 20% of patients that arrive aim to attend a group medical session.

In the context of arrival input data, there is substantial variability that may be simulated to address the complexities inherent to real-world scenarios in a CBOC. ProModel offers arrival customization to include constant arrival rate, poison arrival process, scheduled arrivals, peak hour arrivals, random arrivals, patient admission patterns, emergency arrival events, day-night variations, weekday-weekend differences, seasonal variations, and more.

<u>Processing</u>: Within ProModel, processing is the input feature that illuminates life in the simulation. Processing refers

to the activities and transformations entities will endure as they move through the simulation. Within the processing input, the user identifies various stages, steps, or tasks the entity will experience within the simulation. Customization includes activity definition, activity duration, resource utilization, routing logic, queue management, concurrent processing, feedback loops, and performance metrics. Within a hospital, a user can input to processing the admissions process, triage process, diagnostic testing, consultation time, surgical procedures, medication administrative steps, inpatient care, rehabilitation services, discharge of patients, follow-up appointments, radiology procedures, patient transport, pharmaceutical services, and more. For the proof of concept, we built the three routes as stated above into processing. Within these routes, we leveraged the feature to ensure completion of service for individuals arriving at the CBOC before closure, and redirecting patients out of the system if they arrive after closure. Depending on the services being utilized by each entity, we inputted varying distributions to reflect real world criterion.

<u>Variables and Attributes</u>: Variables and attributes are additional inputs a user may incorporate in ProModel. Variables are the dynamic elements in the simulation, including cycle times, processing times, and arrival rates. Attributes are elements that provide additional information about the entity in the simulation. Variables may change throughout the simulation while attributes remain constant. More so, variables and attributes can be strategically utilized to standardized output measures of the simulation. A user may define the performance measures they intend to analyze, such as throughput, cycle time, or resource utilization. Within the proof of concept, variables and attributes were used to provide direct data on total patients serviced, average patient service time, total examined patients, average examined patient time, total laboratory patients, average laboratory patient time, total group care patients, and average group patient service time. Lastly, variables and attributes can be displayed on the simulation to strengthen visual understanding of the processing system.

Altogether, the inputs for the proof of concept regarding CBOC in ProModel can be viewed in Figure 3.

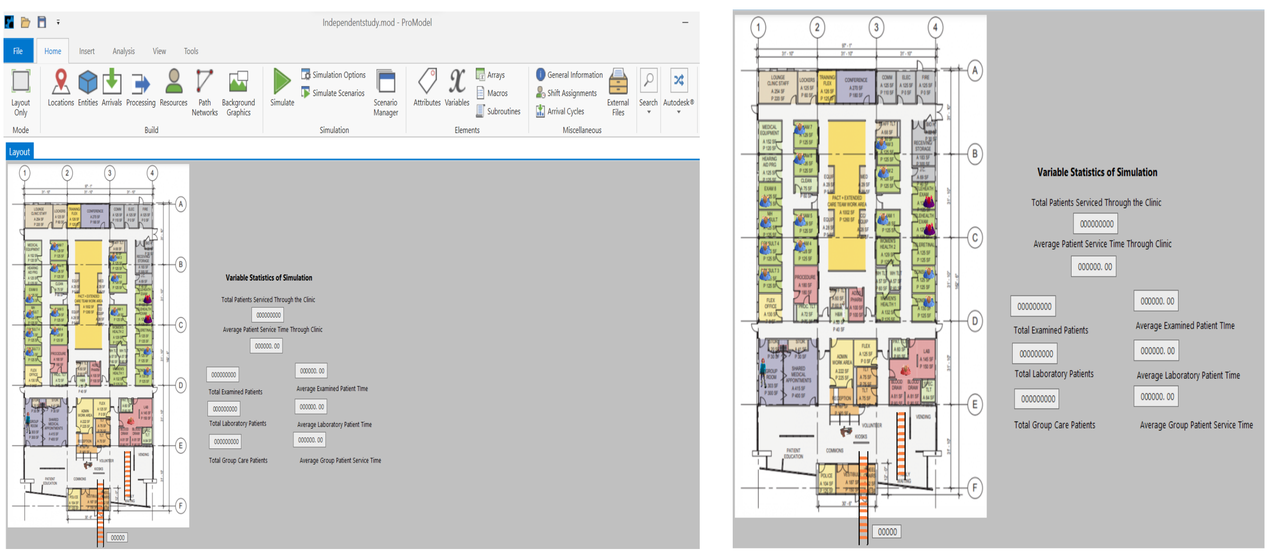

Figure 3. Zoomed Out Picture of ProModel Simulation of CBOC One-PACT Design Laid Out Within ProModel Tool.

After running the simulation, ProModel provides various output measurements and reports to assist the user in analyzing, assessing, and improving performance of their process systems. Upon the competition of a simulation trial, ProModel will first provide the user with an analytical dashboard exemplified in Figure 4 below. Key output measurements and reports in ProModel include:

1. <u>Utilization Rate</u>: ProModel analyzes the utilization rates or resources including equipment, personnel, and locations. Utilization rates can assist the user in identifying bottlenecks and optimizing resource allocation.
2. <u>Cycle Time Analysis</u>: ProModel allows users to measure the time it takes for an entity to move through the entire processing system. This allows users to identify delays and inefficiencies in the workflow.
3. <u>Throughput</u>: Throughput allows the user to assess the rate at which the system completes the services to the entity. This allows the user to assess overall efficiency of the process.

4. Queue Length: ProModel provides lengths of queues within the processing system. This allows the user to understand where congestion is present and its impact on the performance of the processing system.
5. Resource Costing: ProModel analyzes the costs of different resources, allowing the user to make informed decisions about resource utilization, allocation, and optimization.
6. Scenario Analysis: ProModel can be utilized in a wide variety of scenarios to assess impact of changes to the situation or atmosphere. This allows the user to make informed decisions about process improvements.
7. Visualization Tools: ProModel offers flowcharts, animations, and more, allowing the user to understand the flow of the processes and identify areas of improvement.
8. Sensitivity Analysis: ProModel offer sensitivity analysis on the impact to the system from change in input parameters or variables. This allows the user to identify crucial characteristics or factors influencing the system's performance.
9. Custom Reports: ProModel enables users with the ability to customize reports intended to inform them of their specific requirements. This allows users to be detailed and intentional in their analysis of the system's results.

From the proof of concept, the location utilization rate, the variable summary report, and the Entity Summary report can all be accessed for decision making quality via the ProModel Output Viewer. Given the simplified limitation of the proof of concept, the additional display of other output metrics cannot be articulated at this time. Looking at the Output Viewer below, it tells us each patient is spending an average 46.59 minutes and 39.37 of those minutes are attributed to interaction with a physician. This confirms, there is a small wait time of 46.59-39.37 = 7.22 minutes on average for each patient. This is verified in the Entity States – Baseline box that shows Patients are occupied about 84% of the time in Operation. This shows us there is a satisfactory proportion of physicians working to patient demands. Additionally, we can see the Service Queue in the Lobby is empty with no patients having to wait 99% of the time. The Waiting Room Queue is occupied 42% of the time showing patients are not spending their time waiting to check in, but rather they're waiting for their appointment to begin from the lobby. This shows the check in services are exceptional at this time. Lastly, the Single Capacity Location States box shows only Exam/ Consult Room #1 is used and the rest of the Exam/ Consult Rooms remain empty throughout the entirety of the workday. This allows decisions makers an opportunity to decide if these rooms can be best used in a different manner.

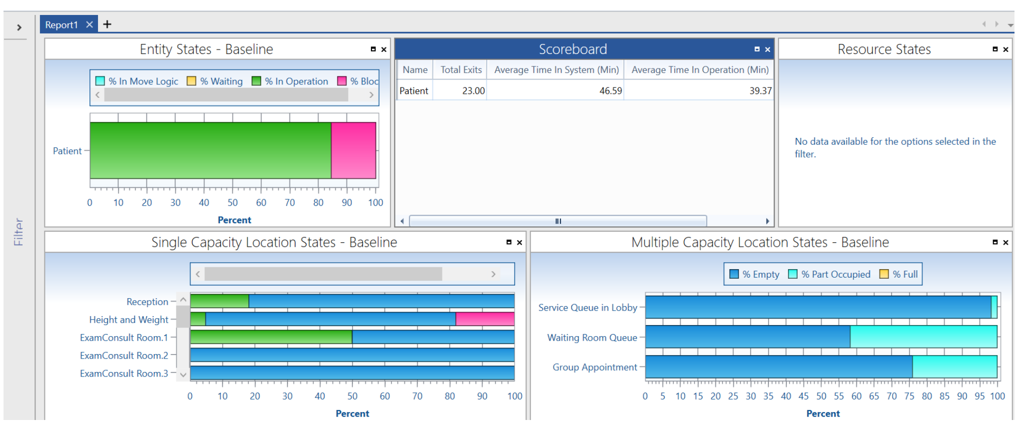

Figure 4. ProModel Analytical Dashboard of Simulation.

4. Conclusions and Future Work

In this surge of healthcare expenditures, environmental factors continue to burden healthcare institution owners and operators to enhance the quality of care while simultaneously limiting operating costs. In 2017, the American Society for Health Care Engineering reported the average age of healthcare infrastructure was 11.5 years, a 33% increase over twenty years (VA, 2024). Since this statistic was presented, the global pandemic in 2020 seized and slowed capital construction, to include healthcare construction, further aggravating the rise of outdated healthcare infrastructure. Facility Health Incorporated published in 2021, "U.S. healthcare facilities had deferred 41% of their maintenance and will need $243 billion to complete the backlog" (VA. Gov, 2024). Deferred maintenance is defined by the postponement of infrastructure and asset repairs. They claimed if healthcare infrastructure continues to age at this rate without an answer to deferment, 68% of the healthcare infrastructure will exceed its expected useful life by 2031 (Ibid., 2024). Outdated physical environments of hospitals and clinics are further outgrown by emerging clinical processes and technological advancements, introducing inefficiencies into patient

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care systems.

In the face of a perpetual demand for healthcare from humanity at large, it is important to proactively address these existing friction points and rising tensions. As mentioned, one part of the strategic approach involves new medical infrastructure. From November 2022 to November 2023, the United States Health Care Construction Spending increased 11.68% reaching 63.35 billion (US Total Health, 2020). Moreover, over the preceding four years, it experienced a substantial 30.8% growth since November 2019 (Ibid., 2020) With this escalation in investment, there is a heightened importance in deliberate decision-making in healthcare infrastructure design. This scenario presents an opportunity for the integration of data-driven practices into the processes of healthcare facility design and decision-making. Considering the statistical correlation between facility design and impact on healthcare quality and experience, the strengthening of informed decisions regarding capital investments may be best achieved using computer simulation. Multi-criterion data driven models, including ProModel, will enable stakeholders to incorporate the optimization of design, operations, and management within their healthcare systems, fostering continual improvement in healthcare outcomes. The utilization of ProModel coupled with existing intuitive methodologies, presents a unique and robust avenue for advancing the essence of medical facility design.

Overall, the Veterans Health Administration's commitment to providing exceptional care to veterans necessitates an innovative and data-driven approach to facility design within their Community Based Outpatient Clinics. While the VHA has standardized design objectives for their CBOCs, there is an opportunity to enhance the decision-making by incorporating generative simulation tools. Simulation, found in the use of ProModel, offers an ability to model and analyze the complexities of patient flow, resource utilization, and scheduling within CBOCs. We recommend the VA builds simulations for the One-PACT, Two-PACT, and Three-PACT models and then compare analysis to assist in making construction decisions. With this shift, the VHA can optimize healthcare processes, improve resource allocation, and enhance the efficiency of their healthcare operations. In doing so, they will remain in alignment with their mission.

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