LEAN ENTERPRISE PRINCIPLES APPLIED TO HEALTHCARE

Kambiz Farahmand, North Dakota State University; Reza Karim, North Dakota State University; Raghavan Srinivasan, North Dakota State University; Reza Sajjadi, North Dakota State University; Lori Fisher, Fargo VA Medical Center

Abstract

In this study, a discrete event simulation model was developed in order to evaluate current processes and to improve the overall efficiency of the clinic. The performance measures considered were maximizing throughput, minimizing wait time, minimizing flow (transportation) and maximizing utilization of nurses and providers. The virtual simulation model was developed using ARENA software Version.12 (Rockwell Automation Technologies, Inc). From the comparison of the results, it was observed that moving the exam room of the busiest provider closer to the waiting area achieved a considerable reduction (8.5%) in the yearly distance traveled, from the patient's perspective. Changing the location of nurses and providers when compared with the current scenario resulted in a reduction of 18% for the total distance traveled by the patients in any given year. Assigning one nurse to each provider when compared with the current scenario resulted in an 8.48% reduction in the total distance traveled by the patients. The analysis indicated that by improving overall space utilization, the utilization rates for exam and procedure rooms were increased where it subsequently improved the flow of patients and equipment.

Introduction

Clinic space utilization was studied from the aspect of Lean Healthcare. The goal of the study was to develop a simulation model which can be readily adapted to the large variation in clinic structures that maximizes efficiency and workflow within the constraints of existing architectural limitations. Variations in mode of operation and space utilization were observed believed to be based on inefficient flows and lack of standardized layout. There is an increasing demand for both capacity and service quality in healthcare. Studies show that clinic examination rooms are idle for a significant part of the patient care cycle. Studying patient flow characteristics throughout a facility based on need provides insight into optimizing space use. The authors set out to develop an idealized clinic layout that would maximize clinic efficiency and work flow and could be used as an initial platform layout to launch future clinical space designs. To increase the utilization of space, resources, and equipment, and to increase the patient throughput without sacrificing quality care, seven flow designs were identified in the clinic: patients, staff, information, equipment, supplies, diagnostic tests and procedures, as well as medications. The simulation model was built considering flow of patients, staff and information. Arena software was used to develop the simulation model. This project was conducted in the VA Medical Center.

Literature Review

An in-depth literature review was conducted in the areas of Lean Applications and Operations Research (OR) concerning space utilization and optimization of healthcare facilities. Benninger and Strode [1] developed a methodology for maximizing efficiency of staff and resources which was simulated in the general Otolaryngology department. The authors measured total clinic time, number of patients seen, patient waiting time, physician and nurse productivity, and examining-room use. The simulation showed that there were increases in physician time spent with patients, and a reduction of patient waiting time.

Eneyo [2] used simulation software to design the new unit taking into consideration production and assembly activities, which are subject to the future expansion of the company. The design of the new facility was conducted in four phases: 1) Data collection, 2) Simulation of existing conditions, 3) Simulation of an expansion phase, and 4) Layout development of the new facility.

Joseph [3] employed the lean methodology in designing the layout of a laboratory. This was done in order to design an optimal facility layout which would have a smooth process flow, minimized handling distances, reduced walking distances, and improved visibility for effective management of operations, enhanced work environment and better inventory management. The first step here was to study the existing state of operations in the process including measurement of cycle time, lead time and TAT time (task time). The next step led to implementation of lead strategies such as proposing a U-shaped design that would minimize operator walking. This was followed by a projection of growth for the future. Based on the results, predicted values of space requirements were developed for each of the units. The next step involved the development of a high-level layout using optimization. This was done in four steps: Quantify all work flows, workflow weights, flow matrix and layout optimization. Based on these optimizations, layouts were drawn and evaluated. These block diagrams of the space layout were then modified into detailed drawings. Implementation of lean culture and mock-ups were integrated into the detailed planning. The lean design resulted in an efficient design that optimizes specimen flow, increases staff productivity and reduces waste throughout the life of the facility. The lean process improvement as applied to healthcare settings needs to be studied more in depth and feedback of patients should also be incorporated into the analysis so as to gain efficiency related to patient flow and patient satisfaction.

Eric [4] applied lean concepts to the Emergency Department (ED) and looked for improvement in service delivery by emergency–care personnel. The measurement of satisfaction of patient visits was conducted before and after the implementation of lean techniques for a period of one year. The authors applied a six-step process of lean education, made observations of the emergency department, analyzed patient flow, redesigned the process based on findings, and developed new testing procedures that could be implemented in the ED. Outcomes were measured using patient satisfaction, expense per patient, length of stay (LOS) in the emergency department and patient volume. These outcomes were compared for 2005 data (before) and 2006 data (after). Lean concepts were tested to see if the implementation of the fundamental change of thinking improves patient satisfaction as well as staff satisfaction. A change-of-thinking requirement was developed due to the demands of safe, efficient and quality-driven needs in the healthcare system. Lean concepts from the Toyota Production System (TPS), if applied to healthcare, indicate that clinic personnel need to care for patients. A lean team is first formed from all departments. The processes involve process mapping and then assessing the amount of waste using value-stream mapping (VSM). VSM documents the time taken in each step with the arrival of each patient and quantifies time at different steps as value-added or not value-added. From here, the determination is made which step adds value to the patient experience and which step takes up resources and time and incurs cost without adding value. Then, the lean team determines if all steps involved in the patient visit are required and redesigns the process by modifying or eliminating the waste. This newly developed process was tested and implemented with continuous feedback for improvement from the frontline staff that has more insight of the process. In non-lean environments, reduction of cost is emphasized. In lean environments, quality and flow are evaluated first; when these are improved in current staff, synchronization of staff can then be focused on after which factors of efficiency can be evaluated. It was found that lean improved the value of care to the patient. The end result of applying lean in healthcare was a higher-value product when compared with one produced using a management style analysis focusing on single-step efficiency. One of the findings in this study was an increase of 9.23% in patient visits.

Cote [5] described patient flow and resource utilization under an individual physician in primary health care. An analysis of service (time a patient spent in consulting) and sojourn (total time spent at some location in the clinic) was conducted. A discrete-event simulation model was constructed in order to find the relationship between examination room capacity and patient flow across four clinic-based performance measures.

Hasson et al. [6] conducted a study of methodological issues in nursing research such as preparation, action steps and difficulties that are inherent within the Delphi technique. There were issues in identifying the problem, research skills to conduct the investigation and data presentation. The authors studied these problems. Reliability of this method was based on the assumption that several people were less likely to come to a wrong conclusion. The validity of this method was enhanced by a reasoned argument in which assumption were challenged. Findings from Delphi study helped to streamline the work. Baker [7] utilized mathematical modeling in a teaching clinic to improve patient care. The model was used in the planning and decision-making process establishing a relationship between physicians, time and space.

Feyen et al. [8] studied workflow of a clinic in the VA medical center in Indianapolis. The process here involved discussion with the staff, data collected on the current workflow for a week, current room utilization and any other time data. A Gantt chart was developed to evaluate usage of each room each day. Three specific approaches were considered to improve room management. AutoMod was used to analyze workflow. Authors implemented movement monitoring systems in each room, utilizing notification systems and using computers in the nurses' station. Physical room layout was analyzed. Through VA staff input and general industrial engineering principles, it was determined that changes such as putting in additional walls, doorways and shelving units would reduce unnecessary time and improve room management. The authors were informed about several areas that contributed to inefficient room management. The room assignments were handled arbitrarily, resulting in inefficient use of rooms.

Gibson [9] used a discrete-event simulation tool for the purpose of planning and designing of the hospital building.

The approach began with the problem formulation phase of setting the objectives and developing a project plan based on the Baldridge National Quality Program for the healthcare sector. In the planning phase, a value management study which considers the information process mapping and workplace study information was taken into account to reduce cost of service while improving and maintaining quality. The next step involved the simulation of the planning phase for which real-time data were collected. Next came the master planning phase where resources such as waiting area and reception would be taken into account. The last and final step considered the schematic design phase which involved preparation of architectural and engineering drawings.

Miller et al. [10] studied the new hospital space allocation and schedule configuration design using tools-simulation, linear programming and spreadsheet analyses. A new 600-bed hospital for women and children was being constructed at the hospital facility to replace the existing one. The requirements as summarized by the author were to a) maintain a large number of specialty and sub-specialty outpatient services, b) maintain significantly less space to house these services in the new facility, and c) meet complex scheduling requirements, both clinically and operationally, due to teaching requirements. The current structure was completely studied using process maps, and future requirements/ constraints were noted. Parameters were set up by the design team, including number of exam rooms and number of clinics. The next step after making initial assumptions was data collection, the last step prior to simulation. The data here were collected by observing the process and gathering information from the hospital staff, after which the data were analyzed. A multi-faceted approach consisting of modeling, linear programming and discrete event simulation was used to predict and forecast future behavior. For the purpose of validating the model, the software developers ensured that the models would behave similar to the real system. Two types of models were studied here. Various scenarios were simulated with different clinic configurations. Several iterations of the models were performed in order to determine the optimal location. The decision was made after the service department and the project team reached a conclusion. The results did not show an optimal solution but yielded a more realistic and practical solution. This analysis of high-level and low-level model led to a better and optimized utilization of the space. Stake holders' input was taken into account after the results but prior to implementation.

Based on a review of the literature, a wide array of issues within the healthcare delivery system were observed that included inefficient space utilization, unnecessary travel time of clinic staff and patients, improper allocation of rooms, and lack of desired equipment and capacity constraints for space. To improve these issues, discrete event simulation and lean concepts were applied. Review of specific case studies that were developed in numerous healthcare clinic settings found that simulation was used to examine bottlenecks and to improve utilization and access. Lean techniques such as Six Sigma, Five S, and Value Stream Mapping were also widely used by management to improve the level of service. It was also observed that a number of researchers stressed the importance of gathering reliable and comprehensive information about the system being studied, and the obvious solution was to interview and/or survey the individuals interacting with the given clinical setting [11].

Numerous strategies such as RFID, bar-coding and videotaping were considered for data collection and field observation, but due to time constraints, interviews, questionnaires and on-site observation were selected as the primary modes to gather data. Face-to-face interviews with staff provided an understanding of the standard operating process and the type of problems faced by management, providers, nurses, and staff during daily operations, not only from a space perspective but also from the other perspectives of flow as noted earlier. Due to the fact that many practitioners were not able to go through the interview process, questionnaires were provided to be completed at their convenience. The observation process included patient and provider shadowing, where redundant activities and motions were identified, and necessary suggestions were developed through the application of Lean.

Lean Consideration

Issues contributing to the inefficient use of space in the macro-level simulation model developed for this study included: Inefficient use of space, unnecessary travel time to waiting area for staff and patients, poor layout, non-value-added activities, waiting, inefficient procedures, understaffed clinics, nurses' station too small for clinic traffic, and the need for more storage space.

From the interviews and observations, the non-value-added activities identified are listed below. Some of these issues were thought to define appropriate performance measures for the simulation model.

- Inefficient use of space (nurses' station overcrowded; clerk desk layout does not provide human factor considerations; only one room is provided for provider)
- Unnecessary walking of staff and patients back and forth to the waiting area

- Poor layout (quantitatively verified by the simulation model)
- Two times waiting for patient (one for nurse and the other for provider)
- Inefficient procedures (no signage to guide patients into the appropriate space, minimum balance between waiting area and patient demand)
- Lack of equipment (only one printer for the entire team, separate printer is needed for printing letters and envelopes for clerical staff, need a counseling desk facing the patients)
- Clerks reach over the nurses to place charts in the cabinets while nurses are on the phone or computer
- Privacy issues as nurses need more privacy while on the phone
- Access issues as patients walk into the clinic and grab doctors and nurses
- More storage space is needed behind desks (maybe consider overhead storage)
- Disorganized chart holders

Field Observations and Data Collection

As part of the data-collection procedures, interview tools, questionnaires and observational methods were applied and are discussed below. Data collection included acquiring data from the clinic database and time studies, which included manual collection of time for each activity. The data collected served as input parameters for the simulation model. Data collected through the databases and time studies provided the information needed for utilization of clinical space and individual rooms. Figure 1 shows the patient distribution calculated from the data analysis of one year data.

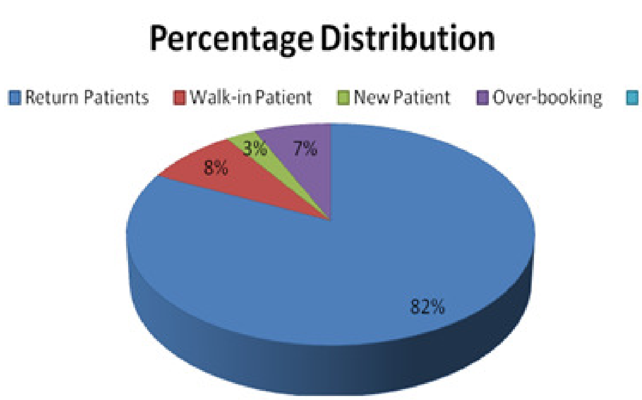

Figure 1. Percentage Distribution of Patients

A series of face-to-face interviews conducted with various staff in the clinic led to some key findings about the operation of the system. Interviews provided valuable insight about individual staff processing the patients and problems they face in a given day. The interview process took an average of 25 minutes per session. In some cases, follow-up interviews were necessary in order to validate the information. The interviews focused on daily job functions and the system's inefficiencies. Data collected were verified with the interview results to measure reliability.

Questionnaires were sent to staff who were unavailable for direct interviews and to collect data that could not be captured from the data bases. Questionnaires included checking whether all of the staff classifications are following the same operating procedures and whether there are differences between them which are difficult to capture from face-to-face interviews due to time constraints.

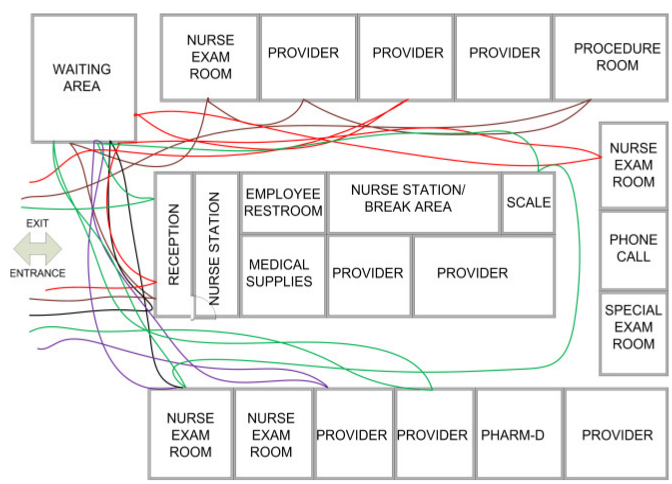

Figure 2. Spaghetti Diagram for Patient Flow

The observation process consisted of tracking patient flow from the moment they check-in at the clinic until they leave the system. This observation process enabled the authors to get an insight into the standard operating procedure and to draw process maps based on the spaghetti diagram shown in Figure 2. Figure 3 indicates the partial process map for the clinic under study.

The data-collection process started at the early stages of the simulation. Based on observations and completed interviews/questionnaires with staff, a comprehensive understanding of the operations and functions within the clinic was obtained. Based on knowledge of the current operating procedures and feedback from the Delphi study with clinic management and staff, a conceptual model was developed which eventually was used to develop a conceptual model

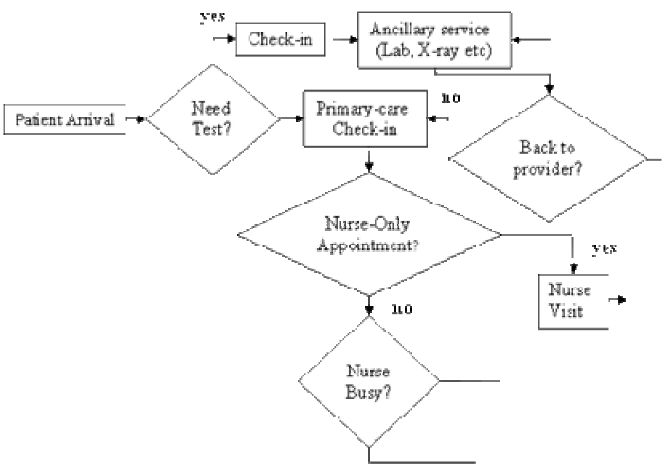

Figure 3. Snapshot of Patient Flow in a Typical Clinic Setup

required for building the simulation model, as shown in Figure 4.

Simulation Model

The simulation model considered utilization of providers, nurses and clerks. Providers were considered the primary resource utilizing the space in the simulation model. The utilization of nurses as a secondary resource was considered to be another important feature of the model. Nurses provide triage and assessment services to patients, which include taking vitals, doing clinical reminder tests, reviewing medications, etc. After the nurse assessment is complete, the patient is seen by the provider. Nurses typically work eight hours per day. Table 1 shows the input parameters and assumptions for one of the scenarios. The

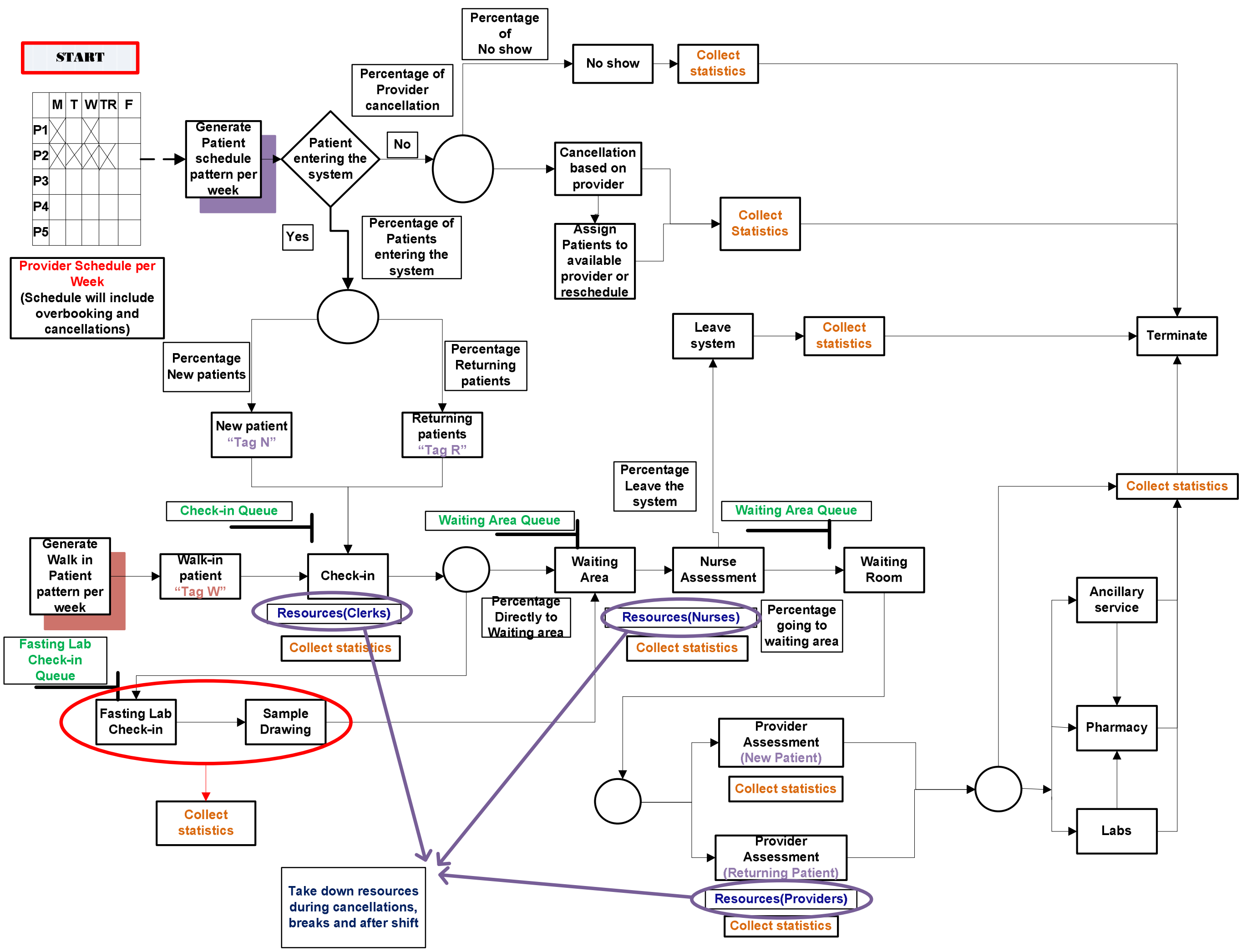

Figure 4. Snapshot of the Conceptual Model for the Clinic

utilization of clerks is also considered as an integral part of service provided to the patients. The clerks are mainly involved in patient check-in, verification and scheduling activities. Clerks typically work an eight-hour shift. A simulation model was built to examine impacts of various activities within the clinic and to provide an efficient environment within the clinical space for both patients and staffs. This model will also help to maximize the utilization of space and other resources; a simulation model was built to examine the impacts of various activities within the clinic. The performance measures considered for development of the model were maximize throughput, minimize wait time, minimize flow (transportation), and maximize utilization of nurses and providers. Figure 5 shows the partial simulation model developed in Arena.

Table 1. Input Parameters and Assumptions

Input	Type of input
Simulation run period	One month
Number of Replications	10
Patient arrival	Schedule based
Nurse only patient arrival	0
Walk-in patient arrival	0
Walk-in patient type (nurse only vs. provider visit)	50%
No Show rate	0
New vs. Return patient	0
Clerk service time	N(1,0.05)
Nurse service time	N(18,3)
Provider service time	N(25,5)
Distance between any two areas in the clinic	Distance in feet

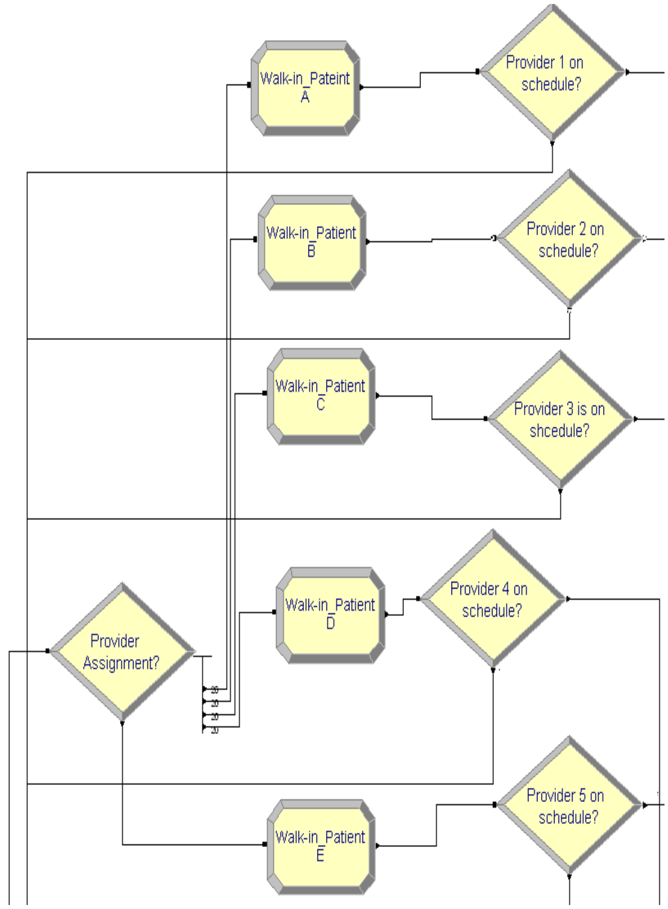

Figure 5. Snapshot of the Model in ARENA Version 12

Simulation Results

The simulation was analyzed considering the following resources: resource utilization, scheduling and distance traveled within the clinic. Four different scenarios were run to study these resources.

Resource Utilization

Utilization of resources focuses on the servers, receptionist, nurse and providers. One scenario was to add and remove assistants (nurse and/or receptionist) during busy and empty schedules. Another scenario was to change the providers' working time; in general, all providers start their work at the same time (8:30am and 1:30pm). This causes a heavy load for the nurses. By staggering the slots of the providers and nurses, this variation was expected to be controllable. This can be applied for all working days or only busy days.

Structured Scheduling

The scenario for this measure was to improve the system through patient type. What happens if patients are scheduled based on their type? For example, regular patients are visited in the morning while patients requiring long visits are scheduled in the afternoon; or, a scheduling pattern such as two regular patients following one long-visit patient could be defined.

Traveling in the System

It was important to determine the distances between any two areas in the system and approximate the daily traveling distance/time/cost in the clinic. It was also possible to figure out heavy traffic areas in the clinic. Based on that, a number of scenarios were tested and the best was selected. Scenarios included movement of resources and equipment and/or adding new resources and equipment. A summary of these scenarios is illustrated as follows:

Scenario 1: Changing the provider's workstation
From the results, when the scenario was compared to the current situation it could be concluded that by moving the exam room of the busiest provider, (i.e. having their exam room closer to the waiting area) one can achieve a considerable reduction (8.5%) in the yearly distance (feet) traveled from the patient's perspective.

Current Situation	Proposed Scenario	Improvements
Total distance traveled by the patients seen by providers is 2646828	Total distance traveled by the patients seen by providers is 2417004	8.51 % reduction in travel of the patients

Scenario 2: Changing location of nurses and providers
The analysis for this scenario, when compared with the current scenario, resulted in a reduction of 18% for the total distance (feet) traveled by the patients in one year.

Current Situation	Scenario 2	Improvements
Total distance traveled by the patients seen by providers is 2697984	Total distance traveled by the patients seen by providers is 2209356	18.11 % reduction in travel of the patients

Scenario 3: Assigning one nurse to each provider
This scenario, when compared with the current scenario, showed an 8.48% reduction in the total distance (feet) traveled by the patients in one year.

Current Situation	Scenario 2	Improvements
Total distance traveled by the patients seen by providers is 2697984	Total distance traveled by the patients seen by providers is 2469168	8.48 % reduction in travel of the patients

Scenario 4: Reducing staff travel/walking by improvising communication
The manual flow of information takes place between check-in clerks and nurses. For this, the check-in clerk prints documents related to the scheduled patient and places them in the nurse's document stack. If this flow of information could be done electronically, then the nurses need not come every time to the nurses' station to check for the patient information. The electronic information flow to the nurses can also be accompanied by some notification system such as color or light signals to indicate the arrival of a patient. A maximum of 3,000,000 feet of walking would be eliminated if this scenario were adopted.

Recommendations

From the study, the authors determined strategies to increase patient throughput and optimize clinic space utilization by changing flow and scheduling practices leading to an increased number of patients seen and a reduction in overall patient wait time. Such recommendations include quality improvement activities, continuous improvement interventions, redesigning inefficient processes, Lean tools, development of process maps, and standardization of process. Such recommendations are listed as follows:

1. Based on the interviews conducted with staff and management, the issues that lead to the inefficient process with respect to space were outlined and some of these issues were incorporated into the macro-level simulation model developed in this study. Simulation could be used as a tool to examine first-hand what impact any change would have on the system.
2. Minimizing no-show rates can be accomplished by scheduling and reminder strategies in advance. If successful, the utilization of the staff could decrease by around 10%.
3. Implement the use of Lean tools including 5S, VSM and Kanban cards.
4. Train staff on Lean techniques.
5. Standardize the process.
6. Develop cross-functional teams for continuous improvement implementation.
7. A systematic approach by which performance measures can be quantitatively measured on a regular basis needs to be developed. The performance measures identified in this study were resource utilization, patient waiting time and cycle time, traveling in system (patient and staff), patient accessibility and throughput.

Conclusions and Future Work

Lean implementation in a clinical setting focuses on increasing the throughput in the system, reducing patient waiting times, and increasing utilization of resources by reducing idle time of staff. This optimization of clinic space is classified based on the flow, layout and application of Lean tools. From the study conducted here, the strategy was to increase patient throughput by changing scheduling practices, thereby increasing the number of patients seen and reducing overall patient wait time. Additional recommendations for future study include:

1. Splitting the current simulation model (which considers clinic flow and space utilization in the same model) into two separate models; one to consider the flow patterns and the other to focus on the space utilization aspect. As such, the first model can analyze the flow more efficiently and the output of such a model can be plugged into the second part.

2. Customize the simulation model for Lean interventions. It is possible to observe the impacts of Lean intervention before they are implemented. Once the manager determines what intervention will be implemented, a customized simulation model could be developed.
3. Implement a digitized data-collection system which can be used for simulation of data. Inaccurate data result in sub-optimal analyses.
4. Add more advanced features to the developed model to make it user friendly. Users can easily run the model from a friendly environment such as Excel.
5. Expand the scope of the model by considering the impact of other clinics which have interaction with primary care clinics such as lab, specialty and pharmacy.
6. Customize the simulation model for Lean interventions. It is possible to observe the impacts of Lean intervention before they are implemented. Once the manager determines what intervention will be implemented, a corresponding simulation model can be developed. However, to do that the current model should be customized case by case.

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Biographies

KAMBIZ FARAHMAND is currently a Professor at the Industrial and Manufacturing Engineering and Management at North Dakota State University. He is an internationally recognized expert in Productivity Improvement. Dr. Farahmand has over 28 years of experience as an engineer, manager, and educator. He is a registered professional engineer in the state of Texas and North Dakota. Professor Farahmand may be reached at Kambiz.Farahmand@ndsu.edu

REZA KARIM is in Ph.D. program at Industrial Engineering Department at North Dakota State University. He is currently conducting research in improving Healthcare facilities design and management. His research interest is in the area of healthcare, simulation, product design, process analysis, lean application and human factor consideration. He has work experience in the field of equipment design, process development, CFD analysis and project management. Mr. Karim may be reached at Reza.Karim@ndsu.edu

RAGHAVAN SRINIVASAN is a student at North Dakota State University pursuing his MS degree in Industrial Engineering. His research interests are in the area of Human Factors Engineering, Safety, Respiratory Heat Transfer, Healthcare Management and Facilities Design. Mr. Srinivasan may be reached at Raghavan.Srinivasan@ndsu.edu

S.REZA SAJJADI is currently a post-doctoral research fellow and instructor in the Industrial and Manufacturing Engineering department at North Dakota State University. Dr. Sajjadi may be reached at Reza.Sajjadi@ndsu.edu

LORI FISHER is currently working as a Health System Specialist in System Redesign Division of Fargo VA. MS. Fisher may be reached at Lori.Fisher2@va.gov