



Application of Agile and Simulation Approaches for the Maximal Benefits of Reduced Turnaround Time from the Point of Care Testing

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Abstract

This paper uses simulation to explore improvement opportunities in the orthopaedic care process. Secondly, this study used a combination of simulation and agile strategies to explore agile operational plans that can be adopted to maximize the benefits of reduced turnaround time. Data used for this study was collected by observing the entire orthopaedic care process. A total of 635 observations were obtained, with 179 out of these observations undergoing the whole care process. The actual collected patient data were compared with the simulation output to validate the developed simulation. Different scenarios were developed to test operational plans for the maximal benefit of reduced turnaround time. Deployment of point-of-care platforms reduced turnaround time for sample tests. Flexibility was introduced as an agile operational plan to ensure the maximal benefit of the reduced turnaround time. The effect of flexibility on the orthopaedic care process was significant. The simulation results showed a significant decrease in patient waiting time by 86%. This study was limited to orthopaedic patients. Studies focusing on other clinical settings are encouraged. This study recommends using agile operations practices to maximize the benefit of reduced turnaround time in healthcare processes.

Keywords: Point of care, Turnaround time, Agile and simulation.

Introduction

Globally, approximately 1.71 billion populations have musculoskeletal injuries and diseases, with orthopaedic cases being one of the leading contributors to disability worldwide (Liu et al. 2022, WHO 2023). The global number of road traffic injuries and deaths remains unacceptably high at 1.24 million yearly. This estimate is forecasted to increase to 1.9 million deaths annually by 2030 if no measures are taken (WHO 2016). More than 90% of deaths that result from road traffic injuries occur in developing countries (Joshi et al. 2020). Orthopaedic cases significantly affect the populations by

limiting mobility and dexterity, which leads to early retirement from work and reduced ability to participate in society activities (Liu et al. 2022)

The disability burden is much higher due to lack of timely access to treatments or insufficient resources to meet the fast-growing and variable orthopaedic demands (Salazar et al. 2019, Dawson et al. 2022). Given the complexity of increasing daily orthopaedic demands, healthcare managers are looking for efficient ways to accommodate more patients within limited resources. Delays resulting from central laboratory sample testing have greatly

concerned healthcare managers. Common factors that lead to these delays include excessive demands, overlapping activities, and sometimes equipment problems (Shiferaw and Yismaw 2019). Excessive delays in receiving test results are vital contributors to the inefficient exploitation of scarce hospital resources. Furthermore, the extended waiting time is associated with adverse effects on clinical and patient outcomes (Reichert and Jacobs 2018, Bhartia et al. 2019).

Even though no one factor can be acknowledged as a root cause of this problem, nevertheless decreasing the time between patient sample collection and test results can enhance a healthcare provider arrive at a quicker care management decision and reduce patient waiting time (Larsson et al. 2015, Kankaanpää et al. 2018). Healthcare providers have introduced the fast-growing point-of-care system technology to decrease the time between sample collection and test results.

The point-of-care platform contains mobile laboratory devices different from the central laboratory positioned directly where patient treatment occurs. Point-of-care systems greatly benefit patients and hospital resources (Lingervelder et al. 2022). Reduced turnaround time between patient sample collection and test results is the primary benefit because test results are available to healthcare decision-makers within minutes. Nevertheless, the ability of clinical processes (patient process) to take advantage of the reduced turnaround time is the critical determinant of the effects of point-of-care testing on patient care (Harder et al. 2019, Lingervelder et al. 2022).

Literature documents that shortening the turnaround time alone will not shorten the time to clinical interventions if the clinical flow is not improved to act to the fast delivered test results (Larsson et al. 2015). The key questions healthcare providers should ask themselves before implementing point of care tests is, "Are the capabilities of our clinical processes sufficient enough to accommodate the increased patient flow due to reduced turnaround time?"

Furthermore, to enhance clinical processes and take advantage of reduced turnaround time, the healthcare organization can adopt operational management tools, techniques, and philosophies such as agile and simulation. At the operational level, agile strategy solves the problem of demand uncertainty and variability by increasing resource flexibility. It focuses on achieving timely responses to volatile and unpredictable demand environments using flexible capacity (Patri and Suresh 2019). On the other hand, simulation is the most powerful tool to represent the occurrence of healthcare delivery events by incorporating the characteristics of the existing system.

Drawing from the discussion above, it can be noted that redesigning healthcare processes for the maximal benefit of reduced turnaround time is critical. Therefore, this study used simulation and agile strategy to explore how to maximize the benefits of reduced turnaround time in patient care processes. The main focus of this study was on the entire orthopaedic care process from when the patient comes to the point of discharge. However, the waiting time analysis focused on the clinic since 80% of orthopaedic patients are nonsurgical cases (Comans et al. 2014). To accomplish these objectives, the following research questions were addressed: (i) How can the best of reduced turnaround time benefits be maximized? (ii) What are the critical agile characteristics or operational plans that can be adopted to maximize the benefits of reduced turnaround time?

Theoretical Framework

Agile strategy

Since the beginning of the 21st Century, healthcare systems globally have experienced significant changes as they move from volume-based to value based healthcare delivery systems to meet fast growing demands for care and enhance efficiencies in care delivery processes (McAlearney et al. 2018, Nelson 2020). Moving to value based healthcare delivery model demands agility driven processes and people, which have pushed healthcare providers to focus on agile

healthcare processes that guide healthcare delivery.

Agile based processes redesign: Application of resource flexibility

Agile strategy, which focuses on increasing resource flexibility to respond to demand volatility and uncertainty, has been documented to positively impact patient care delivery (Patri and Suresh 2019). The agile strategy emphasizes flexibility for the entire organization system to meet patient demands at the lowest costs. Agile is the ability to react to new chances and issues by incorporating new designs quickly (Vaishnavi and Suresh 2020). It gives organizations the ability to withstand the volatile and uncertain operating environment.

In an operating environment with volatile and unpredictable demands, the agile approach responds to this situation by increasing resource flexibility of the delivery capacity to ensure fixed lead times (Karman 2019). Flexible capacity requires the high availability of extra personnel or any resources needed to perform a process on time, regardless of the actual demand volume (Abdelilah et al. 2018, Christofi et al. 2021). The main advantage of this approach is that adjacent steps in the process receive reliable deliveries. Receiving timely deliveries shortens throughput time and increases patient access to care (Akpobolokami 2022).

The agile strategy emphasizes adopting flexible capacity, remarkably increasing flexibility along the dimensions of service volume, customer input varieties, and the ability to meet unexpected new events in response to unpredictable shifts in demands (Abdelilah et al. 2018, Ravichandran 2018). Responding to actual customer demands requires the availability of flexible human and physical resources capacity, which capacity should be directly proportional to the delivery requirements. It means when demands rise, the capacity must be there to deliver on time; likewise, when demands decrease, capacity should also decrease. Flexible capacity enhances the achievement of fixed lead times (Tolf et al. 2015). Therefore, flexible capacity is of critical

importance to facilitate a high speed of response and capabilities to withstand variations and instabilities (Fayezi et al. 2017)

Resource flexibility can be created by increasing the number of resources by adding new resources or extending the use of the available resources (Olsson and Aronsson 2015). Operational practices to increase resource flexibility can be obtained in various ways, such as having a flexible workforce with members cross-trained or able to fulfil a diversity of tasks dedicated to demand situations (Ajgaonkar et al. 2022). With orthopaedic patients, this might mean cross training nurses and non-physicians to help during periods of high demands.

The positive impacts of cross training flexible workforce

Time: Cross training enables shorter processing time and more reliable delivery by reducing the mean and variance of the circle time required to produce a particular service or product. Increasing worker flexibility, improving task speed, and minimizing task time variations can reduce congestion resulting in shorter circle times. Congestion is a major factor generating waiting time that usually constitutes a significant fraction of total lead time. Thus reducing congestion improves the production flow of products or services (Hopp and VanOyen 2004, Ajgaonkar et al. 2022)

Variety: Cross training positively affects organization production flexibility, enhancing the ability to deliver customers a broader range of services. Healthcare managers can achieve diversity by developing a workforce with multiple skills so that they can do a variety of tasks efficiently and by equipping the workforce with redundant tasks so that the organization can provide a range of products or services reliably (Hopp and VanOyen 2004, Bhatia and Shrivastava 2022).

Introducing an agile workforce in the patient care processes can improve patient flow. Since the reduced turnaround time increases patient flow, workforce agility can enhance the speed of flow of patients in the

care processes. State differently agility workforce can improve clinical operations and the ability to take advantage of reduced turnaround time.

Due to the sensitive nature of surgical patients, cross trained workforce can focus on minor surgeries and nonsurgical cases. The proposed cross-trained workforce is referred to non-specialist clinicians for this study. These can be, e.g. registered nurses or any supportive staff whom the hospital can be willing to cross train. Whenever non-specialist clinicians are mentioned, it implies flexible workers.

Despite the theoretical positive effects of agile strategy on healthcare delivery, discussion of an agile and flexible workforce in healthcare is rare. Empirical tests of operational plans or practices that can increase agility are also missing. Most agile theoretical concepts are not tested empirically. This study focuses on filling this gap by exploring how increasing resource flexibility can improve healthcare delivery.

Materials and Methods

System description

Department environment

Bugando Medical Centre (BMC) is one of Tanzania's four teaching and consultant hospitals. It serves primarily the Lake and Western zones of the United Republic of Tanzania. The BMC is situated along the shores of Lake Victoria in Mwanza City. This 900-bed hospital employs about approximately 1000 employees. Bugando Medical Centre is a referral hospital for tertiary specialist care serving six regions: Mwanza, Tabora, Kigoma, Kagera, Mara, and Shinyanga. In general, the population served by this hospital is around 13 million people.

Bugando hospital is the sole referral orthopaedic service in the area providing elective and emergency orthopaedic services at a referral level. The hospital has high rates of orthopaedic patients and other patients with limited laboratory capacity. Some of these patients must undergo sample testing at the central laboratory. Since the central laboratory serves the entire hospital, patients

experience high waiting times. Waiting time includes before the sample is taken and waiting for sample test results. Due to the high number of patients, a patient can wait an average of one to two hours, sometimes even three hours, depending on the nature of the sample test ordered and the queue found on that day. Patients with ordered ancillary tests have high waiting times as they have to join the surgeon queue twice. The first meeting is for preliminary examination and receiving the laboratory test required. The second time is when the patient has received the laboratory test results. Introducing point of care systems in this department could greatly benefit patients and the hospital. But with only four orthopaedic surgeons, the benefits of reduced turnaround time cannot be realized. Introduction flexibility (flexible workforce) may enable the maximal benefits of the reduced turnaround time. Exploration of the impacts of point of care on the orthopaedic patient outcome will allow healthcare managers to get more insights about point of care when considering its implementation. Furthermore, analysis of the effects of flexibility on resource constraint problems may lead to process improvement opportunities for effective utilization of point of care in the orthopaedic department.

Orthopaedic department resources

One of the essential steps in building the simulation model is identifying resources and entities in the studied systems. Bugando hospital has four specialized orthopaedic surgeons and five operational theatres for elective and emergency patients. Orthopaedic surgeons are allocated to only two rooms, operating on Monday, Wednesday, and Friday, with two surgeons per day. The total capacity for three days in the operating theatre is six rooms per week. On the clinic side, orthopaedic surgeons attend to patients on Tuesdays and Wednesdays with two surgeons per day. At the clinic, three nurses take patients to surgeons for examination when their records arrive. The hospital also has one central laboratory and an x-ray section.

Process mapping

Figure 1 shows the patient flow in the orthopaedic department. When the patient arrives at the hospital, the registration clerk at the medical record confirms medical information for registration purposes. After registration, the patient goes to the orthopaedic department. The patient file containing medical records and personal information from medical records follows later on. Nurses escort patients to the surgeons when the file becomes available at the clinic. If needed, the surgeon orders ancillary tests (laboratory and x-ray tests) after examination. If requested, the patient

goes for ancillary tests and returns to a surgeon with ancillary test results for further investigation and surgery decision if required by the patient. In the central laboratory, the sample has to pass through different processes like an acknowledgement of sample receipt, sample registration, and specimen processing; after that, the laboratory technician will perform the testing. When the results are ready, they are sent back to surgeons for further patient care processes. The surgeon decides whether the patient can undergo surgery or be discharged, depending on the feedback.

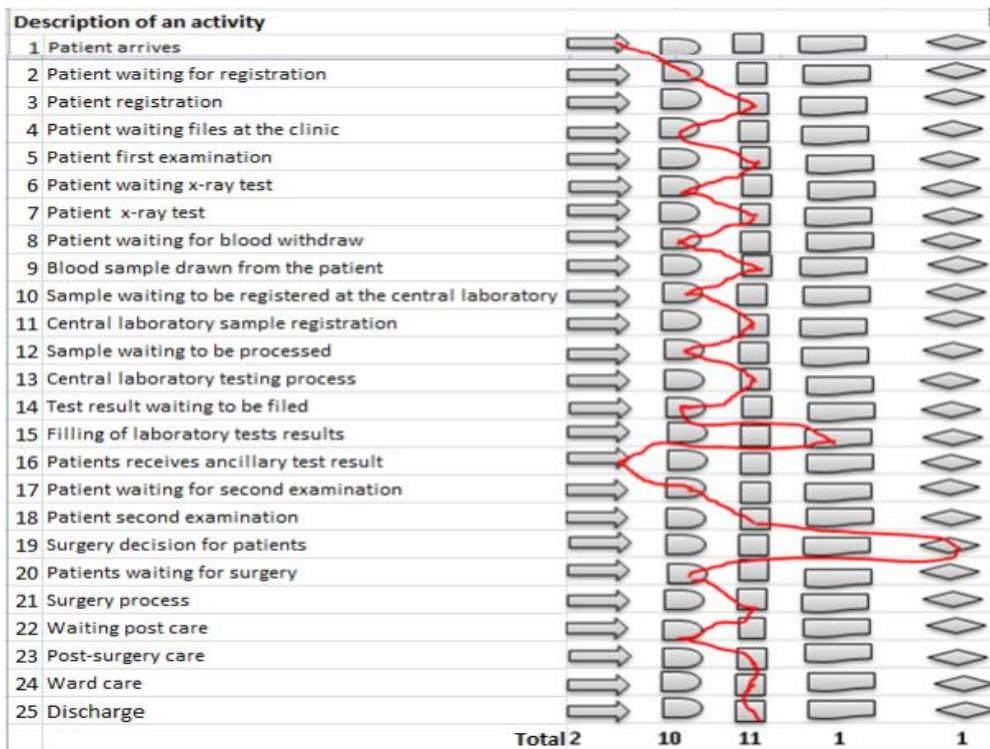


Figure 1: Conceptual model showing patient steps with central laboratory sample test.

Proposed changes

First: Introduce the point of the care system in the orthopaedic department to reduce test turnaround time.

The original work procedure sent patient samples to the central laboratory for testing. The intention of process redesign with the point of care system is to create a process that eliminates the prominent sources of non-

value-adding time, such as pre-analytic steps in the central laboratory. The main objective is to reduce sample test turnaround time. It is proposed that the entire blood sample tests be shifted to the orthopaedic department and performed under the point of care sample tests system. By using point of care systems, patient flow is improved.

Second: Introducing flexibility as agile operational plans

Resource flexibility is a specific agile characteristic that healthcare managers can use in patient processes to enhance their capabilities of maximizing the benefits of reduced turnaround time. Resource flexibility has many meanings depending on the settings and levels of details under analysis. It could imply hiring new resources, changing resource allocation decisions, or having a flexible workforce. The proposed operational change is to increase resource flexibility by cross-training a flexible workforce (e.g. registered nurses) at orthopaedic clinics and other areas. Switching to mid-level providers reduces costs (e.g. low salary) since these are cheap resources compared to specialist surgeons.

We propose a flexible workforce (non-specialist clinicians) because the orthopaedic clinic operates for only two days per week. The cross-trained staff can perform other hospital tasks on days with no orthopaedic clinic. The non-specialist clinician can handle some medical responsibilities surgeons operate before the change. These responsibilities include nonsurgical cases, minor surgeries (e.g. wound debridement, closed fracture reduction, and incision), and other cases that do not require specialist

level. With these changes, the orthopaedic care process will be able to accommodate the workload resulting from the reduced turnaround time.

The proposed model is solved in two stages. In the first stage, a point of care in the department is introduced by assuming that lab test time equals the point of care test time. The critical assumption here is that by removing lab waiting times, the lab test time is approximately equal to point of care tests since it is the same test performed. The model was run to see the impacts on patient waiting time, the number of patients waiting, and throughput in the surgical room. This model was used to explore the constraints in the process, which limited the maximization of the benefits and reduced turnaround time from the point of care.

Incorporating agility practices

In the second stage, capacity adjustment was conducted by integrated resource flexibility. The proposed practice was incorporated in the model as the change for capacity by the addition of two non-clinician workers and routing minor surgeries to this new team. Figure 2 shows the reduced steps in the orthopaedic care process due to replacing the central laboratory process with the point of care.

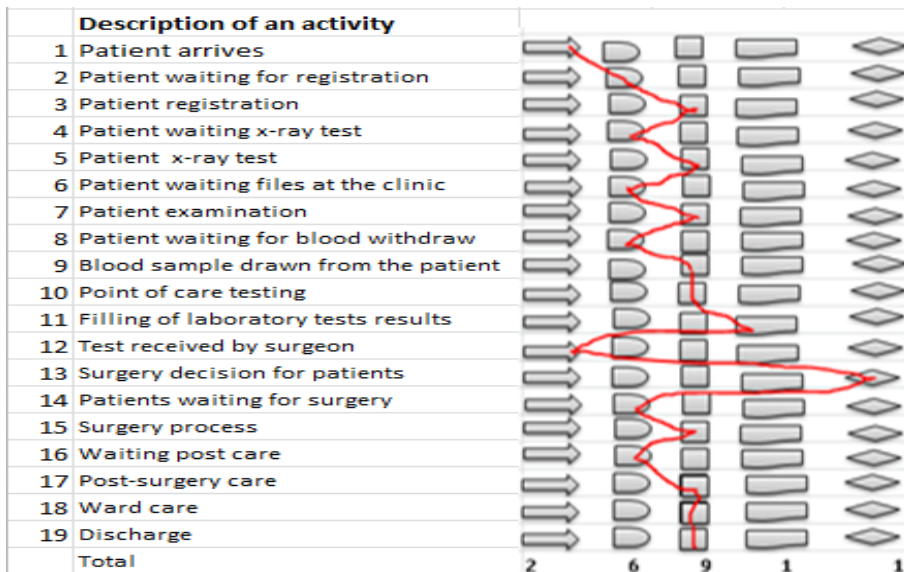


Figure 2: Conceptual model showing patient steps with the point of care testing sample test.

Data

The data from the orthopaedic department of Bugando hospital were used to explore the research questions. Specifically, this study used interviews and observational data from the orthopaedic care process covering three months. A total of 635 observations were obtained, with 179 out of these observations undergoing the whole care process from arrival at the clinic to discharge at the surgical room.

The primary focus was to get essential details on the number of care activities from the orthopaedic clinic to the surgical room. The observed activities include the patient arrival process at the clinic and surgical room, the patient registration process at the medical record, patient diagnostic examination at the clinic by surgeons, surgical procedure, diagnostic testing (x-rays), and blood work at the central laboratory. We differentiated between service time and waiting time for each listed activity. Waiting time represents the idle time a patient experiences while waiting for the service to be delivered, and it adds no value to the patient. Service time means the time that orthopaedic care providers spend with patients.

We hired and trained students at Bugando Catholic University to observe patients moving through the orthopaedic department from the clinic to the surgical room. These students received a two-day orientation on the purpose and the nature of the required study and the planned data collection approach. In addition to these students, the chief coordinator of the orthopaedic room was willing to help data collection process, so he was among the data collection team members. Data collectors recorded all the recommended details of patients at each stage the patient passed. The data collectors documented each process's start and end time using the stopwatch and a unique form for this project. This form included information on patients' arrival times, process times per patient service station, and the number of resources per service station. The chief of the surgical room was concerned with the data in the surgical room and was doing it with one

of us. We filled out the form as the patient went through each process in the surgical room.

Simulation

Model assumptions

Replicating natural systems involving human behaviour and decision into a simulation model is impossible. It is essential to make some assumptions for modelling purposes. We made the following assumptions when building a simulation model based on observing the orthopaedic care process. The current study considers the operational system only between 8.00 am and 4.00 pm. Second, the resources are available for orthopaedic patients all day.

Empirical data analysis

Detailed analysis of empirical data is required to develop a robust simulation model. A detailed analysis of the collected data for distribution fitting was performed. Scatter plots and linear correlation techniques were used to assess data independence. The estimated lag correlation was small and clustered at about zero. The sample produced scatter plots with points distributed over portions based on the respective distribution. Using Arena and Minitab, Summary statistics, histograms, and box plot techniques were used to hypothesize families of distribution. After distribution, Chi-square was used to determine the representativeness of the fitted distribution. Thus, the Chi-Square for the goodness of fit tests led to selecting the respective distribution. An arena input analyzer was used to generate the distribution parameters for the simulation model. Table 1 shows the selected distribution.

We replicated 20 replications, each representing one day of care delivery. Patients in the simulation model are generated based on the clinic and surgical room working schedules. We used Arena (version 14) to perform the simulation experiments. Table 2 shows the selected distribution per process.

Table 1: Simulation model input based on the current clinic operation

Process	Distribution	P-value	Chi-square
Arrival	0.5 + EXPO(2.62)	0.486	3.46
Registration	5.5 + GAMM(1.97, 4.73)	0.638	6.09
Nurse contact	1.5 + WEIB(3.59, 1.49)	0.536	3.15
Examination	3.5 + WEIB(15.4, 1.74)	0.75	5.01
X-ray	13.5 + WEIB(3.79, 2.15)	0.0823	6.8
Laboratory	NORM(25.4, 2.98)	0.0859	15.3
Surgery	10 + GAMM(46.9, 1.34)	0.21	7

Table 2: Effects of point of care systems and flexibility on patient throughput

	Mean	95% Confidence interval for mean	
		Lower bound	Upper bound
Throughput before POC	9.7	5	14
Throughput (POC + Flexibility)	29	23	35

Simulation model verification and validation

Verification assesses whether the conceptual model correctly translates into the simulation computer program (Law and Kelton 2000). In the current study model, verification was done using Arena debugging facilities and animation to determine whether the model was running as intended and was error-free.

Validation determines whether the simulation model reasonably represents the actual system (Sargent 2020). The most acceptable way of validation compares the simulation output to the real data from the existing system using formal statistical methods like confidence intervals (Sargent and Balci 2017). The simulation outputs were compared to the existing observed data to validate the simulation model. The confidence interval of simulation output was calculated at a 95% confidence level and compared it to the observed data values.

Modeling Results and Discussion

This section presents the results and discussion of exploring the point of the care

system in the orthopaedic department. The first scenario presents the effects of the point of the care system in the orthopaedic department with surgeon capacity constraints. The second scenario presents the impacts of introducing a flexible workforce in the surgeon-constrained department. The main objective is to ensure the maximum benefits of the reduced turnaround time. Table 3 shows the effects of point of care systems and flexibility on patient waiting time.

One of the key advantages of using point of care systems is the increased patient flow (Harder et al. 2019). If the healthcare processes are not redesigned to take advantage of reduced turnaround time, the benefits portrayed by the point of care system can be distorted. For example, if there are not enough resources to handle these fast obtained results, congestion at the clinic might occur. With only two surgeons at this clinic, managing the increased workload resulting from reduced turnaround time is impossible. Due to this fact, orthopaedic managers did not realize a significant reduction in patient waiting time before introducing flexibility.

Table 3: Effects of point of care systems and flexibility on patient waiting time

	Mean	95% Confidence interval for mean	
		Lower bound	Upper bound
Waiting time before POC (hrs)	2.41	1.98	2.66
Waiting time (POC + Flexibility) (hrs)	1.61	1.1	1.93

Maximizing the advantage of reduced turnaround time requires redesigning the care process by increasing resource flexibility. Since adding a specialist is extremely expensive and given the unlikelihood of adding specialists on a short-term basis in developing countries, we recommended using non-specialist clinicians (e.g. registered nurses) since they are cheap resources. We analyse the effects of introducing resource flexibility on patient waiting time and throughput by adding two non-specialist clinicians to the clinic's orthopaedic care process. They will focus on minor cases.

Effects of introducing resource flexibility on the surgeon constrained orthopaedic clinic with the point of care system

The aim of introducing resource flexibility was to, first and foremost, maximize the benefits of reduced turnaround time resulting from the application of the point of care system in the orthopaedic department. Increased resource flexibility enabled patients to meet with surgeons earlier in the process than before due to reduced waiting time. The fact that surgeons can evaluate patients earlier and faster than before indicates operational improvement in the patient care processes. The ability of clinical processes to respond quickly to the increased patient flow is enhanced through flexible workers.

The principal finding of this study is that when facing increased patient flow associated with volatile demands for services increasing resource flexibility produces more improvement. The simulation analysis of this study demonstrates that healthcare managers can alleviate problems related to timely access to care by creating a process structure that allows for a more rapid response to care demands. The ability to have flexible workers simplifies the capacity adjustment issues and increases the possibility of achieving better efficiency. Simulation results indicate that congestion could increase without increasing resource flexibility at the orthopaedic clinic, limiting the realization of the benefits of reduced turnaround time. Even though this impact might be insignificant in the surgical

room, it has a positive effect at the clinic, where the patient waiting time is minimized.

Conclusion

Using point of care testing is among the efforts healthcare providers use to reduce patient waiting time so that more patients can access care services. However, healthcare managers cannot realize the effects of reduced turnaround time if the current healthcare processes cannot respond faster to the increasing workflow. This study recommends increasing resource flexibility to maximize the benefits of reduced turnaround time. Indeed, one of the critical contributions of our research is that increasing resource flexibility in the orthopaedic care process could significantly reduce demand variation, surgeons' workload, and patient safety risks.

Generally, we can argue that when facing variable patient cases, modifying patient care processes to increase the ability to match existing capacity to demand results in more improvement in patient access to care. Our main contribution focuses on revealing the advantage of an agile strategy in improving the delivery of patient care, particularly in resource constraints settings. With insights generated from simulation modelling on the impacts of resource flexibility, we have noted that an agile strategy can improve access to healthcare. This results in the maximum benefits of the reduced turnaround time.

This study contributes to the insights concerning the problems of healthcare production processes. Due to rising costs, using cheap resources to accommodate patient care processes is currently a global concern. The cost of developing a cheap non-specialist clinician is not as high as that of a specialist surgeon. Hence, non-specialist clinician is cost-effective, but they are not meant to replace the role of specialist surgeons. In most cases, these resources should be used to cover the resource shortage on a short-term basis.

This study faces several limitations. It focused mainly on the clinical area as the primary constraint. Future research can elaborate on the point of care system by linking it to other modelling alternatives,

such as the scheduling of operating room processes and appointment systems at the clinic to improve resource utilization. The second line of research could include cost implications and total hospital restructuring if the point of care systems are to be used for the whole hospital. The third line of research can be the comparative study of the point of care implemented in this clinic to analyse its impacts.

Practical implications

The results of this study provide significant insights to healthcare managers and policymakers, particularly in the developing world. The reduced turnaround time indicates that more patients can be treated by applying point of care systems and agile operational practices such as cross-training the midlevel staff. These staff can handle minor cases when the demands are high in the system. Agile strategy and simulation have been widely used in the manufacturing industry to improve the production process; thus, from this study's findings, managers should consider implementing agile operational practices to improve healthcare patient processes.

Theoretical implication

This study highlights some contributions to existing literature. First, the reduced turnaround time after redesigning the care process shows that using point of care systems, cross-training middle staff and reallocating them in their relevant areas can maximize the benefits of reduced turnaround time. This study also contributes to the existing healthcare process studies. By considering not only reducing turnaround time but also proposing appropriate agile operational practices models that can maximize the benefits of reduced turnaround time.

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