Yusta Wilson Simwita

Improving healthcare processes: An empirical study based on orthopaedic care processes

Molde University College
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Molde University College - Specialized University in Logistics
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Introduction

1 Introduction

1.1 Motivation

The objective of any healthcare organization is to "provide the right care to the right patient at the right time" (Litvak et al. 2001). However, in practice it is not easy to achieve this goal. Healthcare processes are highly complex and performed under a continually changing operating environment. This environment is commonly believed to be one of the most complex when compared to others (Poulymenopoulou, Malamateniou, and Vassilacopoulos 2003; Rebuge and Ferreira 2012). The dynamic nature and complexity of today's healthcare processes is caused by several societal trends: medical technology is advancing at an ever-increasing speed, leading to the development of new treatments and examinations; patient demands and needs have generally increased with technological and medical advances; and the population is aging, which results in more people suffering from multiple and complex diseases (Winge et al. 2015; Vogeli et al. 2007; Myllykangas et al. 2003; Langabeer 2008; Persson and Persson 2010).

Due to increasing demand, the discrepancy between patients' expectations and the resources that healthcare providers can afford to provide has increased. Healthcare organizations can no longer afford to match existing resources with increasing patient demands (Langabeer 2008; Sheth et al. 2015; Funk et al. 2010; Myllykangas et al. 2003). Healthcare organizations globally are experiencing growing constraints on the healthcare resources, particularly the availability of human resources (Langabeer 2008; Vissers, Bertrand, and De Vries 2001; WHO 2006). The situation is argued to be more acute in the developing world, which represents a global deficit of 2.4 million of doctors, midwives, and nurses. The severe discrepancy is found in the African continent, which bears 24% of global disease with only 3% of the workforce capacity (WHO 2006). The African sub-Saharan countries such as Tanzania are reported to have more severe discrepancies between healthcare demand and existing workforce capacity (Hodges et al. 2007; Sheth et al. 2015)

The global mismatch between resources and patient demands has led to a dramatic increase in the uncertainties and complexities of healthcare delivery systems and processes (Winge et al. 2015). The main challenge posed to healthcare providers today is how to improve healthcare processes in order to accommodate these complex changes.

In recent years, lean and agile strategies have been promoted by many authors as the key process improvement philosophies that can be used to respond to complex changes in healthcare processes (Mclaughlin and Hays 2008; Vries and Huijsman 2011). Although such strategies have been mostly promoted as a means of improving healthcare processes, most of the existing studies focuses at the organizational level (Tolf et al. 2015; Radnor, Holweg, and Waring 2012). However, the growing complexity of healthcare processes cannot be handled at an organizational level. It is argued that to improve the operation and efficiency of care, such strategies must be implemented at process level (Gonçalves, Hagenbeek, and Vissers 2013). Maintaining efficiency at a process level is seen as a means of narrowing the gap between healthcare resources and ever-increasing patient demand (Vera and Kuntz 2007; Nilsson and Sandoff 2015). Thus, this thesis takes a process perspective to find whether healthcare process can be improved by adopting lean and agile strategies.

In additional to lean and agile strategies, simulation has also been widely advocated as a powerful technique that can be used to improve healthcare processes (Barjis 2011; Barjis 2010). Although simulation has proven its viability and capability in designing and improving complex systems and processes in manufacturing and private industries, the literature acknowledges that the application of simulation in healthcare industry is still at an embryonic stage (Mustafee, Katsaliaki, and Taylor 2010; Barjis 2011). Given the increasing complexities in healthcare processes, simulation is argued to be the tool that has the potential of improving healthcare delivery systems (Mclaughlin and Hays 2008; Barjis 2010). However, the immense applications of simulation in healthcare processes are as yet unrealized. Thus, this thesis addresses this gap, showing how simulation can be used to improve healthcare processes.

1.2 Study objective and research questions

The above discussion draws us to the main purpose of this thesis, which is:

To show how healthcare processes can be improved using different process improvement strategies/techniques from manufacturing industries (i.e. lean, agile and simulation).

In the preceding section, it has been shown that the application of lean, agile and simulation in healthcare is still at an embryonic stage (Mclaughlin and Hays 2008; Vries and Huijsman 2011). Thus, this thesis aims to extend this line of research, showing how healthcare processes can be improved by adopting process improvement techniques/strategies such as lean, agile and simulation. To fulfill this purpose, an empirical study was conducted in an orthopedic department of Bugando referral hospital in Tanzania. A detailed discussion of Tanzania's healthcare system, as well as the hospital that was studied, is given in the empirical setting section.

To increase the understanding of how healthcare processes can be improved, the following main research question was developed:

> *How can healthcare processes be improved in order to accommodate the increasing demand?*

This research question is further divided into four sub-questions, each of which is addressed in a specific paper. A brief overview of each question is given below.

1.2.1 Research question 1:

The application of lean and agile strategies in healthcare has recently been advocated as key for the improvement of healthcare processes (Vries and Huijsman 2011). As discussed in section 1.1, these strategies have been widely applied from an organizational point of view. There have been some initiatives of lean and agile studies in healthcare processes (Aronsson, Abrahamsson, and Spens 2011), but no prior research has demonstrated when and how lean and agile strategies can be used in healthcare processes. Thus, issues of when and how to apply lean and agile strategies in healthcare processes is still unclear. Given the increasing patient demands and declining resources it is important for healthcare providers to have a clear understanding of when and how to use lean and agile strategies in healthcare processes in order to improve patient care processes. Due to the crucial need for the understanding of appropriate applications of lean and agile strategies, this study attempts to answer the following research question in paper one:

> *When and how can lean and agile strategies be used to improve healthcare processes?*

During investigation of this care process, we had several discussion with hospital management and surgeons. Critical shortage of orthopedic surgeons and high crowding at the clinic was a major concern raised by hospital management during several discussion. After discussion with hospital management, the next step was to find out how to improve utilization of existing surgeons so that they can be able to handle the increasing patient demand at the clinic. This challenge led us to the research question number 2, which focuses on finding out how to improve surgeon utilization while reducing patient waiting time.

1.2.2 Research question 2

Despite the increasing advancements in medical technologies, the existing human resource constraints pose a critical challenge to healthcare providers (WHO 2006; Edward et al. 2012). According to the World Health Organization (WHO, 2006), there is a critical shortage of healthcare providers globally in all cadres i.e. physicians, nurses, doctors, etc. This crisis is expected to deepen in the future due to various factors such as an aging population. Several strategies are being proposed to handle this situation.

The most prominent strategy is the better utilization of existing human resources. Given the predicted crisis of human resource shortages, it is important to identify better ways of utilizing existing resources. This discussion leads to the second research question, which is covered in paper two. The question is stated as follows:

What factors influence poor surgeons' utilization?

Remaining within the same theme of improving workforce of this orthopedic care process, this study decided to explore how could making the healthcare workforce agile improve patient care processes. As evidenced in paper one, agile strategy is not implemented in this care process. In other words, workers are not aware of the workforce agility concept. Given the importance of having agile workforce in healthcare processes, and lack of workforce agility literature in healthcare this study addressed this challenge by defining the workforce agility concept and showing how it can improve healthcare processes through literature review as explained by research question number 3

1.2.3 Research question 3

Growing uncertainty and volatility in patient demands pose a critical challenge for healthcare providers and how they manage this complexity in healthcare processes (Aronsson, Abrahamsson, and Spens 2011). Workforce agility is widely advocated in literature to have a positive effect on responding to uncertain and volatile environments (Breu et al. 2002; Duguay et al. 2014). In healthcare, this can be translated into the ability to respond quickly to uncertain patient demands. Despite its importance in enhancing organizational agility, prior studies have mainly focused on workforce agility from a technical point of view. There is limited research about workforce agility at the process level (Breu et al. 2002). This gap leads us to the third research question, which focuses on exploring the relationship between workforce agility and healthcare processes. Thus, the following research question is developed and answered in paper three, through a systematic literature review:

What is the relationship between workforce agility and healthcare processes operational outcome?

Based on literature review, lack of empirical studies on work force agility was observed. This study aimed to extend this line of research by exploring the effect of resource flexibility on healthcare processes as explained through research question 4. It was not possible to test workforce agility as the concept itself due to data availability, instead resource flexibility as one of workforce agility characteristic was further examined using research question 4.

1.2.4 Research question 4

The main characteristic of patient demands is that they are highly volatile and unpredictable (Rahimnia and Moghadasian 2010). This feature necessitates the need for a great deal of flexibility in different stages of healthcare processes. The importance and need of key resource flexibility in healthcare processes has been well documented (Aronsson, Abrahamsson, and Spens 2011). Resource flexibility is considered as the key driver of agility in healthcare processes. Enhancing resource flexibility in healthcare processes could improve rapid response to unpredictable patient demand, leading to reduced delays (Olsson and Aronsson 2015). However, there is little empirical research addressing resource flexibility in healthcare processes. This gap leads us to the fourth research question, which is covered in paper four. The question is stated as follows:

What is the effect of surgeon/operating room flexibility on patient waiting time/throughput?

1.3 Structure of the thesis

The first section presents research motivation, followed by study objectives, and research questions. The second section present the theoretical frameworks that guides the thesis, and comprises of discussions about the importance of taking a process perspective, the prominence of applying lean, agile and simulation in healthcare processes, and approaches used to improve healthcare processes.

The third section presents the healthcare delivery system in Africa and the empirical research setting of this thesis. The fourth section presents the empirical setting and general methodology of the study, followed by a summary of the compiled papers. The final section presents the conclusions and areas for further research, after which the four papers constituting the thesis are presented.

2 Theoretical framework

2.1 Process approach in healthcare

To be more efficient and patient centered, healthcare organizations needs to focus on healthcare processes. The most important of these processes may be referred as patient process that involve interactions between patients and care providers that enhance patient health and safety (Perjons et al. 2005). This process involves a number of activities across different departments, collaborating to provide patients with the care that is needed (Vissers 1998). Process may therefore be seen as an effective way of organizing and managing organizations' activities in order to meet patient demands and other organizational needs (Vera and Kuntz 2007; Mango and Shapiro 2001; ISO9001 2015).

The need for a process approach has been suggested as a prerequisite for finding operational solutions to major issues in healthcare delivery (Vera and Kuntz 2007). Recent studies focusing on the implementation of a process orientation in healthcare organizations have concluded that potential solutions to the causes of inefficiencies in hospitals would require a process approach (Nilsson and Sandoff 2015; Fältholm and Jansson 2008). Additionally, the solutions to the inefficiencies in processes will certainly be achieved by shifting the focus from only certain elements of care to the entire process of care (Vos et al. 2009). Simply stated, a process approach means a shift in focus from functional organization to the diagnosis, care, and treatment activities of the patients (Nilsson and Sandoff 2015; Edgren 2008).

High patient waiting times are good indicators of inefficiencies in patient care processes (Santibáñez et al. 2009; Noon, Hankins, and Côté 2003). These inefficiencies are caused by the absence of a process approach in patient care processes (Vos et al. 2009). Poor resource utilization in healthcare processes has also been linked with the absence of a process approach (Santibáñez et al. 2009; Vos et al. 2009; Vera and Kuntz 2007). The inadequate utilization of resources and high waiting times has been linked to adverse effects on patients such as limited access to care (Vos et al. 2009; Patrick and Puterman 2007). Poor resource utilization not only leads to adverse effects for patients, but also contributes to operational inefficiencies in the hospital. Inefficient resources utilization often occurs due to the way internal activities are designed and carried out (Santibáñez et al. 2009; Patrick and Puterman 2007).

Lean and agile strategies are considered as process improvement strategies that can improve efficiencies in healthcare processes (Mclaughlin and Hays 2008). Likewise, simulation has been advocated as a powerful technique, which can be used to improve healthcare processes (Barjis 2010).The next section discusses why lean and agile strategies are important in healthcare processes. Following this, is a discussion about the importance of simulation in healthcare processes.

In this thesis, process is defined as a sequential set of logically related activities across time and space with beginning and end with and clearly defined inputs and outputs (Davenport and Short 1990; Davenport 1993).The main focus is on patient process.

2.2 The viewpoint of applying lean and agile in healthcare processes

Like any other industry, healthcare is structured in functional silos and has a need for well-organized and functioning processes to meet patient demands on availability of services and short lead times as well as on the efficiency of care (Aronsson, Abrahamsson, and Spens 2011). Patient process comprises of a number of activities that must be well organized and managed to enhance healthcare organization and accommodate growing patient demands and needs (Nilsson and Sandoff 2015; ISO9001 2015). Considering the variety of demands and needs for the patient processes and their effect on the availability of services and lead-times, it can be argued that different process strategies are vital to fully describe and design health care processes (Tolf et al. 2015; Aronsson, Abrahamsson, and Spens 2011).

In recent years attention on the application of lean and agile strategies has increased and has been advocated as a means to improve operational efficiency as well as resource utilization in healthcare processes (Radnor, Holweg, and Waring 2012; Rahimnia and Moghadasian 2010; Gijo and Antony 2014). It is argued that improvement of healthcare processes can be achieved by assessing healthcare processes in terms of the main characteristics of lean and agile strategies such as process flow orientation (Aronsson, Abrahamsson, and Spens 2011; Olsson and Aronsson 2015). Literature indicates that the application of lean and agile strategies is a way to increase internal efficiency and external effectiveness in healthcare processes (Tolf et al. 2015).

Although there is growing emphasis on the adoption of lean and agile strategies as a means of improving healthcare processes, academic research in this sector is limited (Jasti and Kodali 2014; Vries and Huijsman 2011). A good number of studies on lean and agile strategies have focused on manufacturing and private sectors as most of the organizations studied have been in manufacturing and private sectors (Tolf et al. 2015; Jasti and Kodali 2014).

A review of the literature concerning trends in healthcare shows that 73.44% of the existing lean studies are based on manufacturing industry, while the healthcare sector constitutes 3% of these studies (Jasti and Kodali 2015). Likewise, another recent literature review of agility in healthcare found that most of the existing studies are based on the manufacturing industry. This study found only one article that reported healthcare based research (Tolf et al. 2015). These reviews show that the gap in lean and agile research in healthcare is obvious.

From a process perspective, empirical research of lean and agile strategies at process level is very limited in both manufacturing and service industries. Table 1 presents a summary of applications of lean and agile strategies in some previous empirical studies. The reviewed literature indicates that lean and agile strategies are widely applied as companywide strategies rather than process strategies. This clearly shows a lack of academic research regarding lean and agile strategies at a process level and on healthcare processes in particular (Aronsson, Abrahamsson, and Spens 2011; Olsson and Aronsson 2015). The literature asserts that there is a need for research that demonstrates how lean and agile strategies are applied in healthcare processes and to what extent healthcare providers can benefit from applying these strategies (Vries and Huijsman 2011). Furthermore, the literature argues that, to maintain operational efficiency and to meet high demands from customers as well as to address political pressures, healthcare organizations must adopt process improvement strategies from the manufacturing and private sectors (Mclaughlin and Hays 2008). This study therefore aims to cover this gap by exploring how healthcare processes can be improved using lean and agile strategies.

2.2.1 Foundational concepts of lean strategy

Process standardization

The central issue of lean is waste reduction in production processes (Harrison and VanHoek 2008; Womack and Jones 2003). Variation in lean concepts is considered, as waste thus, must be eliminated. The widely used lean concept to eliminate internally created variation is standardization. Lean strategy with its emphasis on process standardization has been widely adopted to efficiently manage variations created internally by organization themselves. It is argued that, process standardization is more applicable for administrative activities and in situations where activities are stable and repeated in an identical fashion for all customers or patients (Paul Lillrank and Liukko 2004; Niepce and Molleman 1996; P. Lillrank 2003). By using standardized working procedure it simplifies the activities and sub activities of a given process and hence reducing variation in the activity circle time (Jayaram and Vickery 1998).

Literature further argues that process standardization facilitates communication between and within departments thus enhancing necessary flexibility to respond to any changes in customer demand (Münstermann, Eckhardt, and Weitzel 2010). And more importantly due to simplification of job complexity process standardization creates flexible capacity and enables accommodation of more patients (van Wessel, Ribbers, and de Vries 2006; Joosten, Bongers, and Janssen 2009). At the same time process, standardization has been criticized, on the basis that it limits creativity to employees. However, recent studies has found that, creativity and standardization can be complementary even though standardization moderates the relationship between creativity and employees performance (Gilson et al. 2005). Process standardization is hereby defined as the ability to make the process activities transparent and achieve uniformity of process activities across the value chain and across the firm boundaries (Wullenweber and Weitzel 2007).

Table 1 Previous empirical research on lean and agile strategies

Author	Scope of research	Level of analysis	Industry	Strategy
(Vázquez-Bustelo, Avella, and Fernández 2007);(Sharifi and Zhang 1999);(Sharifi and Zhang 2001);(Blome, Schoenherr, and Rexhausen 2013);(Alavi et al. 2014);(Zhang 2011)	Manufacturing; supply chain	Company, firm	Manufacturing	Agility
(Lin, Chiu, and Chu 2006)	Supply chain	Process	Manufacturing	Agility
(Rahimnia and Moghadasian 2010);(Aronsson, Abrahamsson, and Spens 2011)	Supply chain	Process	healthcare	Lean, agile
(Olsson and Aronsson 2015)	Supply chain	Department	healthcare	Lean, agile
(Radnor, Holweg, and Waring 2012)	Operational	Multiple	healthcare	Lean
(Christopher et al. 2009)(Selldin and Olhager 2007)	Supply chain	Company	Manufacturing/ healthcare	Lean, agile
(Whitten, Jr, and Zelbst 2012);(Qi, Zhao, and Sheu 2011);(Qi, Boyer, and Zhao 2009)	Supply chain	Firm	Mix	Lean, agile

2.3 Viewpoint of simulation in healthcare processes

The complexity of healthcare processes is increasing exponentially and is characterized by the multiplication of specialties and high patient expectations of care delivery. Conversely, current hospitals are characterized by subsystem complexities with intricate healthcare processes and high human involvement, leading to more interconnected and extremely complicated processes. Due to increasing healthcare delivery complexities, simulation has proved to be an effective tool that can be used to improve healthcare processes (Karnon et al. 2012; Barjis 2011; Duguay and Chetouane 2007).

Simulation has been proven to be a powerful technique and method in other industries for analyzing and designing complex systems and processes. One area in which simulation is widely used in manufacturing industries is on improving the utilization of scarce resources in order to improve the efficiency of associated production processes (Lowery 1996; Barjis 2011). This evidence clearly indicates that, in the current era of high pressures to maintain efficiency in complex healthcare processes, simulation is seen to be a potential and powerful tool that can provide healthcare providers with the ability to achieve the efficiency requirement in healthcare delivery systems.

The literature points out that in healthcare delivery systems, simulation allows the replication of reality, thus enhancing the investigation of possible changes and the testing of different scenarios prior to implementation. This implies that simulations can help healthcare organizations to improve efficiency at minimal cost as it enhances the assessment of benefit or loss before investing money or resources (Barjis 2010). Likewise, simulation reduces trial and error risks and thus enhances the implementation of improvement initiatives with expected results (Ferreira, Gomes, and Yasin 2011). These arguments clearly indicate that simulation is an appropriate tool that can be used to improve the efficiency of healthcare processes.

Like any other data analysis tool, the use of simulation in healthcare faces some limitations. First, all simulation models simplify reality and many do so to a great extent. Given the complexity of healthcare operations, the simplification of reality means that the model structure is not completely consistent with medical knowledge. For example, physicians know that it is completely unrealistic to represent complex diseases as a small number of discrete states and that patients are not moving from one state to another at the fixed time interval that occur in the discrete event simulation. Second, external validation tests the ability of the model to predict the actual outcome. However, it addresses only those elements covered by the collected or observed data. Even if the model predicts a number of clinical trials, there is no guarantee that it will be accurate for the next trial. Simulation cannot validate the next trial unless data for that trial become available (Siebert et al. 2012; Eddy et al. 2012).
Another limitation is that simulation models are based on assumptions because it is difficult to simulate the entire systems in the model. Thus, the model may lack some elements needed to accurately simulate a source. The model might not include all risk factors or comorbidities, all patient, physician, hospital, and health care system care processes or behaviors, or all features needed to calculate outcomes. Despite these limitations when it is accurately modeled for a specific need, the model can still be used to sufficiently meet the required needs (Caro and Möller 2016; Eddy et al. 2012).

From a healthcare perspective, simulation has shown significant improvement in various healthcare setting. It has been applied with different operational objectives such as improving patient flows, resources utilization, and reducing patient waiting time. Moreover, it has been applied in healthcare delivery systems where patient crowding poses challenges to the delivery of timely care (Rohleder et al. 2011; Duguay and Chetouane 2007; Swisher and Jacobson 2002). Although simulation has been applied in healthcare for more than a decade, healthcare simulation, particularly in real life applications, is still at an embryonic stage. The great potential of simulation has not been fully exploited when compared to manufacturing and other service related industries (Barjis 2010; Mustafee, Katsaliaki, and Taylor 2010; Eldabi, Paul, and Young 2006).This literature review clearly indicates a shortage of simulation research in the healthcare sector. To cover part of this gap, this study seeks to show how simulation can be used to improve healthcare processes. The main focus is on improving resource utilization while minimizing patient waiting time in order to increase patient access to care.

2.4 Approaches for process improvements

To cope with the increasing complexities in healthcare processes, healthcare providers have been forced to adopt new approaches or models that can be used to improve healthcare processes and meet increasing uncertainty in patient demands. With the aid of operations management techniques, such as simulation, healthcare providers are seeking to improve healthcare processes using different approaches such as the redesign of healthcare processes. In line with increasing pressures to improve healthcare processes, this section describes the need to implement two approaches: process redesign and flexibility in healthcare process.

2.4.1 Process redesign and resource utilization

Growing patient demands and increasing constraints on the availability of human resources have stressed healthcare providers, pushing them to redesign production processes for the efficient utilization of resources (Ferreira, Gomes, and Yasin 2011; Vissers, Bertrand, and De Vries 2001). It is argued that redesigning healthcare processes can lead to the improved utilization of existing scarce resources, thus reducing patient waiting time and increasing patient access to care (Locock 2003; Kumar and Shim 2005; Shim and Kumar 2010). Drawing from this argument, it can be further argued that redesigning healthcare processes is of paramount importance in the current era of growing uncertainty in patient demands and increasing constraints in the healthcare workforce capacity.

To cope with the shortage in workforce capacity and the rapid increase in demand, new designs of healthcare processes must be designed and practitioners' roles must be reshaped. Redesigning practitioners' roles by allowing non-medical staff to perform some work previously performed by medical staff removes bottleneck in the service, resulting in a more efficient care processes that is flexible and able to cope with the increasing patient demand (Lau et al. 2012; Ferreira, Gomes, and Yasin 2011; Greaves et al. 2013). Transferring and adopting standard operating procedures can lead to the better utilization of the limited human workforce capacity (Soliman 1997; Badri and Hollingsworth 1993).

The redesign of healthcare processes for the better utilization of resources has been investigated in many empirical studies using techniques such as simulation, optimization, and scheduling (Bertolini et al. 2011; Patrick and Puterman 2007; Santibáñez et al. 2009). However, the main focus of these studies has been on either waiting time or the duration of individual medical procedures on isolated parts of the care process, thus lacking an holistic view of patient care process (Kujala et al. 2006; Davenport and Short 1990). In order to improve healthcare process from the time a patient arrives to the point of discharge, a holistic view of process should be taken into consideration.

To cover this gap, this study focuses on redesigning healthcare processes in order to improve the utilization of existing surgeon capacities without adding extra resources. The focus is to show how discrete event simulation can be used to improve surgeon utilization, while minimizing patient waiting time. To meet this objective, first the entire orthopedic care process is explored to identify factors that lead to the poor utilization of surgeons. Second, the redesign strategy is proposed, which can be used to improve surgeons' utilization while minimizing patient waiting time. This approach is covered in the second paper, which seeks to find out how to improve surgeon utilization while minimizing patient waiting time and increasing patient access to care.

In this thesis process redesign is adopted from (Davenport and Short 1990), who defines process redesign as “the analysis and design of workflows and processes within and between organization.”

2.4.2 Flexibility in healthcare processes

To cope with ever-increasing volatility and uncertainty in patient demand, healthcare providers now look beyond traditional approaches to increasing patients' access to care. The focus is now on adaptability to change in the healthcare operations and on adopting proactive strategies for meeting patients' needs and demands. Increasing speed and flexibility are now emphasized as a means of responding to growing patients' needs and demands (Aronsson, Abrahamsson, and Spens 2011). An agile strategy has been highly recommended as the key process improvement strategy that can provide the necessary flexibility in different stages of the healthcare processes (Olsson and Aronsson 2015; Vries and Huijsman 2011).

In healthcare delivery systems, an agile strategy solves the problem of demand volatility and variability by improving system flexibility (Lee 2004). Enhancing flexibility throughout the processes is the key to quick response to volatile patient demands. Flexibility reflects an organizations ability to effectively adapt or respond to change and meet the needs of increasingly demanding customers (Lin et al. 2006). To enhance flexibility in different stages of the patient care processes, agile strategies use flexible human and physical resource capacity, where capacity should be directly proportional to the delivery requirement. This implies that when demand rises, the capacity must be there to deliver on time. Likewise, when demand decreases, capacity should also decrease. Using flexible capacity is widely applied by agile strategies for controlling patient waiting times and improving the achievement of fixed lead times (Aronsson, Abrahamsson, and Spens 2011; Tolf et al. 2015).

Flexibility is described as the ability to process different products and achieve different outputs with the same resources (Sharifi and Zhang 1999). From a healthcare perspective, flexibility can be simply regarded as the ability to use the same resources to meet a variety of patients' needs and requirements. Flexibility can be created by increasing the amount of resources, adding new resources, or extending the use of available resources (Olsson and Aaronson et al. 2015). A good example of flexibility is a flexible workforce with members cross-trained or able to fulfill a diversity of tasks, as dedicated by the demand situation (Goldsby, Griffis, and Roath 2006) With orthopedic patients, this might mean, for example, cross training nurses and non-physicians to help during periods of high demand

Despite the great need for flexibility in healthcare today, the literature points out that discussions on healthcare literature regarding flexibility are rare (Pati, Harvey, and Cason 2008). Likewise there is a limited discussion on healthcare literature about agile strategies, despite the fact that it is the key strategy that could provide the necessary flexibility in healthcare processes (Rahimnia and Moghadasian 2010). For healthcare to handle the variety of patient demands and needs, it is of critical importance that the healthcare delivery systems allows flexibility for the continued adoption of improved processes. To state it differently, healthcare providers should implement an agile strategy to enhance flexibility in different stages of the patient care processes (Aronsson, Abrahamsson, and Spens 2011; Debajyoti Pati et al. 2012).

In line with increasing pressures for flexibility in healthcare, this thesis covers part of this gap from two perspectives. First, the study identifies which activities can be executed using an agile strategy in order to increase flexibility in these activities. This objective is covered through the literature review in paper one. Second this thesis shows how resource flexibility at different stages of patient care processes can improve patient throughput as well as patient access to care. This objective is addressed in paper four of this thesis. For the purpose of this thesis resource flexibility is approached as “the ability to dynamically reallocate units of resource from one stage of production process to another in response to shifting bottlenecks” (Daniels, Mazzola, and Shi 2004 p.658).

2.5 The importance of studying orthopedic care process.

The global burden of orthopedic injuries and diseases is reported by World Health Organization to account for 14% of world's disability and 9% of world's mortality (WHO 2009). This is mostly escalated by increase in road traffic injuries as well as aging population. The global total number of road traffic injuries deaths remains unacceptably high at 1.24 million die each year as a result of road traffic injuries; this estimate is forecasted to increase to 1.9 million deaths annually by 2030 if no measures are taken. More than 90% of the death that result from road traffic injuries occur in developing countries (WHO 2016). Since not all injuries kills, the disability burden is much higher due to lack of timely access to the treatment or insufficient resources to meet the current fast growing and variable orthopedic demand (Debas T. Haile, Richard Gosselin, Colin McCord 2006; Derbew et al. 2006)

As a result orthopedic clinics are increasingly experiencing capacity related resource constraints due to increasing patient volume inflated by rod traffic injuries, aging population, and shortage of human resources. The impact of miss matching between orthopedic surgeons' and current growing demand includes, low patient throughput overloaded surgeons' and long waiting queues. In orthopedic clinics efficient utilization of workforce and throughput improvements are critical issues. Therefore, orthopedic care processes should be improved to enhance targeted clinical throughput and reduce patients waiting times (Reynolds et al. 2010,Poder et al. 2010).

Literature stresses that increasing surgeons' supply in short-term basis where there is a critical service need, may not be worthwhile. Ability to handle the current growing orthopedic demand can be achieved by improving patient care processes and better utilization of the existing orthopedic team (Lau et al. 2012, Ferreira, Gomes, and Yasin 2011b, Greaves et al. 2013).

Orthopedic care process comprises two categories of patients, that is emergency and elective patients. However, this study focused only on elective patient due to several reasons. First elective patients comprises large number of patients who experiences long waiting times and waiting lists (Min and Yih 2010). Depending on the patient condition, long waiting time is associated with deterioration of patient condition as well as morbidity and mortality (Aronsson, Abrahamsson, and Spens 2011). Improving care processes on these patients could potentially save life of many patients particularly in developing countries, which experience severe shortage of healthcare workforce.

3 Healthcare delivery systems in African

3.1 Overview

Many national health care delivery systems in developing countries, and Africa in particular, are inefficient, unresponsive, and unsafe (WHO 2006; JI and Frenk 2000; Enyinda et al. 2009). Furthermore, Africa's healthcare delivery systems are faced with increasing demands for care and severe shortages in healthcare workforce capacity (WHO 2006). In their report *Working Together for Health*, the WHO (2006) addresses the critical deficit of the healthcare workforce globally, assessing that there was a shortage of approximately 4.3 million healthcare professionals. It states that the crisis is more acute in 57 countries, which represent a global deficit of 2.4 million doctors, midwives, and nurses. The situation seems extremely acute in Africa, which shoulders 24 % of the global burden of disease with only 3% of the workforce and utilizing less than 1% of world health expenditure. In the African sub-Saharan countries, including Tanzania, shoulder more of the burden of the deficit in the healthcare workforce when compared to other countries (Sheth et al. 2015).

The WHO (2006) further elaborates that, at a global level, the workforce crisis is expected to deepen in the future when the demand for the healthcare workforce will be overwhelmed by the demand for care. This implies that the gap between the healthcare workforce capacity and the patient demand in developing countries will be severe compared to what it is today if no precautionary measures are taken. This situation indicates the need for improvement of the African healthcare delivery systems so that they can accommodate growing patient demands within the existing healthcare workforce capacity.

The challenge created by the shortage in the healthcare workforce is escalated by the inefficient utilization of the existing workforce. Literature acknowledges that developing countries, particularly Africa, are characterized by the inefficient distribution and utilization of the existing but limited resources (Enyinda et al. 2009; Cline et al. 2013). It is argued that poor the utilization of the healthcare workforce leads to complexities and inefficiencies in patient care processes. Among the commonly noted problems resulting from poor healthcare resource utilization are high patient waiting times and crowding in clinics (Patrick and Puterman 2007). This in turn leads to limited patient access to care as well as high patient mortality and morbidity. Excessive waiting times can lead to tardy diagnostic information or a worsening of patient conditions. The inefficient utilization of expensive resources, such as surgical resources, decreases operating margins. Studies document that process improvement for the efficient utilization of resources and reduced patient waiting times is of paramount importance (Patrick and Puterman 2007; JI and Frenk 2000).

The better utilization of scarce healthcare resources is extremely important in developing countries, given the increasing patient demands and the unlikelihood of resolving the existing workforce capacity problem (Hodges et al. 2007; Lokossou et al. 2007; Flessa 2003). The better utilization of scarce healthcare resources means life or death to human beings. Therefore, improvements in healthcare processes through the better utilization of scarce healthcare resources should be scientifically supported, as failure to create an efficient system may lead to negative effects on human lives such as mortality or morbidity (Flessa 2003).

Likewise, the healthcare process in Africa are highly inefficient due to a severe mismatch between the existing workforce capacity and patient demands (WHO 2006). Literature acknowledges that increasing patient demand relative to the existing workforce capacities increases complexities in patient care processes (Winge et al. 2015). Improving different process performance measures, such as patient waiting time and throughput in patient care activities, is critical in these countries to enhance increased patient access to healthcare services. Thus, the application of different techniques to improve healthcare processes is vital in developing countries' healthcare delivery systems to enhance improved patient access to care. In line with the above arguments, this thesis was conducted in Tanzania, which is discussed in detail in the following section.

3.2 Empirical setting: Tanzania healthcare sector

Based on the preceding discussion regarding healthcare delivery systems in Africa, this thesis narrowed down the study setting to Tanzania. Thus, this section presents an overview of Tanzania as well as the hospital studied for this thesis.

3.2.1 Country background

Tanzania is among the East African countries and has a population of 48,775,567 million. It comprises of 25 administrative regions and 113 districts with 133 councils and 10,342 villages. Tanzania covers a total area of 947,300 sq. km; the main borders of Tanzania include the Indian Ocean on the east side; Kenya and Uganda on the north; Rwanda, Burundi, and the Democratic Republic of the Congo on the west; and Zambia, Malawi, and Mozambique on the south (MoHSW 2013).

3.2.2 Tanzania healthcare delivery system

The structure of Tanzania healthcare delivery system is pyramidal, starting with primary healthcare services to tertiary and national level systems. The basement is composed with primary healthcare services facilities which include 4,679 dispensaries and 481 health centers. These numbers constitute facilities from both private and public healthcare found across the county. Following primary level is a hospital level of which there are 237 public and private hospitals. Out of 237 hospitals 57 are public district hospitals under the ownership of Tanzania government and 35 are district hospitals owned by faith based organization. At tertiary level there are 4 referral and specialist hospitals. Bugando hospital is among these four referral and specialists hospitals (MoHSW 2013; MoHSW 2014).

3.2.3 Tanzania human resource challenges

A shortage of qualified staff is a major challenge in Tanzania's healthcare workforce. Like other developing countries, the shortage is more acute at the level of specialists, including surgeons and anesthesiologists (Hodges et al. 2007; Lokossou et al. 2007; MoHSW and WHO 2013) The most recent observations show that Tanzania has 0.003 physicians (general and specialist medical practitioners) per 1000 members of the population (CIA 2016). In terms of full surgeons, Tanzania has 0.25 surgeons per 100,000 members of the population (Derbew et al. 2006; Lynge et al. 2008).This deficit is alarming and unfortunately, there is no likelihood of an increase in the number of surgeons and anesthesiologists in Tanzania (Chu et al. 2009). Hence, several approaches need to be established for the efficient utilization of these resources.

3.2.4 Studied hospital: Bugando Medical Center

The primary source of data for this study is from orthopedic department of Bugando's referral hospital. Tertiary and referral hospitals were the main focus for this study simply because they consume a lot of resources in the healthcare industry and have the highest demand level compared to the lower ranks. An improved performance in these major hospitals would have a great positive impact on the country's healthcare system.

The choice of Bugando hospital is based on the following criteria: the hospital must be at a tertiary level, serving large numbers of the population, and have at least three specialized surgeons. Compared to other tertiary hospitals, Bugando serves about 13 million people, while Mbeya referral hospital and KCMC serve about 6.2 million and 11 million people, respectively. Nevertheless, Muhimbili national hospital was excluded from this study, despite meeting the said criteria, as it is in a higher rank as a national and specialists hospital.

Bugando Medical Center is among the four teaching and consultant hospitals in Tanzania. It was established for the lake and the western zones of the United Republic of Tanzania, situated along the shores of Lake Victoria in Mwanza City. This hospital has 900 beds and approximately 1,000 employees. Bugando Medical center is a referral for tertiary specialist care serving eight regions. These regions include Mwanza, Geita, Simiyu, Tabora, Kigoma, Kagera, and Mara. In general, the population served by this hospital is around 13 million people.

3.2.5 Overview of Bugando orthopedic clinic

Bugando Orthopedic Clinic is a referral clinic for the lake zone, serving patients from different regions as listed above. Both urban and rural dwellers are served by the clinic. It deals with emergency and elective orthopedic cases, depending on the available medical equipment. This study focuses mainly on the electives cases. Generally, Bugando Orthopedic Clinic was established for referral cases from regional hospitals in the lake zone, but some patients go directly to this clinic through self-referral, which increases the number of patients attending the clinic. The clinic days are Tuesday and Wednesday, and surgery days are Monday, Wednesday, and Friday.

4 General methodology of the study

This thesis used three methods to meet stated objectives as well as addressing the aforementioned research questions. This includes discrete event simulation, case study and literature review. This section presents an overview of the methods used and their respective papers.

4.1 Discrete event simulation

4.1.1 Overview

Discrete event simulation is a powerful and flexible modelling approach characterized by the ability to mimic complex behaviour within and interactions between individuals and their respective environments (Karnon et al. 2012). Discrete event simulation is mostly useful in an environment where queuing for resources is common, and where there is a problem of resource constraints or of interactions among individuals. In fact, the identification of bottlenecks and resource adjustments that do not disturb the actual system can be achieved through the use of discrete event simulation (Cooper, Brailsford, and Davies 2006; Wang et al. 2009).

Healthcare processes are very complex and are characterized by the queuing of patients waiting for resources to provide services, resource constraints, and interactions between patients and healthcare providers. Given these characteristics, discrete event simulation was found to be suitable for this thesis.

The strength of discrete event simulation in healthcare is that it allows the replication of reality, allowing the exploration of possible changes and the testing of different scenarios without investing very large amounts of money or resources on developing a system and investing time to see the results (Hamrock et al. 2013; Thorwarth 2009; Joseph Barjis 2011). Given the complexity of healthcare processes, discrete event simulation seems to be a potential tool that can be used to propose different improvement strategies by testing several scenarios prior to implementation. In healthcare processes, simulation facilitates the deep exploration of different patient activities to identify inefficiencies and suggest possible changes that can be used to improve operations. This is essential due to high cost of implementing a new care model before knowing its impact on healthcare delivery operations.

4.1.2 The importance of analyzing orthopedic care process using discrete event simulation.

Like any other healthcare process, the studied orthopedic care process is very complex and involves complex interaction between patients and resources that takes care e.g. surgeons and nurses. Discrete event simulation is a powerful and flexible modeling approach characterized by the ability to mimic complex behavior within and interactions between individuals and their respective environments (Karnon et al. 2012; Pidd, 2004). Translating this to orthopaedic care process, it implies that events occurring to an individual (e.g. patients and doctors) and how that individual interacts with others, the health care system, and the general environment can be modeled simultaneously (Karnon et al. 2012). The key principal of discrete event simulation is that it moves forward in time at discrete interval (i.e. the model moves from time of one event to the time of next event) and those events are discrete (mutually exclusive). This characteristics gives discrete event simulation the flexibility and efficiency to be used in variety of complex environment such as orthopaedic care process (Karnon et al. 2012)

The core concepts of discrete event simulation are entities, queues, events, resources and time. Entities (e.g. patients) are objects that have attribute (e.g. arrival time) experience events (e.g. treatments) , consume resources (e.g. surgeons), and enter queue (e.g. surgery queues) over time (Karnon et al. 2012)

Based on the preceding discussion, discrete event simulation is seen to be most appropriate technique for this study. Thus, we adopted it as the main methodology to investigate the entire orthopedic care process and proposed improvement strategies. Discrete event simulation reflected the current operation of the orthopaedic care process in the simulation model and allowed the visualization of patient flow, identifying inefficiencies. This capability facilitated the investigation of the key performance measures considered for this thesis, which are patient waiting time, the utilization of surgeons, patient throughput, and the number of patients in the queue. We further used discrete event simulation to test different resource scenarios with the objective of finding the best scenario that can be used to improve the orthopaedic care process studied. Through what if analysis we managed to improve the service capacity of this care process. The identified best scenario can be used to improve patient flow in the process as well as patient access to care.

4.1.3 Conceptual model of Bugando Orthopaedic care process

Developing conceptual model is the key to the simulation study. This section presents the conceptual model that was developed and translated into a simulation model.

Process overview

Patients at Bugando Orthopaedic Clinic first arrive at the registration department. After finishing the registration processes, they are then directed to their respective clinic—the orthopaedic clinic in this study. After their arrival at the clinic, patients are supposed to wait for the clinic session to start and the arrival of the orthopaedic surgeons. After the arrival of the surgeons, patients are called and sent to them by a nurse for examination and the ordering of any ancillary tests (x-ray or lab test) if needed. After the examination process, patients are either discharged or, when surgical treatment is necessary, transferred for the surgery process. After the surgery, the patients are put into the recovery room before leaving the operating room. Figure 1 presents the conceptual model developed to represent these processes at the Bugando orthopaedic clinic:

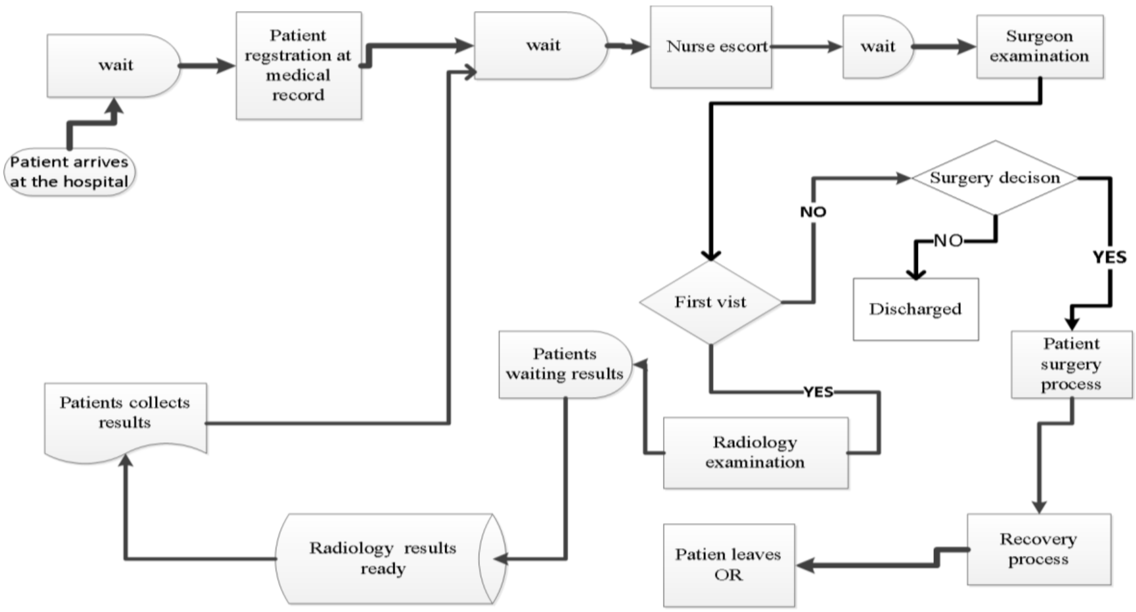

Figure 1: Current process in an orthopaedic department

4.1.4 Data collection and simulation model development

The data used for this study were obtained through the observation of patient processes in the orthopaedic department of Bugando hospital and covers the period of three months from June to August 2012. Initial meetings were held with hospital management and orthopaedic surgeons to understand the operation of this care process. Meetings were also held with the heads of departments, such as Radiology and Laboratory, as well as the operation room with a view to understanding the environment and the processes in place. After these meetings and the orientation process, the data collection process then started in earnest.

Our focus was to get important details on the number of care activities, from when patient arrives at the hospital to the point of departure. The observed activities include the patient arrival process at the hospital, the patient registration process at the registration department, the patient examination at the clinic by surgeons, the surgery process in the surgical room, diagnostic testing (x-rays), and blood work at the central laboratory.

We used a structured data sheet, with each column representing either waiting or service time. Waiting time simply refers to the idle time the patient experienced while waiting for the care service. Service time is the time used by healthcare providers, the time taken by surgeons to deliver services to patients for example. This sheet also includes information on patients' arrival times, and number of resources at each service station.

We hired and trained students from Bugando Catholic University to conduct direct observations of patients moving through the entire orthopaedic care process from arrival to departure. These students received a two-day orientation on the purpose and the nature of the study as well as the planned data collection approach. In addition to these students, the chief coordinator of the orthopaedic room was willing to help in the data collection process, and he too was included in the team. Data collectors recorded all the recommended details of patients at each stage that the patient passes through. The data collectors documented start and end times of each process, using stop watches, and filled in the structured data sheet. The chief of the surgical room was concerned with the data in the surgical room and documented this together with one of the research team. We filled the form as patient went through each process in the surgical room.

During the data collection period, 178 patients underwent the entire process from arrival to the point of departure. These are the patients that are included in this thesis. Patients who didn't undergo the entire process were not considered for this study because the focus was for the entire care process from arrival to the discharge.

4.1.5 Model verification and validation

Model verification

Verification is a key and compulsory step in simulation modeling, ensuring the credibility of the model for the users. Verification is defined as the process of determining whether the conceptual model is correctly translated into the simulation computer program (Law and Kelton 2000). Model verification was successfully completed using arena debugging facilities and animation, which checked that the model was running correctly and was free from errors. To increase model verification, we also used simulation experts who helped to check that everything was running correctly.

Model Validation

Validation is the process of determining whether the simulation model is representing the system under study based on the objective of the study (Law and Kelton 2000). Before conducting any what if analysis the model validation was conducted to check the model's representation of the observed data from the studied orthopedic care process. We took the following steps to validate the model: we first ensured that the face validity of the model was quite high (Banks et al. 2001) by involving key orthopedic specialist surgeons and the head of the operating theatre in the model's development; second, the head of the operating room was also involved in the data collection process inside the operating room; and finally, three performance measures were adopted for validation—surgeon utilization at the clinic, patient waiting time at the clinic, and patient throughput per day in the surgical room.

4.2 Case method

The case study is the research method that focuses on understanding the dynamics present within a single setting (Eisenhardt 1989). It can include data from multiple sources such as direct observation and systematic interviewing as well as public and private archives (Voss 2009; Leonard-Barton 1990). The strengths of the case study are as follows: it enhances the phenomenon to be studied in its natural setting, which enables the derivation of a meaningful theory from the understandings obtained through observing the actual practice; it enhances the questions of why, how, and what should be addressed through a deep investigation of the phenomenon at hand; and finally, it is more powerful in exploratory investigations where the variables are still unknown and the understanding of the phenomenon is at an embryonic stage (Voss 2009; Yin 2009; Meredith 1998).

As stated in the previous sections, the application of lean and agile strategies in healthcare processes is still in its infancy, making the case study approach more appropriate. In order to improve healthcare providers understanding of how they can apply lean and agile strategies for different patient activities, this thesis adopted a case method approach in paper one. The focus was to provide deep insights into when and how lean and agile strategies can be used to improve healthcare processes.

Another school of thought argues that the case study approach is more appropriate when studying complex phenomenon (Meredith 1998). Healthcare processes are highly complex and performed under continually changing operating environments (Poulymenopoulou, Malamateniou, and Vassilacopoulos 2003; Rebuge and Ferreira 2012). Improvement of complex healthcare process requires deep investigation of the activities comprising the patient care process. Thus, the application of a case study approach is more appropriate and develops a clear understanding of its respective operations through deep investigations of various patients' activities. Through questions of what and why, the case study approach facilitates the identification of key causes for inefficiencies in this process and how to eradicate them.

Data

Data used for this method was collected in the same orthopedic care process, and the same conceptual model presented in Figure 2 was used. Qualitative interviews and observations were the main approach used for data collection. Deep investigations involved meetings and interviews with hospital management and key personnel of each department. The information obtained from the interviews and meetings helped map the conceptual model of the orthopedic care process (Figure 2). The validity of the conceptual model is critical; hence, we involved key personnel from the orthopedic department in process mapping. The data collection process began immediately after mapping the process.

Patients were followed from their arrival at the registration department to the point of discharge.

4.2.1 Reliability and validation of the collected observation

The literature asserts that the use of multiple observers increases the reliability of the observed or collected data (Yin 2009). Multiple observers were used during the entire data collection period; this included trained university students, the head of the operating room, and the researcher. These observers recorded times as follows: assessment times during registration, examination at the clinic by the surgeon, x-ray testing, surgery process in the operating room, and recovery. The main tools that guided the data collection process were stop watches and structured data sheets, of which each column represented an assessment time of an observed patient activity. Data for 178 patients were obtained. These were the patients that underwent the entire process from arrival to the point of departure.

The literature argues that the validity of the collected observations can be increased by conducting several discussions with the key personnel involved in the study (Yin 2009). For this particular study, the validity of the collected observation was ensured by conducting several discussions and unstructured interviews with key personnel from each department during the entire process of data collection. To maintain data triangulation, we approached some nurses and patients for unstructured discussions. High data triangulation was maintained to ensure that all pertinent information was collected, for the accuracy of the collected information, and to understand the operational characteristics of this care process (Bonoma 1985).

4.3 Systematic Literature review

The literature review is a key part of any academic research and may be in the form of a narrative or a systematic review (Im and Chang 2012). In this thesis, both perspectives were used. A narrative literature review was used to build the foundation for the ideas in the three papers. This included literature on lean and agile strategies in paper one; resource utilization and simulation in healthcare, which is covered in paper two; and agile strategy and simulation in healthcare, covered in paper four.

A systematic literature review was used as the main methodology for paper three of this thesis. A systematic literature review is simply a process of synthesizing existing literature in a systematic, transparent, and reproducible manner. Systematic literature reviews focus on minimizing bias through comprehensive literature searches and providing an audit trail of the reviewers decision, procedures, and conclusions (Cook et al. 1997; Tranfield, Denyer, and Smart 2003). Since the workforce agility concept is still at an embryonic stage in the research world, a comprehensive, transparent, and unbiased literature review must be adopted to facilitate academic understanding. This is in line with the literature as, when a topic is relatively new, it is worth developing the idea based on existing multidisciplinary studies (Gunasekaran

1999; Torraco 2005). Thus, this thesis presents a comprehensive systematic review of the role of workforce agility on the outcomes of healthcare processes.

4.3.1 Integrative literature review approach

To ensure a comprehensive exploration of workforce agility, the concept we deployed a holistic multidisciplinary integrative literature review. Integrative reviews are described as a process that involves summarizing past research by drawing overall conclusions from various studies regarding a particular concept (Broome 1993).The major strength of an integrative literature review is that it facilitates the building of relationships between the studied variables or concepts (Cooper 1982). As stated in the previous section, the main objective of the literature review in this thesis is to investigate the relationship between workforce agility and healthcare processes. To meet this objective, an integrative literature review seems to be a potential approach. Another key objective of an integrative literature review is to enhance the definitions of the new concepts studied (Broome 1993). Given that workforce agility is a relatively new concept, the use of an integrative literature review is vital for developing the definition of this concept.

4.3.2 Data collection and analysis

To enhance a comprehensive and unbiased evaluation of the relevant literature we followed recommended systematic literature review guidelines (Denyer and Tranfield 2009; Cook et al. 1997). The review focused on all relevant studies between 1990–2015 and included peer reviewed articles; it was conducted using two databases: ProQuest and Science Direct. In line with the recommendations of Tranfield, Denyer, and Smart (2003) we identified key search terms by reviewing the literature and through discussions within the review team. Key search terms that were used include agility, agile, workforce agility, agile organization, healthcare processes, patient process, and patient care process. Citations in the relevant articles were also traced to find more articles.

4.3.3 Inclusion and exclusion criteria

In line with the recommendations of Denyer and Tranfield (2009) we developed inclusion and exclusion criteria based on conceptual and empirical studies with a focus on agile organization and the workforce. Included articles displayed at least one of the following criteria: it should define agility; it should have descriptions of workforce agility, or attributes of workforce agility; it should have descriptions of characteristics or managerial practices of agile organization that enhance workforce agility. For the healthcare processes literature, the inclusion criteria were based on only articles that described characteristics of healthcare processes. Figure 2 demonstrates the entire process of literature review.

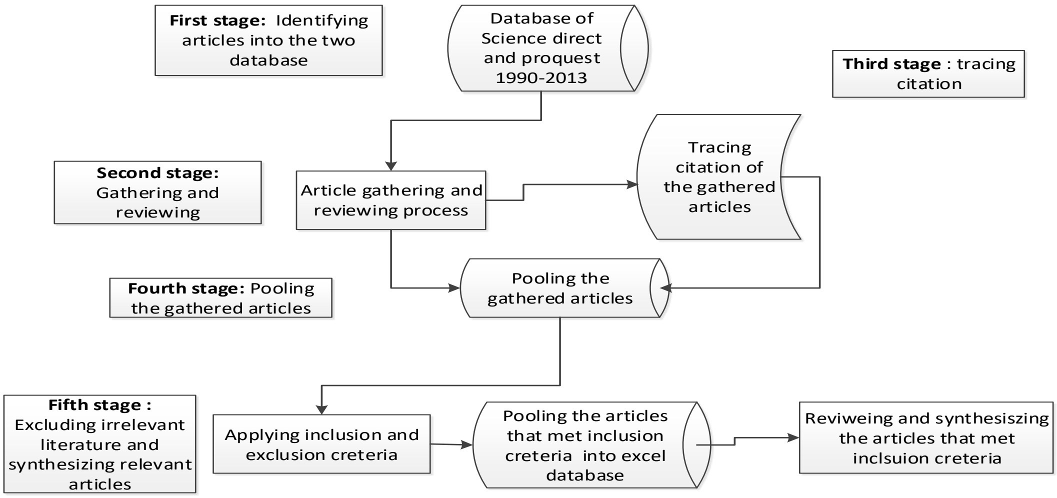

Figure 2: Literature review process

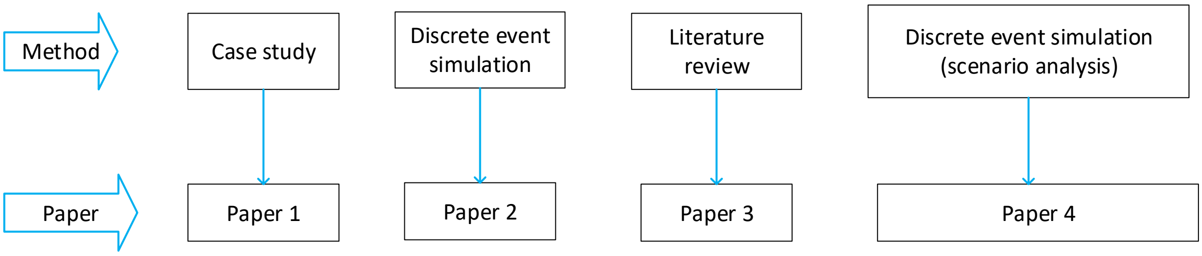

Figure 3: Research methods for this thesis

5 Summary of papers and scientific contribution

This is a paper based thesis, consisting of four papers. Although each paper addresses a specific topic, all contribute to the central theme of the thesis—improving healthcare processes. Thus, this section presents an overview of each paper and its scientific contribution.

Paper 1. Analyzing orthopedic care process: Proposing lean and agile strategies to reduce variation

Although previous research has examined lean and agile strategies and their impact on healthcare, questions of when and how to use lean and agile strategies are still unanswered. This paper draws from the existing lean and agile literature to propose when and how to use lean and agile strategies in healthcare processes; it specifically identifies activities that can be performed using lean or agile strategies. The results indicate that a lean strategy is most appropriate in highly repetitive and standardized activities such as lab tests, x-rays, and registration. On the other hand, an agile strategy is more appropriate in those activities related to examination activities such as surgery. Using a case study method, this paper investigates the entire process of the real world orthopedic department and demonstrates how healthcare providers can benefit from the application of lean and agile strategies for different patient activities. By applying lean and agile strategies in their respective activities, healthcare providers can benefit by improving efficiency and responsiveness in healthcare processes.

This study contributes to the existing literature by proposing when and how to use lean and agile strategies in healthcare processes. Our contribution to the lean and agile literature is our examination of how lean and agile strategies can be used in patient treatment process activities such as examinations, lab tests, x-rays, and registration. This study shows the importance of lean and agile strategies in improving the internal efficiency of patient processes and increasing response to the demand of care.

Paper 2. Improving surgeon utilization in an orthopedic department using simulation modelling

Despite significant technological and medical advances, a critical shortage in the health workforce poses key constraints in healthcare service delivery. This problem is more critical in the field of surgery as more than two billion people worldwide lack access to surgery services due to the global deficit of human resources (Funk et al. 2010; WHO 2006). This problem cannot be solved using the traditional approach of adding more resources. Instead, the efficient utilization of these resources is the solution.

Using discrete event simulation, this paper explored the orthopedic care process to identify the factors that influence the utilization of surgeons. Simulation results indicate that ordering of ancillary services by surgeons is among the factors that contribute to this. The simulation results further show that if ancillary services can be standardized and transferred to upstream staff, so that they can be ordered before the patient meets the surgeon, then the surgeon's capacity can be improved as well as reducing patient waiting times. This can further be translated as an improvement of patient access to care as the improved capacity can be used to treat more patients either in the queue or on the waiting list.

This study contributes to reducing the global concern for the problem of patient access to healthcare facilities due to a mismatch of resources and the demands for care. The application of industrial strategies can enhance the efficient utilization of resources and respond to a highly volatile demand. Simulation simplifies the process of identifying inefficiencies in patient processes.

Paper 3. The role of workforce agility on healthcare process operational outcome: A systematic literature review and conceptual framework.

In order to cope with increasing complexities in healthcare processes healthcare providers has been forced to adopt new approaches from manufacturing and private industries. Agility has been recently promoted as a means for achieving a high responsiveness to increasing patient volatility and uncertainty (Vries and Huijsman 2011). It has been argued that agility is a powerful strategy that can aid healthcare providers in reducing delays to increasing patient demands and needs. It is argued that for organizations to achieve agility objectives, its workforce must be highly adaptable to increasing businesses volatility (Sherehiy and Karwowski 2014).

Agile workforces are seen to play a fundamental role in meeting organizational agility goals. However, prior studies on workforce agility have mainly focused on technical factors such as technology limiting a comprehensive exploration of the workforce agility concept (Breu et al. 2002; Gunasekaran 1999). Furthermore, prior research has focused mainly on the strategic level, leading to a limited focus on agile workforces at the process level (Van Oyen, Gel, and Hopp 2001). Through a systematic literature review, this study facilitates understandings of workforce agility in healthcare processes by examining the relationship between workforce agility and the operational outcomes of healthcare processes. A conceptual model demonstrating the relationship between workforce agility and healthcare process has been developed for further empirical tests.

Paper 4. Simulation analysis of healthcare processes with resource flexibility

Despite the fact that the agile strategy has often been promoted as a strategy for improving healthcare processes, its adoption in this field is still at an embryonic stage (Vries and Huijsman 2011). Little empirical research exists in the healthcare literature exploring its positive linkage with improvements in healthcare processes. Using discrete-event simulation, this study explores the improvements that can be achieved by deploying resource flexibility in patient treatment processes. After testing different scenario, the best scenario shows that more resources should be added in the clinic than in the surgical room.

This result is consistent with the literature, which demonstrates that many orthopedic elective cases are non-surgical. Thus, adding more resources to the clinic is more logical. The results of this study indicate that if this scenario is to be implemented, it can potentially improve patient access to healthcare services and thereby contribute to reduce morbidity and mortality in orthopedic surgical cases.

Our study builds a foundation towards an understanding of the need for flexibility in patient treatment process variables. Our contribution focuses on revealing the advantage of an agile strategy in the improvement and delivery of patient care, particularly in resource-constraint settings.

6 The researcher contribution to the thesis papers

Paper 1: Associate professor Berit Helgheim developed the outline of the paper. I conducted data analysis and wrote the entire paper. Associate Professor Berit Helgheim gave all necessary feedback as well as writing some parts of the papers. Early version of this paper was accepted for publication at EUROMA 2016: Trondheim Norway. This paper is under the review process of the International Journal of Operations and Production Management.

Paper 2: Associate Professor Berit Irene Helgheim developed the idea for the paper. We collaborated with my supervisor to develop the outline of the paper. I performed all the necessary steps required for the simulation model design, development, and validation. I was also responsible for writing the entire paper. Associate Professor Danielsen Ketil supervised the technical aspect of the model, while Associate Professor Berit Helgheim supervised the theoretical aspects. The early version of this paper was presented at INFORMS USA 2013. This paper is published in the Journal of Leadership Healthcare.

Paper 3: I started writing the paper from its initial stage—that is designing, conducting literature reviews, and writing the entire paper. Associate Professor Berit Helgheim provided all necessary feedback during paper writing process. This paper was submitted to the International Journal of Management Reviews.

Paper 4: The paper idea was developed and discussed together with associate professor Berit Helgheim**.** I performed all necessary steps required for the design, development, and validation of the simulation model. I also designed the experimental scenarios and wrote the entire paper. Associate Professor Berit Helgheim and Associate Professor Danielsen Ketil provided all necessary feedback during paper writing process. Early versions of this paper were accepted for publication at EUROMA 2016: Trondheim Norway. The paper is published in the Journal of Multidisciplinary Healthcare

7 Conclusion and Future research

This study focuses on showing and investigating how lean, agile and simulation from manufacturing industries can be used to improve healthcare processes. Given the fact that these strategies are still new in healthcare industry more research is still needed to validate on how these strategies can be used to improve healthcare processes. In this context we can argue that application of lean, agile and simulation in healthcare is still an open issue and more research is needed.

This study faces some limitations. First, patient waiting time includes the early arrival of patients before the start of examination services as well as surgeons' lateness. The arrival of surgeons at the beginning of clinic sessions could decrease patient waiting times. Likewise, if patients could arrive a few minutes before the start of the clinical session, this could further decrease their waiting time.

Second, our study was limited to a single case study. Involving more than one case study is recommended. Also the methods used were intended to solve the outlined problems. Further studies can focus on using more methods and techniques.

Finally, although our study was conducted in a single orthopedic clinic, the results can be generalized to other clinics with similar operational settings. This is due to the fact that some of the problems addressed in this study, such as high waiting times, seem to be common in other orthopedic clinics (Rohleder et al. 2011; Bowers and Mould 2004). Thus, this result can be applied globally to orthopedic clinics.

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Paper 1

Analyzing healthcare processes: Proposing lean and agile strategies to reduce variation

Abstract

Purpose – Drawing from the existing lean and agile literature, this paper proposes when and how to use lean and agile strategies in healthcare processes, specifically identifying which activities can be performed using either lean or agile strategy. Using empirical case study, this paper investigates how healthcare processes can benefit by applying lean and agile strategies to reduce variation.
Design/Methodology/Approach – An exploratory approach was used for the empirical case study. We used semi-structured interviews, meetings, and direct observation methods to collect data. We also used control charts to analyze variation in patient process.
Findings: Lean and agile strategies can be used to reduce variation in different parts of the healthcare process. Through a literature review, this study found that four activities (registrations, lab tests, x-rays, and other administrative activities) can be executed using lean strategies while agile is a more appropriate strategy for another three activities (examination/treatment, surgery, and recovery activities). Nevertheless, hospitals can still use lean strategies in activities requiring agile strategies to increase operational efficiency.

Research limitation/implications – This study was limited to a single patient care process. Future studies can focus on more than one process.
Practical implications – To reduce variation in healthcare processes, lean strategy can be implemented in administrative and diagnostic activities and agile strategies in treatment and surgical activities.
Originality value – This study is the first to investigate when and how to use lean and agile strategies in care processes. The activities identified under lean and agile strategies can be applied to other healthcare processes with similar operational characteristics.
Key words: Agile strategy, lean strategy, variation, process.

1 Introduction

In recent years, the application of lean and agile paradigms has been expanded from manufacturing industries to the healthcare sector (Radnor, Holweg, and Waring 2012). These paradigms have recently been proposed as the means to improve healthcare processes (Vries & Huijsman 2011; Mclaughlin & Hays 2008). However, the majority of early research has applied lean and agile strategies primarily from an organizational point of view and have overlooked core healthcare processes (e.g., Tolf et al. 2015; Radnor and Osborne 2013; Radnor and Boaden 2010). To cope with increasing uncertainties and challenges in patient demands, healthcare organizations must focus on the processes they perform rather than the departments, they consist of (Trkman et al. 2007; Nilsson & Sandoff 2015). The process approach is an effective way to organize and manage organizational activities to meet patients' demands. Moreover, the process approach enhances hospital efficiency in achieving its defined objectives (ISO9001 2015; Vera & Kuntz 2007; Nilsson & Sandoff 2015). Thus, implementing these strategies at the process level is crucial.

To contribute to the discussion on lean and agile strategies in healthcare, this paper takes a process perspective. A process is a series of logically related activities whereby each activity may have different characteristics. The main challenge facing healthcare providers today is how to manage these activities from the moment a patient arrives at the hospital to the point of departure (Girija & Bhat 2013). These activities involve several departments, making it more challenging to design an efficient care process. The challenge is amplified by the fact that these activities are also subject to high variation resulting from unpredictable patient demands as well as the very structure of healthcare delivery systems (Haraden & Resar 2004). Identifying appropriate strategies to increase efficiency and reducing variation in these activities in order to become more flow oriented contribute to the pressure on healthcare providers (Haraden & Resar 2004; McLaughlin 1996). Thus, proposing which activities can be lean or agile is an essential step needed to extend this topic.

While there are a few empirical studies in the healthcare literature on lean and agile strategies (Aronsson et al. 2011; Rahimnia & Moghadasian 2010), to date, no study has tried to identify which activities in the care process can be lean or agile. Previous researchers have focused on either a lean or agile approach to hospital processes. Drawing from the lean and agile literature, this paper proposes when and how to use lean and agile strategies in the care process, specifically identifying which activities can be performed using either strategy by first using the existing literature to identify the characteristics of each of the two. Second, through a case study of the orthopedic care process, this study investigates the entire process and examines how healthcare can benefit by applying lean and agile strategies to reduce variation and hence increase efficiency in different patient activities. The main focus of the paper is on proposing when and how a combination of lean and agile strategies can be applied in the same process of care, depending on the characteristics of the activity.

2 Literature review

2.1 Lean and agile activities in production processes

The origin of lean concept can be traced back to the Japanese manufacturing shop floor, particularly the innovation of Toyota Motor Corporation (Womack et al. 1990). Faced with shortages and a lack of resources, Japanese car manufacturing companies responded by using lean strategies to develop processes aimed at operating at a minimum level of waste (Harrison & VanHoek 2008; Cusumano 1988). From the lean perspective, variations in production processes are considered as waste and must thus be eliminated (Olsson & Aronsson 2015). A process is defined as a sequential set of activities across time and space, with a beginning and an end, and clearly defined inputs and outputs (Davenport & Short 1990). The main characteristic of a process is that it contains a mixture of both repetitive/standard and customized/unique activities. Lean processes are regarded as suitable for reducing internally created variation in those activities/tasks performed in a standardized way (Lillrank 2003; Aronsson, Abrahamsson, and Spens 2011). A standard task is described as an activity performed in the same manner regardless of who has been assigned to perform it. In these activities, variation is widely generated internally by organizations and results from the design of their activities (Walley et al. 2006).

Standard activities are commonly found in most processes because they are appropriate for high volumes products such as assembly lines. These activities are highly automated, thus requiring little or no labor input. Also, these activities are performed in a similar way regardless of who is performing it, hence facilitating standardization. Due to high levels of standardization, low-skilled laborers are generally capable of performing them. To achieve efficiency in these activities, the lean strategy dictates high collaboration between the parts involved in the production processes, which is enhanced by rapid information sharing (Stavrulaki & Davis 2010; Christopher et al. 2006; Joosten et al. 2009). Translating this discussion into healthcare processes, standard activities might involve high volumes operational activities that are commonly used to serve a large part of hospital community. Most of these activities are usually administrative in nature.

In processes where demand is uncertain and customer requirements for variety are high, a greater level of agility is required (Towill & Christopher 2002). Agility is the ability of an organization to respond quickly to changes in demand in terms of volume and variety (Christopher 2000). The main focus of agility is to handle variation. An agile strategy is seen as most appropriate in handling externally created variation in customized activities/products (Christopher et al. 2006). These activities focus on the complete customization of the product; thus, higher labor skills are usually needed. Most of the variation in these activities is externally created because customers are empowered to incorporate their individual preferences into the final design of the product.

Because each customer has his/her unique requirements, variation is very high, which makes the execution of these activities highly complex. This characteristic requires a high level of flexibility to meet individual customer requirements. These activities are mainly based on producing low volumes with high variety products, for example, custom-made suits (Christopher et al. 2006; Lamming et al. 2000; Stavrulaki & Davis 2010). Flexibility is simply described as the ability to process different products and achieve different outputs with the same resources (Sharifi and Zhang 1999). Flexibility is a key characteristic of the agile strategy and is needed in order to achieve prompt responses to rapidly changing demands and requirements from customers. Stated differently, flexibility is the key driver to achieving agility in production processes (Aronsson, Abrahamsson, and Spens 2011). In the context of healthcare processes, activities requiring high levels of flexibility might involve unpredictable activities that mostly focus on individual patients' care needs.

Since production activities often involve several interdependent departments, this requires high levels of coordination (Kritchanchai & MacCarthy 1999; Croxton et al. 2001). For example, the production planning must collaborate with the material purchasing and sales departments. To facilitate a collaborative environment, a highly reliable information system must be established. Likewise, a high response speed in these activities is enhanced by the adoption of flexible capacity or capacity flexibility, e.g., having several options for delivery systems to ensure a high speed of response to customer needs. Flexible capacity implies that available capacity should be directly proportional to the delivery requirement. Put it simply, it means when demand rises, the capacity must be there to deliver on time, likewise when demand decreases capacity should also decrease (Tolf et al. 2015). Even though flexible capacity requires more personnel, but it increases speed of response to unexpected needs of the customer.

Capacity flexibility on the other hand is the ability of production system to accommodate variation or changes in demands while maintaining a satisfactory level of performance. This implies that when demand increases production should increase to accommodate that demand likewise when demand declines production should decline (Morlok and Chang 2004).

Thus, these activities involve a number of personnel performing tasks in terms of either cross-functional teams or as individuals (Kritchanchai & MacCarthy 1999; Keely & Croxton 2003; Lee 2004). Within healthcare, a comparable situation might involve collaboration between several departments and personnel to accomplish what is required from a patient's case.

The literature further argues that one single process can comprise both lean and agile strategies at different stages, referencing this as a "leagile strategy" (Christopher 2000). It claims that a lean strategy is most appropriate upstream where activities are characterized by high volume and low variety. An agile strategy is advocated to be highly suitable downstream where activities are characterized by high variety and low volume. The separation point between lean and agile strategies is the decoupling point (Aronsson et al. 2011; Naylor et al. 1999). Thus, a lean strategy is implemented up to the decoupling point to enhance process efficiency through standardization. After the decoupling point, an agile strategy is implemented by being highly responsive to real customer demand (Christopher & Towill 2001; Harrison & VanHoek 2008). Table 1 summarizes the comparisons between lean and agile activities.

Table 1: Comparison of lean and agile activities in the literature

Distinguishing activity characteristics	Lean	Agile	Author
Variability	Low	High	(Christopher, Peck, and Towill (2006); Hilletofth (2013)
Volume of customers	High	Low	Christopher, Peck, and Towill (2006); Stavrulaki and Davis (2010)
Typical tasks	Standard	Customized	Christopher, Peck, and Towill (2006); Stavrulaki and Davis (2010)
Educational level	Low	High	Joosten, Bongers, and Janssen (2009); (Stavrulaki & Davis 2010)
Complexity	Low	High	Lamming et al. (2000)
Collaboration	High	High	Croxton et al. (2001); Kritchanchai and MacCarthy (1999)
Coordination	High	High	Keely and Croxton (2003); Kritchanchai and MacCarthy (1999)
Number of tasks	High	High	Croxton et al. (2001); Keely and Croxton (2003)
Number of people or employees	High/low	High/low	Kritchanchai and MacCarthy (1999); Croxton et al. (2001)
Technical	High	Low	Lillrank (2003); Joosten, Bongers, and Janssen (2009a)

2.2 Variation in healthcare processes

Healthcare processes are subject to both special and common cause variations (Rojas et al. 2016). Special variations originate in the design and management of healthcare delivery systems (Benneyan et al. 2003) while common cause variations originate from the natural variation of the process, which can either be internally or externally created (Breyfogle 2008). Internally created variations derive from multiple factors, including the multiple ways and sequences in which activities can be performed by resources (physicians, nurses, and other professionals). Conversely, externally created variation emanates from a variety of individual patient demands. Individual patient needs suggest that each patient uses a distinctive set of resources, leading to high variability in patient treatment and waiting time (McLaughlin 1996; Rojas et al. 2016).

Lean and agile strategies are proposed as the key strategies for healthcare organizations in order to reduce variation in their care processes (Vries & Huijsman 2011). Lean strategies are arguably the most powerful in managing internally created variation than externally created variation in the healthcare context. Lean strategies fail to manage externally created variation in healthcare because such strategies utilize queues to guard against external variation. Some studies conclude that in healthcare, lean strategies face some practical limitations because patient queues must be of limited length to avoid a deterioration of patients conditions (Aronsson et al. 2011). To accommodate lean shortages, an agile strategy accommodates externally created variation by means of flexible capacity. The capability to work with flexible capacity enhances high levels of flexibility in production processes, leading to an increase in the rate of responses to a variety of patient demands (Aronsson et al. 2011; Tolf et al. 2015).

Even though lean and agile strategies seem to be most appropriate in healthcare processes, the question of when and how to use them has remained unanswered in the existing literature. This study illustrates when and how to use lean and agile strategies by identifying which activities can be lean or agile based on the reviewed lean and agile literature. For the purpose of this study, variation is categorized as either internal or external in nature. By internal variation, we refer to special variation that originates from any internal intervention as well as common cause variation that originates from the multiple ways and sequences in which activities are carried out. Conversely, by external variation, we refer to variation originating from individual patients' demands and needs. In this study, variation is simply defined as the deviation from the observed mean, for example, deviation from the observed mean service time of a particular activity.

3 Empirical case study: Bugando Orthopedic Department

This section presents the empirical case study that will be used to demonstrate how healthcare processes can benefit from using lean and agile strategies in different patient care activities. The case study is an orthopedic clinic in the Bugando Medical Center (BMC). The approval to conduct this study was given by the Research and Ethics committee of the Catholic University of Health and Allied Sciences and Bugando Medical Centre. Patient written consent was not necessary as this was a process improvement study and no medical or personal information was taken from the patients. Data collection was anonymous. The BMC is one of the four teaching and consultant hospitals in Tanzania. It serves primarily the Lake and Western zones of the United Republic of Tanzania. It is situated along the shores of Lake Victoria in Mwanza City. This 900-bed hospital employs approximately 1000 employees. The BMC is a referral hospital for tertiary specialist care and serves eight regions: Mwanza, Tabora, Kigoma, Kagera, Mara, Geita, Simiyu and Shinyanga. It serves 13 million people.

Growing and rapidly changing patient demands and requirements are the main challenge facing this clinic. Like any orthopedic clinic, this clinic handles a variety of procedures and diagnoses. To demonstrate this, a variety of observed surgery procedures and diagnoses are presented in Figure 1 and Table 2, respectively. The majority of diagnoses are different types of fractures, 81% of which comprise the Sign nail/K nail, debridement, and open reduction internal fixation (ORIF) – the most commonly observed surgery procedures during the data collection period. Time needed to perform each patient case varies for different procedures carried out in this care process because each patient demand is unique and requires a unique set of resources, e.g., surgeon's time is unique for each patients since each patient has unique case and surgeons have different level of experience. This in turn creates high variability in the service time that affects resource utilization as well as patient waiting times.

The same trend is experienced in internally created variations, which are mainly caused by the various ways in which activities are carried out. High variation in this process has contributed to high patient waiting times, long queues, and limited access to care, which has further resulted in poor patient flows. A lack of appropriate strategies to handle these variations is a key problem at this clinic. Developing appropriate process strategies could enhance efficient operations and quick response times to ever-increasing patient demands.

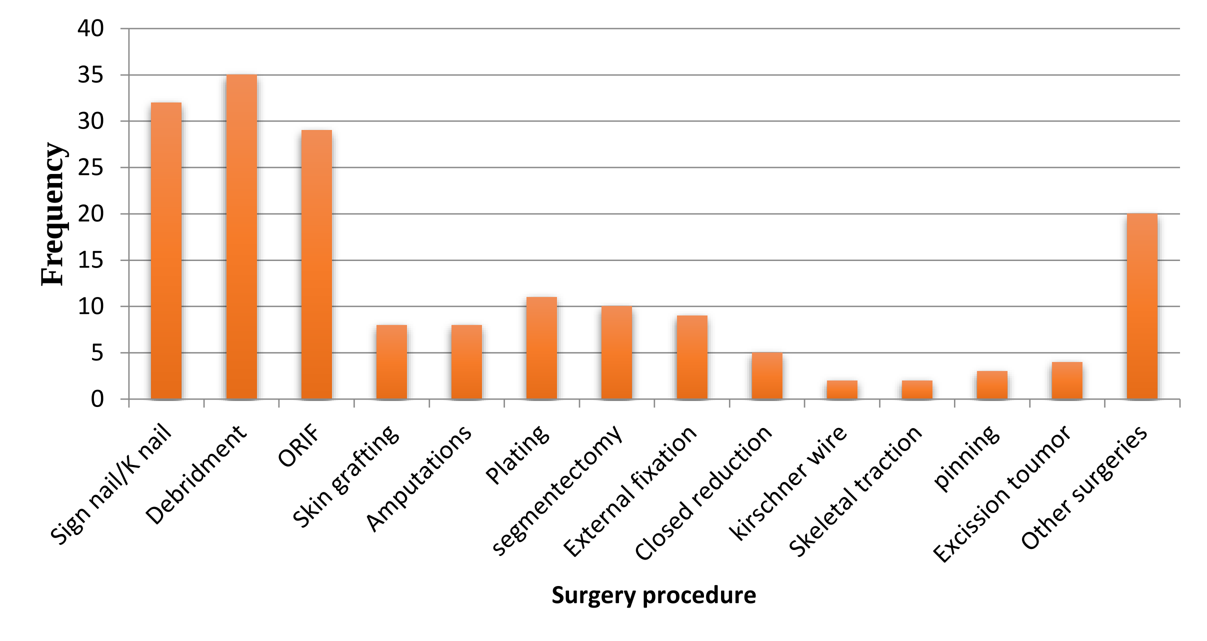

Figure 1: Observed surgery procedures

Table 2: Observed diagnosis

Diagnosis	Frequency	Percentage
Fractures	145	81.46
Head/neck injuries	3	1.69
Arthritis left hip	2	1.12
Dislocations	7	3.93
Osteomyelitis	8	4.49
Osteosarcoma left arm and left knee	2	1.12
Other diagnoses	11	6.18
Total	**178**	**100**

3.1 Describing clinical operations

A patient first arrives at the registration department of the hospital to begin the administrative activities. Patients at this hospital tend to arrive much earlier, before the start of clinical services. This is most likely due to the high number of patients attending this hospital per day; some patients prefer to arrive earlier so that they can be served before the queues lengthen. Upon arrival, clerks at the registration counter collect all necessary patient information, including treatment cost payment if needed. Patients are then transferred to the orthopedic clinic to await the start of the clinical sessions. Due to other hospital duties like ward rounds, surgeons sometimes arrive late at the clinic.

Upon their arrival, patients are escorted by a nurse to the examination room. During the examination, surgeons may require further ancillary tests (i.e. lab or x-ray test). Not all ancillary tests are included in this study. Due to a lack of operational information, lab test activity is not included in the model. However, most of the tests ordered at the clinic were X-rays. Patients with ordered X-ray tests would then go to the X-ray area. Upon receiving their X-ray test results, they would return these results to the nurse, who would then take them to the surgeon for further diagnosis. Following a second examination, a patient is either discharged or transferred for further surgical examination. Figure 2 shows the conceptual model of the orthopedic care process used to represent this clinic.

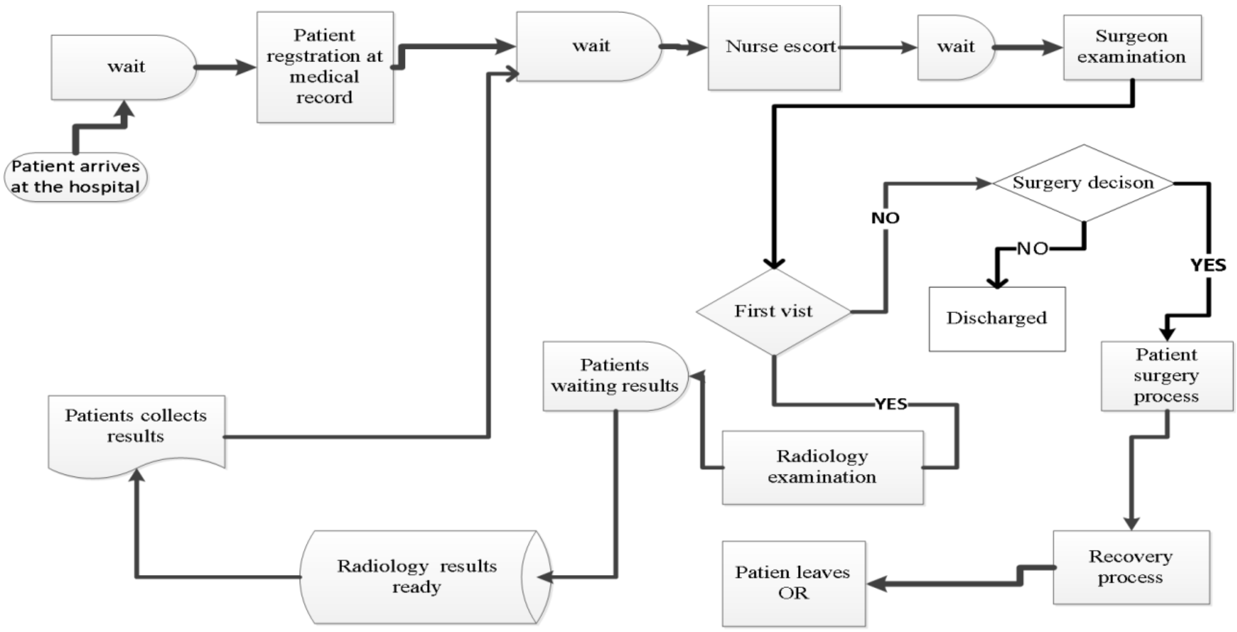

Figure 2: Current process in an orthopaedic department

4 Methodology and data collection

Our study was conducted in the orthopedic department from June 2012 to August 2012. Our focus was first to conduct an in-depth investigation in order to get all necessary information on the activities involved in the orthopedic treatment process and, second, to assess the benefits of applying lean and agile strategies to reduce variation in different patient activities.

This study adopted an exploratory design. We used the case study approach to get a holistic view of the process. Case studies facilitate a deep understanding of complex real-life activities and events using multiple sources of evidence through in-depth investigations that focus on understanding questions of what and why (Yin 2009; Mohd Noor 2008). We used semi-structured interviews, and observation to collect data.

The process of investigation involved meetings and interviews with hospital management and key personnel from each department, each lasting about 30 minutes. To facilitate a good understanding of the variations regarding each patient activity, questions were non-standardized and varied from interview to interview. To meet these objectives, the main question guiding this process was: what are the main causes of variation in patient activities? The answers to this question were further used as a basis for the discussion on how each activity can benefit from using lean or agile strategies to reduce variation.

The information obtained from the interviews and meetings helped map the care process. The validity of the conceptual model is critical; hence we involved key personnel from the orthopedic department on process mapping. The data collection process began immediately after mapping the process. Patients were followed from their arrival at the registration department to the point of discharge. Reliability was ensured by involving multiple observers (Yin 2009) during the entire data collection period. The time recorded includes assessment times during registration, examination at the clinic by the surgeon, X-ray testing, surgery process in the operating room and recovery. For the data collection process, we used stop watches and structured data sheets whereby each column represented an assessment time of a particular observed patient activity. Data for 178 patients were obtained.

To increase the validity of the collected observations, we conducted several discussions and unstructured interviews with key personnel from each department during the entire process of data collection (Yin 2009). Further insights into the care process were obtained from unstructured interviews and discussions with some patients and nurses. We maintained high data triangulation to enhance the availability of pertinent information as well as a high understanding of the orthopedic patient process (Bonoma 1985).

4.1 Data analysis

4.1.1 Variation analysis using control charts

To understand variation behavior in this process, we analyzed the recorded service times for each activity using control charts for individual values (x chart). We used control charts (x chart) to plot the observed patient data in SPSS. Before using the control charts, recommended statistical assumptions (Mohammed et al. 2008; Woodall et al. 2011) were checked: we checked the data for independence using autocorrelation charts. We further performed normality tests by graphically visualizing data using SPSS; the graphs for all the activities showed that the observed data could be normally approximated. In line with the suggestions from Woodall, Adams, and Benneyan (2011) for phase I variation analysis, means and control limits for this paper were calculated on the basis of collected historical data in SPSS.

We used the highly recommended control limits of $\pm 3\sigma$ and $\pm 2\sigma$, referred to as action and warning limits, respectively (Montgomery 2009). Stability in this process is interpreted by investigating the pattern of extreme values, i.e., one or more points outside the control limit $+3\sigma$ constitute a statistically significant variation; therefore, the causes of that shift must be investigated (Montgomery 2009; Mohammed et al. 2008; Saturno et al. 2000). Two additional rules for individual charts, were used to assess variation in each activity: two out of three consecutive observations beyond 2σ on the same side of the center line but still inside the control limit; and a repetitive pattern of 12 or 14 alternating up and down across the center line (Mohammed et al. 2008; Montgomery 2009).

We summarized the empirical data on service time observations and used them for the quantitative assessment component of the study. Descriptive statistics were performed for each activity service time to explore variability characteristics based on standard deviations, means, and medians. Using descriptive statistics, activities with high standard deviations were considered to be more variable than activities with lower standard deviations (Keeling et al. 2013), as presented in Table 2.

In addition to the quantitative assessment, we transcribed information obtained during the interviews, and discussed the result with heads of respective departments. During those discussions, further clarification was obtained, which enhanced eradication of any prior misinterpretation. We used the transcribed information to further assess the orthopedic care process characteristics.

5 Findings

This section presents the findings from the two analyses. First, it presents the analysis as well as the results proposing lean and agile activities in healthcare process settings based on the reviewed lean and agile literature. Second, it presents the findings from the in-depth exploration of the characteristics of the orthopedic process using control charts. We present our findings using both qualitative and quantitative results for each activity. The qualitative results are based on the interviews and observations. Furthermore, Table 2 presents the quantitative results from the descriptive analysis of the service times.

5.1 Findings based on the reviewed lean and agile literature

5.1.1 Proposing lean and agile activities in the healthcare process setting

This section focuses on identifying which activities can be lean or agile in healthcare processes based on the framework developed in Table 1. The characteristics of each activity involved in the patient care process are discussed so that they can be matched with either lean or agile activities, as demonstrated in Table 1.

Repetitive/standard activities are evident in healthcare processes, for example, x-ray and registrations (Lillrank and Liukko 2004; Aronsson, Abrahamsson, and Spens 2011). Contact with patients in these activities occurs only once, e.g., during sample taking for lab activities or imaging for X-ray activities. Patients are not involved during the actual activity of, e.g., testing. Likewise, in administrative activities, patients are not involved in the actual activity, e.g., information entry into the computer. Similar to the assembly line in the manufacturing industry, these activities are characterized by high volume and low variability (Aronsson et al. 2011; Rahimnia & Moghadasian 2010).

By high volume, we mean the number of patients attending the activity and who do not depend on individual needs to execute the activity. For example, all patients attending the hospital must be registered at the registration counter before being routed to their respective clinics. Registration involves the gathering of personal information from the patient. Even if this activity involves a high patient input, it is the same set of information collected; therefore, this activity can be considered standard. The activity does not require a specific qualification in healthcare, but general knowledge in handling information manually and as well as computer. This knowledge is considered basic, and workers can be trained in-house.

In general, these activities are highly automated, which implies that they are performed in a similar manner for all patients. For example, the main part of lab activity is machinery based. Blood sampling is done manually, but it is standard, and the examination is strictly machinery based. The opposite is the case for X-rays: the procedure for carrying out the X-ray is machinery based while examination is done manually. Even if these activities are a combination of manual and machine performance, given the same test, they are all repetitive and standard across diagnoses. The workers performing these activities can be characterized as having obtained a medium-to-high degree of education.

From this analysis, it can be observed that most of the characteristics found in these activities have a high resemblance with manufacturing activities such as those involved in high volume assembly lines. As shown in Table 1, the lean and agile literature highlights that high volume and low variability activities should be matched with lean strategies to enhance efficiency in production processes (Stavrulaki & Davis 2010). Based on these views, we propose that these activities may be performed using a lean strategy.

Customized or unique activities are typical in healthcare processes where individual needs are the basis for executing an activity. For example, in the examination of a patient, the decision of a treatment plan is highly individualized. Likewise, surgical activity may also be considered as an individualized process because no surgical process is repeated exactly the same way twice (Rahimnia & Moghadasian 2010). Nevertheless, one could argue that each surgical procedure is standard because the surgeon uses the same technique every time. However, this procedure needs to be adjusted depending on the patient's condition. Furthermore, surgeons often plan for one surgical procedure, however, during the operation, it might be necessary to change or conduct additional procedures because the patient's conditions might be different from what was assumed before starting the operation. It is well known that procedures for these activities are standardized but that the time to accomplish these tasks may vary greatly from patient to patient due to unforeseen complications (Aronsson et al. 2011).

Because each patient has his/her unique requirements, the degree of complexity also varies from case to case. This in turn result in high variability in these activities, thus requiring high levels of flexibility to manage them. These activities are low in volume. For example, comparing the hospital's central lab and the orthopedic department, the former receives a large number of patients from the entire hospital while the orthopedic department only receives orthopedic patients (Rahimnia & Moghadasian 2010; Aronsson et al. 2011).

Based on this analysis, the characteristics of these activities largely resemble those of the job shop and project-based production processes, which are characterized by high variety and uncertainty. The lean and agile literature highlights that low volume and high variability activities/products should be matched with agile strategies (see Table 1; Stavrulaki and Davis 2010). Thus, on this basis, we suggest that treatment activities such as examination and surgical activities are well-suited for agile strategies.

Healthcare processes are very complex and comprise a number of interdependent administrative and clinical activities across a number of departments (Anyanwu et al. 2003). This in turn requires high levels of collaboration and coordination. For example, when a patient has to undergo an operation, several departments, e.g., the lab, X-ray, and ward departments must collaborate with the operating room at different stages of the process. The execution of patient care activities involves a number of personnel as well as tasks. For example, registration comprises the entry of patient information and the storage of patient information.

The literature asserts that the leagility concept faces some practical limitations in healthcare processes. It is difficult to establish a decoupling point because patients are involved in the entire treatment process. Instead, each activity in the process should be explored to identify which strategy may be appropriate based on, e.g., volume and variety (Aronsson et al. 2011). The lean strategy is advocated as the most appropriate for standard activities, which are characterized by low volume and predictable demand. Conversely, agile strategies are advocated as suitable for customized products/activities, which are characterized by unpredictable demand, and low volume (Christopher et al. 2006; Christopher 2000). It can be concluded that in a hospital process, there are three types of activities: activities that can be performed in a standardized manner, those requiring a combination of standard and manual procedures, and activities where standardization is only possible to a minor extent. This section discussed and gave examples of the three different activities. To sum up, Table 3 matches lean and agile activities in the healthcare setting to the comparison characteristics summarized in Table 1.

5.1.2 Enhancing agility in the agile proposed activities in healthcare processes setting

Literature asserts that the key issues for examination and surgery activities are ability and flexibility of personnel to handle variety of patient cases (Rahimnia and Moghadasian 2010). To enhance agility in proposed agile activities, healthcare providers should focus on increasing resource flexibility by developing flexible capacity, as well as investing on training and education of personnel. Even though flexible capacity requires more personnel but it, increases speed of response to unexpected needs of the patients. Additionally adjusting capacity and demand is more important so that the quickest response can be achieved in a better way (Aronsson, Abrahamsson, and Spens 2011; Rahimnia and Moghadasian 2010)

Process integration is the key to successful achievement of agility in these activities. Process integration means collaborative working between departmental units, patients and care providers, common systems and shared information (Towill and Christopher 2002) Hospitals should integrate examination and surgery process with their respective supporting activities (i.e. x-ray, lab, and registration). Collaboration between these departments should be strengthened with the key objective of meeting patient demands and needs at a very short lead time. Hospitals should invest on developing cross function teams and flexible management that leverage the intellectual power of employees within these departments. Moreover information flow should be smooth between these units and uninterrupted to enhance departmental integration (Hormozi 2001)

5.1.3 Enhancing leanness in the lean proposed activities in healthcare processes setting

The findings suggest that lean activities experience low variety and high volume at (x-ray, lab, registration and other administrative activities). It is well known that most of the procedures for each of these activities are the same for all patients. The key issue for internal processes that are the same for all patients (low variety) is to increase internal efficiency through improving patients flow (Brandao De Souza 2009). This necessitates these activities to be highly lean.

Standardization is proposed as the preferred operational practices from lean strategy that can be used to increase clinical efficiency in patient treatment activities. Standardization by redesigning job responsibilities reduces job complexity resulting into more simple and repetitive jobs building the possibilities for these jobs to be executed by less highly trained professionals. This creates flexible capacity and enables critical resources such as surgeons to focus on their core activities (Joosten, Bongers, & Janssen, 2009).Thus to make these activities more lean their respective procedures can be standardized to increase efficiency and enhance patients flow. For example standardizing all procedures related to registration process, can speed up the registration process. Another action that can help to make these activities leaner is the use of temporary workers during periods with peak demands. These temporary workers can be trained to be used in more than one department during peak periods to assist in administrative activities.

Table 3: Proposed lean and agile activities in the setting of healthcare processes

Distinguishing activity characteristics	Lean	Proposed lean activities	Agile	Proposed agile activities
Variability	Low	X-ray, Lab tests, registration, Administrative activities	High	Examination/treatment activities, surgery, recovery activities,
Volume of customers	High		Low	
Typical tasks	Standard		Customized	
Educational level	Low		High	
Complexity	Low		High	
Collaboration	High		High	
Coordination	High		High	
Number of tasks	High		High	
Number of workers	High/low		High/low	
Technical	High		Low	

5.2 Findings based on the analyzed empirical orthopedic care process

5.2.1 Variation analysis using control charts

This section presents variation analysis of the collected historical data. It should be noted that the historical data used to plot lines contains the outliers studied. This is due to the fact that this study was limited only to phase I, thus the collected data were used to show the actual behavior of the process without removing any data points. Also we didn’t set any size for standard deviation, because in phase I we focused on comparing the collected historical data with a set of control limits computed from those points . This argument is also supported by the literature which states that in phase I it’s more appropriate to compare the historical data with control limits computed from those points in order to get the real behavior of the process under study (Montgomery 2009). Also from the studied hospital perspective, there is no any standard deviation size that is used as a benchmark. Thus, we compared historical data with control limits as suggested by the literature(Montgomery 2009).

Variation analyses of the studied orthopedic process by means of control charts demonstrated wide variability in these activities. In Figures 3 to 9, the lower black dashed line represents $\pm 2\sigma$ while the uppermost blue dashed line represents $\pm 3\sigma$ line. A general observation shows that most of the common cause variations are within two standard variations commonly referred to as the warning limit. Consistent with the reviewed literature, activities relating to examination processes demonstrate high variability. However, contrary to expectation, standard activities such as X-rays and registrations also demonstrate high variability. Given the fact that variation is a source of inefficiency in patient processes (Noon et al. 2003), it is worth investigating the operational characteristics of each activity to identify the causes of this variation. An analysis of each activity is presented below.

Despite the fact that the registration process is to a large extent repeated in the same manner for all patients, the registration activity chart demonstrates high variation in service times, with one patient going above the specified $+3\sigma$ control limit (see Figure 3). The graph indicates that this patient used more time for registration. Likewise, a few patients were beyond two standard deviation points; registration times for some patients were high at more than 20 minutes; for some patients, registration was lower. This indicates that this activity is not operating efficiently. By observing the activity and conducting interviews with key personnel within this department, it was found that most of this variation was internally created.

According to an interviewee, the registration process comprises three steps, namely, the entry of patient information, payment of treatment cost, and the finalization of the registration when a patient is given a payment confirmation. These steps contribute to variation in this activity. Another crucial problem in these steps is caused by the fact that no two patients are the same and that some of them require more assistance, e.g., older patients. These patients usually require more time with registration personnel during the information gathering process. In addition, during the data collection period, some variation was observed among the registration staff who attended to patients; it is not always the same registration staff conducting this activity every day. Staff variation was pointed out by a registration-based interviewee as another source of registration activity creating time variations due to different levels of experience and capability among registration staff in performing this activity.

Despite the fact that the X-ray process is largely executed in a similar way for all patients, the X-ray time chart in Figure 7 demonstrates some variation with two patients going beyond +3σ. These patients used more than 20 minutes. Within two standard deviation points, the common variation was still high, with few patients going beyond this limitation. During meetings and discussions with key personnel in the X-ray department, it was gathered that this variation was internally created due to staff variation in this activity, i.e., differences in abilities and experiences were the main driver for this variation. Again, the more common explanation for high patient volumes was pointed out as another driver for this high variation.

Looking at the examination process (Figures 4, 5, 8, and 9), the same pattern of substantial variation is observed. Even though few patients went beyond three and two standard deviation points, the common cause variation was high. This variation was externally created and mainly caused by variety in individual patient conditions. As stated in the previous section, this clinic delivers a variety of diagnoses and surgical procedures. Each patient has a unique condition, and the time required to perform each diagnosis or surgical procedures varies significantly from patient to patient, leading to high variability in the process.

Variability in examination and surgery service times is further introduced by the fact that surgeons possess different experiences as well as speeds in performing examinations or surgical procedures. For example, one surgeon may use less time on a patient than another in a similar case (McLaughlin 1996). To validate this argument, for example, the first examination chart in Figure 6 shows that three patients experienced high examination times. This is also noted in the second examination time where eight patients experienced high examination times. Additionally, for the surgical process, six patients experienced high surgery times of more than two hours. For all examination-type activities, 17 patients matched a special cause variation, i.e., one falling beyond the control limit. Thus, some variation in examination and surgical activities can be explained by differences in individual surgeon performance. Individual surgeon performance is determined by patient medical condition. The more critical and complicated patient case necessitate the surgeon to use more time than in less critical cases. Thus, variation in surgeons performance increases as the variation in patient medical condition increases. Surgeon with more critical case will obvious take more operation time than surgeon with less critical case.

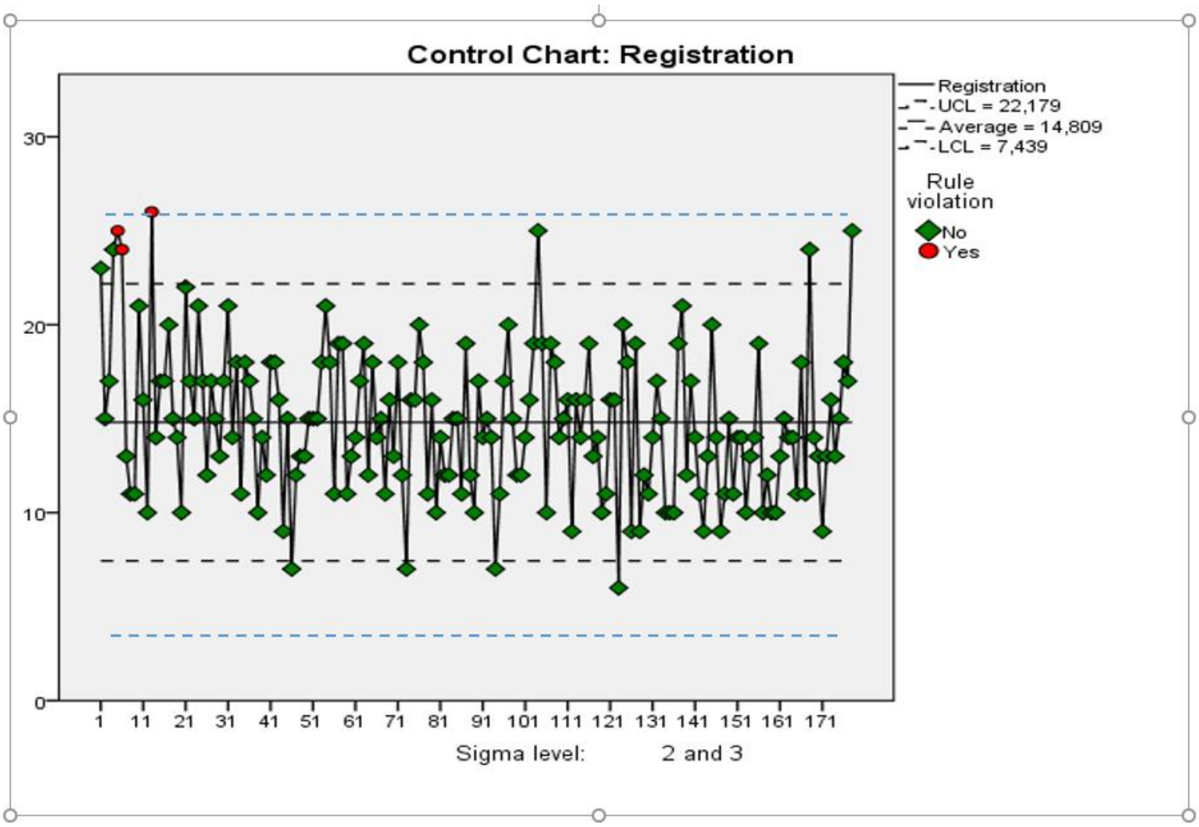

Figure 3: Registration time

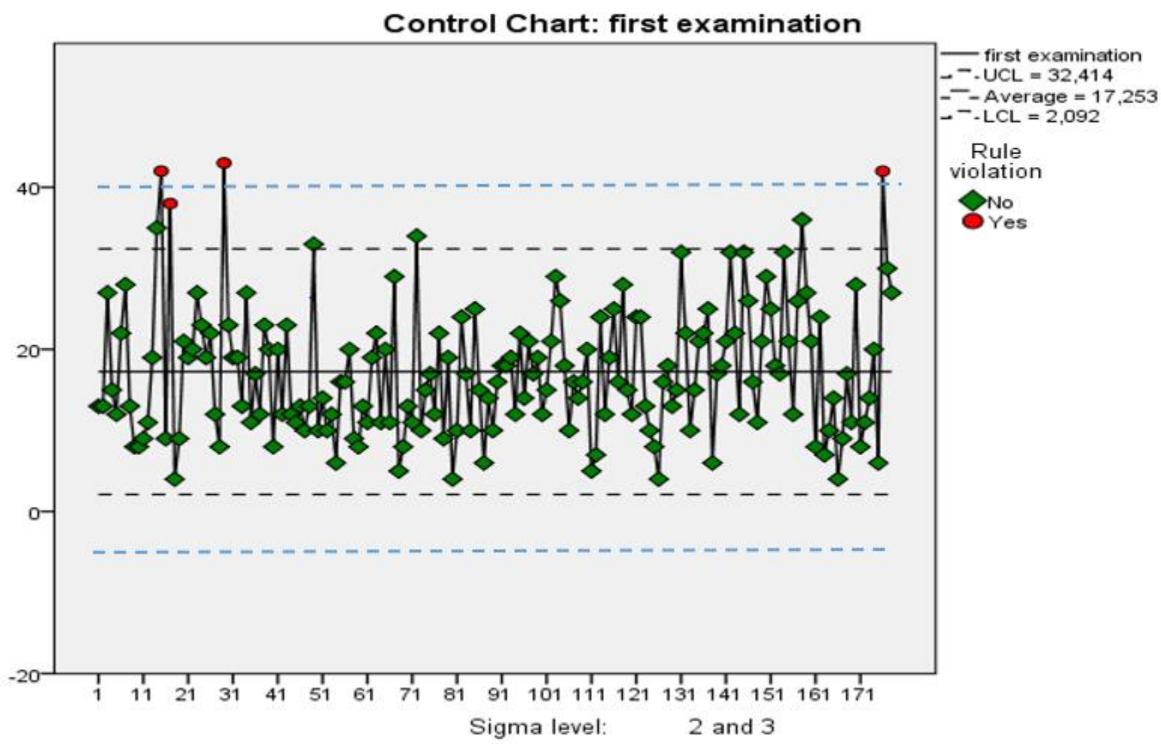

Figure 4: First examination time

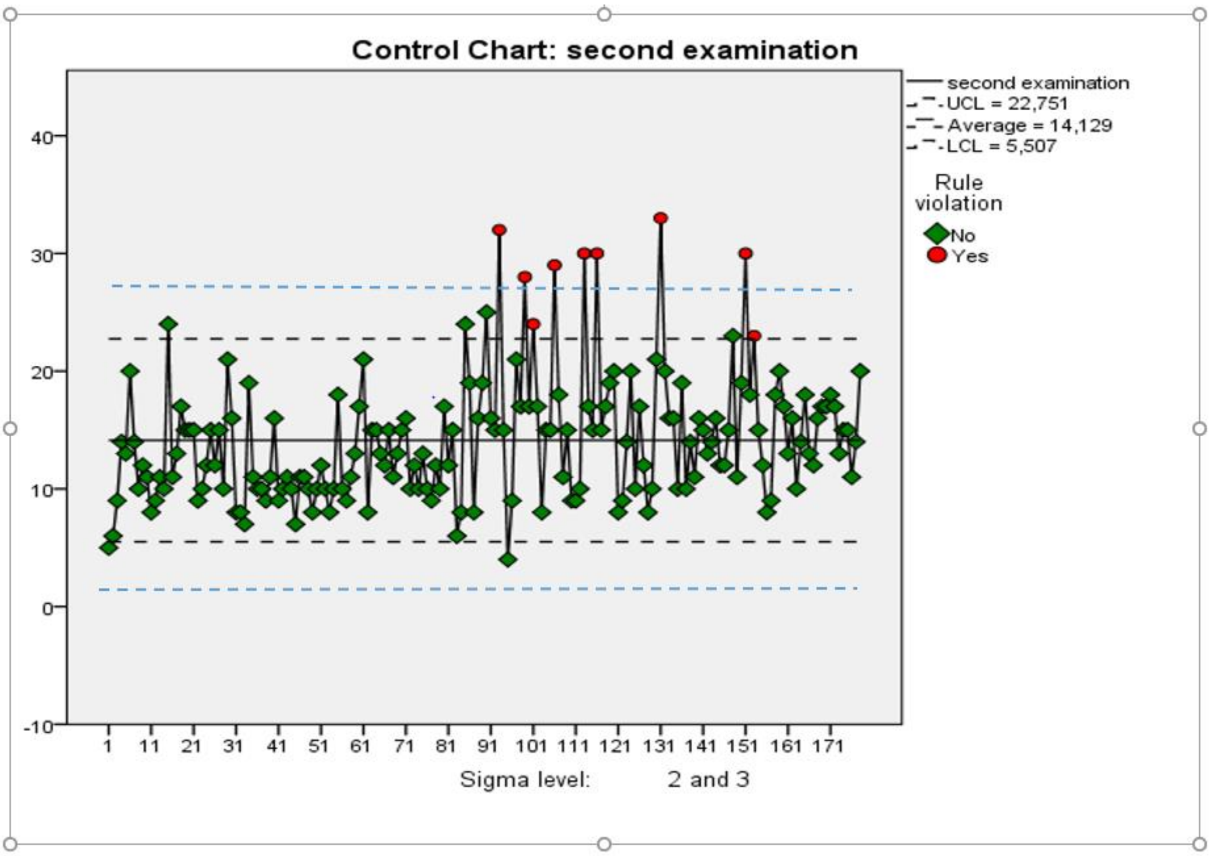

Figure 5: Second examination time

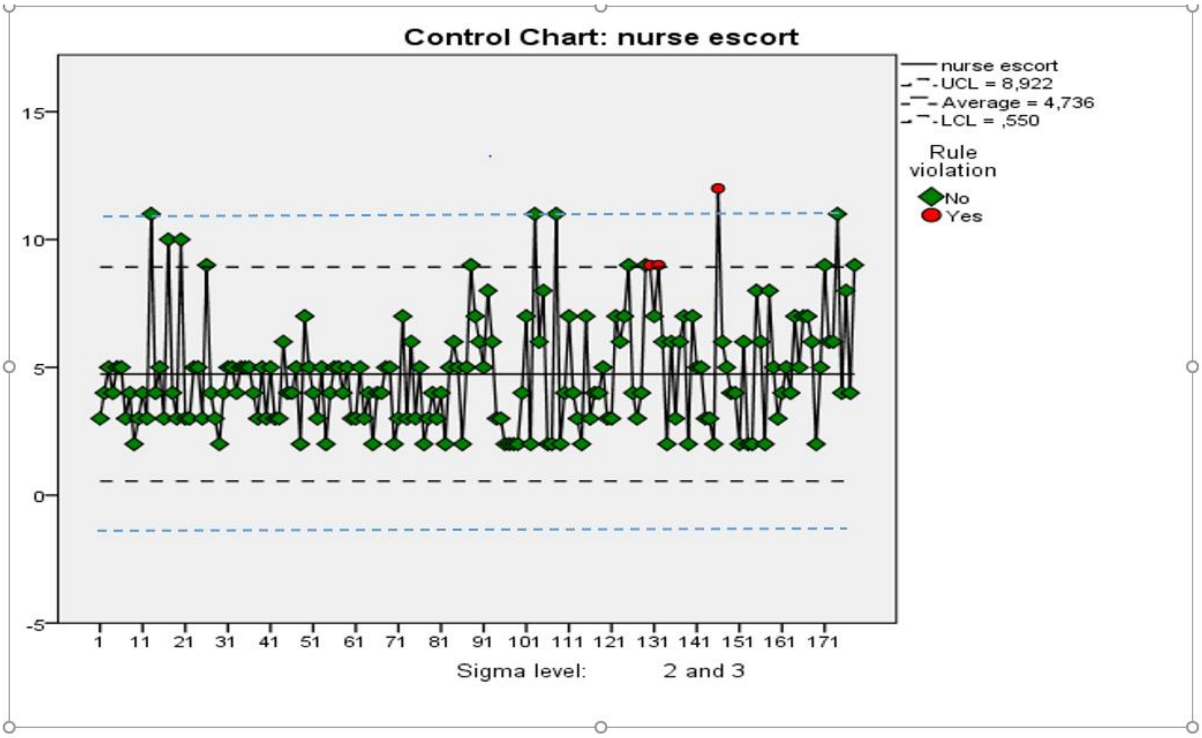

Figure 6: Nurse escort

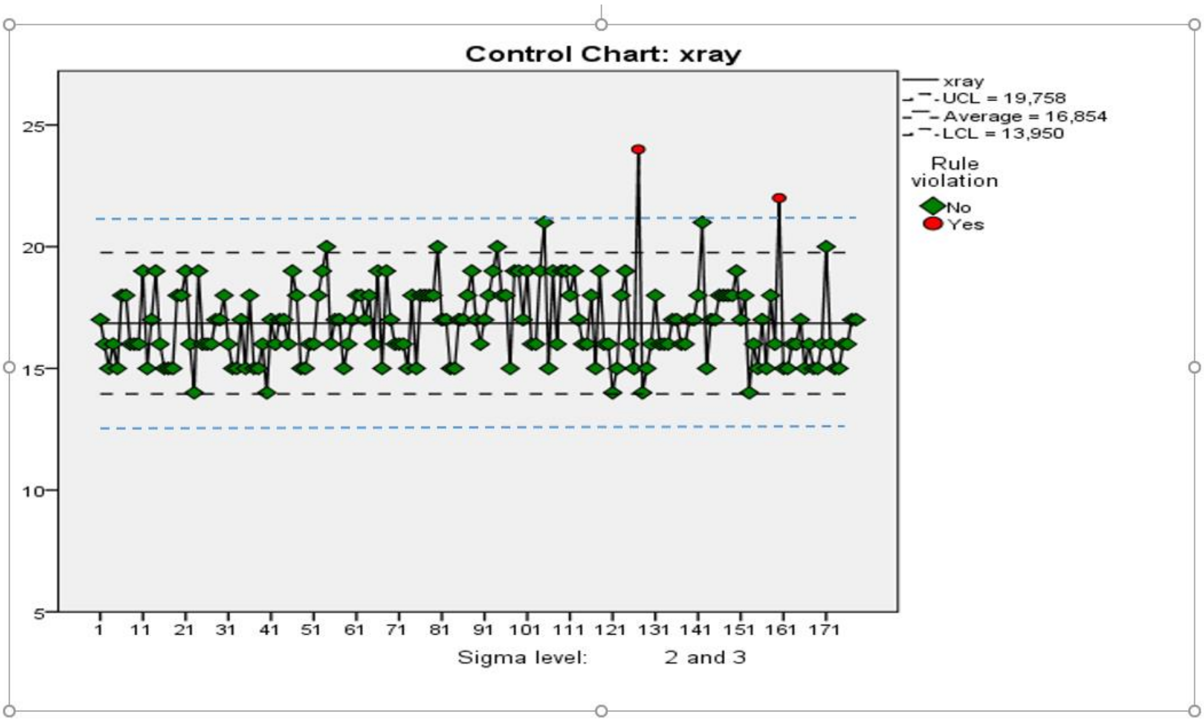

Figure 7: X-ray time

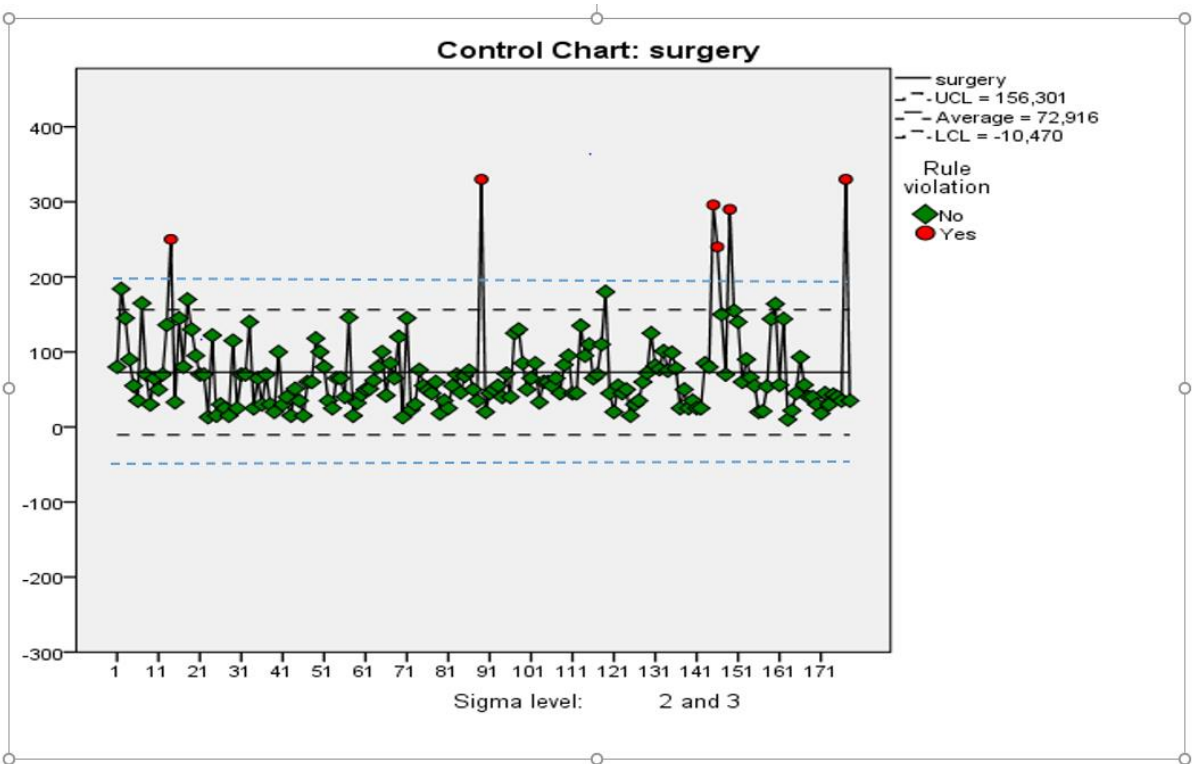

Figure 8: Surgery time

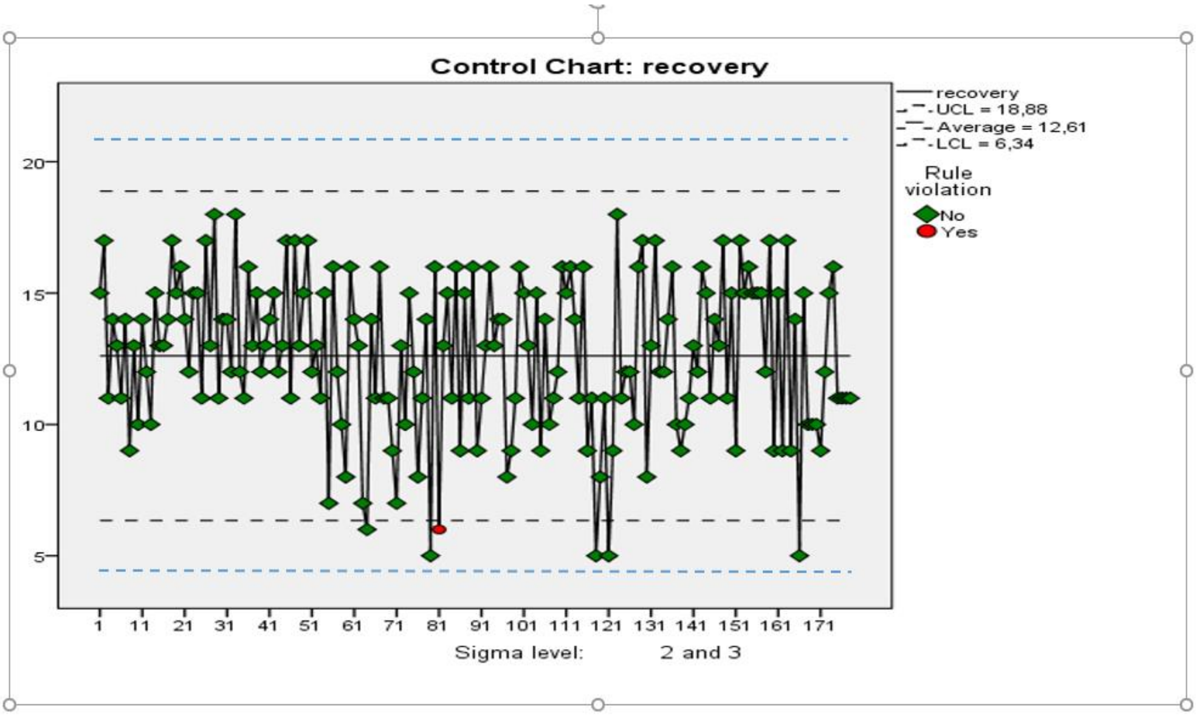

Figure 9: Recovery time

Table 4: Activity descriptive statistics (minutes)

Activity	Mean	Median	Standard deviation
Registration	14.87	15	3.88
Nurse contact	4.7	4	2.21
First examination	17.17	16	8.23
Second examination	13.98	13	5.31
X-ray	16.38	17	1.65
Surgery	72.848	60	4.25
Recovery	12.61	13	2.969

6 Discussion

This section presents the discussion on how healthcare organizations can benefit from the use of lean and agile strategies in different patient care activities. By drawing from the findings from the literature review regarding which activities can be lean or agile, the benefit of applying these strategies in real-world examples is discussed. The objective of investigating the orthopedic care process was achieved by using control charts to conduct detailed investigations regarding variations in each patient activity. Control charts were used to visually analyze how patient service times varied from the observed means obtained from the historical data on each activity. Interviews and observations were further used to explore the causes of variation in patient activities. The necessity of applying lean or agile strategies is discussed for each activity.

6.1 Lean operational activities

According to the extant literature, X-ray, registration, and nurses' administrative activities are typical examples of lean activities (see Table 3). However, empirical findings show that no appropriate strategy is used to manage variation in these activities in this orthopedic process. The application of lean strategies is of paramount importance for reducing observed variation resulting from the design of these activities. Lean strategies can lead to the elimination of internally created variation by streamlining internal processes and operations (Brandao De Souza 2009). For example, lean strategies can be used to standardize all steps relating to registration and X-ray activities. To reduce number of steps during registration, patients can have payment option for treatment including making post-treatment payment. Due to the simplification of the job complexity process, standardization will create flexible capacity and enable the accommodation of more patients. This is more beneficial in healthcare, given the growing resource constraints problem (van Wessel et al. 2006; Joosten et al. 2009).

Another lean strategy that can be used to reduce variation and increase patient flow during periods with high demand can be the use of temporary workers e.g. at registration department to speed up registration processes. Likewise, at nurses station in the clinic a temporary nurse can be used during periods of high demand to help move patients to surgeons' .These temporary workers can be borrowed from other administrative departments or trained.

6.2 Agile operational activities

The reviewed literature asserts that examination, surgery, and recovery activities are suitable for an agile strategy (see Table 2). However, despite the fact that these activities demonstrate high variability resulting from individual patient conditions, no appropriate strategy is used to manage them in this care process. To eliminate variation healthcare providers at this clinic should consider applying agile strategies to this part of the process. Under these conditions, the elimination of waste, the main focus of a lean strategy, assumes a lower priority than the need to respond rapidly to volatile and uncertain demands (Harrison & VanHoek 2008). Unique patient conditions make treatment and surgery activities unpredictable, thus necessitating high levels of flexibility. Applying an agile strategy at this stage of the process could enable the necessary flexibility to reduce variation by responding quickly to variety in patients demands (Aronsson et al. 2011). One of agile strategy that can be used in the process is increasing flexibility by either altering the number of surgeons or extending the use of surgeons (Olsson and Aronsson 2015; Hopp and Spearman 2000). In this regard, junior doctors can be used to increase the capacity of the existing surgeons, who will in turn increase the responsive rate and accommodation of uncertainties in-patient demands and needs.

Another strategy that can be used to handle external variation is to extend the use of operational theater. For example when there is high demand operation theater can be opened one hour before and start with complex cases such as amputation early in the morning and minor cases later in the day. Likewise having staff that can be used during periods with high demand and released during periods with lower demand can increase flexibility to handle externally created variation. Forexample a hospital can train staffs who can be used in more than one surgical clinic depending on the need. In orthopedic care processes these trained staffs can be trained to deal with minor cases and give surgeons time to deal with complex cases during periods with high demand.

7 Managerial implication

This study provides significant insight to healthcare providers on the necessity of matching patient care activities with lean and agile strategies. Many healthcare organizations today have placed great emphasis on implementing a lean strategy to handle internal variation. An overemphasis on lean strategies has caused many healthcare providers to implement these strategies in the wrong activities. This has in turn increased the complexities involved in healthcare processes as lean strategies cannot handle external variation. Literature, demonstrates that it is not a matter of relying heavily on lean strategies but rather that healthcare providers should focus on implementing both sets of strategies (Aronsson et al. 2011).

This is because healthcare processes are a mixture of both standard and customized activities. Thus, to gain from both increased clinical efficiency and flexibility in handling variety in patient conditions, healthcare providers must implement lean and agile strategies based on their prerequisite conditions.

8 Conclusion

Even though the existing literature discusses lean and agile strategies in healthcare processes, the question of when and how to use them has remained unanswered. Thus, this paper contributes to the existing healthcare literature by proposing which activities can be lean or agile. Our findings suggest that the adoption of both lean and agile strategies could increase process efficiency and improve responsiveness. These findings contribute to the literature on how lean and agile strategies can positively impact healthcare processes by implementing them at the appropriate stages of the process.

Finally, even though our study has been primarily conducted using data collected in a specific orthopedic clinic, our results can be generalized to other orthopedic care processes with similar healthcare operations. Given the fact that each process is subject to variation, the proposed strategies in this care process can be used to reduce variation in other care processes with the same operational setting.

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Paper 2

Improving surgeons utilization in an orthopedic department through simulation modelling

Abstract

Purpose: Worldwide more than two billion people lack appropriate access to surgical services due to mismatch between existing human resource and patient demands. Improving utilization of existing workforce capacity can reduce the existing gap between surgical demand and available workforce capacity. In this paper, the authors use discrete event simulation to explore the entire care process at an orthopaedic department. Our main focus is first improving utilization of surgeons while minimizing patient wait time. Second, exploring the effect of delegating ancillary services on surgeon utilization.

Methods : The authors collaborated with orthopedic department personnel to map the current operations of orthopedic care process in order to identify factors that influence poor surgeons utilization and high patient waiting time. The authors used observational approach to collect data. The developed model was validated by comparing the simulation output with actual patient data that were collected from the studied orthopedic care process. The authors developed a proposal scenario to show how to improve surgeon utilization.

Results: The simulation results showed that if ancillary services could be performed before the start of clinic examination services the orthopedic care process could be highly improved. That is improved surgeons utilization and reduced patient waiting time. Simulation results demonstrates that with improved surgeons utilizations up to 55% increase of future demand can be accommodated without patients reaching current waiting time at this clinic. Thus, improving patient access to healthcare services

Conclusion : This study shows how simulation modelling can be used to improve healthcare processes. This study was limited to a single care process; however, the findings can be applied to improve other orthopedic care process with similar operational characteristics.

Keywords: waiting time, patient, healthcare process.

1 Introduction

Despite significant technological and medical advances, critical shortage in health workforce poses key constraints in healthcare service delivery [1–3] This problem is more critical in the field of surgery as more than two billion people worldwide lack access to surgery services [4,5]. Funk et al [5] noted that rising constraints on the availability of human resources, inadequate surgical facilities and poor infrastructures are the main problems associated with inadequate surgical treatment service. Thus, to meet increasing surgical demand and needs, healthcare providers must learn to better utilize existing workforce capacity. This can be achieved by applying operational management tools such as simulation, lean and agile to explore patient care processes in order to improve utilization of existing resources and patient care delivery process. Incorporating lean and agile can lead to improved resource utilization as well as care processes [6–9]. However, this study is limited only to simulation.

In spite of the growing number of academic research on the patient care process, time-related studies focus mainly on wait time or the duration of individual medical procedures in the care process, thus lacking a total, holistic view of the patient care process[10,11]. In order to facilitate increased access to care services through better utilization of existing workforce capacity, a holistic view of the process should be taken into consideration. This paper aims to fill part of this gap by using a discrete event simulation model to explore the patient treatment process and investigate how to improve surgeons utilization without adding extra resources. This objective will be achieved by first, using simulation model to explore and identify factors that influence poor surgeon utilization and high patient waiting time. Second, suggesting and testing a proposal scenario that can be used to improve surgeon utilization and reduce patient waiting time. And lastly, investigating to what extent the improved process can accommodate future increasing demand.

The remainder of this paper is organized as follows: The Second Section presents the literature review, and the Third Section presents the description of orthopaedic department and its workforce capacity problem. The Fourth Section presents data collection and the methodology used for simulation model development. The Fifth Section presents the proposal scenario suggested to improve utilization of surgeons and decrease patient wait time. The modelling results are presented in Section six. The seventh Section presents a discussion of the simulation results, followed by the managerial implication and conclusion in the last Section.

2 Literature review

Healthcare resources have become increasingly scarce and expensive, thus placing greater emphasis on better utilization of resources to improve health services. One of the major operational issues in healthcare delivery systems involves maximizing resource utilization goals while minimizing patient wait times. Simulations have proven their capability and viability as a technique for improving resource utilization and reducing patient wait time [7,12,13]. This has led to a number of simulation studies being carried out on orthopaedic care processes.

Bowers and Mould [14] conducted a study in orthopaedic trauma theatres to explore the balance between maximizing the utilization of operating room sessions and ensuring improved throughput. They found that a willingness on the part of elective patients to postpone their treatments could result in achieving greater throughputs. Bowers and Mould [15] adopted simulations to explore the potential for increased efficiency with an increased volume of non-elective patients in an orthopaedic department. They found that the concentration of non-elective activity could offer potential savings in terms of the theatre time allocated for trauma cases. Meer et al [16] conducted a study in an orthopaedic department using a series of projects. The goal was to give their clients a better understanding of the reason for increased patient wait times.

Baril et al[17] studied the relationships and interactions among patient flows, resource capacities, and appointment scheduling rules in order to improve an orthopedic outpatient clinic. They found that in order to improve the outpatient orthopedic clinic’s performance, resources and appointment scheduling rules must be applied to the various patient flows. Bowers and Mould [18]used a simulation to explore the balance between maximizing orthopedic theater utilization, minimizing the number of overruns, and ensuring high quality during theater sessions. They suggested that including deferred, elective patients in trauma theater sessions has the potential to generating excess theater capacity using existing resources. Steins et al [9]deployed discrete-event simulation to explore how various management polices affect various performance metrics, such as patient waiting time, cancellations, and the utilization of orthopaedic theatre time. They noted that the performance of an operating room department can be significantly improved by utilizing policies that focus on reserving operating room capacity.

Despite the wide application of simulations on healthcare processes, the literature points out that, application of simulation in healthcare is still at an embryonic stage [19,20]. And this is evidenced by the above reviewed literature as most of them have focused on using simulation to either reduce patient waiting time or improve resource utilization. This study extends this line of research by considering not only patient wait time and resource utilizations but also exploring extent to which this department can accommodate future increasing demand as a result of process improvement. In this paper, the authors explore on how to improve surgeon utilization while minimizing patient wait time from when the patient arrives to the point of discharge. Here, surgeon utilization is defined as the proportional of time in which orthopaedic surgeons are busy with patient examination and treatment.

3 Description of orthopaedic department

This study was approved by Research and Ethics committee (REC) of Catholic University of Health and Allied Sciences and Bugando Medical Centre (CUHAS/BMC). Patient written consent was not necessary because this was a process improvement study and no single medical or personal information from the patient was taken. Data collection was anonymous. The authors conducted this study at Bugando referral hospital, one of the four teaching and consultant hospitals in Tanzania. It serves mainly the Lake and Western zones of the United Republic of Tanzania. Bugando hospital is located along the shores of Lake Victoria in Mwanza City. This 900-bed hospital has approximately 1,000 employee. The Bugando hospital is a referral hospital for tertiary specialist care serving eight regions: Kigoma, Mwanza, Kagera, Tabora, Shinyanga, Simiyu, Geita and Mara. This hospital serves a population of about 13 million people.

Orthopaedic department of this hospital was experiencing workforce capacity challenges. Specifically, its existing surgeon capacity was facing an increase of demand for orthopaedic care services and high patient wait times. Hospital management noticed that process improvement was necessary for this department. Improving utilization of existing surgeon capacity, without adding extra resources, was one of the improvement initiative proposed to enhance this care process. The management of this hospital concerned with finding a better way of utilizing the current limited number of surgeons in order to reduce patient wait times and increase patient access to care. The main interest was on identifying factors causing the poor utilization of surgeons and the strategy or actions that can be used to improve surgeons utilization, reduce patient wait times and increase patient access to care.

3.1 Orthopedic Department Resources

Bugando hospital has four specialized orthopaedic surgeons and five operational theatres for both elective and emergency patients. Orthopaedic surgeons are allocated only two rooms, operating on Monday, Wednesday, and Friday, with two surgeons per day. The total capacity for the allocated three days in the operating theatre is six rooms per week. On the clinic side, orthopaedic surgeons attend to patients on Tuesday and Wednesday, with two surgeons per day. Orthopaedic clinic has three nurses that guide and take patients to surgeons for examinations. Bugando Hospital also has a central laboratory and an X-ray section, which serve the entire hospital community.

3.2 Describing process Operations

In order to understand and map the entire orthopaedic care process, the authors held interviews with orthopaedic surgeons, heads of departments related to orthopaedic care (lab, x-ray, registrations, and the orthopaedic ward) and hospital management. To increase model validity and credibility, the authors involved key surgeons at the orthopaedic clinic and the head of operating room during conceptual model development. To gain more insights into the orthopaedic care process, the authors held unstructured discussions with nurses and patients attending orthopaedic clinic. The entire patient orthopaedic care process is described below.

Upon arrival at the hospital patient first start at the registration department where individual patient information is collected as well as any associated treatment if needed. It is common for patients to arrive at registration department from six in the morning, even though registrations start from seven and clinic services start from eight in the morning. Patients are allowed to drop off their information cards at the registration counter which are used by registration personnel to collect patient information for registration purposes. The registration counter sometimes opens before seven to allow early arrival patients to drop their information cards. Being the sole registration department for the entire hospital, this approach helps registration personnel to successfully accommodate high volume of patients attending this department. When registration process is complete patients are directed to their respective clinics: orthopaedic clinic in this case.

After their arrival at the orthopaedic clinic, patients are required to wait for the examination activities to start, including the arrival of the orthopaedic surgeons. Although, there is no clear reason as to why some patients tend to arrive early in the morning before the start of clinical services, it is probably due to high volume of patients attending this hospital per day. Thus, some patients would prefer to arrive early in the morning so that they can receive treatments before the queues for healthcare providers piles up. Occasionally nurses at this clinic arrives early though not necessarily an hour earlier, and upon their arrival helps patients with administrative issues before surgeons arrive. This might be due to high number of patients attending this clinic. Sometimes the surgeons arrive 15-45 minutes after clinic has opened due to other duties at the hospital. When surgeons arrive at the clinic, nurses escort patients to the examination rooms.

During first examinations surgeons usually orders ancillary test such as x-ray and lab test. Patient with ordered ancillary test are then required to undertake their respective ordered test which can be either x-ray or lab test. After obtaining their ancillary tests results, patients bring their results to the clinic and handle them to the nurse, who takes the result to the surgeons for further diagnosis. At the end of the second examination patients are either transferred for surgery activity or discharged. Figure 1 presents a conceptual model of the current orthopedic care process that was translated into the computer simulation model.

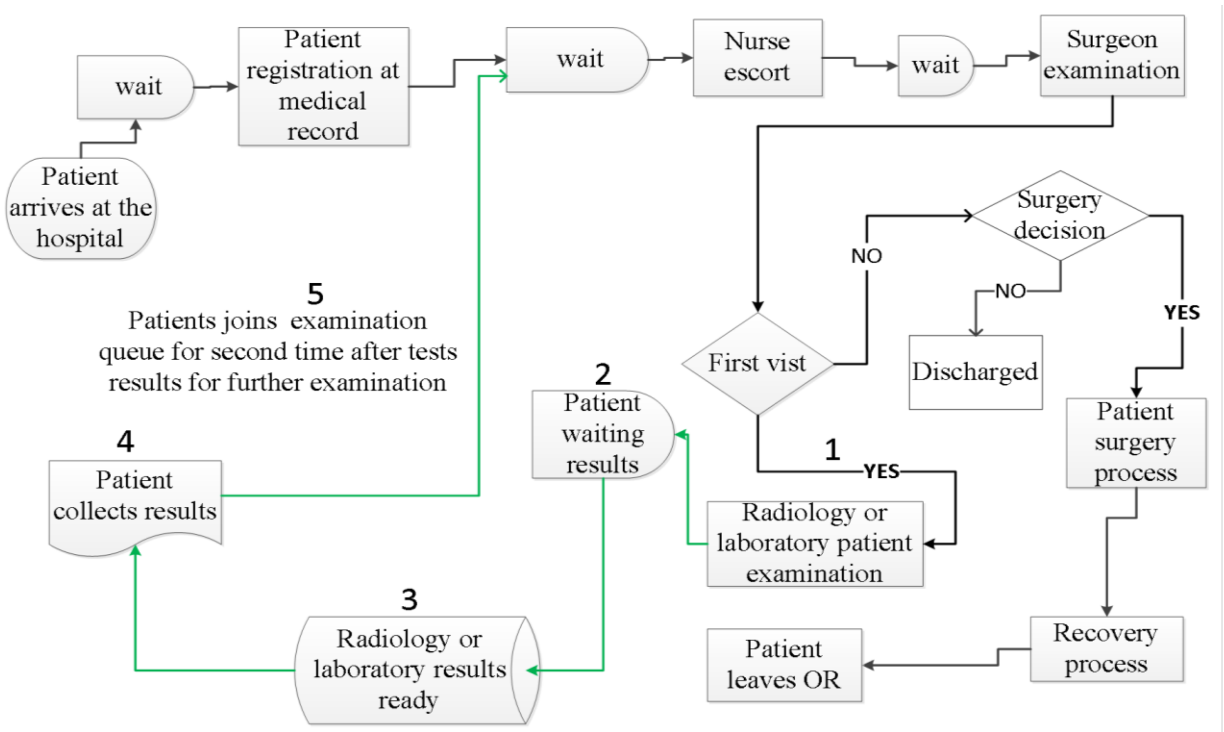

Figure 1: Current process in the orthopedic department: The five numbered steps show the ancillary service follow up process.

Abbreviation: OR: Operating room

4 Methodology and Data Collection

Our study is based on the observational and interviews data from the orthopaedic care process from June 2012 to August 2012. The authors followed patient from when they arrived at the registration department to the point of discharge. For data collection process the authors used stopwatches and structured data sheets where each column represented either waiting or assessment time of a particular observed patient activity. The authors recorded patient assessment time and waiting time for registration, examination at the clinic by the surgeon, x-rays, lab tests, the surgery process and recovery. Based on collected data for the two allocated clinic days (Tuesday and Wednesday), a daily average of 35 patients attends the clinic per day, of whom 80% are discharged while 20% undergoes the whole process up to surgery.

During data collection period, 178 patients underwent the entire process from arrival to surgery to discharge.

The authors performed a comprehensive analysis of the collected data in order to identify and fit appropriate distribution. Starting with statistical overview, Table 1 summarizes the statistical information on the durations of activity time of the observed 178 patients. Linear correlation techniques and scatter plot were further applied to assess data independence. Histograms and box plot techniques were used to hypothesize concerning the families of distribution. Subsequently, the authors used a Chi square test to determine the representativeness of the identified distribution[21]. Thus, Chi square tests for goodness of fit guided the selection of the appropriate distribution. This study adopted discrete event simulation as the main methodology and used Arena (Version 13.0) to develop simulation model. The authors used the Arena input analyser to generate the parameters of the selected distribution (Table 2), which were used in the simulation model.

Table 1: Descriptive statistics of the observed data for 178 patients (minutes)

Activity time	Mean (minute)	Median (minute)	Standard Deviation(minute)
Registration waiting time	35.134	33	21.35
Registration time	14.87	15	3.888
Nurse Escort	4.7	4	2.21
First examination waiting time	144	48.5	41.7
First Examination	17.17	16	8.236
Second examination waiting time	53.41	50	22.99
Second examination	13.98	13	5.31
X-ray waiting time	43	45	28.5
X-ray	16.38	17	1.65
Lab test waiting time	41	42	12.7
Lab test	25.39	25.5	2.98
Surgery time	72.848	60	4.25
Recovery time	12.61	13	2.969

Table 2: Simulation model input current orthopedic care process operations (Minutes)

Process	Distribution	Resources
Inter arrival	0.5 + EXPO(2.62)	
Registration	5.5 + GAMM(1.97, 4.73)	Clerks
Nurse escort	1.5 + WEIB(3.59, 1.49)	Nurse
First examination	3.5 + WEIB(15.4, 1.74)	Surgeons
Second examination	3.5 + ERLA(2.66, 4)	Surgeons
X-ray	13.5 + WEIB(3.79, 2.15)	X-ray technician
Laboratory	NORM(25.4, 2.98)	Lab technician
Surgery	10 + GAMM(46.9, 1.34)	Surgeons
Recovery	4.5 + 14 * BETA(2.42, 1.65)	Operating room personnel

4.1 Model Development and Assumptions

It is difficult to imitate complex healthcare delivery systems that involve human decisions and behavior in a simulation model[22]. Thus, the authors made a number of assumptions that guided simulation model development. First, this paper considers operations systems from 6:00 a.m. to 4.00 p.m. because observed patients began to arrive at the hospital from 6:00 a.m. Second, this paper explored the entire orthopedic care process, thus it focused on patients who undertook the whole process from arrival to discharge after surgery. Third, in line with the second assumption, the authors assumed that surgeon decisions on whether surgery is required are made only at the end of second examination (i.e. after bringing to surgeons the ordered x-ray and lab test results). Fourth, the authors assumed that resources are available to patients for the two clinical and three allocated surgical days. Fifth, the second examination queue (queue with patients bringing back ancillary tests results) has priority over the first examination queue (queue before ancillary tests are ordered). The model limitations were based on the following grounds: transfer times (transport times) within the orthopedic department were not taken into account because the main focus of this study was the orthopedic department, particularly the interaction between specialist orthopedic surgeons and patients.

The simulation model was then developed within the aforementioned assumptions and ran for 100 independent replications and the system was reinitialized between replication. In this model each replication stands for a single day of orthopedic care delivery at this clinic. The normal operations of the studied clinic is from 8am to 4pm, however, the authors simulate the model for 9 hours because during data collection process, the clinic was most of the time closing at 5.pm. Patients in this care process are examined based on first in first out service discipline (i.e. for both first and second examination queues) . Likewise, in the simulation model patient were also served using the same first in first out queuing discipline. Patient arrivals were generated based on the observed schedule of the two allocated clinic days. Also in the surgical room, the model simulates based on the schedule of the observed three allocated surgical days. During analysis, it was observed that the surgeon at the clinic is the key bottleneck due to high patient wait time of more than two hours and high number of patients waiting in the queue. The authors further used the model to identify the factors creating this high wait time.

4.2 Model Verification and Validation

Model verification is a key step used to ensure that the conceptual model is well translated into the simulation computer program and the model is running free of errors[21]. To meet this requirement the authors verified simulation model using Arena debugging tools and animation and the model was running correctly. The authors took several steps to validate the developed model. First, the authors maintained high face validity of the model by involving the head of the operating room and key orthopaedic specialist surgeons in the conceptual model development. Further, the authors used three performance measures to validate the developed model: patient wait time at the clinic, patient throughput per day at the surgical room and surgeons utilization at the clinic. Observed surgeon utilization is calculated as the total hours that a surgeon has worked divided by the total scheduled hours[23]. In addition, throughput is measured as average number of patients that complete surgery per day in a surgical room.

The average patient wait time for a surgeon at the clinic from simulation output is 2.8 hours, at 95% confidence interval. This is not very different from the observed patient wait time for a surgeon at the clinic, 2.4 hours. Furthermore, the average surgeon utilization is 94.5% based on the collected patient data. This surgeon utilization is considered as a poor surgeon utilization in the context that the patient visits surgeons twice on the day of visit limiting number of patients that access healthcare service. The observed surgeon utilization is very similar to the simulation output surgeons utilization, which is 91.5%, at 95% confidence interval.

The average throughput based on the simulation output, at 95% confidence interval, is 5 patients. And the observed average patient throughput at surgical room, which are 7.3 patients. The observed discrepancy in throughput might be due to systematic errors in the simulation model. However, when number of replication are increased no substantial effect in this error is observed. Thus, this discrepancy has no impact on decision-making. Lastly, the authors increased model validity by running the simulation using the collected patient arrivals instead of sampling from the selected exponential distribution, and the similar results were achieved.

The major difference between simulation output and observed data was found on waiting time for second examination at the clinic. The average waiting time from the simulation model is 0.14 hours while based on the real data the average waiting time is 0.8 hours. This is probably because in the simulation model second visit patients were given priority over the first examination patients. Thus, in the model it was assumed that patients bringing their ancillary results for second examination were always given first priority in the queue over the first examination patients. Normally, patients with ancillary test coming for second examination are always preceded by other patients in the queue. Despite this discrepancy the model is considered valid because other performance measures such as first examination waiting time, and surgeons utilization are close to the actual collected data.

5 Proposal Scenario

The main focus of simulation model was to explore the key reasons for high patient waiting time and poor surgeons utilization. After the simulation analysis of process variables, the authors identified that the key source of high patient wait time and the poor utilization of surgeons was follow-ups in the form of ancillary services (X-ray and lab tests) ordered by surgeons. Due to these ancillary tests, patients join the examination queue twice, thus experiencing high total wait times. The authors examined one strategy relating to the standardization and transfer of ancillary-service-ordering activities to upstream staff. If implemented, this could significantly enhance surgeons to handle more patients than before. Figure 2 shows a revised conceptual model.

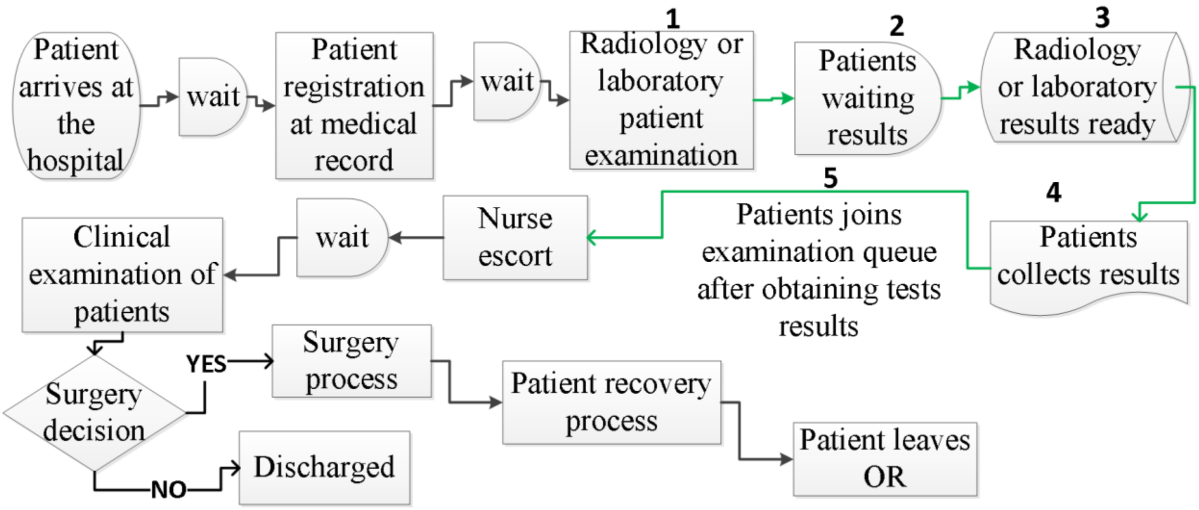

Figure 2: Revised Conceptual Model.

5.1 Care procedure for Proposal Scenario

The major change in the proposed scenario is that ancillary services will be ordered at the beginning of the process by upstream staff, immediately after the registration process. Upstream staff can either be a nurse or any mid-level trained staff. It should be noted that these resources are not accounted for in the current model. This change implies that surgeons' examination processes will be initiated once the ancillary tests results are obtained, after which the patient is discharged or undergoes surgery. With this change, the authors further wanted to explore if the new system can accommodate more than 50% increase in demand without patient waiting for an average of more than two hours at the clinic. The main focus is to investigate how the new model of operations can cope with future increasing demand if ancillary tests are ordered at the beginning of the process. It should be noted that surgeons can still order certain tests if further diagnosis is needed.

6 Modelling Results

Output analysis of the proposed scenario was performed using the arena output analyser at a 95% confidence interval. Table 3 presents the average of performance measures before and after the proposed changes. As expected, simulation model results indicate that patient waiting time can be reduced by 59.2% after delegating ancillary services to upstream staff. The simulation model shows that transferring ancillary services improves surgeon utilizations at the clinic (Surgeons 1 & 2) by 17%, thus allowing the accommodation of more patients at the clinic. Given the fact that more than 80% of orthopaedic patients have non-surgical cases[16], this alternative is still viable for these care providers. The model didn't show high improvement of throughput in the operating room before and after the changes because arrival rate has not changed. The authors used a paired t-test validation procedure to explore whether there was a significant change in performance measures before and after dedicating ancillary services to lower-level staff. All changes were found to be significant as presented in Table 3.

Table 3: Comparison of performance measures before and after transferring ancillary services

Note. Surgeons 1 and 2 represent two surgeons at the orthopaedic clinic, whereas surgeons 3 and 4 represent two surgeons at the surgical room.

			95 % Confidence Interval for Mean			
	Mean	Median	Lower bound	Upper bound	T	Sign
Throughput at OR						
Base scenario	5	5	3	12	6.6	000
Proposal scenario	6	7	2	12		
First exam wait time						
Before (hours)	2.8	2.9	1,43	3.1	36.7	000
After (hours)	1.14	1.18	0,38	1,93		
First exam number of patient waiting						
Before	14.6	13,9	5.7	21.3	20.6	000
After	5.3	5,2	2	9		
Second exam wait time hours						
Before	0.13	0.16	0,1	0.18	-	-
Surgeon 1 utilization						
Base scenario	95.1	96	72.7	97.6		
Proposal scenario	64,9	65.1	56,9	78,7	29.4	000
Surgeon 2 utilization						
Base scenario	94.3	95.2	70	97.2	29.8	000
Proposal scenario	64,4	63.5	51,3	75,7		
Surgeon 3 utilization						
Base scenario	49.2	46.8	36,9	38	2.67	000
Proposal scenario	62.4	62.6	9.3	1.16		
Surgeon 4 utilization						
Base scenario	38	39.6	35,4	49.4	5.8	000
Proposal scenario	57.2	57.5	26.7	1.67		

The authors further explored future demand that can be accommodated as a result of a released surgeons capacity. The simulation model demonstrates that 55% increase in demand can be accommodated without patient waiting for an average of more than two hours at the clinic. It should be noted that these two hours are the average waiting time at the clinic for surgeon 1 &2. Results are shown in Table 4 and Figure 3.

Table 4: System behavior for 55% demand increase after change (95% Confidence Interval)

	Average waiting time (hours)	Surgeon 1 utilization	Surgeon 2 utilization
Base model	2,8	64.4	64.9
55% demand increase	1.89	88.4	89,3

Note: The authors assume patient is not supposed to wait for an average of more than two hours at the clinic.

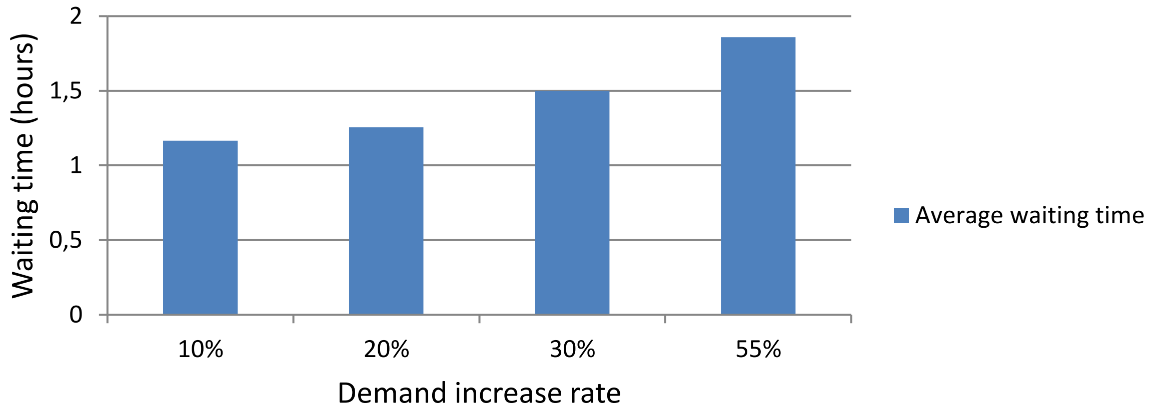

Figure 3: Percentage of demand that can be accommodated.

7 Discussion

This study focused on exploring the entire orthopaedic care process. The authors explore the efficiency of the process, focusing on the inadequate utilization of surgeons and high patient wait times. The focus is identifying process inhibitors that lead to poor utilization of surgeons and showing how surgeons utilization can be improved and also, investigating the effect of improved utilization on future increasing demand. Discrete event simulation was used to explore the base scenario that represents the observed orthopaedic care process and to develop a proposal scenario that can be used to improve surgeons utilization as well as reducing patient waiting time.

The simulation results from the base scenario reveals long patient wait times and poor surgeon utilization. Poor surgeon utilization has several negative effects, such as long patient wait times, as well as morbidity and mortality. The authors suggested a proposal scenario that demonstrates a change that may lead to the improvement of the orthopaedic care process, without any increase in resources. The primary objective of the proposed scenario was to improve surgeon utilization and shorten the time patients had to wait at the orthopaedic clinic. The proposed scenario was further used to test if the proposed system changes can accommodate an increase of more than 50% patient demand without patient waiting for an average of more than two hours at the clinic. As expected, the results of the simulation analysis show significant decrease in patient wait time. The results presented in Table 3 indicate that if ancillary services could be performed before the start of clinic examination services for all patients in need of ancillary services, orthopaedic care process could be highly improved.

The authors further explored the effect of delegating ancillary services on surgeon utilization. The main objective of delegating ancillary services to upstream staff is to free up surgeon capacity by reducing the number of patients meeting the surgeons twice on the same day. The freed capacity will thus be used by surgeons to accommodate increasing patient demands and needs. As expected, the simulation results in Table 3 showed a significant reduction of surgeons' utilization at the clinic after dedicating ancillary services to downstream staff. This implies that the capacity that had been used patients' second visits, bringing with them the results of the ordered ancillary tests, can be utilized to accommodate other patients in the queue or those on the waiting list.

From healthcare processes perspective the necessity of improving patient access to care through the use of discrete event simulation is presented in this study. A simulation model demonstrates that if these changes will be implemented up to 55% additional patient demand can be accommodated without patient waiting more than two hours. Thus, freeing up surgeon capacity is necessary to enhance the flexibility of responding to increasing patient demands. According to [24]Chadha, Singh, and Kalra (2012), the benefit of having excess capacity in inpatient clinics would include the provision of efficient and timely patient services. The simulation results showed that dedicating ancillary services to upstream staff reduces patient wait time; thus, patients can see the surgeons earlier in the process than before.

It is worth noting that, implementing the proposed improvement initiatives will undoubtedly present a significant challenge. A shift to using upstream staff to order ancillary tests poses a risk of unnecessary or wrong tests being ordered by these staff. Previous studies demonstrate that unnecessary ordering of tests is a global concern and contributes to overall hospital cost as well as inappropriate use of resources in labs, and x-ray sections [25–27]. This effect could then outweigh the improved surgeons' utilization at the clinic in this study because part of the freed capacity will be used to order more new tests. This will lead to poor utilization of improved surgeons capacity as well as increased cost to hospital as a whole due to inappropriate utilization of lab and x-ray resources.

Nevertheless, previous studies investigating how to reduce the associated cost of unnecessary tests ordering have shown that, staff training and involvement in the development of tests guidelines reduces the aforementioned cost and improves resource utilization[27,28].Thus, to ensure that the proposed improvements are achieved, hospitals should focus on training the upstream staff before implementation of the proposed model. In addition, the process of developing standardized protocols should involve surgeons, x-ray, lab as well as upstream staffs. This will enhance the development of a comprehensive standardized protocol that will help to reduce the effect of ordering unnecessary tests and hence utilize effectively the improved surgeons' capacity[28] .

It is a common practice for surgeons to order some additional tests in a situation where they need more investigation for patients. In the proposed model, if surgeons still need to order some tests for patients this will partly reverse the proposed model. But it will not look exactly like the current model, because not all patients will be needed to go for additional tests. The authors believe that if upstream staff will be well trained and be able to manage their work few patients will be redirected for additional tests. Since the volume of these tests will not be as high as the volume of tests in the baseline model, the inefficiencies observed in the base model such as high waiting time may not be observed in the same pattern. Hence improved surgeons capacity will to a large extent still being used to treat more patients than in the baseline model. The above raised issues need to be carefully considered during the implementation of the proposed model. For example unnecessary ordering tests if not carefully handled could potentially increase figures of surgeons utilization in real life because more tests will still need to be ordered by the surgeons. This will increase the inefficiency utilization of the surgeons. As stated above, these problems can be eliminated through training and collaborative working between surgeons and upstream staffs. If all necessary precautions and educational steps will be taken into consideration, the proposed model can lead to improved patient access to care and improved surgeons utilization.

7.1 Managerial implications

The simulation result from this study provides significant insights to healthcare providers aiming to improve patient care processes. First the reduced patient waiting time and improved surgeon utilization indicates that improving patient care process does not necessarily need additional workforce capacity. Instead healthcare providers should focus on better utilization of existing workforce capacity to enhance flexible capacity that can be used to accommodate ever increasing patient demands and needs

Second, the implication of increased demand that can be accommodated as a result of released capacity suggest that patients access to care can be improved through better utilization of existing surgeons. The released surgeons capacity can be used to reduce not only patients waiting time but also to improve patient access to orthopaedic care services. This improvement further indicate that, healthcare providers should focus on finding better ways of utilizing the existing surgeons capacity in order to accommodate more patients within the existing workforce capacity.

Finally globally hospitals are facing increasing trend of human resource constraints[1], thus it is important for healthcare providers to adopt operational management tools such as simulation in order to improve the utilization of existing surgeons. With increasing human resource constraints particularly in developing countries the importance of increasing patient access to care through better utilization of resources is imperative

8 Conclusion

This study used discrete event simulation model to show how the care process can be explored to identify critical factors that inhibit better resource utilization, leading to high patient wait times. We have further suggested ways in which surgeons, as critical resources, can be utilized efficiently to improve care services and reduce patient waiting time. The simulation results shows that if the proposed changes will be implemented, it will be possible to achieve reduced patient wait time and improved surgeon utilization, thus increasing patient access to care.

Even though most of the results in this study was expected, the use of simulation enhanced identification of where exactly the bottleneck was located in this process. Thus, it was necessary to use simulation in order to avoid trial and error risks and enhance the investigation of possible changes and the testing of different scenarios prior to implementation.

Our study faces some limitation: First, patients wait time includes the early arrival of patients, before the start of examination services, as well as surgeons lateness. If surgeons could arrive at the start of clinic sessions, patient waiting time could decrease. Likewise, if a patient could arrive a few minutes before the start of the clinical session, this could further decrease their wait time.

Also, our study was limited to a group of patients who underwent the entire process from arrival to discharge after surgery. However, the authors believe that the improvement initiatives can still impact patients ending their journey at the clinic. To realize this improvements all patients must be treated based on the proposed model. This limitation calls for future research evaluating both patients ending their journey at the clinic and those taking the entire process to surgery.

Despite the fact that our study was conducted in a single orthopaedic care process, however our findings can be generalized to other orthopaedic care processes with the same operational characteristics. From patient care process perspective, high patient waiting time problems are typical issues facing healthcare organizations today[14,29] Thus, process redesign proposed in this study can be applied with other orthopaedic care processes globally to address the issue of high patient waiting time as well as improving surgeons utilization.

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Paper 3

The role of workforce agility on improving healthcare processes operational outcomes: A systematic literature review and conceptual model

Abstract

Purpose: The purpose of this paper is to comprehensively explore and contribute to the academic understanding of the role of workforce agility on healthcare processes outcome and investigate the relationship between them. Specifically, we focus on the role of workforce agility on process operational outcomes, such as better resource utilization and improved patient throughput. This study also examines future research directions for studying the concepts of workforce agility.

Design/Methodology/Approach: In this paper, we conducted a systematic review to evaluate and synthesize agility and workforce agility literature published between 1990 and 2015. Literature on healthcare processes was also reviewed to identify the different characteristics that can be affected by workforce agility.

Findings: From this review, we developed a conceptual model that show the relationship between workforce agility and healthcare process operational outcomes. The developed conceptual model demands further empirical research to test the proposed relationship. We also managed to identify some research gaps (methodological, contextual, and conceptual) that require further investigation.

Research Implications/Limitations: The main limitation of this study is that it used the existing literature to develop the conceptual model. Further research is needed to empirically test the developed relationship.

Practical Implications: Workforce agility can improve the operational activities in healthcare processes leading to better operational outcome. Thus, it is important that healthcare providers and academicians become more knowledgeable about the role of workforce agility in healthcare process operational outcomes.

Originality/Value: To the best of our knowledge, this is the first paper to explore the role of workforce agility in healthcare process outcomes, particularly operational process outcomes.

Keywords: workforce agility, healthcare processes, agility

1 Introduction

Today’s healthcare organizations operate in extremely dynamic and complex environments (Winge et al. 2015). Medical knowledge is advancing, leading to new treatment and diagnostic procedures that require adaptation. In addition, new diseases are constantly being discovered, which requires healthcare organizations to implement new process strategies. Similarly, aging populations mean that more people are suffering from multiple diseases, creating increased medical care needs (Langabeer 2008; Myllykangas et al. 2003; Rebuge and Ferreira 2012; Tolf et al. 2015; Vogeli et al. 2007). These changes have led to a dramatic increase in uncertainties and complexities in healthcare delivery systems and processes (Langabeer 2008; Winge et al. 2015).

Therefore, healthcare providers are obliged to adopt new approaches that can help healthcare organizations respond to changing patient care needs. Lean and agile paradigms have been recently proposed as means to improve healthcare processes and are regarded as key strategies that healthcare organizations must adopt in order to improve their processes (Mclaughlin and Hays 2008; Vries and Huijsman 2011).

The lean approach has been considered in healthcare literature. Findings from one recent review show that 3% of existing lean research is based on healthcare (Jasti and Kodali 2015). In contrast, a recent review found only one article that focuses on the agile approach healthcare-based research (Tolf et al. 2015). These findings indicate that existing research on healthcare is based more on lean processes than on agile processes. Although more research is lean oriented, a recent study also showed that the lean approach has failed to accommodate increasing external volatility and uncertainty in the current business environment (Burgess and Radnor 2013). This is a good indicator that agility research is needed in healthcare, both in conceptual and empirical forms.

Agile strategies are primarily concerned with the ability of organizations to cope with unexpected changes, to survive unprecedented threats from operation environments, and to take advantage of change as an opportunity (Goldman, Nagel, and Preiss 1995; Zhang and Sharifi 2000). A successful and rapid response to change requires organizational workforces to be able to quickly adapt and react to unexpected changes (Sherehiy and Karwowski 2014). Agile workforces are seen to play a fundamental role in meeting organization agility goals; however, no prior studies has performed a comprehensive exploration of the concept of workforce agility (Breu et al. 2002; Gunasekaran 1999).

Furthermore, prior research on workforce agility has mainly targeted the strategic level, resulting in a limited focus on agile workforces at the process level. The literature acknowledges a shortage of research on the impact of workforce agility on organizational operational outcomes (Alavi and Abd Wahab 2013; Van Oyen, Gel, and Hopp 2001). In our view, this is a critical deficiency because workforce agility enhances organizational agility goals at the operational level through executing different operational activities such as lab tests, x-ray, registration surgery and treatments (Hopp and Van Oyen 2004). In addition, processes are the building blocks of an organization's success and more appropriate for improvement objectives (Anyanwu et al. 2003; Lillrank, Groop, and Venesmaa 2011).

From the healthcare perspective, existing studies focus on exploring the effect of workforce agility only on medical outcomes, such as better management of chronic disease and improving quality of life while overlooking the underlying process operational outcomes, such as better resource utilization and improved throughput (Bosco 2007; Lewandrowski and Lewandrowski 2013). Improved process operational outcomes, such as better resource utilization, build the foundation for good patient-centered outcomes (Vanhaecht et al. 2010). Thus, facilitating a better and comprehensive understanding of the role of workforce agility in healthcare process outcomes at the operational level is critical in helping healthcare providers fulfill their organizational goals. In addition, it has been claimed that workforce agility enhances organizations' quick reactions and responses to increasing volatility in operational business environments (Hopp and Van Oyen 2004); therefore, healthcare providers need to know how they can improve their processes using agile workforces.

A model demonstrating the relationship between workforce agility and healthcare process operational outcomes can be established either empirically or through a systematic literature review of existing studies. The literature argues that, when a topic is relatively new, it is worthwhile to develop the idea based on existing multidisciplinary studies (Gunasekaran 1999; Torraco 2005). As workforce agility is a relatively new concept and therefore has been sparsely researched, this paper aims to present a comprehensive systematic review of the role of workforce agility in healthcare process operational outcomes and to suggest some areas for future research. Building on the reviewed literature, a conceptual model for exploring the relationship between workforce agility and healthcare process operational outcomes is developed for future empirical testing.

The objectives of this study are as follows: first, to comprehensively explore the concept of workforce agility and the management practices that enhance it, and, second, to facilitate an academic understanding of workforce agility in healthcare processes by investigating the relationship between them. We hereby define process operational outcomes in terms of operational outcomes that reflect improvement of clinical operations or efficiency, such as improving throughput, resource utilization, reduced patient delays and design of complex operations (Lewandrowski and Lewandrowski 2013). The primary process that is focused in this paper is the patient treatment process which involves a number of patient activities such as x-ray, lab tests, registration and surgery. Implementing workforce agility in these activities may lead to improved operational outcomes of the patient treatment process.

The remainder of this paper is organized as follows: The second section presents the methodology used, the third section presents a review of the findings, and the fourth section presents a discussion followed by the conclusion and suggested areas for further research.

2 Methodology

2.1 Integrative literature review approach

An integrative review summarizes past research by drawing an overall conclusion from various studies about a particular concept (Broome 1993). This type of literature review is argued to be the most suitable methodology when the purpose of the study is to synthesize the extant literature in order to find a relationship between different concepts as well as any unexplored gaps (Cooper 1982). As the main focus of this study is to explore the relationship between workforce agility and healthcare processes, the use of an integrative literature review was deemed to be suitable. The literature further argues that an integrative literature review is appropriate when the concept under study is relatively new and a definition of the concept is needed (Broome 1993). For this study, it was necessary to use an integrative literature review in order to facilitate the definition of the concept of workforce agility.

Five main steps are suggested for a comprehensive integrative literature review process: (1) problem identification (2) a literature search (3) evaluation of the collected data (4) data analysis and interpretation, and (5) presentation of the findings (Cooper 1982; Whittemore and Knafl 2005). In this study, problem identification was achieved by documenting the purpose of the study and the problems to be addressed (Whittemore and Knafl 2005), which are: (1) to explore and develop a holistic perspective for the concept of workforce agility and (2) to facilitate the understanding of workforce agility in healthcare processes by examining the relationship between workforce agility and healthcare process operational outcomes (Alavi & Wahab, 2013).

To achieve the second step, we searched literature in the Science Direct and ProQuest databases. For the third step, we evaluated the literature based on inclusion and exclusion criteria. As part of the third step, agile literature that met the inclusion and exclusion criteria was reviewed to obtain a clear understanding of the concept of agility. Subsequently, literature on workforce agility was reviewed to enhance the understanding of workforce agility attributes and enablers. The third step was completed by reviewing literature on healthcare processes in order to determine the characteristics that demand workforce agility. The characteristics were used as the foundation for identifying a relationship between workforce agility and healthcare process operational outcomes. Step four was accomplished by reviewing, synthesizing, and summarizing the accumulated literature in an Excel sheet using the database that was developed using Excel spreadsheet. Finally, in step five, we presented the findings based on the reviewed literature.

2.2 Data collection and analysis

This study was guided by the recommended systematic literature review guideline, which allow for a comprehensive and unbiased assessment of accumulated literature (Cook et al. 1997; Denyer and Tranfield 2009). A systematic literature review is described as the methodology that comprehensively involves searching for, selecting, critically evaluating, and summarizing the results of accumulated literature. This methodology also uses a transparent approach to report its findings so that the path followed to a conclusion can be easily understood (Cook et al. 1997). It also comprises distinct and scientific principles that aid in representing the procedures used and the decisions reached by reviewers (Denyer and Tranfield 2009). Following the recommended systematic review guideline, we conducted a comprehensive review of the existing literature on workforce agility, agility, and healthcare processes. The entire literature review process is presented graphically in Appendix 1.

To facilitate a comprehensive review of the existing literature, we focused on all relevant literature between 1990 and 2015. We concentrated on peer-reviewed articles using two databases: ProQuest and Science Direct. In line with the recommendations of Tranfield, Denyer, and Smart (2003), we identified the key search terms through a review of the literature. The main search terms used were as follows: agility, agile, workforce agility, agile organization, healthcare processes, patient process, and patient care process. During the review, citations in the accumulated and relevant literature were traced to find further information. The traced articles were found in different databases such as google scholar, emerald, and Wiley. As a result of this procedure, we found 68 articles, which were further filtered using inclusion and exclusion criteria.

2.3 Inclusion/exclusion criteria

Building on the recommendations of Denyer and Tranfield (2009), we developed inclusion/exclusion criteria for the collected articles, with a focus on agile organizations and workforces. Articles that were deemed to be relevant and included in the analysis were those that met at least one of the following criteria: (1) defines agility; (2) describes workforce agility or presents attributes of workforce agility; and/or (3) describes the characteristics or managerial practices of agile organizations that enhance workforce agility. For literature on healthcare processes, the inclusion criteria were based only on articles that described the characteristics of healthcare processes.

This reduced the number of articles from 68 to 58. To identify the different definitions agility, 48 articles were synthesized, and 40 articles were identified for workforce agility. The workforce agility and agility articles were further analyzed to identify managerial practices that enhance workforce agility; 36 articles were identified in this area. Finally, 9 articles were identified that described the characteristics of healthcare processes.

An Excel sheet was the main tool used in the data analysis process. Using Excel columns, we defined the following article elements: title, author, and year of publication. To enhance the comprehension of the analysis, we added the definitions of agility and workforce agility, a description of workforce agility enablers, a description of managerial practices that promote workforce agility, and the characteristics of healthcare processes. A summary of this process can be found in Appendix 1.

3 Findings

This section presents the findings from the reviewed literature by focusing on agility and the identified managerial practices, as well as their relationship to workforce agility and process operational outcomes.

3.1 Defining agility

Before defining workforce agility, it is crucial to define the concept of agility. Workforce agility is a key component of agility; therefore, defining agility will provide a greater understanding of workforce agility. An exploration of the reviewed literature revealed a number of definitions of agility from different researchers, as expounded below.

The historical origin of the term agility can be traced back to 1991 at the Iacocca Institute in the USA, where it was introduced as a response to increasing uncertainty and turbulence in various business environments (Dove 1993). Since its inception, the concept of agility has been regarded as an extremely broad and multidimensional concept that is linked with many disciplines (Swafford, Ghosh, and Murthy 2006). The multidimensionality of agility has caused researchers to offer different conceptualizations and definitions. It is interesting that all of these definitions remain within the boundaries of the objectives of the agility concept. The following is an elaboration on the definition of agility.

The reviewed literature refers to agility as a strategy that organizations can use to respond to changing business environments and improve the quality of their customer service (Mehralian, Zarenezhad, and Ghatari 2013; Mehralian, Zarenezhad, and Ghatari 2015). Some authors defined agility as "…the successful exploration of competitive bases (speed, flexibility, innovation proactivity, quality and profitability) through the integration of reconfigurable resources and best practices in a knowledge-rich environment to provide customer-driven products and services in a fast changing market environment" (Yusuf, Sarhadi, and Gunasekaran 1999, p.37). Agility is defined by some as the capability to survive and prosper in a competitive environment of continuous and unpredictable change by reacting quickly and effectively to changing markets, driven by customer-designed products and services (Gunasekaran 1998).

Other schools of thought, such as those of Sharifi and Zhang (1999), define agility as the ability to cope with unexpected challenges, survive unprecedented threats to business, and take advantage of changes by turning them into opportunities. Remaining within the same themes and terms, other definitions of agility include the capability of operating profitably in a competitive environment of continually and unpredictably changing customer opportunities (Goldman, Nagel, and Preiss 1995). Furthermore, Sherehiy, Karwowski, and Layer (2007) describe agility as a concept that comprises the characteristics of both flexibility and adaptability. They further elaborate that flexibility and adaptability represent the evolution of an idea by an organization or enterprise that is able to adjust. They refer to an agile organization as one with the ability to adjust to unpredictable environmental changes by combining all-important notions from the concepts of adaptive and flexible organizations.

When analyzing the above definitions of agility, common themes are observed. Almost all of the definitions consider agility to be the ability of an organization to withstand increasing turbulence in operational business environments. Despite the numerous definitions for agility, a common objective is maintained: agility is described as the capability of an organization to survive in a volatile and uncertain business environment.

3.2 Defining Workforce Agility

Among the factors that have increased the popularity of the concept of workforce agility is its importance as an enabler of organizational agility. The literature asserts that a lack of workforce agility is a key driver of failure in an organization's achievement of agility. Furthermore, workforce agility helps organizations to react quickly to increasing volatility and uncertainty in the business environment (Qin and Nembhard 2010). Given these facts, it is imperative to have a broad understanding of the concept of workforce agility. This study facilitates the understanding of the concepts of workforce agility and their respective attributes by further analyzing the agility literature.

Interestingly, in the synthesis of the literature, no accurate definition of workforce agility was identified. Most studies define workforce agility based on how employees respond and adapt to volatile and unpredictable business environments with the focus on their respective attributes. In this review, an in-depth definition of workforce agility is provided by Gunasekaran (1998), who defines workforce agility as IT-skilled workers, knowledge in teamwork-empowered employees, a multifunctional workforce, a multilingual workforce, and self-directed teams. Most of the reviewed literature defines workforce agility in terms of responsiveness and regard this characteristic as the key attribute of an agile workforce (Crocitto and Youssef 2003; Gunasekaran 1998; Yusuf, Sarhadi, and Gunasekaran 1999). Responsiveness is defined as "the ability to react purposefully and within an appropriate timescale to significant events, opportunities or threats (especially from the external environment) to bring about or maintain competitive advantage" (Kritchanchai and MacCarthy 1999, 814). In this context, an agile workforce is expected to be highly responsive to uncertain business environments.

Another school of thought defines an agile workforce in terms of the attribute of adaptability (Ramesh and Devadasan 2007; Sharifi and Zhang 1999; Sherehiy, Karwowski, and Layer 2007; Yusuf, Sarhadi, and Gunasekaran 1999). Adaptability is considered to be the ability of workforce to accept changing working circumstances and to meet duties and expectations (Huang 1999). Research by Breu et al. (2002) identifies collaborative behavior as an attribute of workforce agility. Several studies have also defined workforce agility in terms of this attribute (Hopp and Van Oyen 2004; Sharp, Irani, and Desai 1999; Sherehiy, Karwowski, and Layer 2007; Yusuf, Sarhadi, and Gunasekaran 1999).

An agile workforce has the ability to work effectively in a collaborative environment (Forsythe 1997). The reviewed literature further identifies different perspectives of collaborative forms, for example, team-based collaboration, collaborative ventures, or virtual organizations (Breu et al. 2002).

Some researchers define an agile workforce in terms of flexibility (Harper and Utley 2001; Pateli and Dibben 2001; Strader, Lin, and Shaw 1998; Yusuf, Sarhadi, and Gunasekaran 1999). Based on this attribute, agile workforces are regarded as resources that are capable of moving flexibly and rapidly to any working condition (Forsythe 1997). Flexibility is described as the ability to process different products and achieve different outputs with the same resources (Sharifi and Zhang 1999).

Based on these definitions, we attempted to define workforce agility as the ability of an organizational workforce to react and respond quickly to externally and internally changing business environments. Table 1 presents the summarized workforce agility attribute.

Table 1: Summarized workforce agility attribute

Attribute	Reference
Adaptiveness	(Sharp, Irani, and Desai 1999), (Yusuf, Sarhadi, and Gunasekaran 1999), (Sharifi and Zhang 1999), (Breu et al. 2002), (Huang 1999), (Sherehiy, Karwowski, and Layer 2007), (Ramesh and Devadasan 2007), (Panteli and Dibben 2001), (Strader, Lin, and Shaw 1998), (Sherehiy and Karwowski 2014), (Fliedner and Vokurka 1997), (Sharifi and Zhang 2001), (Goldman, Nagel, and Preiss 1995)
Responsiveness	(Sharifi and Zhang 1999), (Yusuf, Sarhadi, and Gunasekaran 1999b), (Gunasekaran 1999)(Gunasekaran 1998), (Breu et al. 2002), (Plonka 1997), (Hopp and Van Oyen 2004), (Sumukadas and Sawhney 2004), (Sherehiy, Karwowski, and Layer 2007), (Nijssen and Paauwe 2012), (Ramesh and Devadasan 2007), (Alavi et al. 2014), (Crocitto and Youssef 2003), (Van Oyen, Gel, and Hopp 2001), (Qin and Nembhard 2015), (Powell 2000), (Yauch 2007), (Eshlaghy et al. 2010), (Duangpun Kritchanchai and MacCarthy 1999), (Mehralian, Zarenezhad, and Ghatari 2015), (Muduli 2009)
Collaboration	(Dyer and Shafer 2003), (Dyer and Shafer 1999), (Dyer and Jeff 2006), (Sharp, Irani, and Desai 1999), (Yusuf, Sarhadi, and Gunasekaran 1999), (Breu et al. 2002), (Forsythe 1997), (Hopp and Van Oyen 2004), (Sherehiy, Karwowski, and Layer 2007), (Fliedner and Vokurka 1997), (Charbonnier-Voirin 2011)
Flexibility	(Yusuf, Sarhadi, and Gunasekaran 1999), (Sharifi and Zhang 1999), (Harper and Utley 2001), (Panteli and Dibben 2001), (Strader, Lin, and Shaw 1998), (Zhang 2011), (Prahalad and Hamel 1990), (Plonka 1997), (Griffin and Hesketh 2003), (Chen, Hwang, and Raghu 2010), (Qin, Nembhard, and Barnes II 2015)

3.3 Managerial practices and characteristics to create workforce agility

Managerial practices are work practices used to improve the knowledge, skills, and abilities of an organization’s current and potential employees, increase their motivation, reduce shirking, and enhance the retention of quality employees (Huselid 1995; Jayaram 1999). An organization with well-established managerial practices can improve its workforce agility. Therefore, this section is an in-depth analysis of the managerial practices and characteristics that promote workforce agility conducted to determine the relationship between workforce agility and healthcare process operational outcomes. This was achieved by further reviewing and analyzing each of the above articles on agility and workforce agility. Four prominent managerial practices that enhance workforce agility emerged: information system infrastructures, training and learning environments, collaborative working environments, and organic structures.

3.3.1 Information system infrastructures

The literature regards information systems as key enablers of workforce agility. When information systems are well designed and implemented, technology facilitates fast access to the appropriate information because the systems are fluid, flexible, and adaptive to dynamic environments (Breu et al. 2002). The contribution of information technology is well acknowledged for its speed of action by providing the timely access to relevant information and by improving timelines for information management. As a result of this characteristic, information technology has been linked to the enhancement of autonomy, trust, flexibility, and free information sharing among employees and collaborative work environments (Breu et al. 2002; Crocitto and Youssef 2003; Harper and Utley 2001; Strader, Lin, and Shaw 1998).

As a part of information systems, mobile communications and internet-based communication promote workforce agility for workforces operating through virtual space (Breu et al. 2002). They enhance the speed of communication and provide easy access to information. Through mobile communication, traditional functional boundaries are reduced, providing a high degree of operational flexibility, speed, and adaptability, as well as the development of more dynamic operations (Breu et al. 2002; Panteli and Dibben 2001; Strader, Lin, and Shaw 1998).

3.3.2 Training and learning environments

To accommodate volatile and highly unpredictable business environments, employees may need to engage in regular learning and training in order to attain the ability to work under volatile working conditions. Thus, implementing training and learning environments can promote workforce agility (Qin and Nembhard 2010; Qin and Nembhard 2015). The most common type of training to promote workforce agility is cross training, through which workers can be dynamically shifted to where they are needed when they are needed (Hopp and Van Oyen 2004). Cross training forces employees to acquire different sets of skills and enables them to perform a variety of tasks, leading to a flexible and adaptable workforce and allowing for the delivery of a broader range of services or products. Cross training is linked with other positive effects on the workforce, such as improved process efficiency, learning abilities, and customer service. Cross training may further facilitate communication, which helps employees to better manage their jobs. However, the literature demonstrates that cross training is not an appropriate strategy for highly unpredictable and changing environments. Instead, agile organizations can facilitate rapid employee learning through on-demand training, which provides flexibility and adaptability to changed external business environments (Dyer and Shafer 1999; Hopp and Van Oyen 2004; Plonka 1997; Qin and Nembhard 2015; Sumukadas and Sawhney 2004).

3.3.3 Collaborative working environments

Collaborative working environments are considered key enablers of workforce agility, as they enhance the ability of an organization to cope with increasing business volatility and turbulence. When an organization establishes collaborative working environments, it increases its workers' speed of response, thus increasing the efficiency of production processes. There are different forms of collaborative workers; the most commonly known is the formation of teams, whereby more than one worker collaborates to perform a certain task. Combining skills and efforts from different workers increases the speed of response to increasing volatility and uncertainties in business environments. This, in turn, enhances workers to accomplish a given task within a short timeframe (Hopp and Van Oyen 2004; Powell 2000).

Multifunctional teams are another form of collaboration, whereby employees within the same profession combine their skills to perform a certain task. In multifunctional teams, a team can be formed by employees with specialized skills, who each bring unique talents to the group, or by employees who are multi-skilled or have been cross trained (Yauch 2007). The first team-based approach is mostly used with teams consisting of highly professional workers, for example, specialized surgeons, while the second team-based approach is mostly used in high-volume operational areas, such as on production floors, where assembly and production activities occur. Multifunctional teams have been linked to several workforce benefits:

On the team level, collaboration helps improve labor utilization and the efficiency of production processes. Furthermore, multifunctional teams can speed up responses to unpredictable and volatile conditions (Hopp and Van Oyen 2004; Fliedner and Vokurka 1997; Plonka 1997; Qin and Nembhard 2015; Yauch 2007). Multifunctional teams has also been linked with enhancing rapid employee learning. During team, working employees can increase their skills through observation and discussion with other workers (Van Der Vegt and Bunderson 2005)

3.3.4 Organic structures

Organic structures are organizational structures that are flexible and adaptive to rapid and unpredictable environmental changes, allowing employees to respond quickly to any changing working conditions (Alavi et al. 2014; Zhang 2011). Organic structures are characterized as being flat, flexible, and team-based structures with an informal management style and with few rules and procedures to restrict the free flow of information and communication. Employees at all levels are trusted and empowered while receiving continuous training, simplifying decision making at all levels (Alavi et al. 2014; Eshlaghy et al. 2010; Nijssen and Paauwe 2012; Vinodh, Madhyasta, and Praveen 2012; Vinodh, Prakash, and Selvan 2011; Zhang 2011).

At the operational level, organic structures improve employee responsiveness by reducing response time through the free flow of information and communication. This allows the workforce to react quickly to volatile and uncertain business environments. Moreover, organic structures improve production processes because workers are given full control or autonomy and are therefore motivated to be more responsive (Alavi et al. 2014; Gunasekaran 1998; Qin and Nembhard 2015; Ramesh and Devadasan 2007; Sharp, Irani, and Desai 1999; Zhang 2011). Table 2 presents the summarized managerial practices and characteristics as discussed in this section.

Table 2: Management practices and characteristics that enhance workforce

Factor	Reference
Information technology infrastructures	(Gunasekaran 1999), (Jayaram 1999), (Harper and Utley 2001), (Zhang 2011), (Eshlaghy et al. 2010)
Training and learning environments	(Yusuf, Sarhadi, and Gunasekaran 1999), (Gunasekaran 1999), (Sharp, Irani, and Desai 1999), (Gunasekaran 1998), (Forsythe 1997), (Prahalad and Hamel 1990), (Plonka 1997), (Hopp and Van Oyen 2004), (Youndt, Dean, and Lepak 1996), (Dove 1993), (Sumukadas and Sawhney 2004), (Jayaram 1999), (Dyer and Shafer 1999), (Nijssen and Paauwe 2012), (Chen, Hwang, and Raghu 2010), (Zhang 2011), (Qin and Nembhard 2015), (Sharifi and Zhang 2001), (Dyer and Jeff 2006), (Muduli 2009)
Collaborative working environment	(Plonka 1997), (Hopp and Van Oyen 2004), (Yauch 2007), (Powell 2000), (Fliedner and Vokurka 1997), (Worley and Lawler 2010), (Jayaram 1999), (Harper and Utley 2001), (Qin, Nembhard, and Barnes II 2015), (Charbonnier-Voirin 2011), (Goldman, Nagel, and Preiss 1995)
Organic structures	(Ramesh and Devadasan 2007), (Alavi et al. 2014), (Worley and Lawler 2010), (Sharp, Irani, and Desai 1999), (Yusuf, Sarhadi, and Gunasekaran 1999), (Sumukadas and Sawhney 2004), (Powell 2000), (Gunasekaran 1998), (Sharifi and Zhang 1999), (Worley and Lawler 2010), (Eshlaghy et al. 2010), (Vinodh, Madhyasta, and Praveen 2012), (Vinodh, Prakash, and Selvan 2011), (Zhang 2011), (Nijssen and Paauwe 2012)

3.4 Defining healthcare processes

Defining healthcare processes is critically important to facilitate an understanding of the role of workforce agility on healthcare process operational outcomes. Our definition is based on those of Davenport and Short (1990) and Davenport (1993), who define a process as a sequential set of logically related activities across time and space with a beginning and an end that have a clearly defined input and output. Here, an input is a mix of medical knowledge, procedures, and items. In other words, inputs, in processes, comprise all resources and patient activities (e.g., medical knowledge, lab tests, treatment procedures). Therefore, these processes are a mix of medical knowledge and items, whereby medical examination knowledge determines the inputs of the medical procedure. These inputs result in clearly defined outputs, which include patient health and safety (Lenz and Reichertr 2007; Perjons et al. 2005).

The most important healthcare process is the patient process in which various care providers interact with patients in order to increase patients' quality of life (Perjons et al. 2005). Patient treatment process involves a number of interrelated activities such as surgery, x-ray, and laboratory tests. Figure 1 presents a simple example of patient treatment activities that are involved in patient care process. Improving operations of these activities can lead to improved process operational outcomes such as throughput and resource utilization. Thus, the focus of this paper is on patient care processes.

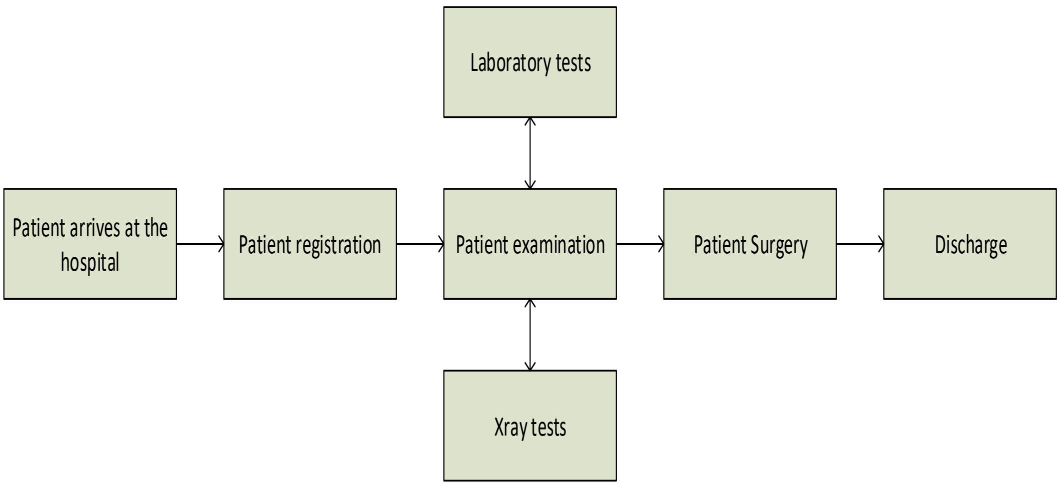

Figure 1 Simple patient treatment process

3.4.1 Characteristics

The objective for healthcare organizations is to provide patients with timely care (Litvak et al. 2001). However, in practice, it is very hard to meet this goal, as healthcare processes are performed under volatile, continually changing, and complex operating environments (Poulymenopoulou, Malamateniou, and Vassilacopoulos 2003). In this section, we present the key characteristics of healthcare processes.

- **Complex processes:** Healthcare delivery systems comprise highly complex patient care processes. The increasing volatility and unpredictability of patients' demands and their respective treatments are causes for the high complexity of patient care processes. Patient treatment processes are highly customized, demanding a unique knowledge and individual-specific decisions. Sometimes, complexity arises from unexpected diagnostic findings during data interpretation or when patients react negatively to treatments or drugs, necessitating a change in the prescribed medication. Therefore, medical decisions and patient treatment processes are unpredictable and volatile, resulting in complexity in patient care processes (Mans et al. 2009; Mans et al. 2008; Anyanwu et al. 2003; Lenz and Reichertr 2007; Poulymenopoulou, Malamateniou, and Vassilacopoulos 2003; Rebuge and Ferreira 2012).
- **Dynamic processes:** Healthcare processes are subject to change due to several factors, including the introduction of new administrative procedures, technological advancements, and treatments. The literature asserts that technological advancements have increased demands in patient care processes due to the invention of new diagnostic and therapeutic procedures. These changes require a highly adaptable and flexible workforce and overall healthcare operational systems (Anyanwu et al. 2003; Poulymenopoulou, Malamateniou, and Vassilacopoulos 2003; Lenz and Reichertr 2007; Lenz and Kuhn 2004).
- **Ad hoc processes:** Healthcare delivery depends on human collaboration with participants that have the expertise and autonomy to create their own procedures. Physicians have full autonomy in patient treatment processes and therefore can deviate from normal guidelines in order to deal with individual patients' needs. This results in processes with high variability and unpredictability, which are associated with high complexity in operations (Mans et al. 2009; Mans et al. 2008; Rebuge and Ferreira 2012).
- **Multidisciplinary processes:** Healthcare operations involve a number of departments, units, and medical disciplines, whereby high levels of interdisciplinary cooperation and coordination are needed. Healthcare processes are executed through a highly interdependent network of professionals who have different skills and knowledge (Lenz and Reichertr 2007; Anyanwu et al. 2003; Lenz and Kuhn 2004).

Table 3: Summarized healthcare processes characteristics

Characteristics	Reference
Complex	(Poulymenopoulou, Malamateniou, and Vassilacopoulos 2003), (Lenz and Reichertr 2007), (Anyanwu et al. 2003), (Mans et al. 2009), (Mans et al. 2008), (Rebuge and Ferreira 2012), (Rojas et al. 2016)
Dynamic	(Lenz and Reichertr 2007), (Poulymenopoulou, Malamateniou, and Vassilacopoulos 2003), (Anyanwu et al. 2003), (Rebuge and Ferreira 2012)
Ad hoc	(Lenz and Reichertr 2007), (Rebuge and Ferreira 2012)
Multidisciplinary	(Lenz and Reichertr 2007), (Rebuge and Ferreira 2012)

3.4.2 Defining healthcare process operational outcomes

Processes are commonly considered to be fundamental building blocks for organizations to archive their strategic goals (e.g., patient throughput) (Anyanwu et al. 2003; Ronen et al. 2006). The literature defines process outcomes in terms of interim process performance measures, such as reliable lead times (Melville, Kenneth, and Kraemer 2004; Dehning and Richardson 2002; Raschke 2010; Saeed, Malhotra, and Grover 2005). In the healthcare context, the literature classifies outcomes into three categories: medical outcomes, which focus on improvement in quality of life and disease management; financial outcomes, which focus on cost management; and operational outcomes, which reflect the improvement in clinical operations or efficiency such as improving throughput and resource utilization (Lewandrowski and Lewandrowski 2013).

The operational outcomes that are focused in this paper are those that result from improved patient operational activities such as treatments, surgery, registration and x-rays. Thus, as stated previously, we define process operational outcomes in terms operational outcomes (commonly used performance measures), that reflect improvement of clinical operations or efficiency, that is, throughput, resource utilization, waiting time, and service availability (Ronen et al. 2006; Cardoen, Demeulemeester, and Beliën 2010; Lewandrowski and Lewandrowski 2013). Improvements in these process performance measures are commonly linked to improved patient flow in patient treatment processes (Vanhaecht et al. 2010).Additionally, the aforementioned performance measures are referred to as key components of process operational outcomes in the literature (Samarth and Gloor 2009; Kujala et al. 2006).

Literature points out that workforce agility enables the achievement of the aforementioned process performance measures at operational level, leading to improved patient flow in processes (Breu et al. 2002; Hopp and Van Oyen 2004). State it differently at operational level workforce agility enhances reduced lead times, improved throughput, improved resource utilization, and service availability (Clague et al. 1997; Rinaldi, Montanari, and Bottani 2015; de Mast et al. 2011; Hopp and Van Oyen 2004). Thus in this study, the role of workforce agility in healthcare process operational outcomes is expressed in terms of patient throughput which is regarded as the number of patients treated, patient waiting times (delays), service availability, improved resource utilization (e.g., examination rooms), and labor utilization (Hopp and Van Oyen 2004).

4 Discussion

4.1 Linking workforce agility and healthcare process operational outcomes

This review managed to identify the relationship between workforce agility attributes and healthcare processes. The reviewed literature shows that workforce agility attributes can positively influence healthcare process operational outcomes. The assessment of healthcare literature highlights that healthcare processes are characterized by volatile and unpredictable patient demands, which lead to high delays and high variations in terms of the amount of resources and treatments durations. To reduce delays and improve patient throughput, the healthcare literature emphasizes a need for flexibility and responsiveness in different patients activities such as surgery and treatments (Aronsson, Abrahamsson, and Spens 2011; Rahimnia and Moghadasian 2010).

Adopting workforce agility in healthcare could provide flexibility and responsiveness in different stages of patient treatment processes, leading to improved throughput, service availability, and reduced lead times (Aronsson, Abrahamsson, and Spens 2011; Yusuf, Sarhadi, and Gunasekaran 1999; Gunasekaran 1998). In this context, workforce agility reflects the abilities that allow healthcare organizations to react and respond quickly to changing patient demands and needs. Research on workforce agility indicates that an agile workforce can be regarded as a key strategic resource that makes it possible for an organization to respond quickly to demand volatility and uncertainty (Hopp and Van Oyen 2004).

The reviewed literature further asserts that healthcare processes require interdisciplinary collaboration and coordination in different patient treatment activities (Lenz and Reichertr 2007). The interdependent nature of healthcare patient activities allows for a single patient to receive care from multiple care providers or departments, which easily results in a situation that involves networks of professionals within the broader framework of the treatment process. This has increased the need to effectively support interdisciplinary collaboration in patient treatment processes (Winge et al. 2015; Lenz and Reichertr 2007; Bij and Vissers 1999). In this context, workforce agility could play a fundamental role in building a collaborative working environment in different stages of patient treatment processes (Hopp and Van Oyen 2004; Breu et al. 2002). Collaboration in multifunctional teams leads to increased responsiveness, thus reducing lead times and improving labor and resource utilization (Hopp and Van Oyen 2004).

Interestingly, collaboration in healthcare can be facilitated by adopting information technology (Lenz and Reichertr 2007). The literature suggests that the adoption of information technology contributes to collaboration in patient care processes; in fact, well-designed and well-implemented information technology creates structures that are fluid, flexible, and adaptive to dynamic environments (Breu et al. 2002).

The adoption of information technology is well acknowledged in its contribution of improving process operations by speeding up action through providing timely access to relevant information as well as improving information management timelines. This enables several departments and units to access relevant information within a short period of time. The main advantage is that any patient case at hand can be handled quickly because the necessary information is easily accessible (Harper and Utley 2001; Breu et al. 2002; Crocitto and Youssef 2003; Lenz and Reichertr 2007).

Healthcare processes are subject to change. Both internal causes (e.g., new diagnostic or therapeutic procedures) and external causes (e.g., the introduction of Diagnosis related groups (DRG) enforce process change and create a need to rapidly adapt to new changes (Lenz and Kuhn 2004; Lenz and Reichertr 2007; Rebuge and Ferreira 2012). This characteristic of healthcare processes increases the need for a high level of workforce agility. Workforce agility allows for adaptability to changing work conditions. An agile workforce possesses a high degree of tolerance to unexpectedly altered work conditions as well as a capability to make individual adjustments in order to adapt to new working conditions (Qin and Nembhard 2015).

4.2 Linking management practices and healthcare process operational outcomes

As defined previously, management practices can be used to improve the knowledge, skills, and abilities of an organization's current and potential employees and increase their motivation (Huselid 1995; Jayaram 1999). In addition to promoting workforce agility, the reviewed literature demonstrated that management practices have a direct relationship with healthcare processes. Information systems allow healthcare providers to obtain relevant information in a quick and reliable manner. This, in turn, facilitates fast decision making in terms of patient cases (Lenz and Reichertr 2007). Organic structures are another prominent factor that can improve healthcare process operational outcomes. Reduced layers of decision making as well as flat and flexible structures increase employees' responsiveness by reducing response time because employees are able to access relevant information; thus, they are able to make decisions quickly and respond to changing conditions (Rahimnia and Moghadasian 2010; Qin and Nembhard 2015).

Moreover, organic structures can lead to improved processes because employees are given full autonomy and are thus motivated to be more responsive (Ramesh and Devadasan 2007; Sharp, Irani, and Desai 1999; Gunasekaran 1998; Zhang 2011).

Collaborative working environments also improve process operational outcomes by reducing the response time and by improving labor and resource utilization (Hopp and Van Oyen 2004), for example, in terms of meetings or interactions among the teams involved in care processes (Rahimnia and Moghadasian 2010; Olsson and Aronsson 2015). Systematic training and learning environments give employees the ability to respond to any uncertainties in the work environment. Systematic training can be individual or team-based (e.g., daily staff training in the morning before the start of patient care activities). Training can also be given based on the currently forecasted need; this, in turn, gives employees fresh knowledge on how to deal with current or forecasted situations. Having many skills facilitates employee flexibility in handling their daily operations (Rahimnia and Moghadasian 2010).

4.3 Establishing relationships between management practices, workforce agility, and healthcare process operational outcomes

This review found that different research fields define workforce agility in different ways and from different perspectives. Some studies consider workforce agility to be a dependent variable (Sumukadas and Sawhney 2004), while others considers it to be an independent variable (Charbonnier-Voirin 2011). Conversely, in some studies, workforce agility is considered to be a mediator variable (Vázquez-Bustelo, Avella, and Fernández 2007; Ye-zhuang, Fu-jiang, and Hai-feng 2006; Bosco 2007). When used as a mediator, key focuses included investigating the influence of factors such as a turbulent environment on workforce agility and the impact of workforce agility on manufacturing outcomes (Alavi et al. 2014).

In this particular study, workforce agility is regarded as a mediator. This relationship is also established in the reviewed literature, which indicates that several characteristics of workforce agility have a relationship with healthcare process operational outcomes. In addition, management practices have a clear relationship with workforce agility as an enabling factor. Further, the literature also shows a relationship between management practices and healthcare process operational outcomes. Thus, the developed model demonstrates the relationships between these three concepts. In particular, the conceptual model shows the influence of management practices on workforce agility and on healthcare process operational outcomes and the influence of workforce agility on healthcare process operational outcomes, as shown in Figure 2.

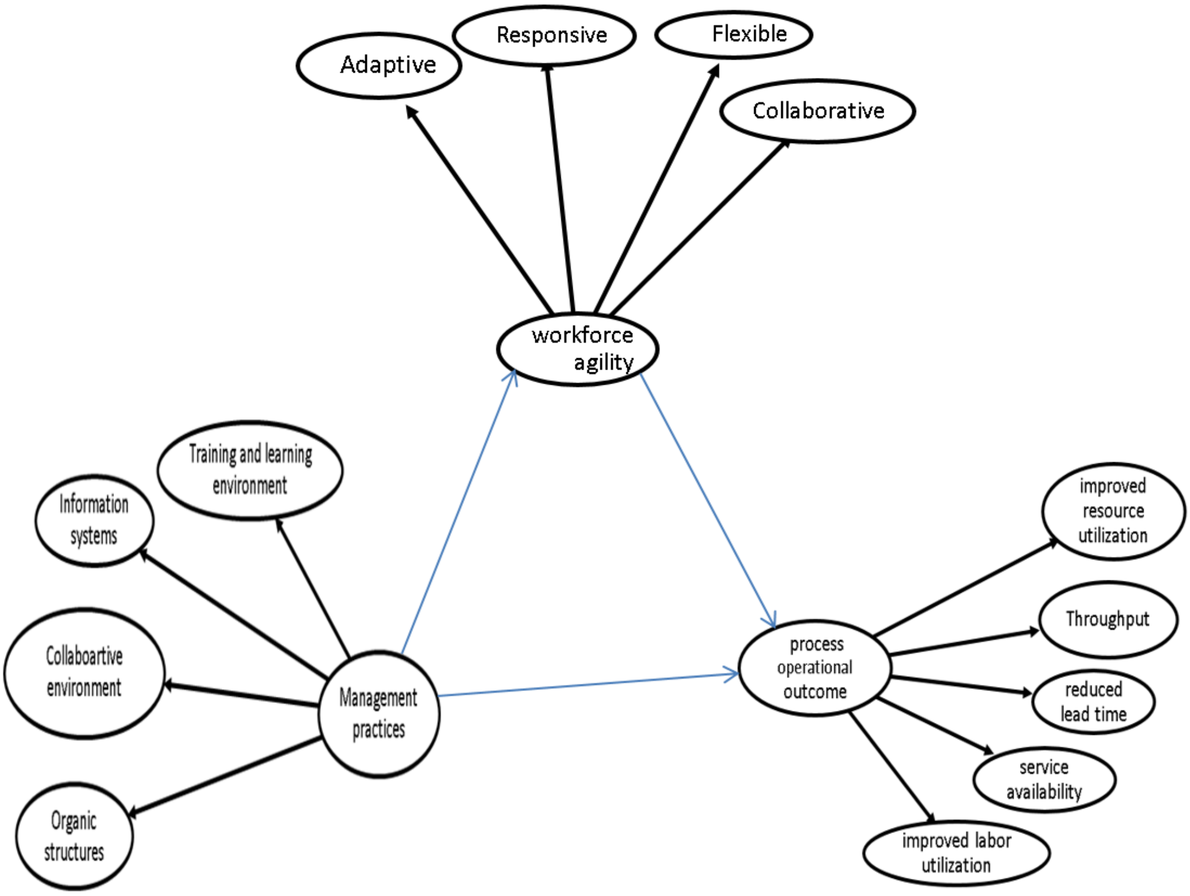

Figure 2: Conceptual model showing the relationship between management practices workforce agility and healthcare processes operational outcomes

5 Future directions and unexplored areas of workforce agility

During the review process, this study managed to identify research gaps that require further investigation. The identified research gaps were subdivided into three groups: conceptual gaps, methodological gaps, and contextual gaps.

5.1 Conceptual gaps

Through the synthesis and analysis of the literature, some conceptual gaps were identified. As a new concept, workforce agility lacks a comprehensive definition in the current literature (Breu et al. 2002). The existing literature has widely defined workforce agility in terms of its respective attributes. Given the importance of workforce agility in achieving organizational agility, we assert that establishing a comprehensive definition of the concept is vital. This can facilitate the implementation of this concept in different sectors, particularly in the service industry, where the concept is still at a very embryonic stage.

5.2 Methodological gaps

After reviewing the literature, some methodological gaps were identified. Based on this review, the most common methodology used in this field was found to be structural equation modeling (Charbonnier-Voirin 2011; Sumukadas and Sawhney 2004). Other methods include fuzzy logic (Vinodh, Madhyasta, and Praveen 2012; Vinodh, Prakash, and Selvan 2011) and descriptive statistics (Sharp, Irani, and Desai 1999). The simulation modeling gap in this research field is obvious; we found no studies that used simulation to explore workforce agility. These findings are consistent with the arguments in the literature, which also highlights that simulation studies on workforce agility are rare (Alavi & Wahab, 2013).

Simulation modeling is proposed to be a powerful operation management tool that can facilitate an understanding of the effect of workforce agility on different process outcomes (Law and Kelton 2000). A good example is the use of discrete event simulation to study the effect of workforce agility on healthcare process operational outcomes, such as throughput and patient waiting times. Given the power of simulation to explore complex processes (Barjis 2010), we argue that it is of critical importance to conduct studies that use simulation to explore healthcare process outcomes.

5.3 Contextual gaps

While reviewing the literature, this study found that workforce agility is still at an embryonic stage. Most of the reviewed articles are conceptual (27 articles), with very few empirical studies (13 articles). Even though both conceptual and empirical research are both needed, the empirical research gap is obvious. More empirical research is needed to explore workforce agility in healthcare and in other fields, as well.

Furthermore, there is a clear shortage of studies that examine the impact of workforce agility at the process level, particularly in healthcare processes. This might be a reason for the limitations in implementing this concept in healthcare operations. Implementing workforce agility in healthcare processes could allow healthcare providers to respond and react to ever-increasing patients' demands. Thus, it is of critical importance for healthcare providers to have a clear understanding on how workforce agility can impact healthcare process outcomes. There is a clear need for studies that focus on investigating the impact of workforce agility on healthcare process operational outcomes, such as throughput and resource utilization. This can be facilitated by validating this theoretical concept in the field of study.

6 Managerial implications

From a managerial point of view, our study has presented and described the necessity of understanding the relationship between workforce agility and healthcare process outcomes, particularly operational process outcomes. The role of workforce agility in healthcare processes is to allow healthcare providers to react and respond to volatile and unpredictable patient needs and demands. Thus, healthcare providers need to be aware of how workforce agility can lead to the improvement of healthcare process operational outcomes, including reduced waiting times, improved throughput and resource utilization, and increased service availability.

To achieve these benefits, healthcare managers must establish different practices and characteristics that enable workforce agility. It is critical for healthcare managers to establish organic structures and information systems to simplify information flow and speed up decision making. Collaborative environments and training and learning environments are also critical catalysts to promote workforce agility. Therefore, it is imperative for healthcare providers to establish strong systems and environments that promote workforce agility.

7 Conclusion

Workforce agility is still at a stage of infancy; hence, this study contributes to the existing literature by building a theoretical foundation for this concept. To facilitate an understanding of workforce agility, its main attributes and managerial practices that promote it were identified. Drawing on healthcare processes and literature on workforce agility, a conceptual model was developed to demonstrate the relationship between workforce agility and healthcare process operational outcomes.

This paper is the first to establish a conceptual model on the relationship between workforce agility and healthcare process operational outcomes. Further study on the relationship between workforce agility and healthcare processes is needed; it would be especially interesting if the determined relationship was tested empirically, as doing so would ascertain the effect of workforce agility on healthcare process operational outcomes.

This paper faces some limitation, for healthcare processes articles we limited only to those that has described characteristics of healthcare processes such as complexity and uncertainty and in particular patient care processes. Including other inclusion criteria could include more articles and increase the level of analysis. Further, even though other articles were traced from other databases such as google scholar, we mainly focused on two major database (Science direct and ProQuest). Thus, future studies can include more inclusion variables and searching terms in healthcare processes and use more than two databases

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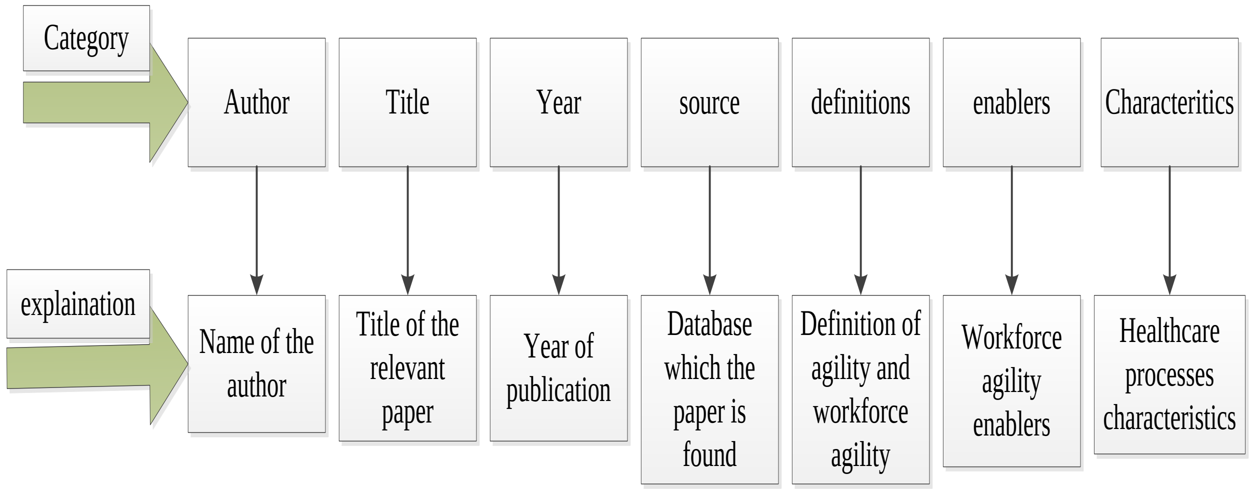
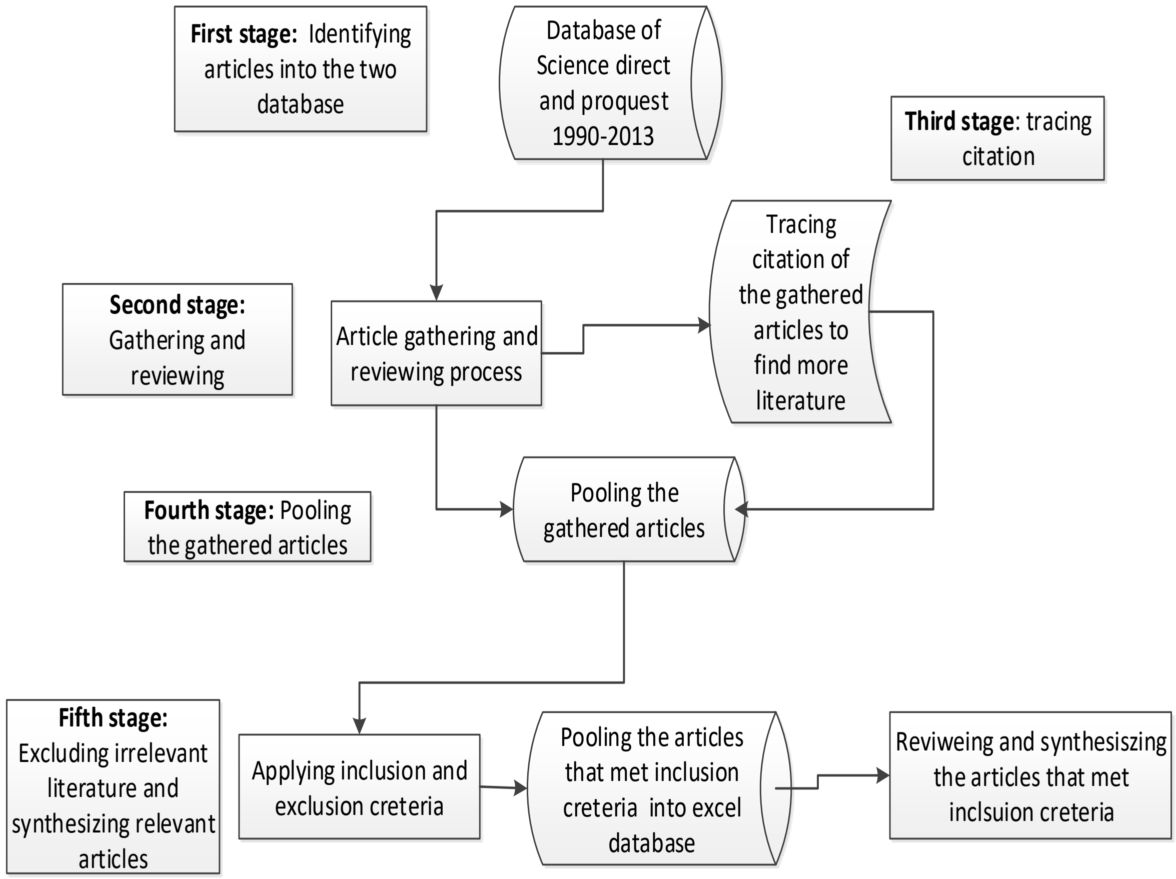
9 Appendix 1

Details of Excel extraction sheet



Literature review process



Paper 4

Simulation analysis of resource flexibility on healthcare processes

Abstract

Purpose : This paper uses discrete event simulation to explore the best resource flexibility scenario and examine the effect of implementing resource flexibility on different stages of patient treatment process. Specifically, we investigate the effect of resource flexibility on patient waiting time and throughput in an orthopedic care process. We further seek to explore on how implementation of resource flexibility on patient treatment processes affects patient access to healthcare services. We focus on two resources namely, orthopedic surgeon and operating room.

Methods : The observational approach was used to collect process data. The developed model was validated by comparing the simulation output with actual patient data collected from the studied orthopedic care process. We developed different scenarios to identify best resource flexibility scenario and explore the effect of resource flexibility on patient waiting time, throughput and future changes in demand. The developed scenarios focused on creating flexibility on service capacity of this care process by altering the amount of additional human resource capacity at different stages of patient care process and extending the use of operating room capacity.

Results : The study found that resource flexibility can improve responsiveness to patient demand in the treatment process. Testing different scenarios showed that the introduction of resource flexibility reduces patient waiting time and improves throughput. The simulation results show that patient access to health services can be improved by implementing resource flexibility at different stages of the patient treatment process.

Conclusion : This study contributes to the current healthcare literature by explaining how implementing resource flexibility at different stages of patient care processes can improve ability to respond to increasing patients demands. This study was limited to a single patient process; studies focusing on additional processes are recommended.

Keywords: Agile strategy, waiting time, throughput, patient access, responsiveness.

1 Introduction

Over the last twenty years healthcare industry has experienced significant changes, with patient demands changing at an ever increasing speed[1–3]. These changes require greater flexibility at different stages of patient care processes, which can increase the ability to respond quickly to changes in patient demands and needs[4–7]. A new process improvement technique- agile- has been proposed as a key strategy that can be used to improve healthcare processes [8]. Flexibility is a key characteristic of the agile strategy and is needed in order to achieve prompt responses to rapidly changing demands and requirements from patients. Flexibility in patient care processes enhances care providers to handle unique patient demands and needs [5,9] .

Despite the fact that the agile strategy has been proposed as a strategy for improving healthcare processes, its adoption in this field is still at an embryonic stage. Little empirical research exists in the healthcare literature exploring the effect of agile strategy on healthcare processes. In general agile has been widely studied as a companywide strategy leading to limited research of agility at a process level [5,8,10,11] Also, most of existing studies focus on creating flexibility on a single resource such as human resource or facility resource (e.g. operating room), thus lacking a holistic view of the process [4,12,13]. In order to facilitate increased patient response for the entire care process, from when patient arrives to the point of discharge, flexibility on both human resource and facility resource is vital [12]. This study aims to fill part of this gap by exploring the effect of creating flexibility on service capacity of this care process by focusing on two critical resources namely, orthopedic surgeons and operating room capacity.

This objective will be accomplished by using discrete-event simulation to explore the improvements that can be achieved by deploying resource flexibility on different stages of patient treatment processes. The specific objective of this paper is twofold: first, to explore the best resource flexibility scenario and to investigate the effects of implementing resource flexibility on patient waiting time and throughput and, second, to explore on how implementation of resource flexibility on different stages of patient treatment processes affects patient access to healthcare services. To achieve this objective, the following question will be addressed: What is the effect of surgeon/operating room flexibility on patient waiting time/throughput?

The rest of this paper is organized as follows: the Second Section presents a literature review while the Third Section presents material and methods. The fourth Section presents the simulation results from the scenario testing and modelling. The Fifth Section presents a discussion of the simulation results, followed by the conclusion Section.

2 Literature Review

The origin of the agile strategy can be traced back to the agility forum of a group of scholars at Iacocca Institute, Lehigh University, in 1991 [14]. Agility was introduced as the response to increasing business turbulence and uncertainties [15]. Agility is the multidimensional concepts, hence several definitions have been offered since its conception. However all the definition still remain within the same theme of increasing responsiveness and flexibility to increasing uncertain customer demands[16]. In this paper agile is defined as the ability of being customer responsive and mastering increasing demand changes [17].

The key objective of agile strategy is to enhance flexibility in care processes in order to respond to the needs of increasingly demanding patients [5]. Working with flexible capacity is the key component of an agile strategy to enhance reduced throughput time and increased response speed. Flexible capacity requires high availability of extra personnel or other resources required to perform processes in a timely manner, regardless of the volume of real demand. The main advantage of this approach is that adjacent steps in the process receive reliable deliveries, i.e., on-time deliveries. This reduces throughput time and increases access to services [2,5].

In this paper, resource flexibility is defined as “the ability to dynamically reallocate units of resource from one stage of production process to another in response to shifting bottlenecks” [4]. To supplement this definition, literature points out that resource flexibility can further be created by the ability to alter amount of resource or ability to extend the use of a resource[7]. Drawing from this description resource flexibility is in study is created through altering amount of resource capacity or extending the use of resource capacity at different stages of patient care process. When each unit of a resource can be allocated to any stage of the production process, it leads to substantial improvements in operational performance. The literature further asserts that resource flexibility positively and significantly contributes to agile process improvements [4,18].

Despite the fact that the agile strategy has received the attention of many healthcare scholars, limited empirical research has been conducted to explore the possibility of applying this strategy in healthcare[10]. Aronsson et al[5] conducted a study in a Swedish healthcare setting to explore the link between the agile strategy and healthcare supply chain performance. By focusing on how lean and agile can be used as process strategies, they pointed out that the key requirement in healthcare today is about organizing for quick response and flexibility at the system level. Olsson and Aronsson[7]conducted a study in a Swedish hospital to identify strategies for different actions used in patient treatment. They noted that the hospital's agile actions were reactive and lacking in proactive measures. They found very few actions that directly managed external variation. In the current study, agile is used as a process improvement strategy whereby the main objective is to explore entire patient treatment process and to examine the effect of resource flexibility in different stages of patient treatment process. This study will focus on creating flexibility on the service capacity of this care process by altering the amount of human resource capacity at different stages of care process and extending the use of operating room capacity.

2.1 Simulation in Healthcare Processes

Due to the complexity and uncertainty of the healthcare process, simulation has become the most important tool in analyzing and evaluating the responses of systems under various scenarios. It has proven its viability and capability as a powerful technique and method in exploring resource-driven processes [19–21] This has led to a number of simulation studies on care processes.

Weerawat et al[22]deployed discrete-event simulation to estimate the capability and service level of an orthopedic outpatient clinic. They found that allocating the availability of critical resources over an extended time span by employing a flexible work schedule on the basis of patient demand can increase system efficiency. They developed a strategy that can be used to match patient demand with resources. Rau et al[23] constructed a discrete-event simulation model to explore the bottlenecks of the operations in the physical therapy room. They further discussed the impact of pooling resources on clinic efficiency, which they noted increases flexibility in critical resource schedules.

Baril et al[24]studied the relationships and interactions between patient flows, resource capacities, and appointment scheduling rules in order to improve an outpatient orthopedic clinic. They found that to achieve this, the clinic's performance, resources, and appointment scheduling rules must be applied to different patient flows. Duguay and Chetouane[25] deployed discrete-event simulation in an emergency department to reduce patient waiting times and to improve service delivery and throughput. They developed a linkage between patient waiting time and resource availability and found that matching critical resources with patient demand reduces patient waiting time.

This paper focuses on using discrete event simulation to explore orthopedic care process and propose resource flexibility scenario that can be used to reduce patient waiting time and improve patient throughput. Further discrete event simulation will be used to explore how the best scenario can accommodate future increasing demand.

3 Material and Methods

3.1 Bugando Orthopedic Clinic as empirical evidence

The Bugando Medical Centre (BMC) is one of the four teaching and consultant hospitals in Tanzania. 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 has approximately 1,000 employees. The BMC is a referral center for tertiary specialist care serving eight regions: Mwanza, Tabora, Kigoma, Kagera, Mara, Geita, Simiyu, and Shinyanga. In general, this hospital serves a population of approximately 13 million.

Globally road traffic injuries is a growing concern that put much pressure on healthcare providers on how to meet increasing surgical demand[26]. This is the same challenge experienced by the Bugando orthopedic department. It is faced with increasing surgical demand for orthopedic services. This is to a large extent associated by the increase of road traffic injuries, frequently caused by motorcyclists across the region and Tanzania as a whole. One recent study at this hospital reported that road traffic injuries contributed up to 68.5% of orthopedic cases. This trend is expected to continue unless critical measures are taken [27]. The increasing demand has led to high crowding and excessive waiting times and lists for orthopedic patients visiting this department. Hospital management highlighted that existing surgeons and operating room capacity are main constraint in this care process as they cannot accommodate the current orthopedic patient demand. Creating flexibility in these critical resources may lead to increased patient access to care at this clinic.

3.2 Orthopedic Department Resources

The hospital under study has four specialized orthopedic surgeons and five operating theatres that serve the entire hospital community of 13 million people. The orthopedic department has only been allocated two operating rooms out of the existing five. Two orthopedic surgeons per day perform operations on Mondays, Wednesdays, and Fridays. The total capacity for the three allocated days in the operating theatre is equivalent to six rooms per week. At the clinic, two orthopedic surgeons per day attend to patients on Tuesdays and Wednesdays. Other resources at the clinic include three nurses who take patients to surgeons for examination. Bugando Hospital also has a central laboratory and an X-ray section, which serve the entire hospital community.

3.3 Describing Clinical Operations

As part of the process exploration, and before mapping this process, we held interviews with hospital management teams, surgeons, and heads of departments related to orthopedic care (lab, x-ray, registrations, and the orthopedic ward). Model credibility and validity was ensured by involving key surgeons at the orthopedic clinic and the head of the operating rooms during the conceptual model development. Further insight on the orthopedic care process was obtained by holding discussions with nurses and patients at the clinic. The entire orthopedic care process is described below.

Upon arriving at the hospital, patients register with the registration department. They usually arrive at the registration department from about 6:00 a.m. even though registration starts at 7:00 a.m. and clinical services start at 8:00 a.m. Consequently, most patients arrive at the clinic before the start of clinical services and must wait for the start of the clinical session, including the arrival of surgeons. Even though, no clear reason as to why some patients tend to arrive before the start of registration and clinical services, it is most likely due to high number of patients attending at registration and clinic per day. Thus, some patients would like to arrive early so that they can be among the first patient in the registration and treatment queues. Surgeons occasionally delay their arrival at the clinic by 15–45 minutes after the clinic has opened because of other tasks/obligations in the hospital. When surgeons arrive, examination services begin, and patients are escorted by nurses to the examination rooms. During the first examinations surgeons normally orders ancillary tests such as X-ray or laboratory tests. Patient with the ordered tests will then undergo their respective ordered tests which can be x-ray or lab tests. When ancillary test results are ready, patients take their results back to the nurse, who then takes the results to the surgeon for further diagnosis. After a second examination, a patient is either discharged or transferred for surgery. Figure 1 presents a conceptual model of the studied orthopedic care process that was translated into the computer simulation model

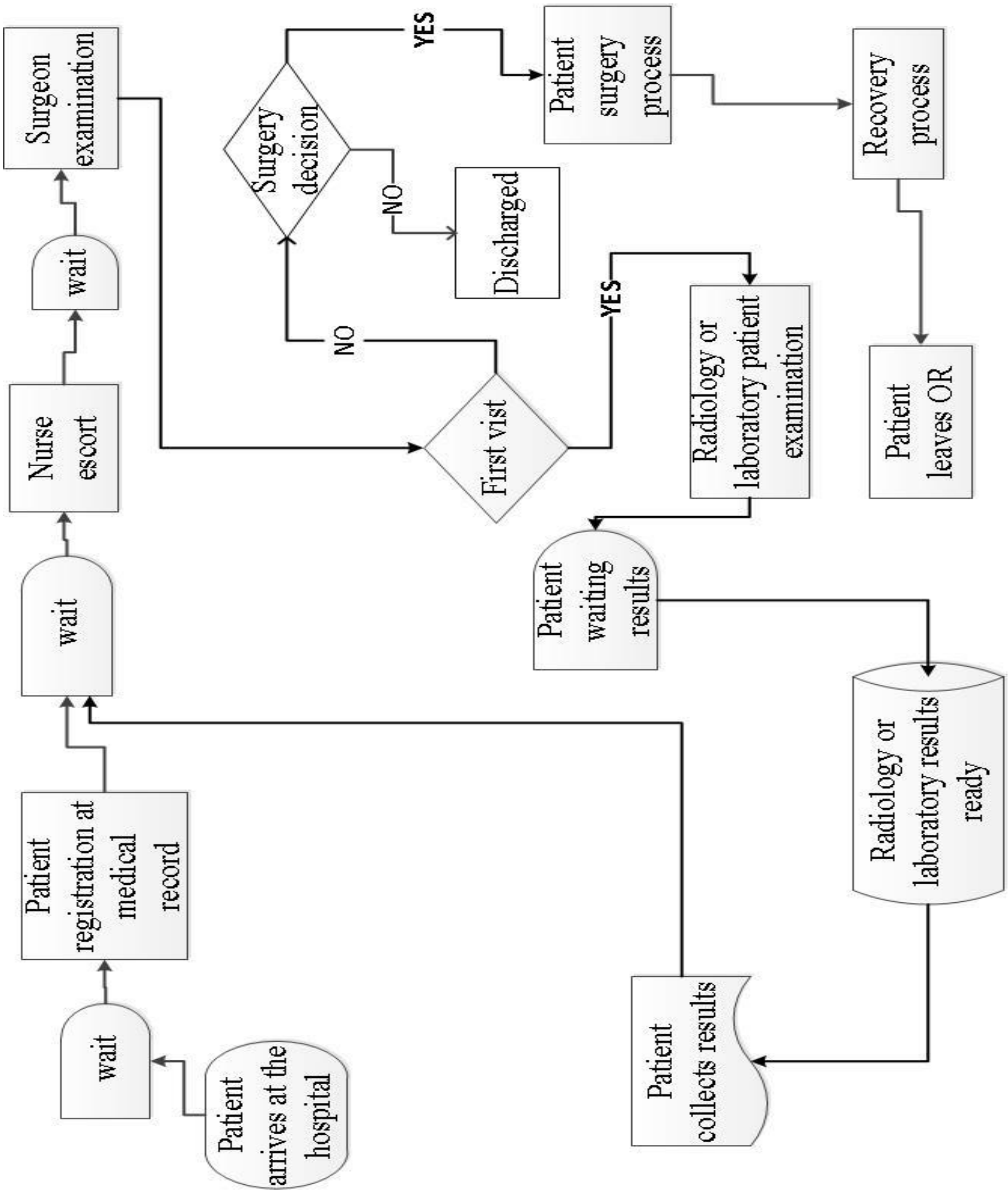


Figure 1: Current process in the orthopedic department.

Abbreviation: OR, operating room

3.4 Data collection and analysis

This study was approved by the Research and Ethics committee of the Catholic University of Health and Allied Sciences and Bugando Medical Centre. Patient written consent was not considered necessary by the committee as this was a process improvement study and no medical or personal information was taken from the patients. Data collection was anonymous. This study is based on the interviews and observational data from the orthopedic clinic from June 2012 to August 2012.We followed patient from arrival at the registration department to the point of discharge. For data collection process we used stopwatches and structured data sheets whereby each column represented either waiting or assessment time of the observed patient activity. The time recorded includes waiting time and service time during registration, examination at the clinic by the surgeon, the surgical process, recovery, x-rays, and lab tests. Based on the observations, an average of 35 patients attends the clinic per day, of which 20% undergo the entire process up to surgery, while 80% are discharged. During the data collection period, 178 patients underwent the entire process from arrival, to surgery, to discharge.

We followed all necessary steps to perform the analysis of the collected data for distribution fitting. We used scatter plots and linear correlation techniques to assess data independence. Furthermore, we used summary statistics, histograms, and box plot techniques to hypothesize the families of distribution. After identifying the distribution, we used a chi-square test to determine the representativeness of the fitted distribution[28]. Thus, chi-square tests for goodness of fit led to the selection of the final distribution. Discrete event simulation was used as the main methodology for this study. Additionally the model was developed using Arena (Version 13.0). We used the Arena input analyzer to generate the parameters of the selected distribution, which were used in the simulation model. Table 1 shows the selected distribution.

Table 1: Simulation model input based on the current orthopedic care process (Minutes)

Process	Distribution	Resources
Patient arrivals	0.5 + EXPO(2.62)	
Registration	5.5 + GAMM(1.97, 4.73)	Clerks
Nurse escort	1.5 + WEIB(3.59, 1.49)	Nurse
First examination	3.5 + WEIB(15.4, 1.74)	Surgeons
Second examination	3.5 + ERLA(2.66, 4)	Surgeons
X-ray	13.5 + WEIB(3.79, 2.15)	X-ray technician
Laboratory	NORM(25.4, 2.98)	Lab technician
Surgery	10 + GAMM(46.9, 1.34)	Surgeons
Recovery	4.5 + 14 * BETA(2.42, 1.65)	Operating room personnel

Note: [a]Mean.
Abbreviations: EXPO, exponential; GAMM, gamma; WEIB, Weibull; ERLA, Erlang; NORM, normal.

3.5 Model Development and Assumptions

It is impossible to replicate complex healthcare delivery systems that involve human behavior and decisions in a simulation model[29]. Thus, we made a number of assumptions that guided simulation model development. First, our study considers the operational system only between 6:00 a.m. and 4.00 p.m. because patients begin to arrive from 6:00 a.m. Second the main objective of this study is to explore the entire patient treatment process, thus it focused on patients who underwent the entire process from arrival to discharge after surgery. Third, based on the second assumption decisions on whether surgery is needed are made only after the second examination (i.e. after bringing to surgeons the ordered x-ray and lab test results). Fourth, resources are available to orthopedic patients for the two clinical and three allocated surgical days. Fifth, this study assumes that the second examination queue has priority over the first examination queue. The model limitations were based on the following grounds: transfer times (transport times) within the orthopedic department were not taken into consideration because the main focus of this study was the orthopedic department, particularly the interaction between specialist surgeons and patients.

The simulation model was then developed within the aforementioned assumptions and ran for 100 independent replications and the system was reinitialized between replication. In this model each replication stands for a single day of orthopedic care delivery at this clinic. The normal operations of the studied clinic is from 8am to 4pm, however, we simulated the model for 9 hours because during data collection process, the clinic was most of the time closing at 5.pm. Patients in this care process are examined based on first in first out service discipline. Likewise, in the simulation model patient were also served using the same first in first out queuing discipline. Patient arrivals were generated based on the observed schedule of the two allocated clinic days. Also in the surgical room, the model simulates based on the schedule of the observed three allocated surgical days

3.6 Model Verification and Validation

Model verification is a key step used to ensure that the conceptual model is well reflected in the simulation and the model is running free of errors [30]To meet this requirement we verified simulation model using Arena debugging tools and animation and the model was running correctly. We took following measures to validate the model: First we maintained high face validity of the model by involving key orthopedic specialist surgeons and the head of the operating theatre in the model's development. Head of operating room was also involved in data collection process inside the operating room. Further, two performance measures were used for validation: patient waiting time at the clinic and patient throughput per day in the surgical room. Throughput was measured as the number of patients undergoing surgery per day. The average patient waiting time for a surgeon at the clinic was 2.8 hours, at 95% confidence interval. This not very different form the observed patient waiting time for a surgeon: 2.4 hours. The average throughput based on observation was 7.3 while the average throughput based on the simulation, at 95% confidence interval, was 5. To increase model validation we run the simulation model using the actual patients' arrivals, instead of sampling from the selected exponential distribution and the same results were obtained.

The major difference between simulation output and observed data was found on waiting time for second examination at the clinic. The average waiting time from the simulation model is 0.14 hours while based on the real data the average waiting time is 0.8 hours. This is probably because in the simulation second visit patients were given priority over the first examination patients. Thus in the model patients bringing their ancillary results for second examination were always given first priority in the queue over the first examination patients. Normally, patients with ancillary test coming for second examination are always preceded by other patients in the queue. Despite this discrepancy, the model is considered valid because other performance measures such as first waiting time, throughput and surgeons utilization are close to the actual collected data.

4 Proposed Resource Flexibility scenario

As stated previously this department is facing increasing surgical demand is accompanied by constraints on surgeon and operating room capacity. Thus, our proposal, aimed at exploring the entire orthopedic care process from when patient arrives to the point of discharge and proposing the resource flexibility scenario that can be used to increase the speed of responding to the current growing patient demand at this clinic. Based on the observation of this process during data collection, we suggest implementation of resource flexibility by changing the care procedure from using not only specialist surgeons at the clinic and surgical room but also utilizing mid-level health workers (MLHWs) or non-clinicians physicians[31,32]. These resources are cross-trained to increase care capacity and usually perform multiple tasks, including internal medicine, minor surgery, gynecology, and obstetrics [33]. They may be assigned to more routine parts of the orthopedic process in order to take care of simple treatments such as closing and cleaning wounds or minor surgery. This care procedure will increase flexibility in orthopedic care process since simple cases will be dedicated to mid-level health workers. This will release capacity to surgeons to deal with complex cases. Using mid-level health workers for routine and simple cases and surgeons for more complex cases will increase the speed of response to the increasing patient demands. This will lead to reductions in patient delays and increased access to health services.

We propose that flexibility can be achieved by reallocating these units of resources from one stage of the orthopedic care process to another in order to increase the response to the ever-increasing patient demand at this clinic [4], specifically in the form of sharing these resources between the orthopedic clinic and operating room. To create flexibility that can increase the speed of response in the operating room, we extended the use of the operating room's capacity by assuming that the surgical process starts one hour earlier. Based on discussions with department personnel on current operating room capacity, we further suggested a 10% increase in daily surgeries. The extended operating room capacity will increase flexibility on this process by allowing surgery process to start earlier than before. This in turn will increase patient throughput at this resource. Several scenarios were developed as presented in Table 2. Even though scenarios focuses on adding resources, based on literature resource flexibility in these scenarios is created by reallocating resources from one stage of production to another (clinic and operating room) as well as altering the amount of resources in those stages of production[4,7] . This implies that additional resources are flexible, thus they can be reallocated at any stage of production (clinic and operating room) depending on the need.

Using simulations, we explored the best resource flexibility scenario and explored its effect on the patient care process. For simulation purposes, we assumed that additional mid-level health workers are involved in the surgeons' treatment process because this proposal has not yet been implemented. That is, data for mid-level health workers care protocol is absent.

From the queuing theory perspective, additional mid-level health workers and surgeons are considered as parallel multiple servers and are assumed to have common service time distributions [34]. Thus, we make the following assumptions: (1) Mid-level health workers and surgeons maintain the same examination and surgery time distributions (2) Patient enter examination and surgery through common queues based on first in first out discipline (3) The service systems has identical and multiple servers [34,35]

We know that the current protocol involves orthopedic cases, which were treated by surgeons, but since the main focus is to know the impact of these additional resources before actual implementation we believe that the result based on these assumptions are still relevant for practical decision-making.

In addition, the recommendation of starting surgical activities one hour earlier might have some impact on surgeon time as they were dedicating this time to other activities prior to this change. However, we believe the impact will be minimal since based on discussion with these surgeons and head of operating room these surgical days are to a large extent dedicated for surgical activities. Thus, surgeons mostly has some few issues prior to start of surgical activities. Moreover, head of operating room stated that sometimes surgeons arrive early and wait for the patient to be prepared for surgery. This was also observed during data collection as surgeons were sometimes arriving early in the operating room and waiting for the patient to be ready for surgery.

Patient waiting time is a key indicator of healthcare accessibility. We thus used this as a benchmark for releasing these resources by assuming that when patient waiting time is less than an average of two hours at the clinic, these resources should be released. Specifically, we explored the extent to which current demand can decline so that a patient waits an average of two hours at the clinic. We further explored to what extent these additional resources can accommodate future increases in demand without patients waiting for an average of more than two hours at the clinic. The proposed two hours is based on the current waiting time at the clinic, we assumed that these change should enhance patient to wait not more than the current waiting time at the clinic, which is the average of 2.8 hours (2.8 hours).

Table 2: Scenarios and their corresponding resource changes

	Additional staff at the clinic	**Additional staff in the operating room**	**Extended use of OR by one hour and a 10% increase in daily surgeries**
Scenario 1	1	0	1
Scenario 2	0	1	1
Scenario 3	1	1	1
Scenario 4	1	2	1
Scenario 5	2	1	1

5 Results

5.1 Simulation Results

This section presents the simulation results of the orthopedic care process. The simulation model was used to generate the best resource flexibility scenario and to explore the effect of implementing resource flexibility. It was also used to explore how implementation of resource flexibility affects patient access to healthcare services. Table 3 presents simulation results of the base and six proposed scenarios. The most significant scenario (scenario 5) shows improvements in waiting time by 72.7% and throughput by 94%. We used box plots and whisker charts to identify statistically significant scenarios at a 95% confidence interval in patient waiting time and throughput. Figures 2 and 3 present the results, with red indicating a 95% chance of a best scenario.

Table 3: Simulation results by scenario

	Examination waiting time (hours)	Throughput
Base Scenario	2.83	5
Base scenario with 1-hour increase in OR and 10% surgery increase	2.83	7.56
Scenario 1	1.47	9.16
Scenario2	2.83	7.56
Scenario3	1.47	9.16
Scenario 4	1.47	9.16
Scenario 5	0.77	9.71

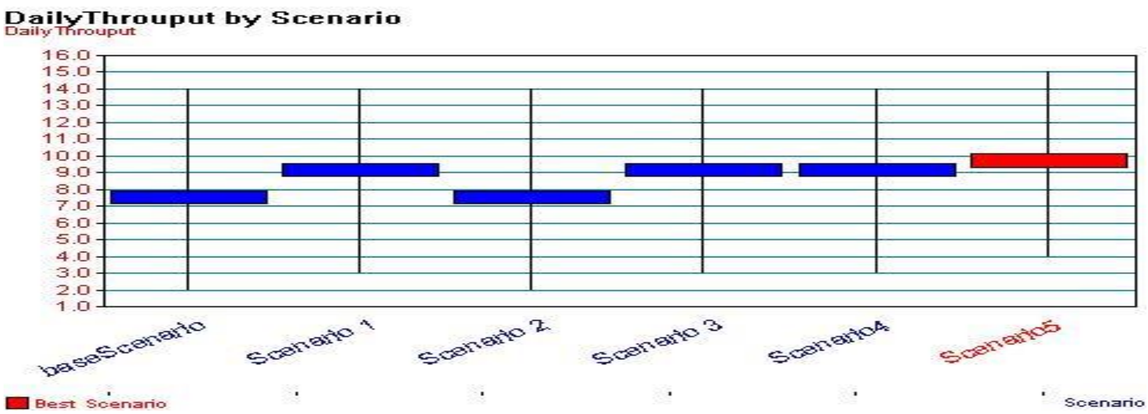


Figure 2: *Daily throughput according to scenario.*

Note: Black lines represent insignificant scenarios and the significant scenario is represented in red.

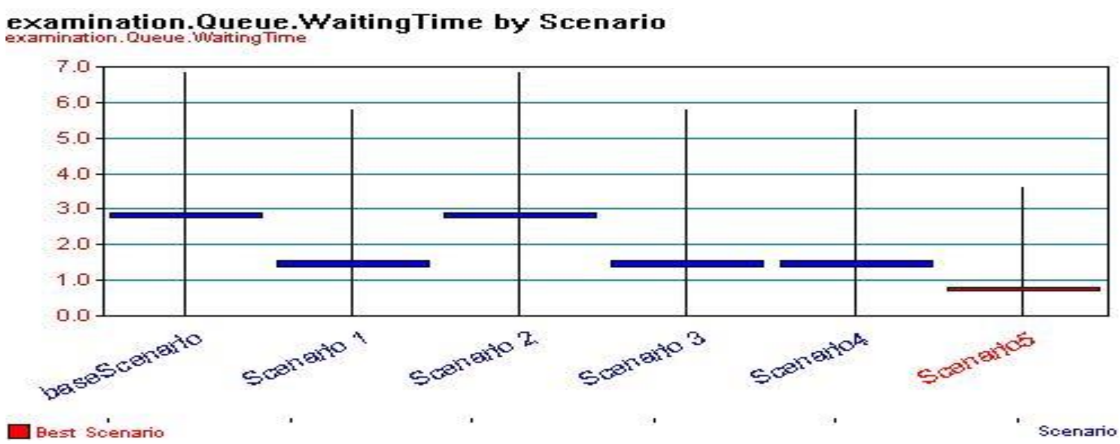


Figure 3: *Examination Queue waiting time according to scenario.*

Note: Black lines represent insignificant scenarios and the significant scenario is represented in red.

Table 4: Evaluating process characteristics when demand changes along with corresponding waiting time (hours)

	Base scenario demand declining by 26.3%	Best scenario (scenario 5)	Best scenario with 84% demand increase
Patient waiting time	2.01	0,77	1.9
Throughput (patients, n)	5	9.71	14.4

The simulation result indicates that if current demand declines by 26.3% (see Table 4); it can be accommodated with current resources without patients waiting an average of more than two hours at the clinic. These additional resources can thus be used for other clinical purposes. The simulation results further indicate that with this flexibility scenario, up to 84% of the increase in future demand can be accommodated with patients waiting no longer than an average of two hours at the clinic.

6 Discussion

This paper explored how resource flexibility affects patient care process outcome. Specifically, the focus was on exploring improvements by deploying resource flexibility in different stages of patient treatment processes. Discrete event simulation was used to run the base scenario that represents orthopedic care process and the proposed six scenarios. The main objective was to ascertain which one is the best scenario. The simulation results indicate that resource flexibility is more beneficial at process stages with bottleneck resources and when processing times are dependent on additional resources. This findings is in line with the literature which demonstrate that resource flexibility is more beneficial in areas with bottlenecks [4].

The aim of introducing resource flexibility was to increase the speed in responding to orthopedic patient demands on this clinic. The impacts of additional resources on patient waiting time and throughput at this clinic clearly indicate that resource flexibility is a key strategy that can be used to improve healthcare processes. The introduction of a flexible workforce in the model showed improved throughput and a significant reduction in patient waiting time. Improving throughput and decreasing patient waiting time indicate process improvement in terms of increasing response speed to enhance patients' access to care.

We further tested how the best scenario can be used to accommodate future demand. The simulation results demonstrate that with introduction of resource flexibility, this care process would increase rate of response to patient demands. The simulation results show that the improved process can accommodate an increase of up to 84% in demand without patients waiting for an average of more than two hours at the clinic. This finding is consistent with the literature asserting that more than 80% of orthopedic cases are non-surgical [36]. Thus, increasing resource flexibility at the clinic would be more beneficial to a greater number of patients, given the fact that most cases are non-surgical.

From the perspective of healthcare processes, this study has shown that implementation of agile strategy can lead to improved care processes. The results presented in Table 3 indicate that resource flexibility can reduce patient crowding and waiting time. Introducing resource flexibility created conditions for improved patient flows, decreasing response times in addressing patient needs. In practice, this improvement can be translated into increased patient access to care since the speed of response has increased; more patients can thus be accommodated.

Worldwide, surgeons and operating rooms are the key constraints resources in patient care processes. Creating flexibility in these resources is of great importance in order to improve patient access to care. In this study we have demonstrated on how flexibility in these critical resources can improve healthcare processes. Thus, healthcare providers should focus on adopting such innovative ways in order to improve healthcare processes and enhance increased patient access to care.

It is worth noting that, to achieve the intended benefit, implementation of this proposal should be done with a careful analysis of mid-level workforce capacity at the hospital. Two options can be used to obtain additional mid-level health workers in orthopedic department. First, additional midlevel health workers in orthopedic department can be taken from departments with more mid-level resources or low service demand, so that service capacity in those departments will not be affected. Second, because training time and cost for mid-level health workers is much lower than specialized surgeons [32], hospital providers can still opt to train more mid-level health workers . Training more mid-level health workers will reduce the effect of moving resources from one department to another, e.g. some staffs may feel overworked.

It should further be noted that even though additional resource in this proposal has cost implication, however this proposal is still viable and useful for practical purposes. Recently several studies has suggested that shifting surgical tasks from surgeons to lower level staff (e.g. clinical officers, non-physicians clinicians) is an effective response to the shortage of specialized medical staffs in resource constrained setting. These studies acknowledged dedicating tasks to mid-level health workers gives healthcare providers ability to deliver healthcare services to a large number of patients at lower training and labor cost [32,37].

In line with the preceding discussion, the proposed resource flexibility has some economic impact to hospital financial position. It is obvious that there will be some increment of cost due to training and other labor cost of these midlevel healthcare workers. Even though there might be some labor and training cost increment in the hospital, however the increased cost is manageable. This is evidenced by the recent empirical study in Tanzania, which shows that the economic impact of using mid-level workers or non-physicians is manageable to most Tanzanians hospital. This study further states that the training and labor cost of these mid-level healthcare workers or non-physicians is lower compared to the cost of developing specialized surgeons [32]. In this context, we can argue that the proposed changes can be accommodated with the studied hospital.

Lastly, literature asserts that shifting surgical task to mid-level staffs cannot compromise quality and patient safety if these staffs are well trained (Beard et al and Gupta et al)[32,37].Thus, healthcare managers should invest more on training these mid-level workers prior to start using them. Recently empirical study has evidenced that mid-level staffs or non-physicians has been able to perform major and sensitive surgery such as cardiac surgery which were performed in India and non-obstetric major surgery performed in Tanzania. Literature states that, there was no different of quality observed between surgery performed by mid-level staffs and those performed by senior surgeons. Literature concludes that shifting surgical care to no physicians may be a safe and sustainable way to address the global surgical workforce crisis (Beard et al and Gupta et al)[32,37].

6.1 Managerial Implications

This study provides significant contribution to healthcare providers regarding the benefit of regarding the of resource flexibility in patient care processes.

First, the simulation results suggest that the deployment of resource flexibility can increase the speed of responding to patient demand, leading to reduced crowding in clinics. Healthcare providers should thus consider the possibility of using mid-level resources in orthopedic fields. The fact that mid-level health workers have already performed major surgery in other surgical fields (Beard et al and Gupta et al)[32,37] might be a good indicator that they can manage simple cases at the orthopedic level.

Second, the simulation results of this study have a major implication for healthcare providers aiming to improve healthcare processes. To meet increasing patient demand as well as reducing patient delays in care processes, healthcare managers should start focusing on introducing flexibility in different parts of care processes. Retaining resources that can be shifted during different stages of the healthcare production process can increase the speed of responding to patient needs and demands at the various stages of their treatment.

7 Conclusion

The results of this study indicate that if this scenario is to be implemented, it can potentially improve patient access to care and thereby contribute to reducing morbidity and mortality in orthopedic surgical cases. This paper focuses on showing the advantage of an agile strategy in the improvement of healthcare processes, particularly in resource-constraint settings. With the result of simulation modeling on the impact of resource flexibility, we point out that an agile strategy can improve healthcare processes as well as patient access to healthcare.

This study faces some limitations. First, patient waiting time includes the early arrival of patients before the start of examination services as well as surgeons lateness. If surgeons could arrive at the start of clinic session patient waiting time could be decreased. Likewise, if patients could arrive a few minutes before the start of the clinical session, this could further decrease their waiting time. Second, our model was limited to orthopedic treatment processes. Future research can focus on exploring more care processes and evaluating how an efficiently proposed flexible workforce can perform multiple tasks between several clinics as well as the tradeoffs involved when trying to introduce flexibility in multiple care processes.

Second, in this study it was assumed that, when the patient waiting time is less than an average of two hours at the clinic the additional resources can be released. Also, it was tested to what extent can future demand be accommodated with the proposed scenario without patient waiting for an average of more than two hours at the clinic. However, there is no specific service level that is associated with this assumption. Thus, future research can focus on choosing a specific service level.

Lastly, observational data for additional mid-level health workers are missing, thus our simulation result is based on the collected surgeons service time data. After implementation, the result may be slightly different because mid-level health workers will have their own protocol i.e. dealing with minor and routine orthopedic cases. However, the impact of reduced waiting time and improved patient access to care will still be relevant. This is because the workload will be distributed between midlevel health workers and surgeons. Hence, surgeon capacity will be freed up and they can focus on more complex cases. Nevertheless, this limitation calls for further research to investigate the impact of additional midlevel health workers after implementation of this proposal.

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Molde University College
Specialized University in Logistics
P.O. Box 2110
NO-6402 Molde
Norway
www.himolde.no

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