AMERICAN UNIVERSITY OF BEIRUT

INVESTIGATING UTILIZATION AND WORKFLOW EFFICIENCY AT THE RADIOLOGY DEPARTMENT OF AUBMC

by
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AN ABSTRACT OF THE PROJECT OF

Rana Abed Saleh for Master of Business Administration
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Title: Investigating Utilization and Workflow Efficiency at the Radiology Department of AUBMC

Given increasing demand for health services and increasing costs of such services, health care units are under high pressure to increase throughput in order to meet the demand while ensuring high quality and low cost of services. This project investigates the operational efficiency of two radiology units at AUBMC, the CT (computed tomography) and MRI (magnetic resonance imaging) units. The investigation of each unit is based on on-site observations during which detailed data about performed procedures has been collected. Utilization of resources is computed and an analysis of inefficiencies is presented for each unit. Possible solutions of inefficiencies and further work are also discussed.

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INTRODUCTION

The applications of operations management have invaded every industry including healthcare; with the alarming increased demand on health services in the previous decade, health care units are under higher pressure to meet those demands by increasing throughput and ensuring operational efficiency. Given the high costs incurred by medical centers and the sophisticated tools that are now incorporated, improving efficiency and quality become key objectives. The American University of Beirut Medical Center (AUBMC) represents a valid example of the challenges described above.

A. American University of Beirut Medical Center

The American University of Beirut Medical Center (AUBMC) is one of the most trusted medical centers in Lebanon and the region handling more than 300,000 patients on an annual basis. The medical center strives to improve the health of the Lebanese community by delivering a quality of care that is both exceptional and comprehensive to its patients while maintaining superiority in education and training, and leadership in innovative research (www.aubmc.org). With an ambitious vision to become the leading medical institution in the region, AUBMC is bringing up the level of medical education, care, and research and practice towards excellence. With a variety of departments and services offered, the diagnostic radiology department is the department of interest for this project.

B. Evidence- based Healthcare Management Unit

The Evidence-based Healthcare management unit (EHMU) is a "cross-disciplinary research unit contributing to the development and improvement of management and leadership at AUBMC along with other national and regional health care services"(www.aub.edu.lb). The unit is based on the aggregate efforts of various departments and faculties and aims to encourage innovation by having multi-disciplinary research and merging the distinct areas of expertise. Generating knowledge and evidence to ensure efficient application of management is an important feature at EHMU. EHMU's vision is to become the leading hub in the region which facilitates knowledge generation and service improvement.

C. Diagnostic Radiology

The diagnostic radiology department has a mission of providing the "highest standards of imaging services and consultation" to meet patients' needs (www.aubmc.org). The department specializes in making diagnosis and providing "state-of-art interventional radiology service" by using advanced radiological equipment (www.aubmc.org). The aim of the department is to minimize patient exposure to harmful radiations and participating in an education program that tailors to the needs of all staff and students. On an operations level, the radiology department's vision is to maintain a leadership position in imaging services while updating to keep up with the technical and medical advances. The services provided by the department are as follows: general radiology and fluoroscopy, ultrasonography, computed tomography (CT), magnetic resonance imaging (MRI), mammography, and nuclear scanning (www.aubmc.org).

D. Challenges faced at the Radiology department

The radiology department of AUBMC is facing a dilemma, there are patients complaining about the long waiting times before they do a scan which is therefore affecting their satisfaction. The staff at the CT and MRI units stated that the reason for long waiting times is machine over-utilization and thus there isn't enough capacity to account for the large flow rate occurring at those units. The staff claims that the problem could be solved if new machines are bought. However, there is no quantitative evidence supporting this claim and thus there is a need to study whether machines are really over-utilized or there might be inefficiencies affecting the workflow while having a relatively low utilization of machines.

E. Project Organization

This paper is organized as such: chapter II presents a review of the literature, chapter III presents the methodology for data collection and analysis, chapters IV and V present a description of the process, utilization rates, observed inefficiencies and possible solutions for both the CT and MRI units respectively, Chapter VI discusses whether new machines should be bought, and finally chapter VII presents some limitations, conclusion, and suggestions for further research.

CHAPTER II

LITTERATURE REVIEW

The literature on the radiology process flow will be divided into two parts: literature describing the process and the literature recommending improvements to the process.

Literature has described the process workflow at the radiology department in the light of the increased use of imaging technology which necessitates the efficient operation of those resources. Efficiency can be defined as the number of scans that are done per operating day of 10 hours. It is driven by technology availability, speed of finishing a single test, and staff productivity (Radiology business Journal, 2012).

Parra et al. (2004) described the operations management applications to radiology. He suggested that utilization is calculated based on the setup time and the capacity of the work center which is defined as the available operating hours for a period of time given equipment constraints and the labor runtime. Evaluating the capacity of the operational unit allows its multi-dimensional assessment (costs, quality, customer satisfaction, etc.).

Tolkki (2004) stated that time is one of the most important resources in radiology for two main reasons; the first being the fact that over 75% of cost streams are related to time and the second is that radiology units are diagnostic units. While conducting research at Helsinki Medical Imaging Center, Tolkki estimated that regardless of the exam type, a patient spends on average 27 minutes in the MRI room whereas a patient in CT spends 14 minutes.

Regarding redesigning the workflow, Boland (2008) suggested that it is better if radiographers are able to plan ahead and know in advance for example, the blood profile of the patient rather than one hour before the start of the exam. Moreover, patients' requests and their respective examination protocols should be chosen the day before the procedure to reduce uncertainty and time loss on the day of the scan.

Duszak et al (2012) discussed the prevailing models for medical utilization management; utilization management is important due to the increased demand in recent years relative to other medical services and the associated rise in costs.

The Canadian Association of Radiologists sets different scopes from which utilization can be assessed. The first being the number of examinations; the second is the number of shifts used per week and the third is the number of staff rotating through the equipment. Table 1 shows the expected utilization of equipment based on the number of examinations per year.

Table 1: Utilization based on the number of exams/year

Device type	**High** **24 hours 5 days/week**	**MID** **16 hours 5 days /week**	**Low** **8 hours 5 days /week**
CT scanner	>15,000	7,500-15,000	<7,500
MRI scanner	>8,000	4,000-8,000	<4,000

Source: Canadian Association of Radiologists; available from http://www.car.ca/; Internet; accessed 20 February 2014.

The American College of Radiology stated that, in 2009, the equipment utilization rate has increased from 50 to 90% for MRI, CT, and PET scans. The new standard assumed that costly machines and equipment (above 1 million dollar cost) should be operated close to its full capacity (www.acr.org).

Moving on to the part of the literature focusing on identifying inefficiencies and suggesting improvements to the process, current programs in radiology focus on optimizing the utilization of its existing resources. Methods such as lean six-sigma and evidence based decision making are used for the purpose of process analysis in order to increase capacity of current resources and improve access to diagnostic imaging while increasing satisfaction of staff and patients (Radiology business Journal, 2012).

Reviewing the relevant literature shows the recommendations for process improvement in radiology departments. The operations management of the radiology services was described by Lev et al (1976) where analysis was focused on finding the reasons behind the long waiting times at the Temple University's diagnostic Radiology department given that equipment utilization was low. While a trivial solution to long waiting times or accumulating queues would be buying new machines or hiring additional staff, this would increase the associated costs to an alarming rate.

Rosenquist (1987) investigated the issue of queuing analysis drawing out to a remarkable observation of having huge waiting times despite a small increase in demand. He assumed that if arrivals have a Poisson distribution, then a 5% increase in demand would double the waiting time (from 40 to 86 minutes).

Cherry et al (2000) studied the effect of applying 6 sigma techniques to radiology, which has led to decreased waiting time from arrival to time of exam, decreased waiting time for registration process, and enhanced radiology scheduling process.

Centeno et al (2000) studied the effect of varying some constraints on the overall costs and utilization of resources; some of these constraints are having one radiographer or two and using a 6 day weekly schedule. The results concluded that having one radiographer is sufficient and more cost effective for the short run at least.

Halsted and Froehle (2008) discussed the impact of the multitasking environment of the radiographer and its subsequent effect on the workflow efficiency. They concluded that multitasking can be a source of distraction and might lead to discarding important investigations or forgetting to report important findings.

Boland (2008) suggested the following three tactics to improve capacity; two of which are the addition of radiographers and redefining the workflow of the process. According to Boland (2008), a radiographer has to do around 34 tasks to process the patient through the scanner. Moreover, these tasks are done in a sequential rather than in a parallel manner which affects profoundly patient throughput which is estimated to be around 2-3 patients per hour.

Nickel and Schmidt (2009) considered a German University hospital and observed the "paradox" that could occur when there is a simultaneous occurrence of waiting times and machines idle time. Nickel and Schmidt (2009) believe that the reason for this inconsistency is organizational reasons or computer technical errors of machines.

A study by Tokur et al. (2011) at the University Hospital of Mannheim, Germany showed that several factors affect the total MRI processing time; some factors include: performing multiple scans, using oral contrast, placing IVs for outpatients, and scanning for young patients. Tokur et al (2011) recommended that during scheduling, more flexible scheduling should be done and for patients who arrive late, there should be a rescheduling policy.

Begen and Queyranne (2011) were interested in scheduling appointments taking into considerations the tradeoffs between underutilization, overtime, and job waiting times. For example, when a procedure finishes earlier than the next scheduled appointment, resources stand idle whereas when a procedure finishes later, waiting time exists. When processing time is variable, scheduling becomes more challenging and valuable.

Schneider (2011) used the practice of the Radiology department of Leiden University to deploy improvements into the process. Different scenarios were considered to give most promising interventions examples include: increasing access times by having additional staff, extending operational hours, and efficiency improvement by decreasing the required staff per procedure.

All of the processes described above fall under the umbrella of quality improvement. The focus of quality improvement in Radiology is to improve the diagnostic procedures, the quality of healthcare delivered, and the effective management of all imaging services (Kruskal et al, 2011).

CHAPTER III

METHODOLOGY

A. Scope of study

This study focused on two major units of the radiology department, the MRI and CT units.

B. Hypothesis

The current operational system is creating inefficiencies that are causing a paradox to occur; on one hand there is a symptom of overutilization validated by customer waiting times and on the other hand, machines might be standing idle and are not being effectively utilized.

C. Data Collection

The radiology department receives outpatients (scheduled and drop ins) from 7:30 am till 7 pm. After 7 pm, the time is allocated for inpatients and emergency patients only.

1. CT

For the CT unit, data collection ranged between different time intervals starting from 7:30 am till 9 pm. Since the scan procedure was fast, only one machine was considered per day of data collection and the 11 days were divided between both machines. The process of scanning was divided into steps and time was recorded for the completion of each step. The time records involved:

- Time patient enters the CT room
- Time taken to change clothes (if required)
- Time patient is prepared for scanning
- Time scanning starts and the time it ends
- Time taken to change clothes (if required)
- Image Reconstruction Time
- Time the patient leaves.

Other considerations were taken into account during data collection such as the type of exam, whether the radiographer injects the IV catheter in the scan room, and the time taken to process the image.

Note: The first 5 days correspond to data collected for Spiral CT, whereas the remaining 6 days were for Siemens machine.

2. MRI

For the MRI unit, the time frame from 7:30 am till 7 pm was considered. Given that the scanning procedure takes relatively longer time than CT, observations were taking into consideration the two machines at the same time for 13 days. After observations and understanding of the process, the following time parameters were deemed significant indicators for the process efficiency:

- The time patient enters zone 3 (an area adjacent to the scanning room)
- The time patient enters the scanning room
- The start and end time of the scanning process
- The time the patient leaves

Exam types were also considered since the time taken by each scan is highly reliant on its type. It is worth to mention that due to the design of the MRI unit, it was unfeasible to accurately estimate the screening time and the time each patient spends changing his/her clothes. There was a locking door that separates the changing room area from the scanning room zone.

Important remark: sometimes when observation time starts, there were already patients being scanned; however the time of actual start was not known. If the observation starts at 10 am for example and there is a patient on the machine by that time, then the fraction of the time that the patient spends until he/she finishes is added to the numerator. This would better reflect the time that the machine is being effectively operated given the total available time.

D. Analysis Method

Initial observations aimed at understanding the process and the workflow in the MRI and CT. Then, after data collection, qualitative analysis of the process led to identifying inefficiencies of the process in each department. Moreover, using the data of processing time helped estimate the arrival process and service time distribution, for each department. Based on the arrival and service time estimates, the system was analyzed quantitatively and the system utilization was estimated. Using the qualitative analysis along with the quantitative analysis helped clarify and identify areas for improvement and allowed for better decision making in terms of the potential actions that can improve the current system's operations.

Chapter IV

COMPUTED TOMOGRAPHY (CT)

A. Brief Description about the unit and its Resources

The computed tomography unit is a major diagnostic tool in medicine. Given its importance, the unit offers a comprehensive range of 113 procedures to patients of all age groups. In terms of **equipment**, there are two CT scanners available: the Siemens machine (64 Multi Slice Detector) and a high definition spiral CT. Both machines can be used for all routine exams; however, for cardiac and severely traumatized patients only the spiral CT is used.

Regarding **staff**, the process can be divided between scheduling and operations. For scheduling, a receptionist is available at a reception desk to handle scheduling, guarantee paperwork is done before the patient performs the scan, informs radiographers of patients arrival, and coordinates inpatient flow for scanning. For process operation, there are six radiographers assigned to the CT unit; three are senior radiographers and three are junior. Each machine should be operated by at least one senior radiographer per shift. During peak hours which usually range from 10 am till 3 pm, one of the radiographers acts as a process flow coordinator and helps speed up the process by aiding radiographers in managing patients and ensuring smooth patients' flow. Additional supporting staff is also available to aid in some types of procedures. Registered nurses (RN) are usually called to take care of patients in case of a Cardiography or a biopsy. In addition, orderly staff is responsible for safe the transport of emergency patients and inpatients. It is worth to mention that a number of professors and resident doctors ensure image quality, patient safety, provide supervision and feedback, and perform biopsy procedures to patients.

B. Types of Patients

In general patients arriving at the CT unit fall into one of four categories:

- **Scheduled Outpatients**: these are patients who are referred by physicians to do a scan; they are usually scheduled well in advance of the scan date.
- **Inpatients**: this category includes patients who are currently under treatment in hospitalized settings. Arrival times are usually known on the day of the scan or a day before and are less predictable than outpatients.
- **Emergency patients:** these patients require immediate medical attention and are given priority over all other patients. Arrival pattern is unpredictable for this category.
- **Drop in Outpatients:** patients in this category arrive without having a scheduled appointment; they usually wait for a vacancy between two appointments. Arrival rate is unpredictable for this category.

By observing data of appointments statistics, it was noticed that the majority of patients who arrive at the CT unit are not given appointments before time on the system. The CT unit does not follow a whole appointment system and a lot of flexibility is available as patients can walk in and ask for a same day scan.

C. Number of Scans & Patient Distribution

Historical data for the past 14 months were obtained in order to have an estimate on the number of patients who visit the CT unit per months. The results are shown in Figure1.

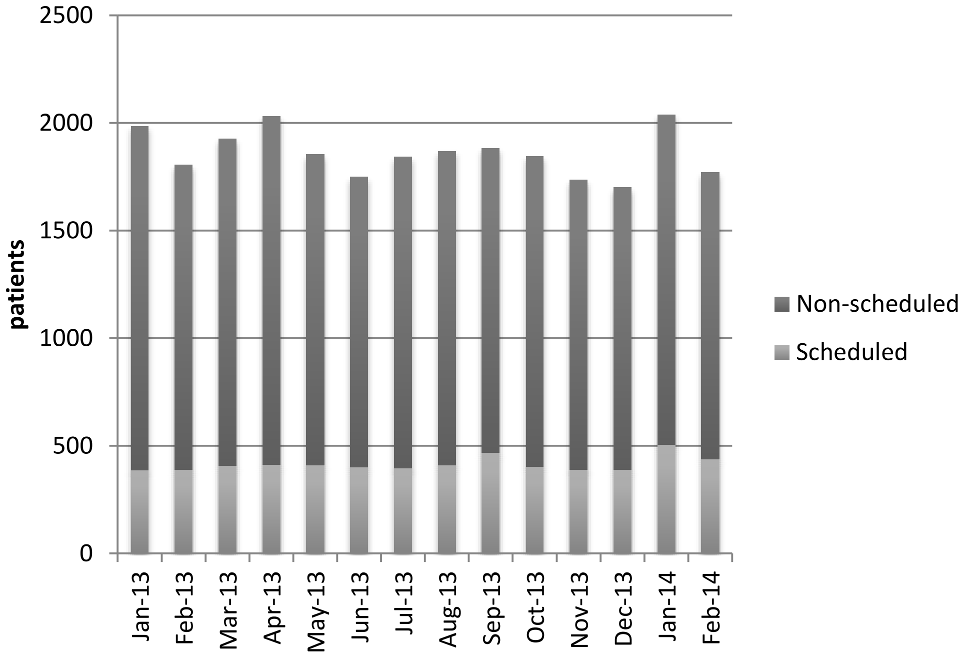

Figure 1:Total Number of Scans for both Machines (Year 2013)

On average, 1860 patients visit the CT unit each month, 416 patients (corresponding to a percentage of 22%) are scheduled outpatients and 1445 patients (corresponding to a percentage of 78%) are divided between drop in outpatients, inpatients, and emergency department patients. Analysis shows that 19% of patients are outpatients who drop in, 28% are inpatients, and 31% are ER patients (Figure 2).

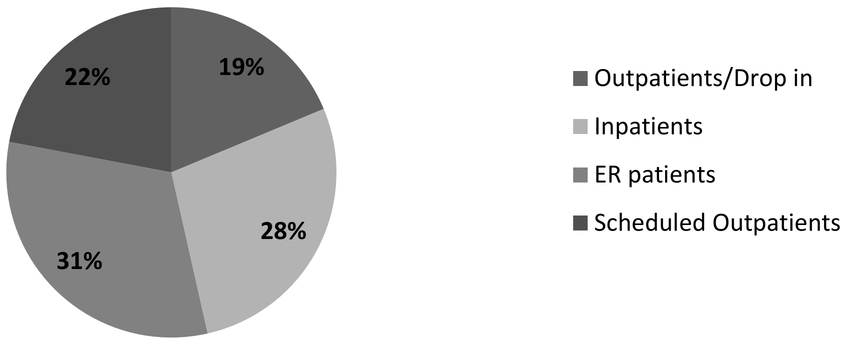

Figure 2: Types of Patients

D. Process Description

Walk-in and scheduled outpatients arrive at the reception desk of the unit after having completed their paperwork and paid at the cashier. The receptionist makes sure that the paperwork is completed, marks the patient's name on the system if scheduled or schedules walk in patients on the system, and then takes the patient's papers into the control room where the radiographer can see the pending work to be processed. For most types of procedures, the receptionist allocates exams based on the availability of radiographers and not based on the machine type. The radiographer then goes into the waiting room and calls for the patient's name. Depending on the type of the exam, the radiographer might ask the patient to change his/her clothes and wear a gown in a changing room based next to the scan room. The radiographer then adjusts the patient's position on the scanning machine and gives a brief explanation about the process. The radiographer then goes back into the control room and starts the scanning process. After finishing, the radiographer enters the scan room to lift the patient from the machine, while informing the patient when to take his/her results. The patient then changes his/her clothes (if needed) and leaves the scan room which becomes ready for the next patient. Inpatients and emergency patients, on the other hand, are usually carried by orderly staff on a stretcher and they are admitted directly into the scan room.

Figure 3 shows the process flow diagram of the CT unit.

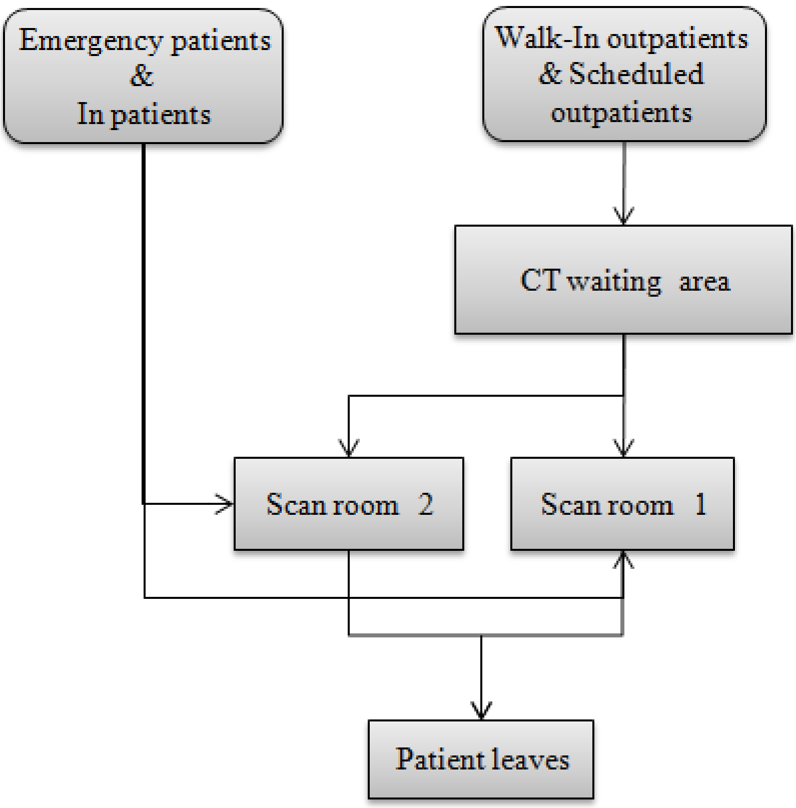

Figure 3: CT Process Flow

E. Machine Occupancy

After data collection, computations were done to assess machine utilization. Machine utilization was assessed based on the total time the patient occupies the machine over the total available time. Thus, utilization is equal to machine occupancy which incorporates the time that is used for patient preparation and an additional time that is used for scanning.

For each day, the following parameters were computed:

- **Preparation time**: this is the time taken by the radiographer to prepare patients for scanning. It is computed by subtracting start preparation time from end time.
- **Scan time (ST)**: ST is obtained by subtracting start scan time from end scan time.
- **Machine occupancy (MO)**: MO is the sum of the preparation time and the scan time.
- **%Utilization**: was calculated based on the following formula

$$\frac{\text{Total machine occupancy time}}{\text{Total available time}} \times 100$$

The total machine occupancy time was obtained by summing the occupancy time for all patients. For example for Day 1, the total time of machine occupancy was 177 minutes. The total available time is based on the duration of data collection. In Day 1, observations took place between 7:45 am and 14:00 pm and then from 18:54 pm and 20:30 pm. This corresponds to a total of 471 minutes.

- **%PT:** is the percentage of preparation time out of the observation time
- **%ST:** is the percentage of scan time out of the observation time

Table 2 shows a summary and results for a sample day, Day 1.

Table 2: CT-Sample day 1 Calculations

Patient Number	**Time patient enters scan room**	**Preparation**		**Scan**		**Time patient leaves scan room**	**PT**	**ST**	**MO= PT+ ST**	**OT**
		Start	**End**	**Start**	**End**					
1	8:13	8:14	8:27	8:27	8:32	8:35	13	5	18	**7:45am - 14:00pm**
2	8:56	8:58	8:59	8:59	9:02	9:06	1	3	4	
3	9:21	9:26	9:35	9:35	9:42	9:52	9	7	16	
4*	9:47	9:47	9:59			10:12	12		12	
5	10:15	10:19	10:25	10:25	10:41	10:50	6	16	22	
6	10:44	10:44	10:46	10:46	10:49	10:50	2	3	5	
4*	10:58	10:58	11:06	11:06	11:22	11:39	8	16	24	
7	11:40	11:42	11:47	11:47	11:56	11:57	5	9	14	
8	11:59	12:00	12:02	12:02	12:05	12:06	2	3	5	
9	12:13	12:13	12:15	12:15	12:18	12:19	2	3	5	
10	12:21	12:21	12:23	12:23	12:27	12:29	2	4	6	
11	12:34	12:34	12:40	12:40	12:48	12:50	6	8	14	
12	13:05	13:08	13:11	13:11	13:17	13:23	3	6	9	
13	13:37	13:38	13:41	13:41	13:43	13:44	3	2	5	
No observations between 14:00pm and 18:54pm										
14	19:38	19:38	19:43	19:43	19:46	19:48	5	3	8	**18:54pm - 20:30pm**
15	19:48	19:48	19:52	19:52	19:54	19:57	4	2	6	
16	20:11	20:19	20:21	20:21	20:23	20:27	2	2	4	
Total time							**85**	**92**	**177**	**471**
Percentage of time							**18%**	**20%**	**38%**	**100%**

PT - preparation time
ST - scan time
MO - machine occupancy
OT - observation time
Patients with cardiography CT are marked with star.
Note: Heart rate for patient 4 was too high to do the scan during the first attempt

The same calculations were applied to all eleven days; results are displayed in Table 3.

Table 3: CT-Results for the eleven days

Day	Number of patients	PT	ST	MO = PT+ST	OT	%PT	%ST	%MO
1	16	85	92	177	471	18%	20%	38%
2	18	67	71	138	505	13%	14%	27%
3	6	56	86	142	321	17%	27%	44%
4	12	28	56	84	315	9%	18%	27%
5	17	56	62	118	327	17%	19%	36%
6	14	46	54	100	290	16%	19%	34%
7	17	56	130	186	335	17%	39%	56%
8	14	56	87	143	298	19%	29%	48%
9	8	62	83	145	252	25%	33%	58%
10	11	32	33	65	272	12%	12%	24%
11	8	15	22	37	298	5%	7%	12%
Total	**141**	**559**	**776**	**1335**	**3684**			
Percentage		**15%**	**21%**	**36%**	**100%**			

PT - preparation time
ST - scan time
MO - machine occupancy
OT - observation time

F. Analysis

Results have shown that the average utilization for the total eleven days was around 36% indicating that both machines are not being effectively utilized. To decompose the results further between the two machines, the parameters were assessed for the first five days which correspond to the Spiral CT. Results indicated a 34% utilization rate while analysis of the last six days showed a utilization of around 39% for the Siemens machine.

Process observations have shown that the majority of gaps during the day and the resulting idle resources are due to patient unavailability; this indicates that the process at the CT unit is demand-constrained which implies that the demand is much less than the capacity of available resources (Figure 4).

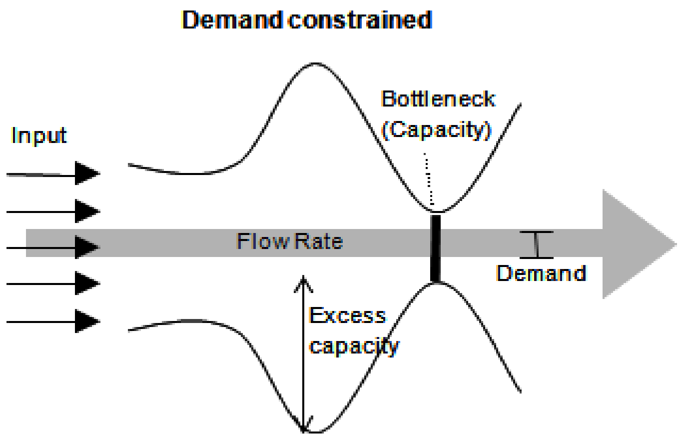

Figure 4: Demand-Constrained Process
Source: Cachon, G., & Terwiesch, C. (2006). *Matching supply with demand* (Vol. 2). New York: McGraw-Hill

Regarding the distribution of patients observed, for the time frame between 7 am and 7:30 pm, there were 106 outpatients (Scheduled and walk-ins), and 22 ER patients and inpatients. On the other hand, considering the time frame after 7 pm, 13 inpatients and ER patients were observed.

To compare the results with the literature, the American College of Radiology recommends machine utilization to be near its full capacity and therefore the recommended rate is 90%. The obtained average of 36% is thus far from the recommended rate.

Other benchmarks were considered to further assess results. Based on the Canadian Association of Radiologists standards, utilization assessment depended on the number of scans that are yearly performed. So last year's scan number was compared with the standards. With a total number of scan of 22,232 scans for both machines for the year 2013, and with results showing an average same utilization for both machines, it will be assumed that scans were divided equally between the two scanners. Thus each scanner is supposed to have performed around 11,116 scans. The Canadian Association of Radiologists sets a medium utilization for a number of scans between 7,500 and 15,000. Therefore, a scan number of 11,116 per machine falls in the range of a medium utilization.

G. Identifying Inefficiencies & Potential Improvements

This section will investigate inefficiencies observed, further elaborate on each and will try to suggest possible solutions.

1. Patient Availability: The Effect of Daily Seasonality

Observations revealed the presence of daily seasonality reflected in patients' arrival patterns. Daily seasonality is a term implying a similar pattern of patients' arrival across the days. For almost all days, there were few patients in the time period between 7:30 am and 10 am. Then patients start to flow into the unit and the bulk of patients who arrive on a given day lie within the time range between 10 am and around 3 pm. After 3pm, patients' flow rate decreases; fewer patients arrive to the CT till 7 p.m. After 7pm, only ER patients and inpatients are scanned with a very few number of patients who do arrive. Daily seasonality was creating a lot of gaps between appointments in non-peak times which resulted in having resources standing idle and therefore a low utilization rate. On the other hand, for observations occurring during peak times, utilization rates were the highest. For example, for non-peak times represented by day 11 (data collected before 10am and after 7 pm), the utilization rate was 16%. Conversely, for a peak observation time represented by day 7 (data collected between 9:30 am and 3 pm), the utilization rate was the highest corresponding to a 56%.

As a possible solution to daily seasonality, it is recommended that increasing the number of scheduled outpatients could increase the number of available patients outside peak periods while maintaining even distribution of the patients among the different time slots. Thus, increasing the number of scans before 10 am and after 4:30 pm would improve the utilization rate.

To improve the flow rate at the unit, it is advisable to market the CT unit further and therefore, increase the awareness of physicians to the unit and the available services it offers. The CT unit should aim at increasing the number of its outpatients in order to increase demand and therefore increase the number of scans.

Recently, after doing data collection for this project and sharing the initial findings with the clinical department administrator, she identified the need to change the theoretical times on PACS to reflect a more accurate estimate of the exam time. As a result, 97 out of the 113 procedures' times were changed and the average reduction in the exam time was around 48%. This would suggest that since the exam time was reduced by almost half, the number of outpatients scheduled would probably increase. Another change that was incorporated in the unit is that outpatient scheduling is now open till 7 pm; it used to be till 4:30 pm. Having this adjustment would improve the utilization of the department's resources as more outpatients would be available for non-peak times.

Given the intended objective of increasing the number of scheduled outpatients, the aforementioned modifications would thus help in more accurate scheduling and increasing the number of scheduled outpatients for a given day.

Note: Now that scheduling is recommended to increase, it is important to draw the attention to some challenges that might be faced; no shows and patients arriving late are two symptoms the CT unit might face. It is therefore important to plan proactively and adjust for these measures by reducing inefficiencies to maximize utilization.

The following inefficiencies are only significant if they occur when there are patients available; otherwise, if they occur in non-peak times, they are not considered sources of inefficiencies and pose no effect on the overall process output.

2. Delays in the Process

There are certain delays that occur in the process external to the radiographers' control; these include: delays in patient transport and delays in physician's arrival.

a. Delays in Patient Transport

Sometimes, there are delays in inpatients and ER patients' transport caused by the orderly staff. Such delays would result in having resources standing idle and therefore are the cause of lower utilization rates.

A possible solution to avoid waiting times during patient transport is to try having some sort of estimate to the number of inpatients who need a CT scan early in the same day in order to plan accordingly and inform orderly staff before time so that the staff is ready.

b. Delays in Physician's arrival

For certain types of exams such as Cardiography procedures specifically, a strict protocol is applied stating that patients' heartbeat should be 70 heartbeats per minute or less to have an acceptable image quality. Ensuring adherence to this protocol was usually delegated to a registered nurse who monitored the patient's heart rate and gave medications to lower the heartbeat if necessary. Sometimes, discussions took place between the radiographer and the nurse on the acceptable heart range before proceeding with the exam which resulted in having delays in the process. However, recently, to ensure adherence to this protocol, a resident doctor is required to be present and make sure that the patients' heart rate allows for the scanning to occur. This still resulted in some waiting time as the radiographer had to wait for the doctor to arrive.

To avoid delays and waiting time in the process, it is advised to inform the physician before time (such as an hour or so before the patient's arrival or at least while the patient is being prepared) on the intended arrival time of a Cardiography patient to reduce instances and durations of delays.

3. Managing Patient Preparation

Patient preparation is ought to be done in a way which minimizes the total preparation time and increases the scan time to machine occupancy percentage. In the current process, although a process flow coordinator (radiographer) is assigned during peak times, radiographers often do not coordinate their activities to overlap some of these tasks. Instead, radiographers take shifts and only one radiographer at a time performs the whole sequence of tasks. This is causing delays in the process as the staff is not reducing the cycle time of the scanning procedures.

To investigate whether the radiographer could be the bottleneck in the process given that patients are readily available, the patient preparation time was compared to the scan time. If patient preparation took longer than scan time, then the radiographer would be the bottleneck. Data analysis showed that in 45% of the cases with contrast, the catheter insertion took more time than the actual scanning process; whereas for the cases without contrast, in 29% of the cases, preparation time was longer than scan time. These findings indicate that patient preparation activity is time consuming and the speed of the radiographer could therefore affect the speed of the process.

Assigning a process flow coordinator to help radiographers with their tasks to be done is a possible solution to reduce the number of radiographers' tasks. The process flow coordinator (PFC) need not to be a radiographer; he/she could be trained on the tasks of the CT scanning process and the different rules and protocols. The PFC could be trained for example to insert the IV catheter which is one of the most time consuming activities in the patient preparation process. Thus, in cases where patients need IV catheters, the PFC could insert IV catheters in a preparation room while the radiographer is scanning a patient. This would help reduce waiting times by reducing the number of activities required for patient preparation inside the scan room and thus improve the scan time to machine occupancy time percentage. Implementing this solution is probably less expensive than hiring an additional radiographer and would help improve the throughput of patients as the number of tasks to be done by radiographers is reduced.

4. Radiographer is overloaded with tasks to be done

Observations have shown that the radiographer has many tasks to do which affects the flow rate of the scanning process. In fact, the radiographer performs around 10 sequential tasks per each procedure some of which are the bottlenecks in the process. The tasks done by the radiographer independent of the exam type include:

- Calling the patient into the scan room

- Giving instructions to the patient about the scan procedure while asking the patient to change his/her clothes
- Seating the patient on the scanner
- If required, the radiographer inserts an IV catheter
- If required, radiographer checks patient's blood profile
- Radiographer chooses the patient's name on the system
- Radiographer starts the scanning process
- Radiographer processes the image to make sure its within required standards
- After scanning, radiographer talks to the patient while helping the patient step out of the scanner
- Radiographer answers calls before, during, or after the scanning process

All of the tasks mentioned above are done in a sequential manner and not in a parallel manner. Moreover, the findings presented in the section above show that process speed up by having multiple tasks done in parallel or having part of patient preparation occurring before patient entry would speed up the process.

Related to this issue is an additional task required which is recording the time the patient starts the exam and the time the patient leaves. Asking radiographers to do manual recordings adds to the number of tasks that are done by the radiographer and is prone to error. Therefore, if possible, the PACS (Picture Archiving and Communication System) should be able to automatically record the start and end time of the scanning process rather than relying on manual recording by radiographers. It is important to have the recordings of scan times to be able to continuously assess the overall efficiency of the process, help detect and proactively avoid any possible inefficiencies.

5. Changing room Impact

The changing rooms could possibly be a cause of some waiting time by limiting the ability of having patients' changing their clothes while another patient is scanning. For example, the Siemens machine's changing room was only able to accommodate one patient at a time. This is due to management's assumption that the Spiral CT would be used mainly for outpatients whereas the Siemens machine would be used for emergency patients and inpatients. However, observations have shown that patient assignment to exam rooms was done according to the availability of each and not according to the type of exam. This resulted in waiting times where the coming outpatient had to wait for the previous patient to change their clothes.

Even in the case of the Spiral CT, which has the ability to accommodate for two patients simultaneously, some waiting time could arise if the time for changing clothes is longer than the actual scan time. Picture this scenario (Figure 5); patient 1 enters the first change room at 9:00 am to change his/her clothes and then goes to the scan room; scanning takes around 3 minutes and then he/she goes back to change. After 5 minutes of changing patient 1 leaves at 9:11 am. If a second patient needs to be prepared while patient 1 is getting scanned, then patient 2 can be admitted to change room 2 at 9:03 am. Each of the activities, changing into a gown and scanning takes around 3 minutes while changing back takes around 2 minutes. Patient 2 thus would leave at 9:11. Now if a third patient is needs to be prepared, he/she can't be admitted before one of the two patients leave. When patient 1 or 2 leaves at 9:11, patient 3 could use one of the vacant change rooms. By the end of scanning the second patient at around 9:09 am, the radiographer would have been waiting for patient 2 to change their clothes and for patient 3 to finish changing their clothes; this totals around 6 minutes of waiting time.

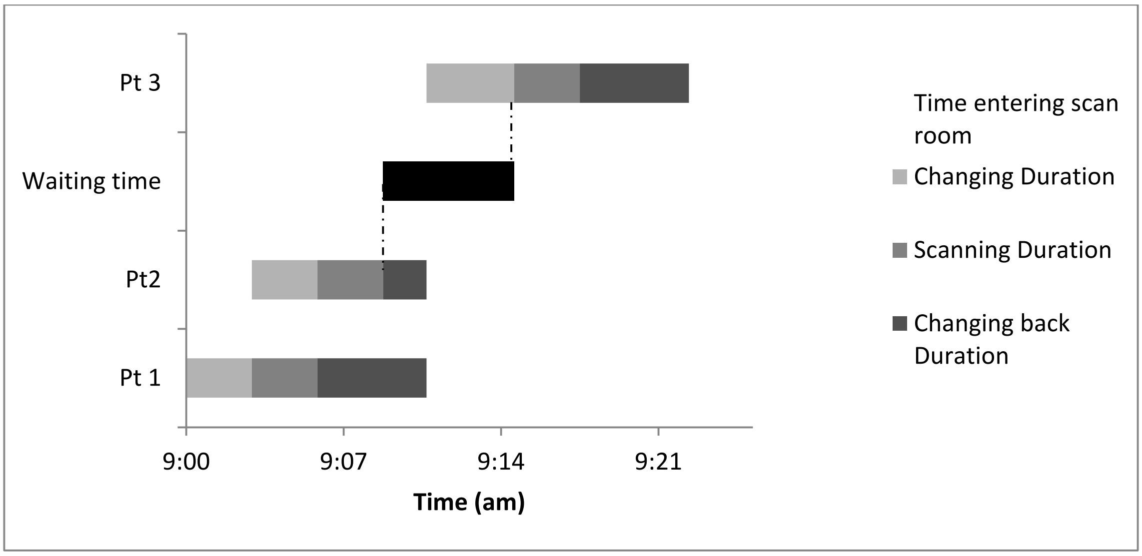

Figure 5: Gantt Chart-Change Room Structure Showing Waiting Time

This issue could become more prominent if scheduling for outpatients increases and thus several patients might need to change their clothes. Also, if a parallel step process needs to be implemented, then the changing room creating waiting time could hinder the effective implementation of a parallel processing method.

A possible solution to waiting time due to change room design could be having the room accommodating for at least 3 patients at a time.

6. Further Suggestions:

a. <u>Have a CT scanner for the Emergency Department</u>

Statistical analysis has shown that around 31%of patient arrivals come from emergency patients. Therefore, in case a new scanner is required, it could be possible to have a CT scanner somewhere near the emergency department in order to ensure faster scans and guarantee patient safety by providing immediate medical testing for patients who are in critical condition.

b. Reduce Noise and Chaos in the Unit

Observations in the unit revealed that the CT is a busy unit with staff such as nurses and physicians continually visiting the control room. At certain points, up to 13 staff members were crowding the CT control room and causing too much noise which would cause radiographers to lose focus and, therefore, increase the risk of having errors. Thus, it is recommended that the unit should be given more privacy and only staff members who are directly involved in the scanning process should be allowed admittance into the control room.

H. Overall Equipment Effectiveness

The overall equipment effectiveness diagram shows how the total observation time is divided between the different activities and inefficiencies discussed above. As it can be shown, 46% of the total planned time is due to gaps which result from patient unavailability. This is the major source of inefficiency. After removing the preparation time from the machine occupancy, only 21% of the time is allocated for the scanning activity. Figure 6 shows a summary of the OEE chart.

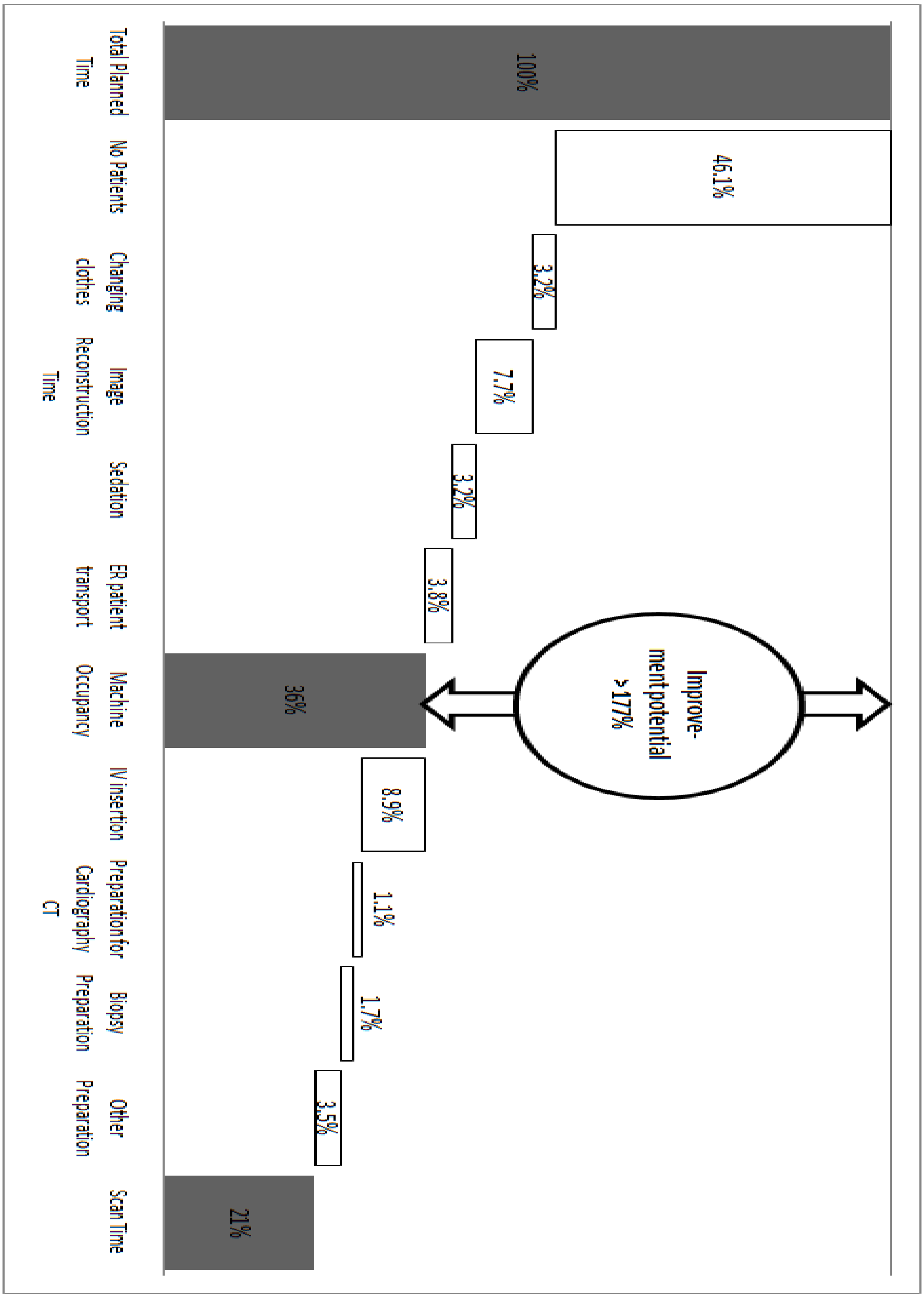

Figure 6: OEE Chart for CT

Chapter V

MAGNETIC RESONANCE IMAGING (MRI)

A. Brief Description of the Unit and its Resources:

The Magnetic resonance imaging is an equally important diagnostic tool that gives detailed images of body organs and tissues. AUBMC's MRI unit provides a comprehensive range of 82 different types of procedures for patients of all age groups. In terms of equipment, there are two MRI scanners available: the MRI 1.5T and the 3 T MR Scanners. Both machines are used interchangeably for most types of exams; however, the 3 T is a more advanced scanner that is exclusively used for some types of exams such as the cardiac scan.

The staff responsible for running the unit is divided between operations (scanning) and scheduling. For scheduling, a receptionist is available at a reception desk to handle scheduling, guarantee paperwork is done before the patient performs the scan, informs radiographers of patients' arrival, and coordinates inpatient flow. For process operations, there are usually two junior and four senior radiographers among of which is a unit supervisor. Additional supporting staff is also available to aid in some types of procedures. Registered nurses are usually called to inject the IV catheter for certain types of exams as well as monitor the patient's heartbeat. In addition, orderly staff is responsible for safe the transport of inpatients. Also, special staff of anesthetic doctors is assigned every Tuesday which is allocated for pediatric scanning. Similar to the CT unit, a number of professors and resident doctors ensure image quality, patient safety, provide supervision and feedback, and perform biopsy procedures to patients.

B. Types of Patients

Patients arriving at the MRI unit fall into one of three categories:

- **Outpatients**: these are patients who are referred by physicians to do a scan; the arrival pattern is usually well known in advance for this category.
- **Inpatients**: this category includes patients who are currently under treatment in hospitalized settings. Arrival pattern is usually known at the same day or a day before.
- **Drop in Patients:** patients in this category arrive without having a scheduled appointment; they usually wait for a vacancy between two appointments. The arrival pattern for this category is not known before time.

C. Number of scans

Historical data for the past 14 months were obtained in order to have an estimate on the number of patients who visit the MRI unit per month. The results are shown in Figure 7.

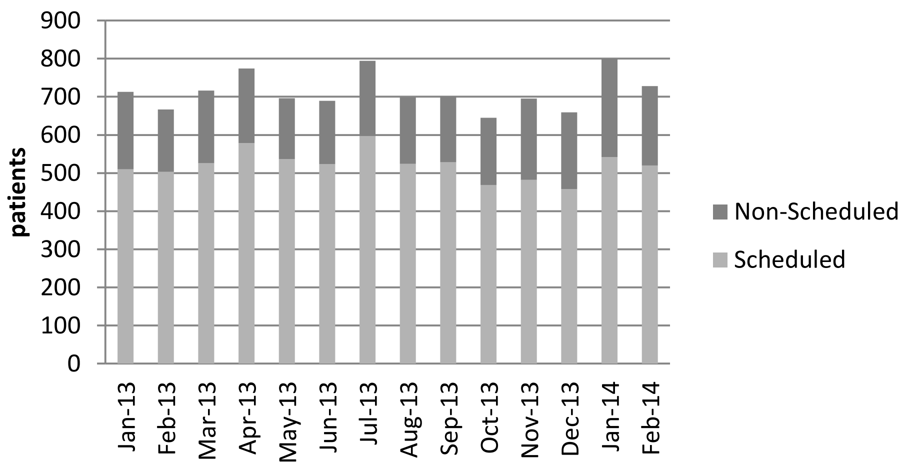

Figure 7: Total Number of Scans for both Machines (Year 2013)

On average, 713 patients visit the MRI unit each month, 521 patients are scheduled outpatients and 191 are non-scheduled patients who are either walk in outpatients or inpatients. Scheduled outpatients represent 73% of the total number of scans whereas non-scheduled patients represent 27% of the total scans.

The MRI unit follows a strictly appointment system and analysis of the various arrivals rate distribution shows that among the 27% of non-scheduled patients, 11% are outpatients who walk in and 16% are inpatients (Figure 8).

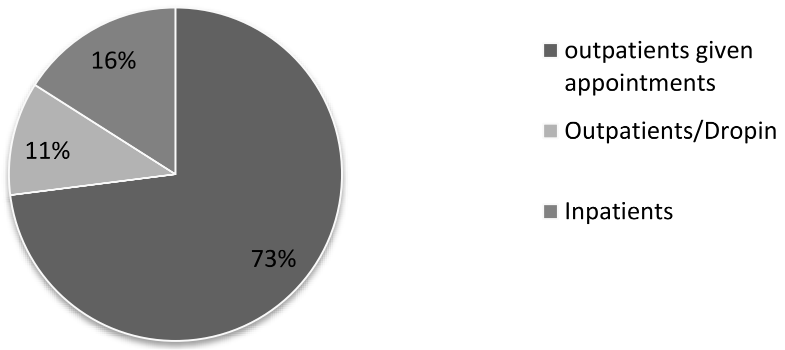

Figure 8: Types of Patients

D. Process Description

Walk-in and scheduled patients arrive at the reception desk of the unit after having completed their paperwork and paid at the cashier. The receptionist makes sure that the paperwork is completed and marks the patient’s arrival on the system so that radiographers are informed. The radiographer then calls the patients and asks them to enter into a changing room zone where he/she screens patients first to identify any risks (example if patient has heart problems and/or has a pacemaker) and if there are special considerations that might affect the scanning procedure such as if the patient is claustrophobic. After finishing screening and signing a consent form, patients are asked to change their clothes into a gown and keep all their belongings in assigned lockers. Patients are then escorted by radiographers into the scanning room. Once the exam is completed, patients go back to the changing area where they change back their clothes, take their belongings, and then leave. Inpatients, on the other hand, are carried by orderly staff on a stretcher or a wheel chair; they are also screened and then they are escorted into the scan room. Figure 9 shows the process flow diagram.

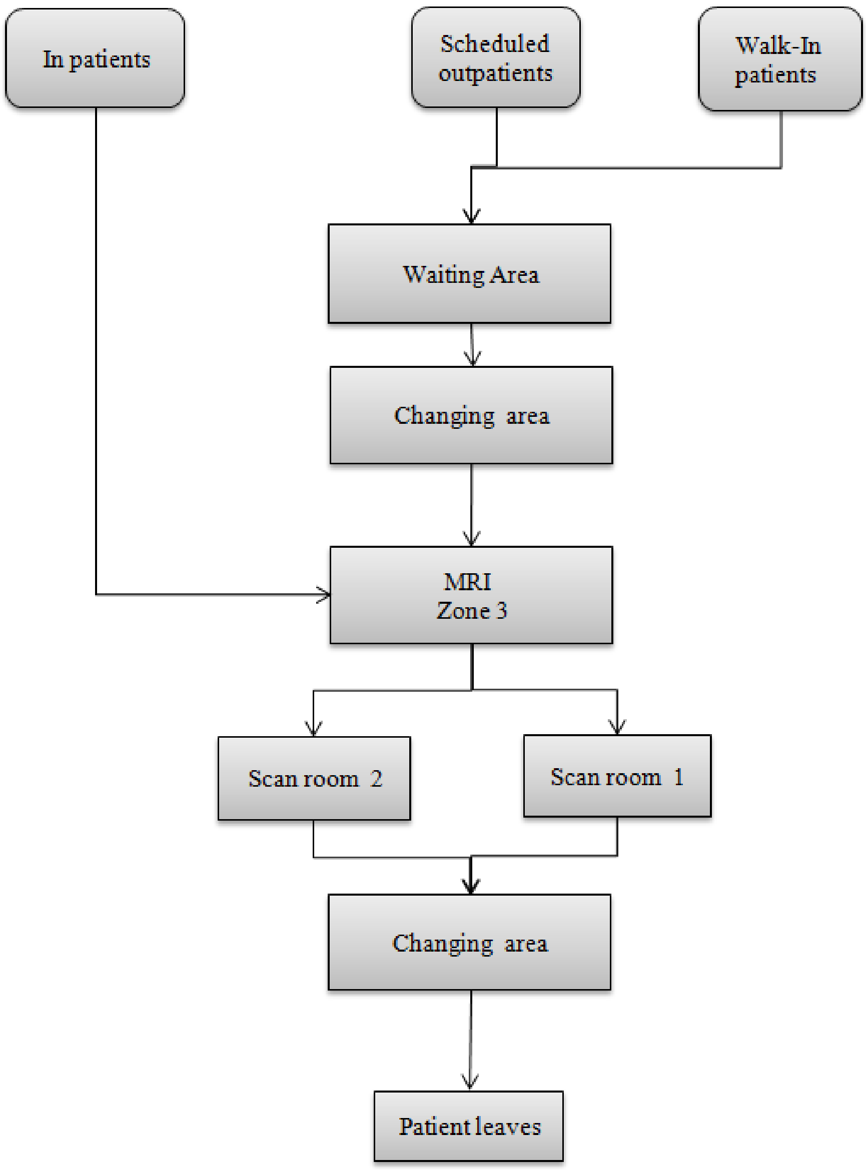

Figure 9: MRI Process Flow

E. Machine Occupancy

Data collection allowed for computations to assess machine utilization. Machine utilization was calculated based on the total time that the patient occupies the machine over the total available time. In the case of MRI, machine utilization was mostly allocated for scanning time as preparation took a small fraction of the overall machine occupancy time.

For each day, the following parameters were computed:

- **Scheduled Machine Occupancy time**: this incorporates the estimated cycle time which is estimated on the PACS. It is calculated by subtracting the start time from end time.
- **Preparation time**: this is the time taken by the radiographer to prepare patients for scanning. It is computed by subtracting start preparation time from end time.
- **Scan time (ST)**: ST is obtained by subtracting start scan time from end scan time.
- **Machine occupancy (MO)**: MO is the sum of the preparation time and the scan time.
- **%Utilization**: is calculated based on the following formula

$$\frac{\text{Total machine occupancy time}}{\text{Total available time}} \times 100$$

The total machine occupancy time is obtained by summing the occupancy time for all patients. For example for Day 4, the total time of machine occupancy was 236 minutes. The total available time is based on the duration of data collection. In Day 4, observations took place between 7:30 am and 12:39 pm. This corresponds to a total of 309 minutes.

- **%PT:** is the percentage of preparation time out of the observation time
- **%ST:** is the percentage of scan time out of the observation time

Table 4 shows the results for a sample day 4.

Table 4: MRI-Results for sample day 4

3T		**Preparation**		**Scan**						
Patient	**Time Pt enters the scan room**	**Start**	**End**	**Start**	**End**	**Time Pt leaves the scan room**	**PT**	**ST**	**MO**	**OT**
1	7:41	7:41	7:45	7:45	9:10	9:13	4	85	89	**observation took place between 7:30 and 12:39**
2	9:27	9:27	9:29	9:29	9:51	9:55	2	22	24	
3	9:59	9:59	10:01	10:01	10:54	10:56	2	53	55	
4	11:28	11:28	11:39	11:39	11:47	11:49	11	8	19	
Total Time							**19**	**168**	**187**	
Percentage of Time							6%	54%	61%	
1.5 T		**Preparation**		**Scan**						
Patient	**Time Pt enters the scan room**	**Start**	**End**	**Start**	**End**	**Time Pt leaves the scan room**	**PT**	**ST**	**MO**	
1	7:45	7:45	7:59	7:59	8:45	8:48	14	46	60	
2	9:01	9:01	9:12	9:12	10:04	10:07	11	52	63	
3	10:07	10:07	10:10	10:10	10:37	10:39	3	27	30	
4	11:08	11:08	11:13	11:13	11:55	11:56	5	42	47	
5	12:02	12:02	12:05	12:05	12:38	12:39	3	33	36	
Total time							**36**	**200**	**236**	**309**
Percentage of Time							12%	65%	76%	
PT - preparation time ST - scan time MO - machine occupancy OT - observation time										

The same calculations are applied for all days; results were divided between 3T machine displayed in table 5 and 1.5 T machine displayed in table 6.

Table 5: MRI-Results for all days (3T)

3 T								
Day	**Number of patients**	**PT**	**ST**	**MO**	**OT**	**%PT**	**%ST**	**%MO**
1	4	23	135	158	300	8%	45%	53%
2	8	29	396	425	570	5%	69%	75%
3	10	82	548	630	740	11%	74%	85%
4	4	19	168	187	309	6%	54%	61%
5	4	14	189	203	300	5%	63%	68%
6	6	20	241	261	312	6%	77%	84%
7	5	22	198	220	312	7%	63%	71%
8	4	25	141	166	225	11%	63%	74%
9	5	19	168	187	285	7%	59%	66%
10	4	17	156	173	300	6%	52%	58%
11	4	19	167	186	210	9%	80%	89%
12	2	15	126	141	326	5%	39%	43%
13	4	19	196	215	286	7%	69%	75%
Total	**64**	**323**	**2829**	**3152**	**4475**			
Percentage		**7%**	**63%**	**70%**	**100%**			

PT - preparation time
ST - scan time
MO - machine occupancy
OT - observation time

Table 6: MRI-Results for all days (1.5T)

1.5 T								
Day	**Number of patients**	**PT**	**ST**	**MO**	**OT**	**%PT**	**%ST**	**%MO**
1	4	12	87	99	300	4%	29%	33%
2	9	44	322	366	570	8%	56%	64%
3	12	32	466	498	740	4%	63%	67%
4	5	36	200	236	309	12%	65%	76%
5	4	26	221	247	300	9%	74%	82%
6	5	23	242	265	312	7%	78%	85%
7	5	18	180	198	312	6%	58%	63%
8	4	27	187	214	225	12%	83%	95%
9	4	25	225	250	285	9%	79%	88%
10	3	42	160	202	300	14%	53%	67%
11	3	18	103	121	210	9%	49%	58%
12	4	21	163	184	326	6%	50%	56%
13	4	20	135	155	286	7%	47%	54%
Total	**66**	**344**	**2691**	**3035**	**4475**	8%	60%	
Percentage		**8%**	**60%**	**68%**	**100%**			
PT - preparation time ST - scan time MO - machine occupancy OT - observation time								

F. Results analysis

As table 6 indicates, the average % utilization for 3T machine was 70% whereas table 7 shows that for 1.5T was 68%. For the 3T machine the maximum utilization reached was 89% and the minimum utilization was 43%. As for the 1.5T, the maximum utilization reached was 95% whereas the minimum utilization was 33%. The main reason for this discrepancy in utilizations was the “no shows”; no shows increased the gap time and thus resulted in lower machine occupancy time and utilization rates.

Comparing both machines, the 3T machine did 64 scans whereas the 1.5 T did 66 scans. So in terms of speed, both were almost equal although it is estimated that the

3T has the ability to increase patient throughput by 30% (Byers, 2012). Therefore, further investigation is needed to determine the reason for why this increased throughput is not achieved.

Analysis of the process at the MRI have has shown that the process is supply-constrained which implies that demand is higher than the capacity of available resources (Figure 10).

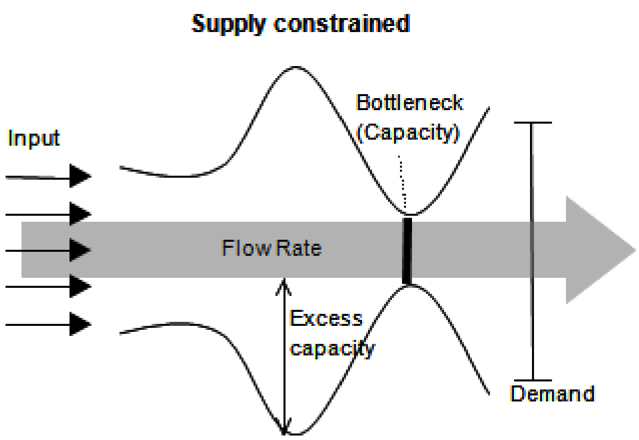

Figure 10: Supply-Constrained Process.
Source: Cachon, G., & Terwiesch, C. (2006). *Matching supply with demand* (Vol. 2). New York: McGraw-Hill

Regarding patient distribution for MRI, the majority of patients were outpatients; the time period after 7pm was not considered. Around 3 inpatients did scans out of the 130 observed patients.

The utilization rates on average (70% for 1.5 T versus 68% for 3T) are below the recommended level of having 90% machine utilization according to the standard set by the American College of Radiologists. The maximum level of utilization that was reached for the 3T was 85% whereas maximum utilization for 1.5T has reached 95%

which proves that the MRI unit is capable of effective process management that would result in having improved utilization rates based on the recommended standards.

To determine the yearly number of scans per machine, the number of scans for year 2013 was obtained. The total number of scans totaling 8,450 was divided equally between the two machines since utilization averages showed almost same results. Thus, each machine would have performed around 4,225 scans. According to the standards of the Canadian Association of Radiologists, a number of scans between 4,000 and 8,000 correspond to a medium utilization level.

Observations have identified the need to change the scheduled times of patient to better reflect the actual scan times. Therefore, the clinical department administrator asked the MRI's supervisor to change the scan times that are recorded on the system. Changes included 46 exam times with an average reduction of 23%. Only one exam time was extended. The reductions in exam time might thus affect the number of allotted patients per day.

G. Identifying Inefficiencies & Potential Improvements

This section will investigate inefficiencies observed, further elaborate on each and will try to suggest possible solutions.

1. Patient Availability

Patient availability is dependent upon no shows, same day cancellations, or patients' late arrival.

a. "No Shows"

Upon comparing patient arrival to the scheduled appointments, it was noticed that there was at least one no show on 11 out of the 13 days of data collection. Calculations of the % of no shows for these 11 days showed that no shows accounted for about 20% of total patients scheduled. This had a drastic effect on the utilization rate which was very low in days it occurred.

To obtain a more accurate estimate, historical data for the last 14 months were analyzed. Table 7 shows that the average percentage of no shows for the last 14 months is 14%.

Table 7: Average "no shows"

	No Show %
Jan-13	12%
Feb-13	9%
Mar-13	9%
Apr-13	9%
May-13	9%
Jun-13	9%
Jul-13	16%
Aug-13	16%
Sep-13	15%
Oct-13	20%
Nov-13	20%
Dec-13	20%
Jan-14	18%
Feb-14	19%
Average	14%

Having patients not showing up to their appointments is creating idle times for the unit's resources in terms of equipment and personnel. The MRI unit can't react immediately and get patients to do the scan because patients might not be readily available. At least one absent patient per day is lost revenue to the hospital. Given a minimum fee of 350$ per exam, and a total of 989 people who did not show up last year, this would result in having 346,150$ of lost revenue (if no shows are not replaced).

b. <u>Same Day Cancellations</u>

Some patients cancel their appointments on the same day not long before their scheduled exams; this gives the receptionist little time to reschedule another patient and results in having the same symptoms as “no shows”: machines standing idle and radiographers waiting for the next patient’s arrival. Patients who cancel on the same day are usually counted as “no show” patients.

The MRI unit needs to adjust for the patients who do not show up or make same day cancellations by having a backup plan to have patients fill in the resulting gap. One solution is to call the floor to have an inpatient scanned which would increase machine utilization and avoid having resources standing idle.

a. <u>Late Arrivals</u>

Some patients who arrive late to their appointments cause two symptoms to occur: first by not showing up to their allotted time slots, resources stand idle (radiographers and scanners) and second, when they do arrive, they cause delays in the whole process by creating waiting times that resonates throughout the whole schedule. This would cause queuing and thus would negatively impact customer satisfaction.

To reduce the incidents of late arrivals, the receptionist should stress on the importance of coming earlier by asking patients to at least come 20 minutes earlier. The receptionist could inform the patients especially those who come during peak traffic hours between 12 pm and 3 pm that Hamra is a busy area and it would be hard to find parking places at these times so that patients could anticipate these sources of delays and adjust their schedules accordingly.

2. Scheduling

The second source of inefficiency is scheduling. Upon observing the appointments sheet, it was noted that appointments were forced on the system to be able to schedule. This resulted in having two consecutive appointments overlapping; the overlap resulted in having machine utilization above 100% on the schedule. Radiographers were using data based on appointments to justify the need to get a new machine. Thus, while the utilization based on the scheduled appointments might jump over 100%, the actual utilization is below the recommended rates and by only considering scheduled appointments, one might make false assumptions regarding equipment utilization.

In addition, observations showed that there is a difference between the theoretical scan time recorded on the system compared to the actual scan time. In most of the procedures, scans take less time than required. Scans might take longer than expected if an error occurs in scheduling exam type as a patient might need having several body organs examined without having it recorded on the system; this would result in taking longer time than expected. Since 78% of the patients are scheduled, having an inaccurate scan time would result in gaps between appointments and therefore resources standing idle which is reflected in the total gaps time per given day. Table 8 shows a comparison between the actual and the theoretical time that is recorded on the system upon scheduling.

Table 8: Actual versus Theoretical scan time

Exam Type	Number of Exams Observed	Observed Time			Scheduled Time	Other Scheduled Times Used
		Avg.	Min.	Max.		
Abdomen & heart	1	72			90	
Abdomen w/o G	5	39	19	60	60	
Angio abdomen	1	56			60	
Angio Brain	2	29	24	33	60	or 75
Arthrography	3	40	39	42	60	
Brain w G	24	32	12	57	40	or 60
Brain w/o G	13	18	8	25	25	
brain+lumbar+ cervical+dorsal	3	103	83	120	135	or 120 or 130
Breast Biopsy	1	75			90	
Breast w G	2	33			60	
Cardiac	3	46	35	52	60	
Cervical w G	4	30	23	42	45	
cervical w/o	1	26			30	
cervical+dorsal+ lumbar	1	82			150	
Dorsal w/o G	1	39			30	
Elbow	1	63			60	
Foot	1	60			60	
Hips	3	40	29	48	40	or 60
Knee w/o G	7	43	29	85	60	
Lower extremeties	1	51			60	
Lumbar & cervical w G	1	53			120	
Lumbar & dorsal	1	63			105	
Lumbar spine w/o G	13	30	17	45	50	
Lumbar w G	2	51	44	58	60	
Lumnar& cervical w/o G	1	53			70	
neck & brain	1	86			60	
Orbit, face &neck	4	44	30	64	120	or 70 or 75 or 120
Pelvis & abdomen	2	52			120	
Pelvis W G	3	49	41	62	60	
Placenta	1	31			60	
Shoulder	4	35	25	43	60	
Spectroscopy	2	29	18	40	45	
Upper extremities	1	44			60	
Wrist & hand	3	55	43	63	60	

As it can be shown, for many exams, results showed a great variability in scan time. The multiple theoretical time slots allocated are indicative of the forced scheduling where the receptionists lower the exam time to be able to schedule other patients and because they know that the exam time would actually be much lower.

Recent changes incorporated an adjustment to the estimated scan times; the supervisor of the MRI department reduced the times of 46 exams by 23% which would ultimately help set more accurate estimates for the scan process and allow for a more precise scheduling. Continuous observation of the effects of these changes should be monitored and if necessary, further adjustments to the scan times could be made.

3. Process Interruptions

a. Managing phone calls while scanning

As part of the process flow, radiographers have phones in the control rooms in order to organize patient flow across the different floors. At certain points in time especially in the morning period between 10 am and 12 pm, radiographers were extremely bothered by the frequent phone calls received. Annoyance in turn affects the attention span of the radiographer and increases the risk of error. As stated by Halsted and Froehle (2008), managing incoming and outgoing calls slows the process and is more likely to increase errors because it might lead to lack of focus.

A possible solution could be giving the receptionist the task to handle all phone calls and therefore avoid using phone calls in the control room; or another solution might be allocating managing phone calls to a radiographer who is not currently scanning patients.

b. Claustrophobic Patients

Some patients are claustrophobic and therefore, they can't handle being under the machine for too long. They usually take longer times to complete the test as the scanning needs to be interrupted several times because of patients being nervous or scared. There are special considerations that are taken for these types of patients. They are usually given valium as a medication to lower their level of discomfort or it can go into extreme forms such as general anesthesia in case of patient's incompliance and severe discomfort. Screening usually identifies whether patients are claustrophobic or not; however, once the radiographer knows, it might be late to react as the patient is about to enter the scan room. The medicine needs at least thirty minutes before it starts taking effect. This in turn results in waiting times as resources stand idle.

Recent adjustments made attempted to identify claustrophobic patients earlier by having the physician requesting the MRI scan to do the screening and record it on the procedure request form. This would help the receptionist identify claustrophobic patients before time in order to act proactively by asking those patients to take an anti-anxiety drug at least 30 minutes before doing their scans. Also, as part of a possible solution, the receptionist could do a preliminary scanning over the phone to help identify claustrophobic patients earlier.

c. Sequence Errors and Repetition

There are two types of sequence errors: patient-related and radiographer related. Patient- related sequence errors occur when a patient moves some of his body parts which therefore affects the quality of the image. The radiographer would have to stop the scanning process and ask the patient to stop moving before proceeding again.

However, a radiographer –related sequence error occurs when the radiographer chooses the wrong protocol for scanning which would result in sequence repetition. The results in both cases would be having wasted time which delays the overall process while resources are not being efficiently utilized. The frequency of occurrence of such incidents was on a daily basis with each sequence taking around a minimum of 5-7 minutes to be repeated. Sequence errors result in “false scan times” as the scanning time is taking longer than it should have which would inaccurately reflect the expected or optimal scan time.

Sequence repetition is a detriment to process efficiency and can cause delays in the process. To reduce sequence repetition due to patients’ movement, the radiographer should stress on the importance of not moving their body parts while preparing the patients. One suggested way to reduce radiographers’ errors is to have the supervisor practice with the radiographers the suggested plan of action for patients who are scheduled. This could be done in the early morning of the same day between 7 am and 8 am where patient flow is still slow. Discussing the required sequences for cases would allow radiographers to reflect on each case before the actual scanning. Also, the supervisor could record the number of errors that each radiographer commits to hold the radiographer accountable and to compare the progress of radiographers’ efficiency. Recording radiographers’ errors could be part of their key performance indicators upon which performance evaluation could occur.

4. Process Delays

a. Pediatric Sedation

Observations have shown that some pediatric sedation procedures were not done in an overlapping manner. That is, sedation of the next patient does not start sometime before the current patient finishes his/her scanning. This in turn creates waiting time and resources stand idle. By considering the time the patient enters the scan area till the time the patient is admitted to the room, it was observed that the sedation process takes on average around 10 minutes. The time to sedate the patient is highly dependent on the pediatric patient's compliance.

To reduce waiting time and increase the number of scanned pediatrics every Tuesday, it is recommended to overlap the sedation procedure of the expected patient with the scanning process of the current patient. Parallel processing is proved effective in optimizing patient flow and reducing waiting time.

5. Further suggestions for continuous improvement

Because the scan time of the MRI exam takes a relatively long time, customers are expected to have longer waiting times compared to processes that take less time such as CT scans. Thus, the supervisor could inform patients about the expected waiting time and their number in the queue in order to reduce complaints and dissatisfaction.
If possible, the PACS should be able to automatically record the start and end time of the scanning process rather than relying on manual recording by radiographers. Recording times manually would add to the number of tasks that are done by the radiographer and would allow for a greater percentage error. Having accurate start and

end times of the scanning process would help detect inefficiencies discussed above especially when it comes to detecting sequence errors.

H. Overall Equipment Effectiveness

The overall equipment effectiveness diagram for MRI (Figure 11) shows how the total observation time is divided between the different activities and inefficiencies discussed above. As it can be shown, 20% of the total planned time is due to patient "no shows" or same day cancellations. The average preparation time consumes around 7.7% of the total planned time. The graph highlights the need for further investigations to be able to estimate effectively the % of sequence error and their respective time in order to have a close estimate of the effective scan time.

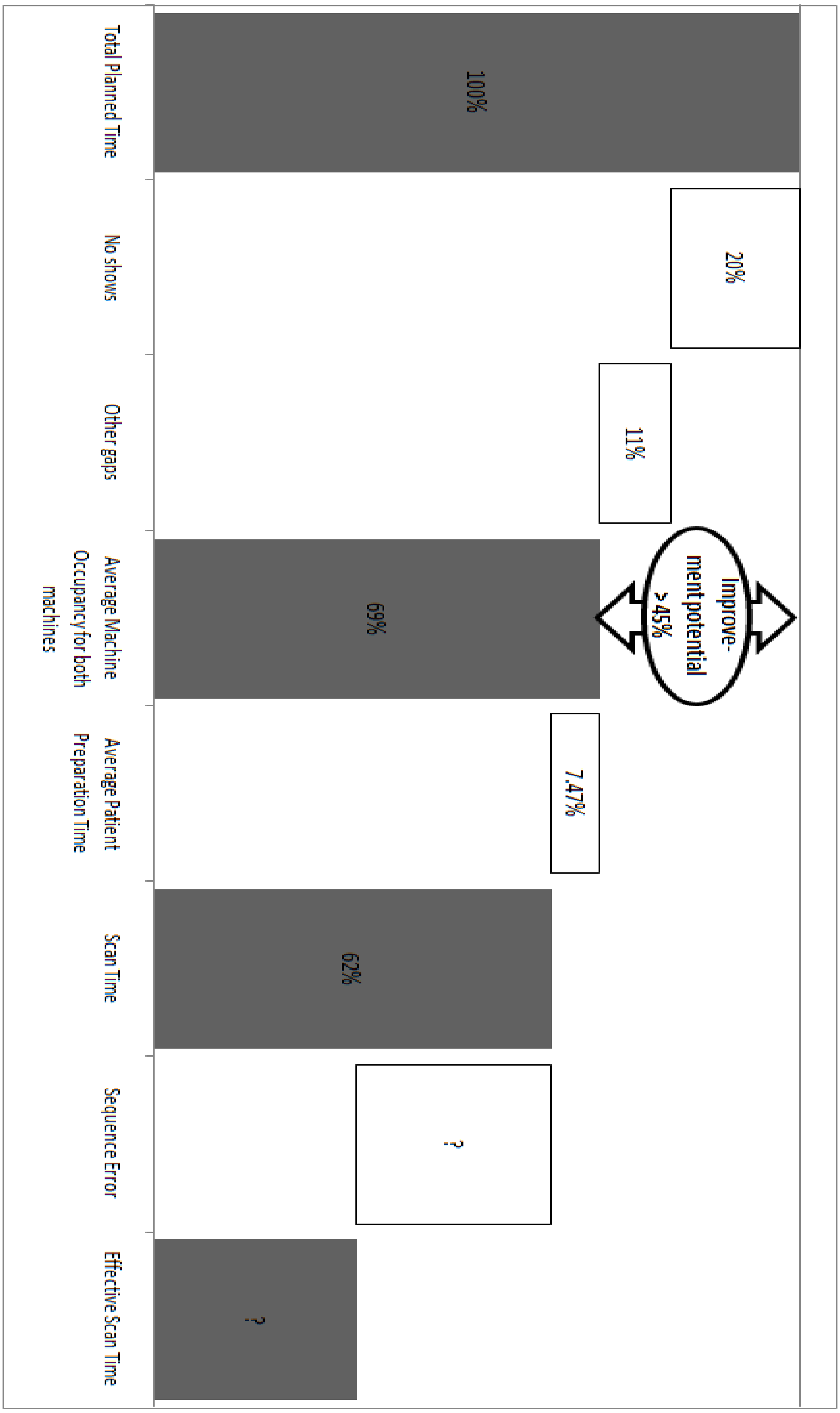

Figure 11: OEE Chart for MRI

Chapter VI

MACHINE PURCHASING DECISION

The average utilization of the CT scan was around 36% which indicates low utilization rates of machines and therefore there is no need for buying new machines for the CT unit unless inefficiencies are eliminated and the utilization is increased to reach 90%. Similarly, for MRI, with an average utilization of 70% for 3T and 68% for that of 1.5T, the rate is still below recommendation and therefore careful considerations are needed prior taking a decision.

The following estimates were used to determine the number of scans above which the department could consider buying a machine.

For CT, the recommended utilization is 90% while the calculated utilization is 36%. Therefore,

$$\frac{Recommended\ utilization}{Actual\ utilization} = \frac{90\%}{36\%} = 2.50$$

The number of scans could be increased by 150% and, therefore, this shows that buying an extra CT scanner is not advisable.

Similarly, the recommended utilization for MRI machines is 90% while the calculated utilization is 69% (average for both machines). Therefore,

$$\frac{Recommended\ utilization}{Actual\ utilization} = \frac{90\%}{69\%} = 1.30$$

The number of scans for the MRI could be increased by 30%. Furthermore, it is important to identify the effects of sequence errors on the effective scanning time before taking the decision of buying the machine. It is thus unadvisable to buy a new machine before improving scanning by 30%, identifying the portion of time wasted on sequence errors, and then attempting to correct this inefficiency.

Chapter VII

CONCLUSIONS AND LIMITATIONS

A. Conclusion

This project presented findings regarding the inefficiencies of workflow and an estimate of the utilization of equipment at the CT and MRI units of AUBMC. Given that these units are the two most revenue-generating units among not only the radiology department but the whole medical center, quality improvement becomes a must to ensure maximum efficiency while providing exceptional patient care. Observations and data collection allowed for process understanding, and calculation and analysis of utilization rates. Process utilization estimates showed that there is no need to buy additional equipment since current utilization rates are below the recommended rate of 90%. The first step towards improving utilization would be tackling inefficiencies and implementing possible cost effective solutions.

It is recommended that the radiology department applies a continuous quality improvement (CQI) method which is composed of seven steps: identifying the process to improve, development of an expert team, clarifying the current knowledge of the process, selecting process improvement, designing specifications and then the last step would be monitoring those specifications (Laurila et al, 2001). CQI allows for systematic understanding of a complex process and the selection of critical decision points. The strength of the process lies in better problem analysis while directly involving personnel who will be responsible for applying the necessary changes such as radiographers in this case (Laurila et al., 2001).

B. Limitations

Throughout the study, several limitations could be pointed out which hindered finding further insights to understand the process thoroughly. Limitations for both units included:

- Patient’s arrival times and the resulting waiting time could not be recorded due to the inability of being at the waiting room and control room simultaneously. Therefore, the focus was only on the control room to be able to observe patients’ service time.
- For the MRI unit, it wasn’t possible to record the time taken by patients to change their clothes since the changing room area was separated from the scanning area.
- It was not possible to quantify the number of claustrophobic patients due to the absence of statistics and some patients already had valium before coming.
- There were no recording of same day cancellations as these were considered part of no shows.
- It was not possible to obtain some cost figures such as machine costs, depreciation, and maintenance costs.
- It would have been better to quantify the number of sequences repeated per day to identify the number of radiographers’ errors.

C. Suggestions for Further Research

Investigations for further research might focus on patient waiting times in a flexible appointment setting such as the CT unit. Customer satisfaction is also an important aspect to be handled as part of process quality improvement.

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