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## Tools to Improve the Patient's Processes at Imaging Centers

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### 1. Introduction

There is a worldwide concern for increased efficiency and cost effectiveness in healthcare delivery which in the USA represents about 16% of the Gross Domestic Product. The variability and complexity of the processes within healthcare systems demand the use of more sophisticated management tools, such as the recommended by a joint study by the National Academy of Engineering and the Institute of Medicine in the USA (NAE 2005), to improve the healthcare delivery system. In this chapter it is seen the integration of three management tools (Activity Based Costing, Lean Healthcare and Process Simulation) to facilitate the development of Medical Imaging Center (MIC) studies in order to improve the patient's processes, which departs from traditional modeling because it uses a pull paradigm for the patients. Activity Based Costing (ABC Costing) is used to identify improvement opportunities from the managers' point of view, Lean Healthcare (Lean) to identify opportunities from the Customers' point of view and Process Simulation (Simulation) to test the potential impact of any proposed alternative identified with ABC Costing or Lean, prior to its implementation. The center to be modeled might be as simple as having one x-ray machine, or, more complex having all kind of imaging machines (magnetic resonance, CT, x-ray, digestive radiology, ultrasound scan, angiography, mammography and others).

Medical Imaging Centers are important units in every hospital or medical center as they are a relevant link in generating a patient's diagnostic. Because of this, it is necessary that these centers be managed with high quality standards but also with efficiency. As an application, an integrated example is provided where ABC costing, Lean and Simulation are applied to an imaging center to improve the patient's waiting times and process costs.

Medical Imaging Centers have made an important investment in PACS systems, which provide data comprising from the reception of patients to the taking of the image. This kind of system gives relevant and detailed information, such as: number and kind of patient, frequency, type of exam, supplies and drugs utilized and personnel involved, all of these entry data are significantly useful to the proposed tools, and, furthermore complement and support the information for the management of MIC.

## 2. Patient flow

Traditionally, when studying a process, the first step is to build a flowchart of the process that the patient will undergo. A typical patient's process is presented in Figure 1. The process begins when a patient and his or her companions arrive to the reception desk at the MIC. The arrivals could be spontaneous, scheduled or sent from an emergency room. The receptionist asks the patient about the type of exams that he/she is requesting, proof of insurance or payment method and all the paper work required. Once this information is entered, the patient waits to be called by a technician/doctor to carry out a preliminary evaluation, preparation prior to the exam in case the patient may need anesthesia, contrast medium or other preparation, and the requested exams. The exams can be classified as: magnetic resonance, CT, X-Ray, digestive radiology, ultrasound scan, angiography, mammography and others. Once the exam is performed, the patient leaves the examination area and meets her/his companion, afterwards, back office activities are performed to digitalize/print the image or make a CD, finally, the results of the examination are communicated to the patient or reported to the physician.

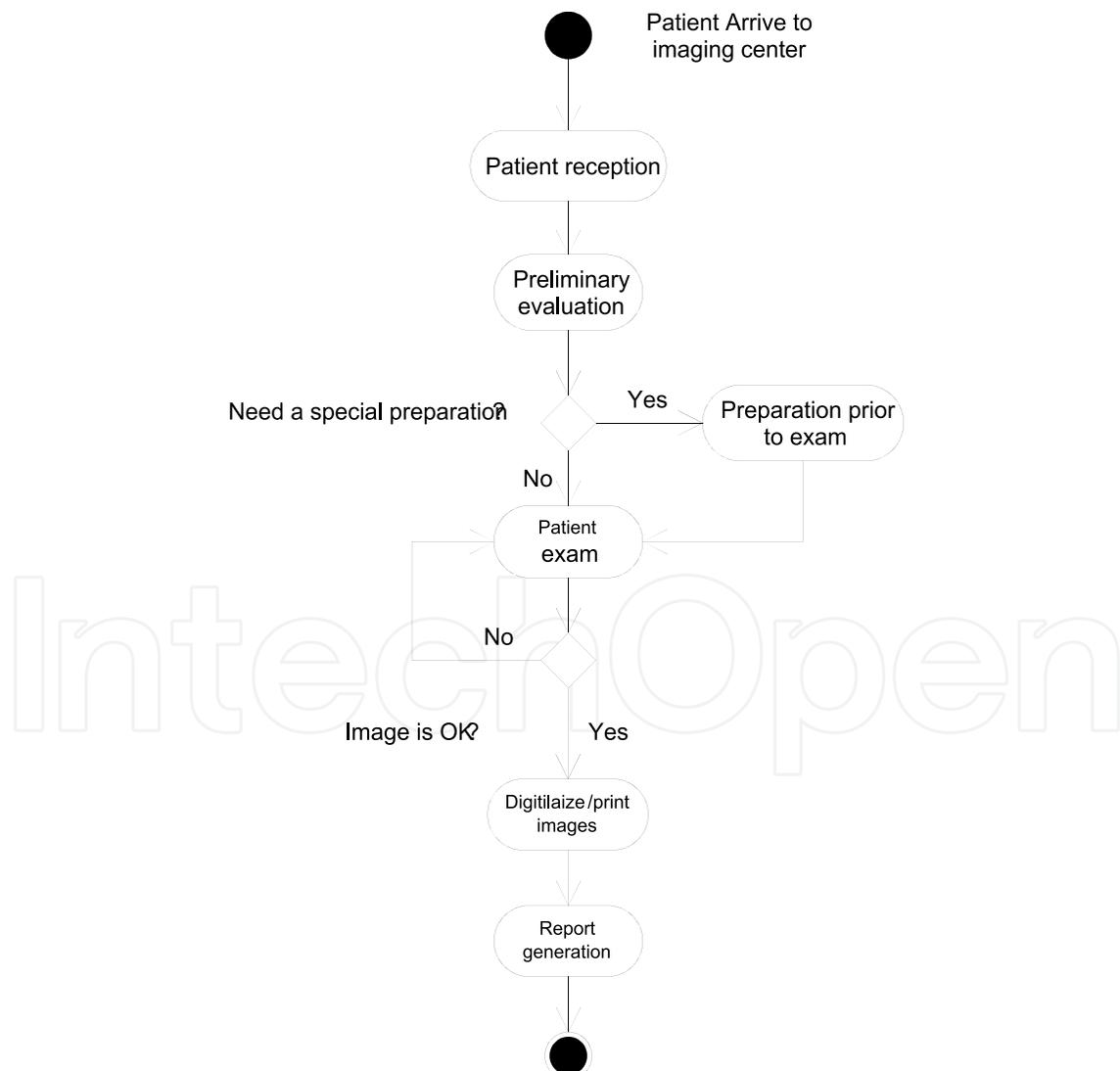


Fig. 1. Patient flow diagram at an Imaging Center

Building and understanding MIC workflow is usually conducted in a brute-force fashion; that is, by taking a stopwatch and physically timing each step of the clinical examination processes. This can be observed as taking a snapshot from the doctors'/technologists' daily activities focusing on a patient examination, including the room preparation prior to an examination, the examination itself, the report generation and the discharge of the patient from the MIC (Wideman and Gallet 2006).

The upper flow diagram is useful for representing the process and the activities involved, the sequence of such activities, and also, as a communication device for the persons working within the imaging center. However, it does not provide any guidelines to identify potential improvements. Because of this, a three steps approach is proposed in this chapter to identify opportunities for improvement: 1) ABC costing to identify important activities from a cost point of view, 2) Lean to identify one of the patients' concerns, the waiting times and process times and 3) Simulation to test the impact of proposed solutions before implementing them. These three tools are explained in the following section.

### 3. Description of management tools

There are several management tools that could be used to manage an imaging center. In particular, this chapter illustrates the use and integration of three of them, which are focused on the processes and generate synergies to support the decision making process more objectively. This way, the manager can get different points of view, take more effective decisions and promote the continuous improvement of the processes. The three tools to be used are described as Activity Based Costing, Lean Healthcare and Process Simulation.

#### 3.1 Activity based costing

Activity Based Costing (ABC) was developed by Kaplan and Cooper (1997). The objective of ABC is to compute the cost of products or services (cost objects) in industries where indirect costs are significant and have more than one product. Traditional costing methods assign indirect costs directly to the products using an allocation criteria (units produced, patients, square feet, etc.), which do not reflect the current use of resources. This is the case of healthcare, where most of the costs are indirect, i.e., the resources utilized to produce the products are used by more than one product.

ABC relates the use of the resources to the products, through the allocation of costs of the resources to the processes, which are represented by activities. These activities consume resources, and then the costs of activities are allocated to the products generated (goods or services). For ABC, a process is a group of activities, i.e., a process is composed of at least two activities. A definition of the concept of activity is a "task that consumes resources."

The ABC basic elements are: direct and indirect resources, activities, drivers and products. Products are tangible goods or services. Drivers represent the way used to allocate resources to activities and then from the activities to the products. The methodology can be summarized as follows: (1) identify the processes in a company, (2) establish the activities associated to those processes, (3) choose drivers for each indirect resource and allocate the costs of the resources to the activities, and (4) calculate the costs of products by assigning activity costs through the predefined cost drivers.

The ABC costing process requires identifying the activities and their characteristics as well as recognizing the direct and indirect resources needed to operate the company. Once the indirect resources have been identified and valued, their costs should be allocated to the activities that use the resources by identifying the appropriate drivers (resource drivers). These drivers relate the activity level to the resources used. Once the activities have been valued, the next step is to allocate the costs of the activities to the products through other drivers (activity drivers), which link the activity with the products. Finally, direct costs are directly allocated to each product. See Figure 2.

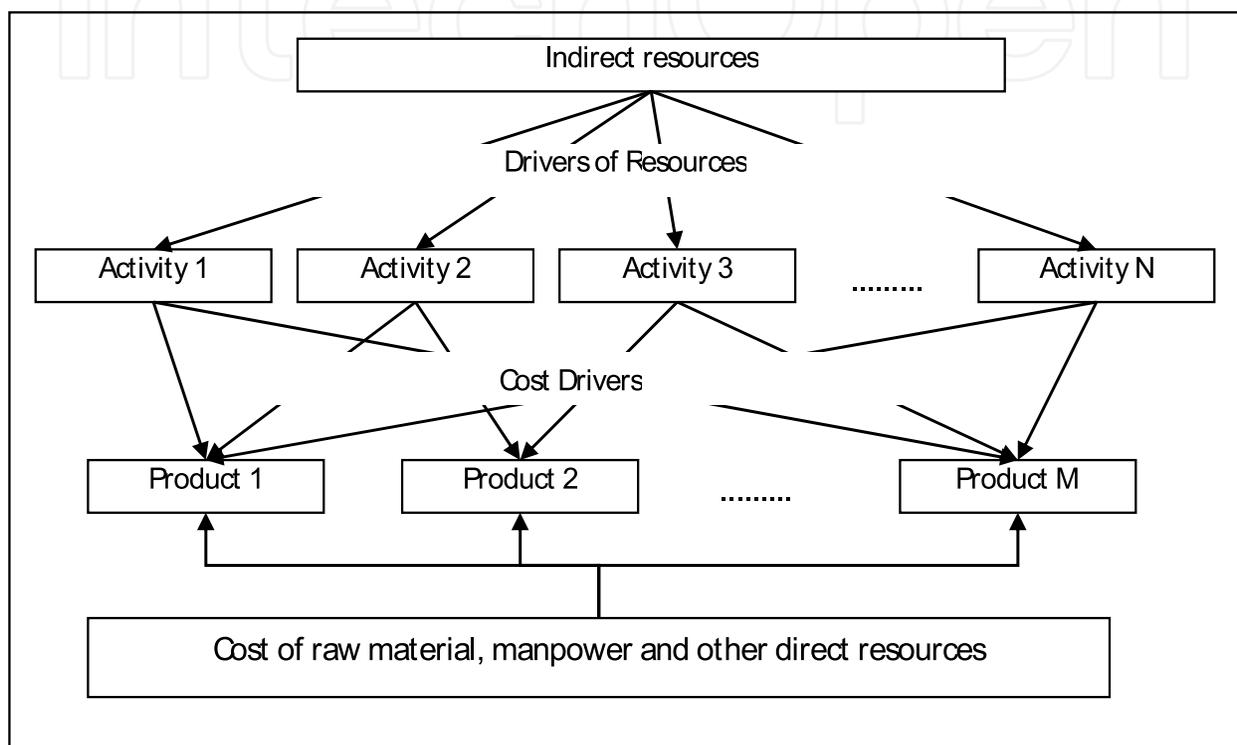


Fig. 2. Activity based costing method.

Figure 2 provides valuable information to the manager, as opposed to traditional costing methods that give the total cost and do not answer why or where the most expensive activities are going to be found or how the process might be improved. Managing the activities is called Activity Based Management (ABM), which is the basis for any initiative of process improvement. As managers know their real costs, therefore they could find original ways to improve their processes and reduce costs or add more value. ABM supports continuous improvement, cost reduction program, re-engineering and other process and quality initiatives (Kaplan and Cooper, 1997).

Imaging procedures are services with a high amount of indirect costs which require many activities; several authors have provided some evidence such as Canby (1995) who, using ABC principles and techniques, calculates costs associated with a x-ray process in a mid-sized outpatient clinic. Laurila et al. (2000) show an informative and detailed picture of resource utilization in a radiology department in order to support its pricing and management. Another research from Laurila et al. (2001), studied the efficacy of continuous quality improvement (CQI) compared to ordinary management from a radiology department. Cohen et al. (2000) applied ABC to test the hypothesis that academic radiology can be separated into three distinct

businesses –clinical activity, teaching and research- in order to determine the effect of the current teaching paradigm on the clinical productivity. This analysis identifies opportunities to improve quality of service, productivity and cost within each business.

There are several ABC studies in different imaging areas such as Enzmann et al. (2001) in mammography services; Gray et al. (2003) in magnetic resonance imaging; Suthummanon et al. (2005) researched how applying ABC to the nuclear medicine unit at a teaching hospital for training interns; and Clevert et al. (2007) who analyzed methods to reduce cost in interventional radiology departments by reorganizing supplies.

### 3.2 Lean applied to healthcare

Lean healthcare tools are focused on those activities that an institution must develop to added value to their customers, represented by the patients of the clinical services. Lean is based in the Toyota Production System (TPS), which, by definition is how to produce more with less (Womack and Jones, 2005).

Lean has four principles: (i) Only perform activities that add value to the customer, (ii) Eliminate waste. (iii) Promote flows, and (iv) Continuously improve processes. Adding value to the customer means only perform those activities that the customer is willing to pay for, the activities are correctly executed at first, and the activity must change the product or service in some way. For example, waiting for an x-ray to be taken does not add value to the customer.

Waste can be eliminated by identifying the seven sources of waste: 1) Production of defects (wrong dose, wrong medication, rework, correction of defects), 2) overproduction (unnecessary tests, reading mails, production to inventory), 3) Unnecessary transportation (inappropriate layout, changing documents), 4) Waiting times (patients waiting for reviews, doctors/nurses waiting for results of exams), 5) Excess inventories (expired drugs), 6) Motion (travel to the laboratory, excessive file search) and 7) Extra-processes (data collection that are not used, defective samples).

The promotion of flows is reached by minimizing the time between activities that add value. For example, minimizing the waiting times of the patients between successive treatments, which is triggered by a pull discipline, where the patient requests successive services as he/she makes progress in the attention process.

The fourth principle states that by doing things a little better every day, this will lead to continuously improve the processes. Ideally, people should arrive to their workplace in the morning and ask themselves: what can I do better today?

This study uses a particular tool of lean called Value Stream Map (VSM), to illustrate the relationship customer – supplier, and also to show the waiting and process times for the entire imaging procedure; as a result, overcrowding and unbalanced flows can be identified. In order to build a value stream map, the following steps should be followed: 1) Identify the boundaries of interest, 2) Identify the activities performed within the unit, 3) Use a pencil and paper to collect field data, 4) Draw the flow based on demand, the customer requirements, and his employer, 5) It is important to consider the flow of material, information and production flow, 6) Check the value chain backwards in every step of the flow, 7) Add boxes to the data on each process, 8) The individual process steps must go from

left to right in the flow of the value chain, sometimes many paths converge on several points, 9) Add the number of operators 10) Add the cycle time and processing time, 11) Calculate the total cycle time and total processing time, 12) Once traced the flow of the chain and when data has been entered in each step, it is necessary to add the information flow and 13) Finally, add the timeline at the bottom of the page.

For a comprehensive view of lean see Womack and Jones (2005) pioneers in the introduction of the concept of Lean. For the specific case of Healthcare, an excellent handbook is provided by Graban (2008), with specific examples and guidelines for implementing lean healthcare. A general overview about how lean has been applied in North American hospitals is provided by Poole et al. (2010).

### 3.3 Process simulation

Simulation is a tool that allows studying complex systems under dynamic conditions (Law, 2007). Healthcare simulation is different from the well known manufacturing simulation, where the entities go through a well defined and standardized process, requesting resources at different locations, waiting in a row if the resources are not available and both the processing and waiting discipline are according to a given priority. In healthcare, patients (the entities) request the resources at a fixed location, or in other words, are the resources (doctors, nurses, paramedics and others) that come to the patient and provide him with the required services. Also, patients cannot wait forever to get service or be stored as inventories in case they are not given service in a given day. Waits have dynamic priorities and physicians give preference to the patients with the highest severity.

In order to build a simulation model with any modern simulation software, for example with FlexsimHC that is the only object oriented simulation software for healthcare processes ([www.flexsim.com](http://www.flexsim.com)), the typical steps are: 1) Import layout of the imaging center, 2) Drag & Drop objects into layout, 3) Adjust visual properties, names and areas of objects, 4) Create the Tracks, 5) Make connections according to tracks/patient flow, 6) Configure the experiment, scenarios and performance measures and 7) Run the model and view results.

Simulation has the flexibility to become a suitable tool for healthcare due to the complexity of these systems, which are integrated by different actors and a large number of parts interacting (Monsef, 1997). For a comprehensive healthcare simulation review see (Eldabi et al., 2007), (Young et al., 2009) and (Neriz et al., 2011). Specific examples of simulation of imaging centers can be found in (Ramis et al., 2008, 2009), where simulation focuses on providing an alternative to reduce the waiting time of the patients, improve the use of physical and human resources, evaluate different alternatives of plant layout, scheduling patients or simply, to study and better understand the inner working of the system.

## 4. Using ABC costing and lean to identify opportunities for improvement

To illustrate the integration of tools, it is presented the case of an Imaging Center at a research hospital, which is a high complexity center with different equipments such as Magnetic Resonance, CAT's, x-ray, Digestive Radiology, Mammography, Angiography, Echography among others. In this center, it was applied an activity-based costing model and as an example in Table 1 it is reported the X- ray section, which shows the annual breakdown of the costs of activities in this unit.

Activity	Total annual costs (US\$)	Activity	Total annual costs (US\$)
Carry envelopes	687.204	Give the report to the patient	7,805.274
Record times	834.288	Give directions	8,275.712
Give indications to patients	1,517.640	Deliver reports to departments	8,648.474
Coordinate people's schedules	1,999.228	Call and receive the patient	8,724.822
Give contrast to patient	1,531.640	Check exams (images)	9,303.936
Assign envelopes	1,999.228	Finish the process	10,217.488
Carry reports (into the envelopes)	2,227.104	Proceed with the process	11,315.038
Label envelopes	2,441.644	Do anamnesis	12,025.192
Arrangements	2,459.968	Digitalize exams	12,089.694
Bring reports	2,576.066	Release exams	12,089.694
Carry cartridge	3,511.320	Admit patient	15,208.386
Building Maintenance	3,732.934	Receive payments	23,444.442
Obey safety measures	4,789.020	Print pictures	23,654.790
Remove safety measures	4,789.020	Check inventory stock	27,519.104
Print report	5,749.998	Check report	36,406.510
Dismiss the patient	6,289.120	Do report	38,048.202
Back to the imaging center	7,397.258	Manage academic duty	84,917.472
Settle the patient	7,469.516	Equipment Maintenance	14,6236.436
Check report	7,501.822	Manage the Center	341,832.954
Go to X-ray portable examination	7,647.588	Take exams	795,188.264
		<b>Total Cost</b>	<b>1,721,125.714</b>

Table 1. Activities in X-ray area

The information from table 1 is summarized in Figure 3. It can be observed that the costliest activity is of taking the exam, a situation that is explained because most of the resources employed in the X-ray section are fixed costs, and correspond to personnel, equipment and facility costs, as can be seen in Figure 4.

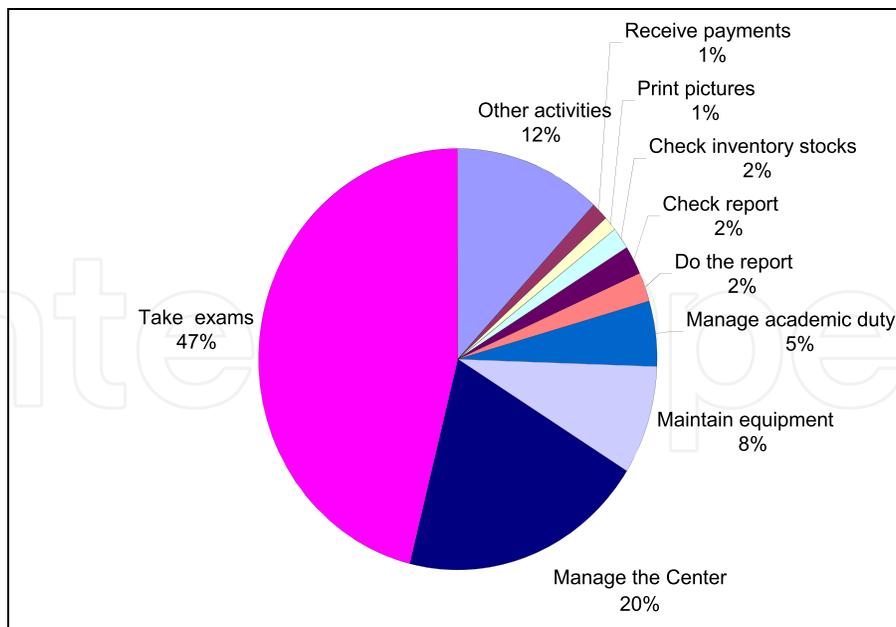


Fig. 3. Activities costs in X-Ray area

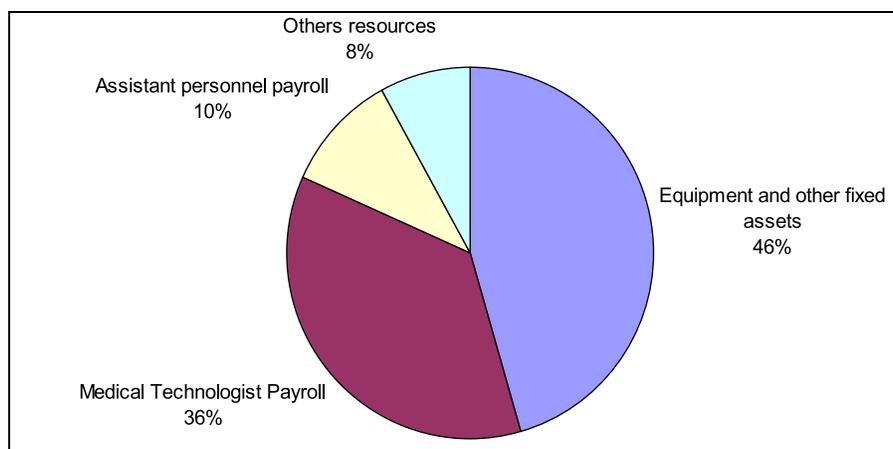


Fig. 4. Costs of resources - Activity take exams.

Considering that the resources employed in the activity of taking the exam are fixed, this says that if 1 x-ray or 1000 x-ray are made, the same fixed cost is incurred. Then, the manager of the MIC realizes that to generate value he must make decisions about the activity of taking the exam, for example, by increasing the production of X-rays the cost of that activity is amortized with more x-rays. Now, the manager wants to increase the production, but the analysis would consider this decision from a customer standpoint, that is, people need to get an X-Ray without long waiting times. In order to do this analysis, a value stream map (VSM) will be used.

From the standpoint of the VSM, there are three main activities: 1) the reception of patients in the reception area. 2) Proof of insurance or direct payment from the patient and 3) Taking the exam in the examination room. Figure 5 shows the VSM with the three main activities mentioned, and it can be seen that the bottleneck occurs in the examination room because the flow of patients, which in the previous stage was an average of 16.76 patients per hour, drops to 5.95 patients per hour.

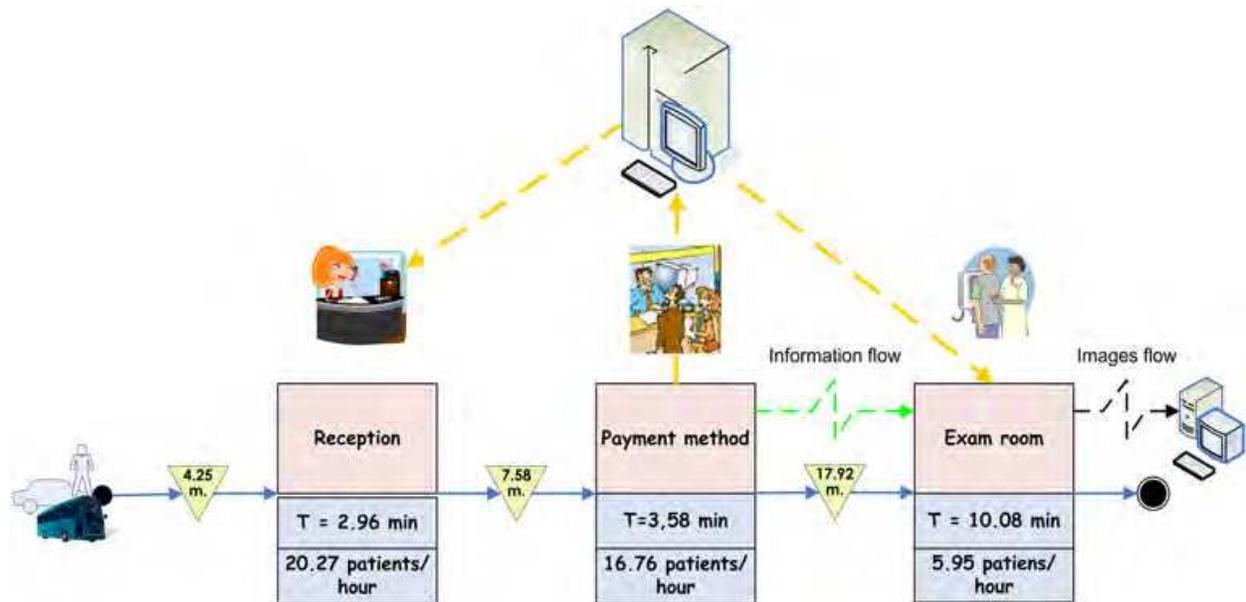


Fig. 5. Map of stream Value of the main processes in the X-ray area.

A more detailed analysis of what happens within the examination room, using the same tool again, established that the flow is leveled in the first three activities, having a capacity of 60 patients per hour. But the flow goes down in the last activity when the patient returns to the dressing room to put on his/her clothes, now, the capacity is to attend only 17.94 patients per hour, which is shown in Figure 6. This drives to the conclusion that as the dressing room is the bottleneck, by increasing the number of dressing rooms an increase in productivity will be achieved.

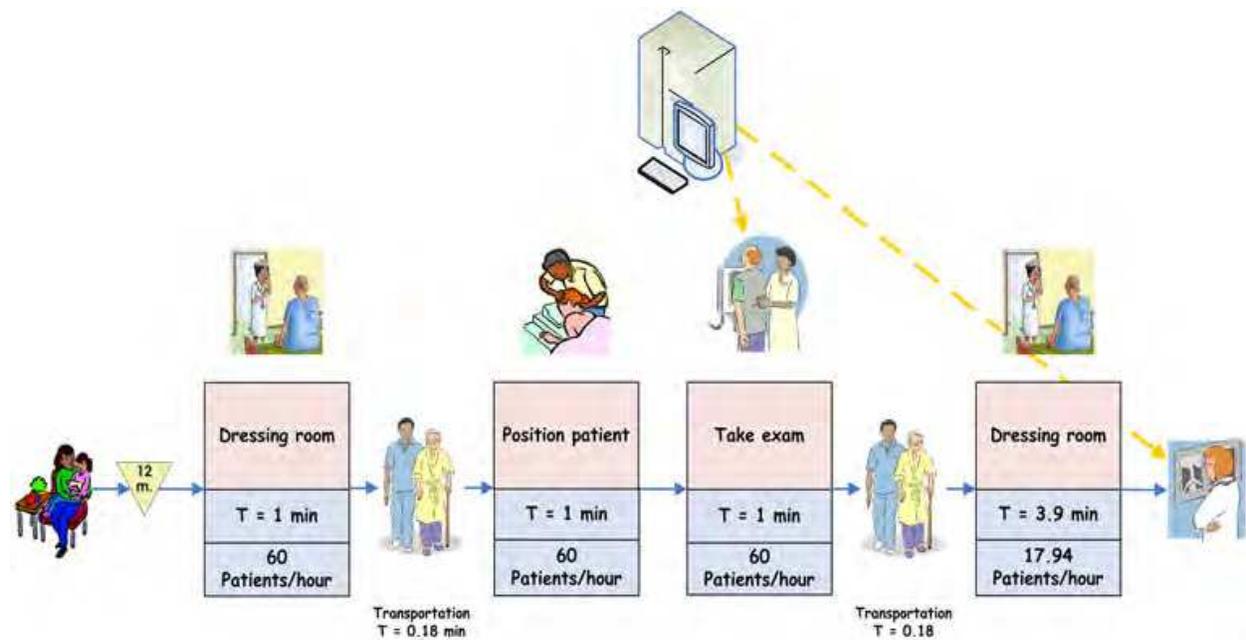


Fig. 6. VSM in the examination room.

## 5. Using simulation to test identified solutions

From the previous section it has been seen that the actual bottleneck is the dressing room, and then, by adding more rooms it should be improved the productivity of the x-ray section. To test this hypothesis, a simulation model was constructed, following the steps described to build a model and using the simulation package FlexsimHC.

The simplified model of the process is shown in figure 7. It is assumed that patients arrive and go directly to the service if the dressing room and the technician are idle; otherwise they go to the waiting room. Once the patient is ready, the technician will get him out of the dressing room, locate him/her into the table and take the image. Then, after some adjustments, the patient is taken back to the dressing room, where he/she gets dressed and then leaves ending the process.

As a result of the simulation it can be observed, by having one dressing room the technician is inactive about 65% of the time, instead by having two dressing rooms this figure goes down to 35%, and with three dressing rooms it sharply decreased to a 5% idle time. In terms of production, for a direct digital machine, with one dressing room a total of 50 patients will be attended, with two a total of 100 and with three dressing rooms a total of 125 patients per day. It is important to notice that increased productivity is achieved having the same resources, except for changing the number of dressing rooms.

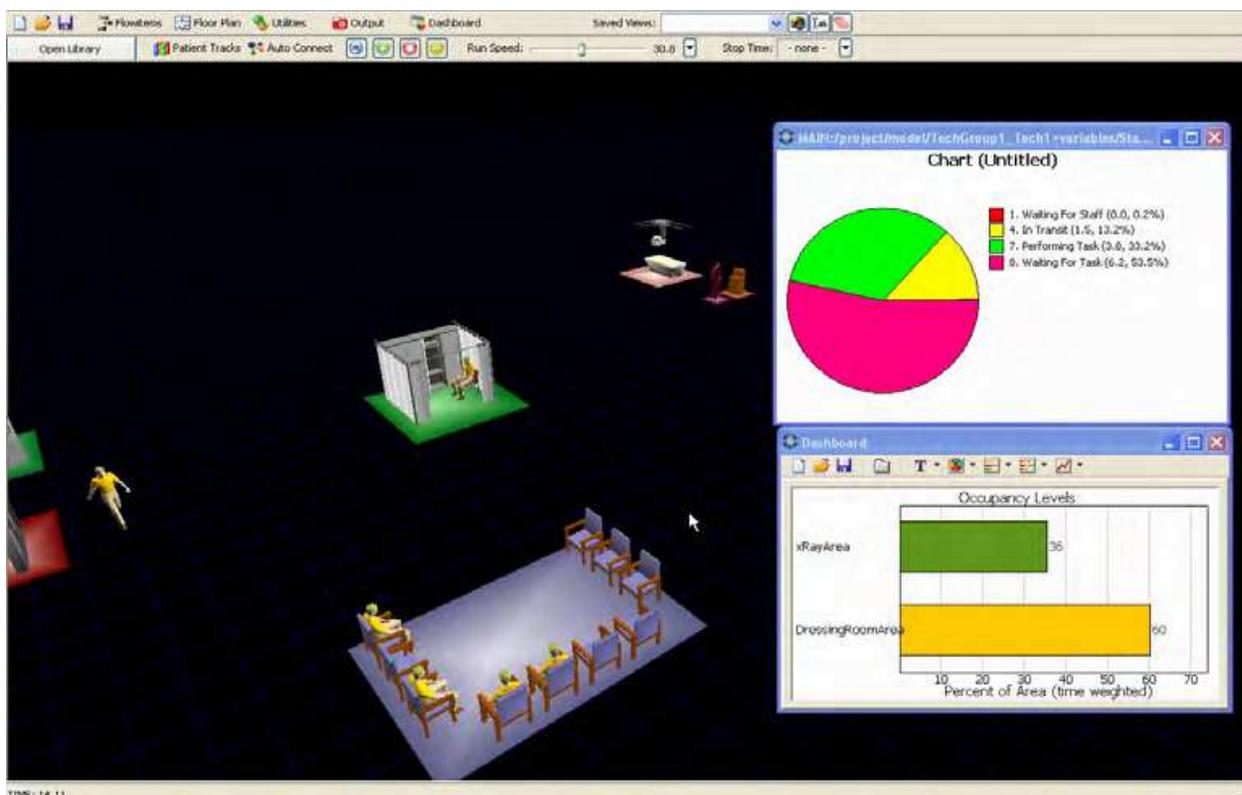


Fig. 7. Screen of simulation model.

## 6. Conclusions

This chapter shows the integration of three management tools, Activity Based Costing, Lean Healthcare and Process Simulation, to improve the waiting times and equipment rate of utilization at a clinical hospital. As a general conclusion we can say that:

1. Activity Based Costing is a valid tool for computing costs of products at healthcare institutions. ABC provides a powerful tool for Activity Based Management (ABM), because it shows the cost of the different activities involved in getting a given service/product.
2. Lean healthcare provides a focus on the wastes from the point of view of the customers, in this case, the waiting times.
3. Simulation is an appropriate tool for modeling in a healthcare environment, because of the complexity of the processes and the flexibility of the tool when modelling different situations. It was used to test solutions identified with ABC and Lean.

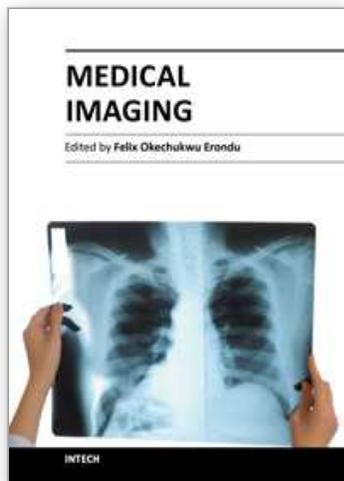
Specifically, we can conclude that, the bottleneck of the system is represented by the dressing rooms. By adding more of them in the X-ray section, the productivity was increased from 50 patients per shift to 125. Similarly, the average idle time of the technician taking the images decreased from 65% to 5%.

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What we know about and do with medical imaging has changed rapidly during the past decade, beginning with the basics, following with the breakthroughs, and moving on to the abstract. This book demonstrates the wider horizon that has become the mainstay of medical imaging sciences; capturing the concept of medical diagnosis, digital information management and research. It is an invaluable tool for radiologists and imaging specialists, physicists and researchers interested in various aspects of imaging.

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