# *Implementation of Lean Methodologies in the Small Radiology Firm Bayamón Radiology Center*

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***Abstract*** *— The Lean methodology was used to reduce examination cycle and lead times for the radiology clinic Bayamon Radiology Center. They clinic had a conventional X-ray system that uses x-ray films. Voice of the Customer and Value Stream Maps were used to the determine areas of improvement and ameliorate bottlenecks to improve customer satisfaction. The investigation was implemented to upgrade the X-ray equipment to a digital system that improves clinic flexibility. The project was implemented in October 2019.*

***Key Terms*** *— Gemba, Gembutsu, Genjutsu, Lean, Micro Business, PACS, X-Ray.*

## INTRODUCTION

The Lean methodology has been widely implemented in medium to large-scale businesses for many years, but micro and small businesses have often failed to take advantage of the potential growth seen with the adoption of this methodology. Lean looks to maximize resources and process speed by providing the tools with which to analyze process flows and delays at each process activity. Micro and small businesses have very tight profit margins; it is therefore crucial to maintain competitiveness and lean methodology can reduce costs, increase productivity, and increase overall profits in the long run as it has for many medium to large companies. [1]

## PROBLEM STATEMENT

The design project will complete an evaluation to a radiology clinic, Bayamon Radiology Center (BRC), a micro business serving to over 2000 patients annually. The clinic has a conventional x-ray equipment that uses x-ray films and digital sonography equipment and does not have a digital storage of all patient x-rays and sonograms with their respective diagnoses. Radiologist must come into the clinic to complete patient examinations reports. For this reason, the lead time given to customers by the clinic is three (3) to four (4) business days to obtain exam results for any study. The long lead times makes it hard to compete with larger clinics that send results on the same day and causes loss of clients, delay in patient treatment and diagnosis.

## RESEARCH DESCRIPTION

This design project is focused on reducing the x-ray examination result lead time for Bayamon Radiology Center (BRC) through the implementation of a new Picture Archiving and Communication System (PACS) system (used to store patient exams and reports) and digital x-ray equipment. Additionally, the digital x-ray would eliminate technician chemical exposure from the x-ray film development process. Lean methodologies were used to improve the process flow. This implementation also evaluated patient examination cycle time.

## RESEARCH CONTRIBUTION

The investigation will identify process waste to reduce the lead time of patient results, cycle time of studies, and provide a flexible system for patient exam analysis. Additionally, the implementation of the digital x-ray and PACS system will reduce technician exposure to harmful chemicals needed to develop the x-ray films and will generally reduce the x-ray cycle time examination process by eliminating x-ray film developing steps.

## RESEARCH OBJECTIVE

The main goal of the project was to reduce the lead time for patient examination results for the BRC. The clinic had conventional x-ray equipment and this project sought to implement digital x-ray equipment with a Picture Archiving and Communication System (PACS). By implementing lean methodologies and the new equipment muda or waste will be reduced improving patient experience through a reduction in examination cycle time and patient satisfaction through a reduction in exam report lead time. Additionally, the patient health was ultimately improved since the diagnosis lead time, and thus a reduction time-to-treatment

## LITERARY REVIEW

Micro businesses classified by the European Union are classified as that have less than 10 employees. Micro, small, and medium sized businesses have flat hierarchy. [2] Given the flat structure these types of businesses rely on the leadership skills and expertise of the owners and lack the resources (labor, financial, time, etc.), organizational structure, and knowledge to implement operational improvement activities that large sized companies enjoy.

Lean manufacturing methodology was first implemented by O. Taiichi with the main goal of reducing waste. The lean Methodology focuses on increasing process speed by providing tools that are used to analyze process flow and delay for each process step encountered. [3] Activities are divided into 2 main groups:

- Value adding activities, which are the activities that the customer is willing to pay in order to receive.
- Non-value adding activities, which are the activities that the customer is not willing to pay in order to receive.

According to Bonnaccorsi et al. non-value adding activities are divided into 10 categories [4]:

- Duplication: performing tasks more than once like data re-entering.
- Incorrect Inventory: not keeping in stock necessary items to complete a task.
- Lack of customer focus: Employee unfriendliness or poor attention to the customer.
- Overproduction: processing paperwork prior to completing a task.
- Unclear Communication: lack of a standard work flow or incorrect information.
- Motion/Transportation: poor workspace layout and ineffective filing.
- Underutilized Employees: in adequate tools and limited authority.
- Variation: lack of standard operating procedures.
- Waiting/Delay: waiting for supplies or equipment downtime during the work day.

The Voice of the Customer (VoC) is important in identifying value added and non-value added activities, by obtaining feedback from customers on products or service. Griffin and Hauser define VoC in their paper as “a complete set of customer wants and needs; expressed in the customers own language; organized the way the customer thinks about it, uses and interacts with the product or service; and prioritize by the customer in terms of both importance and performance”. [1]

The 3G kaizen principles, Gemba, Gembutsu, and Genjitsu, in the kaizen methodology are used by decision makers to observe where and how the services are provided. [5] The information obtained from executing the 3G lead to better decisions. The first principle discussed is gemba or “the actual place”, which refers to where the process occurs, more commonly known as the shop floor. The second principle is Gembutsu, or “the thing” which refers to the product or service which is the main focus of the improvement effort. The last principle is the Genjitsu or “the facts” which refers to the area of the kaizen.

## METHODOLOGY

Lean methodology focuses on the elimination of waste (muda) though tools such as the Value Stream Map (VSM) and the Voice of the Customer (VoC). In order to determine value and customer need a VoC survey was administered to BRC patients. The written survey was provided by the BRC staff to the patients at the end of each examination. Since the BRC clients were predominantly Puerto Rican, the survey was provided in Spanish to prevent misunderstanding. Survey entries were developed by the BRC staff to ensure that if a patient had any questions, staff could answer any questions pertaining to the survey. The survey focused on ranking three choices in order of preference. The following choices were provided:

- Reduction in examination time or time it takes patients to receive the exam and report.
- Reduction in examination results time or the time it takes to complete the x-ray examination.
- Customer Service or the service and assistance provided before, during, and after the patient examination was completed.

After the patients completed the written survey the data was gathered. Since the survey uses ranked data, to identify customer preference customer responses were scaled where Rank 1 was 5 points, rank 2 was 3 points, and rank 3 was 1 point. With the scaled data customer preference in percentage was determined and the investigation was focused on the need of the customer.

Three main lean measurement concepts were used since this project was implemented in the health services industry:

- Cycle Time: time required to complete a task.
- Lead Time: time for patient to obtain the x-ray scans and exam reports.
- Queue Time: the time in between processes.

Gemba, Gembutsu, and Genjitsu, or the 3Gs of kaizen or continual improvement, are used in the study to obtain information at the clinic for ten (10) studies. Gemba refers to where value is created for the patient. Each step of the process flow and operating procedure was gathered for analysis. Measurements like cycle time, lead time, transportation time, and handling time were gathered to obtain a baseline.

The methodology of the investigation was summarized in Figure 1. Value stream data were measured, and a time study was completed (Gembutsu). Then Genjitsu or line observation was captured and used to create a Current Value Stream Map (CVSM). The data in CVSM was based on the flow of information and x-ray films. Based on the data gathered the bottleneck was identified. A kaizen was completed to determine the improvement opportunities. Additionally, the variable costs (cost dependent on output) for the x-ray process was determined by observing historical data of three (3) months on clinic output and required x-ray equipment supply. From the data gathered the variable costs for the conventional equipment was determined.

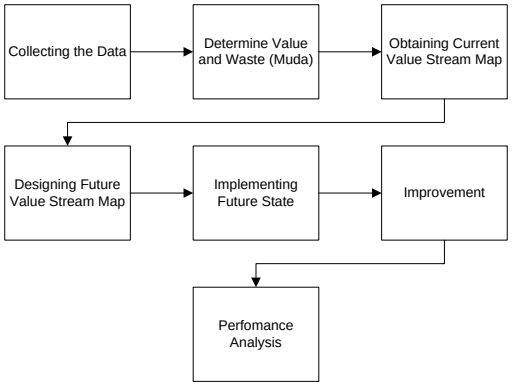


**Figure 1**
**Methodology of Implementing VSM**

The Future Value Stream Map (FSVM) was designed to improve flow, and reduce waste, ultimately leading to a reduction in lead time for the patient exam results. Finally, a performance analysis and cost analysis were conducted to ensure process robustness and effectiveness of the FSVM. To complete the cost analysis the total clinic exam output and the supply costs were identified. Using the data obtained the expected monthly cost was approximated.

## RESULTS AND DISCUSSION

The conventional x-ray equipment uses harmful chemicals like x-ray fixer and developer to produce x-ray films for the radiologist to diagnose. BRC provides services to more than two thousand (2000) patients per year and provides services Monday through Friday from 7:00 am – 3:30 pm. The Voice of the Customer (VoC) analysis was completed through a short survey completed at the end of each visit where patient ranked in order of preference the following entries:

- Reduction in examination time (cycle time).
- Reduction in examination results time (lead time).
- Customer Service (customer employee-interactions).

Each rank was given a scaled value where Rank 1 was 5 points, rank 2 was 3 points, and rank 3 was 1 point. Each choice wording was simplified in order to facilitate customer understanding.

The scaled results are summarized in Figure 2. Results show that patients value exam results time (lead time) with 40%. For this reason, the focus of the investigation was to reduce the lead time for patients obtaining their examination results. Behind the lead time, customer service and cycle time were viewed with approximately the same importance with a preference difference of 2%.

Having focused the investigation using the VoC results, the 3G principles discussed in the methodology section were completed. The Gemba walk was completed for ten (10) x-rays examinations were each step of the process was observed from customer's arrival to exam report retrieval.

Once a new patient arrives to the clinic, employees provided the patient with health history questionnaire. In the meantime, the technician obtained the prescription and patient identification. The technician contacted the insurer to ensure insurance coverage and charged the patient.

After the patient completed the health history questionnaire, the technician brought the patient to the x-ray room.

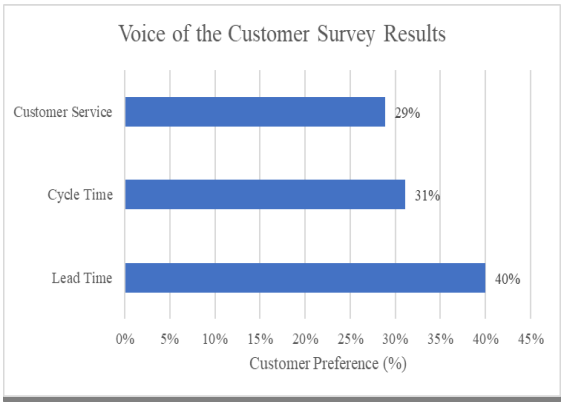


**Figure 2**
**Voice of the Customer Survey Results**

Prior to positioning the patient, the technician obtained the necessary cassettes for the study in the room next door from the x-ray room, since unexposed cassettes cannot be kept inside the x-ray room. The available film sizes used for the x-ray examinations were 11x17", 14x14" 11x14", 10x12", and 8x10".

Depending on the exam requirements x-ray films were chosen but the main constraint for clinic was the 2 x-ray cassettes per size.

The patient was positioned, and the first exposure was completed. The technician took the exposed cassette (with the film inside) to the dark room located across the hallway from the x-ray room and verified the developing equipment the chemical levels. In the dark, the film was removed from the cassette and placed into the developer solution.

Film then gets washed, fixed with the acidic film solution, washed once again and dried using an automatic x-ray film processor. In the meantime, the technician placed an unexposed film in the cassette. The film moved through the developing equipment and came out in the hallway.

The technician inspected the developed x-ray film and repeated the process for each study view. On average patients needed about three (3) x-ray views. After the study was completed, the patient left. The study was placed in the radiologist's office for reporting. When the radiologist arrived, the exam was reviewed and the report was completed. The following day the technicians called the patient

for exam report pickup. Value added activities and waste (muda) were determined, accordingly. Data collected was used to determine cycle time, queue time, and lead time. Takt time, a common Lean manufacturing tool, was not determined since customer demand for the clinic cannot be determined until the day was over.

Table 1 details the summary of the measurements completed at BRC.

**Table 1**
**Process Measurements Before Digital X-Ray Implementation**

| *Process Name* | *Cycle Time (min)* |
|---|---|
| Check In | 5 |
| Verify Patient Insurance and Complete Payment | 5 |
| Patient Prep | 10 |
| Complete Exposure, Develop Film, and Recharge Cartridge | 25 |
| Read Exam and Transcribe | 12 |
| Print and Sign Report | 1 |
| Contact Patient | 3 |

A current value stream map shown in Figure 3 was generated based on the results obtained from the Gemba walk. From the data obtained the x-ray examination and film development completed by the technician has the highest cycle time at twenty-five (25) minutes from the total sixty-four (64) minute cycle time.

Nonetheless, after completing a bottleneck analysis it was determined that the main bottle neck was the queue time from when the exam is completed to when to the study was read and transcribed. As shown in Figure 3, completed x-ray exams throughout the work day were placed in a bin to be evaluated by the radiologist.

The clinic has one (1) radiologist that comes on average every fifteen (15) hours to complete all the studies placed in the kanban. In order to reduce the lead time and cycle time the CVSM was evaluated in a kaizen with all the employees.

The kaizen used the root cause analysis technique of 5 Whys to determine the root cause of the problem. The problem evaluated was as follows: the lead time of the patient exam report wants to be reduced.

- Why does the lead time for the exam report take sixteen (16) hours? The main contributor to the sixteen (16) hours lead time is the queue time between the exam completion and the reading and transcription.
- Why does the queue time for exam reading and transcription fifteen (15) hours? The clinic only has one (1) radiologist than comes in every fifteen (15) hours on average.

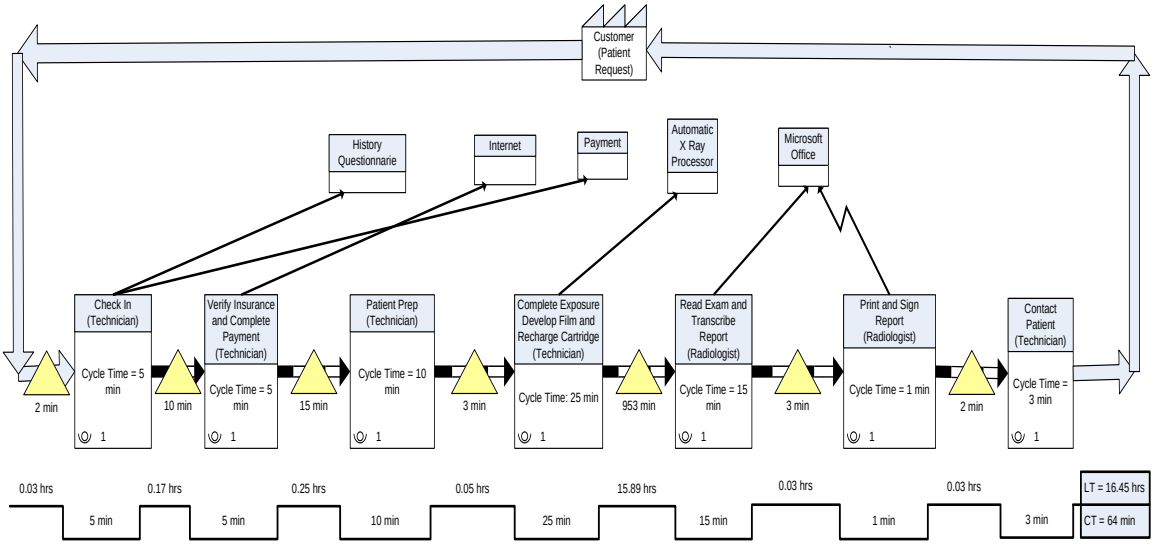


**Figure 3**
**Current Value Stream Map for Patient X-Ray Examination**

- Does the radiologist come in every fifteen (15) hours? The radiologist has other commitments and clinic financial resource constraints prevent clinic from having the radiologist during the working day.
- Why does the radiologist have to visit the clinic to complete the exam report? Conventional x-ray equipment uses physical films that prevent the digitalization of the study.
- Why does the clinic used conventional x-ray films? The clinic has been operating since 1992 and has not upgraded the equipment.

The most effective counter measure based on the analysis completed was that a digital x-ray and a PACS system would enable radiologist to read and transcribe exam reports without having to come into the office thereby completing examination reports throughout the day remotely.

In addition to the time waiting and delay observed in the CVSM, the kaizen identified all the supplies required for BRC to complete the examination process based on three (3) month historical variable costs of x-ray examination supplies. The average cost per supply was summarized in Table 2. The data obtained showed that ninety-three (93) percent of the monthly cost stems from the conventional x-ray system.

**Table 2**
**X-Ray Equipment Variable Cost**

| *Supplies* | *Average Cost ($/month)* |
|---|---|
| X-Ray Films | 676.80 |
| X-Ray Film Envelopes | 83.63 |
| X-Ray Film Developer | 253.88 |
| X-Ray Film Fixer | 117.07 |
| Paper | 20.00 |
| Printer Ink | 63.95 |
| Total | 1215.33 |

Based on the 5 Whys analysis and the variable cost analysis completed in the kaizen the Future Value Stream Map was developed with the new digital x-ray system (Figure 4), where through a wired network the server, digital x-ray cassette, x-ray workstation and receiver were connected securely. The total cost of implementation for the system was sixty thousand (60,000) dollars.

Taking an x-ray exposure patient data was input in the system. The cassette shown in Figure 5 was placed in the correct position and the exposure was taken from the work station. The technician instantly verified each exposure. Once the exam was completed the data was transmitted to the PACS server. The technician contacted the radiologist once four (4) patients were completed the radiologist completed the report due to availability constraints.

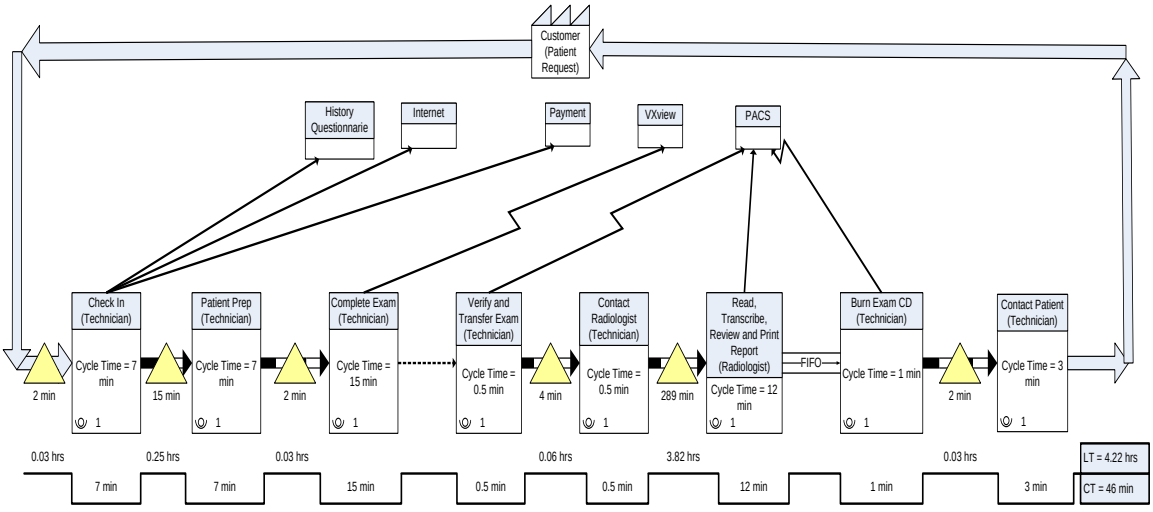


**Figure 4**
**Future Value Stream Map for Patient X-Ray Examination**

**Figure 5**
**Vieworks Digital Cassette Implemented**

The cycle times for each process stage were summarized in Table 3 by collecting data from ten (10) examinations. After the implementation of the digital x-ray and PACS system the queue time was reduced seventy-six (76) percent from fifteen (16) working hours to four (4) working hours. Also, the total lead time was reduced by twelve (12) hours. In line with the VoC survey need, the cycle time was also reduced by ten (10) minutes since the development of each exposure is not required in the digital x-ray system. Since the implementation reduced the developing and fixing steps, the exposure to harmful chemicals was completely removed. Moreover, the check in, insurance verification and payment were standardized into one process step.

**Table 3**
**Process Measurements after Digital Implementation**

| *Process Name* | *Cycle Time (min)* |
|---|---|
| Check In | 7 |
| Patient Prep | 7 |
| Complete Exam | 15 |
| Verify and Transfer the Exam | 0.5 |
| Contact the Radiologist | 0.5 |
| Read Exam and Transcribe | 12 |
| Print and Sign Report | 1 |
| Contact Patient | 3 |

The PACS system reduced the cycle time of patient examination reading and transcription by two (2) minutes. The PACS system functionality included report templates that eliminate the need of creating and modifying reports. The radiologist places the reading in text and the PACS system automatically generated the report with all the clinic requirements.

A variable cost evaluation after the implementation of the digital x-ray equipment was completed. The expected average cost per month was summarized in Table 4. To determine the expected variable costs for the x-ray equipment, the clinic patient output and supply costs were identified Using the data the average cost per month was determined and summarized in Table 4. The average variable cost per month expected after the implementation was one hundred seventy-three (173) dollars. The implementation reduced the monthly cost by eighty-five (85) percent, since the films and development chemicals were replaced by an inexpensive CD-ROMs and envelops.

**Table 4**
**X-Ray Equipment Variable Cost**

| *Supplies* | *Average Cost ($/month)* |
|---|---|
| CD-ROM | 69.00 |
| CD-Rom Envelopes | 20.07 |
| Paper | 20.00 |
| Printer Ink | 63.95 |
| Total | 172.72 |

## CONCLUSION

This investigation focus was to reduce the lead and cycle time for patient examination results at Bayamon Radiology Center, a radiology clinic in Bayamon, Puerto Rico. The investigation implemented Lean methodology techniques to ultimately improve the customer/patient experience. VoC surveys helped identify the value added activities and non-value added activities and focused the investigation on what the customer needs.

Lean tools were designed to improve processes and reduce waste, using root cause analysis and value stream mapping.

Value stream mapping was used to visualize and determine bottlenecks in the process. The hidden waste was identified and quantified. Root cause analysis (5 Whys) was used to determine that the conventional x-ray system was a main contributor to the lead and cycle times. The main

contributor to the sixteen (16) hour lead time was the queue time due to radiologist availability.

The digital X-ray and PACS system led to a reduction in lead time of twelve (hours) and a reduction in cycle time of ten (10) minutes. Additionally, the implementation removed the harmful chemical exposure, since chemicals are not used in the digital x-ray system.

Variable costs using conventional x-ray were determined using three (3) month historical data. An average monthly cost reduction of eighty-five (85) percent was achieved since the digital x-ray equipment removes the need for the x-ray films, enveloped, and developing chemicals.

The study shows that using Lean techniques to identify waste is effective in improving small business productivity, and the lean concepts can be successfully applied in the service industry. With this successful implementation the clinic loses less clients, reduces delay in patient treatment and diagnosis, and eliminates employee exposure to harmful developing chemical exposure.

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