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ΔΙΠΛΩΜΑΤΙΚΗ ΕΡΓΑΣΙΑ

«LEAN THINKING APPLICATION IN THE EMERGENCY DEPARTMENT OF HIPPOKRATION GENERAL HOSPITAL OF THESSALONIKI »

ΤΗΣ

ΟΛΙΒΙΑΣ ΞΕΝΗ ΜΑΥΡΟΜΟΥΣΤΑΚΗ

Υποβλήθηκε ως αιτούμενο για την απόκτηση του μεταπτυχιακού διπλώματος στη Διοίκηση Υπηρεσιών Υγείας

ΑΥΓΟΥΣΤΟΣ 2020

Υπεύθυνη Δήλωση

Βεβαιώνω ότι είμαι συγγραφέας αυτής της εργασίας και ότι κάθε βοήθεια την οποία είχα για την προετοιμασία της είναι πλήρως αναγνωρισμένη και αναφέρεται στην εργασία. Επίσης έχω αναφέρει τις όποιες πηγές από τις οποίες έκανα χρήση δεδομένων, ιδεών ή λέξεων, είτε αυτές αναφέρονται ακριβώς είτε παραφρασμένες. Επίσης βεβαιώνω ότι αυτή η εργασία προετοιμάστηκε από εμένα προσωπικά ειδικά για τις απαιτήσεις του Προγράμματος Μεταπτυχιακών Σπουδών στη Διοίκηση Υπηρεσιών Υγείας του Τμήματος Οργάνωσης και Διοίκησης Επιχειρήσεων του Πανεπιστημίου Μακεδονίας.

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ΟΛΙΒΙΑ ΞΕΝΗ ΜΑΥΡΟΜΟΥΣΤΑΚΗ

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Abstract

Objectives: This study had two main aims. The first aim was to evaluate the current patient flow in the Emergency Department of Hippokratio General Hospital of Thessaloniki in terms of time metrics (both waiting time and actual time spent) in every procedure from the secretarial registry to the final hospital admission or discharge with the administration of a questionnaire to the involved patients while the second aim was, based on the questionnaire findings and interviews with the involved working staff in the ED to apply means and tools of Lean Thinking to identify potential causes of delayed patient flow and propose counter measures aiming to improve the patients' flow in the ED. After a period of time, the applied countermeasures were evaluated in terms of time metric parameters from the involved patients in order to assess whether there was any improvement or not after the countermeasure implementation.

Results: At first, an assessment of the waiting times and actual duration of all 7 procedures was made by asking 644 patients who visited the ED from January 2020 to June 2020 to full in a well-structured self-administered anonymous with multiple-choice questions. It was shown that Laboratory Testing was the one with the higher patient times both in terms of waiting (28.1 minutes) and actual duration (125.4 minutes) while for Clinical assessment, Patient triage, Secretarial registry and Patient discharge or hospitalization, the patients had to wait for at least 15 minutes for each process. The total lead time of an average patient visit at the ED was 406.6 minutes with the average no-value-added time being 119.7 and the value-added time being 287.1 corresponding to 29.43% and 70.57% respectively of the average total lead time during patient flow. After all the patient time metrics were calculated, 34 healthcare professionals, were asked about the procedures, practices, policies and methods that are applied and followed in their ED as well as what they think could be done to improve the entire patient flow with smaller time metrics. An A3 report was created based on the above observations and as a result a number of proper countermeasures were applied. Almost two months after implementation, 345 patients were asked to estimate their total waiting time during each of the previously described procedures from Secretarial registry to Patient discharge or hospitalization as well as the actual time spent for the process itself. It was revealed that every time metric parameter was significantly improved. In terms of patient waiting times, the procedures of Final Diagnosis, Imaging Analysis and Secretary Registry were the ones that showed the greatest improvement having a time

improvement index of 54.5%, 49% and 45.7%. with the improvement index in the remaining procedures ranging from 21% to 38.1%. The overall average waiting time was decreased from 119.7 minutes to 78.7 minutes showing an improvement by 34.2%. In terms of actual duration, all the procedures had improvement indices from 9.8% to 32.6% with Final Diagnosis being the most improved one (32.6%) followed by Laboratory Testing and Secretarial registry (28.1% and 28.5% respectively). The total average actual duration was decreased by over 60 minutes (from 287.1 minutes to 224.4 minutes) showing an improvement of 21.3%.

Conclusions: The way lean management was designed and applied in terms of the ED of Hippokration Hospital revealed promising results with significant improvement indices in patient time metrics which is representative of how much could the hospital benefit from the implementation of total lean management in this working structure.

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Introduction

This study had two main aims. The first aim was to evaluate the current patient flow in the Emergency Department of Hippokration General Hospital of Thessaloniki in terms of time metrics (both waiting time and actual time spent) in every procedure from the initial registry to the final hospital admission or discharge with the administration of a questionnaire to the involved patients ,while the second aim was based on the questionnaire findings and interviews with the involved working staff in the ED to apply means and tools of Lean Thinking to identify potential causes of delayed patient flow and propose countermeasures aiming to improve the patients' flow in the Emergency Department of Hippokration General Hospital of Thessaloniki. After a period of time, the applied countermeasures were evaluated in terms of time metric parameters from the involved patients in order to assess whether there was any improvement or not after the countermeasure implementation.

2. Literature review

2.1 Lean Thinking (LT)

2.1.1 History of LT

Lean Management is the endless transformation of waste into values from the customer perspectives

Lean Management has its origin roots in Toyota Production System (TPS) that cause an incredible evolution in the field of production, one of the greatest success stories in corporate history (Holweg, 2007; Oliver, 2008). As its names implies, TPS is associated with the story of Toyota Motor Company (TMC) dating back in 1918 when the entrepreneur Sakichi Toyoda, established his spinning and weaving business based on his advanced automatic loom. In 1929, TMC sold their automatic loom patents to Platts Brothers for £100,000, and with Kiichiro Toyoda, son of Sakichi, as Head, TMC reinvented itself in the automotive industry. That period, automotive industry in Japan was dominated by local subsidiaries of Ford and General Motors (GM) which had been established in the 1920s, while the beginning of Toyoda's automotive business was fraught with financial difficulties and ownership struggles after Sakichi's death in 1930 (Oliver, 2008; Wada, 2004). However, during the same year, Japanese government released a new automotive manufacturing law that helped Kiichiro during his first step in automotive industry and began designing his Model AA by making considerable use of Ford and GM components (Cusumano, 1985). Toyoda's automotive industry was branded as 'Toyota' to simplify the pronunciation while giving it an auspicious meaning in Japanese. Truck and car production started in 1935 and 1936, respectively, and 1937 was the foundation year of TMC (Oliver, 2008; Seddon, O'Donovan, & Zokaei, 2011).

World War II had a deep impact on automotive production, and the post-war economic hardship resulted in growing inventories of unsold cars, leading to financial difficulties at TMC. Resultant severe labor disputes in 1950 forced a split of the initial TMC into two divisions: a) the Toyota Motor Manufacturing and b) the Toyota Motor Sales, as well as the resignation of Kiichiro (Cusumano, 1985). Eiji Toyoda, cousin of Kiichiro, became the new Managing Director of the manufacturing arm and in 1950 visited USA to study American manufacturing methods. Eiji was determined to implement mass production techniques at TMC, economies of scale, and big equipment to produce as many parts as possible, as cheaply as possible. Yet, capital constraints and the low volumes in the Japanese market did not justify the large batch sizes common at their competitors (Ford and GM). TMC's first car plant was used both for prototype development and production, and had a capacity of 150 units per month. The first high-volume car plant, Motomachi, was not opened until 1959 (Holweg, 2007; Seddon et al., 2011).

While the simple and flexible equipment that Kiichiro had purchased in the 1930s would enable many of the concepts essential to TPS, the person who gave the crucial impulse towards TPS development for economically producing large variety in small volumes, was Ohno who joined the initial Toyoda Spinning and Weaving (TSW) in 1932 ,after as a mechanical and was transferred to the TMC 11 years later after the close of TSW. As expected, he had no previous experience in automotive production, and it has been argued that his 'common-sense approach' without any preconceptions has been instrumental in developing the fundamentally different just-in-time philosophy (Cusumano, 1985). Ohno analyzed in detail the "Western" production systems and found two key logical flaws in them: a) the first logical flaw was that the production of components in large batches results in large inventories that require extensive capital and warehouse space resulting in numerous defects and b) the first logical flaw was the inability to accommodate consumer preferences for product diversity as he observed the dropping sales of Ford's Model T as customers preferred buying second-hand Chevrolets, which offered choice in color and optional equipment. It took Ford one year to introduce the Model A, while GM at the same period introduced 'a car for every purse and purpose' (Hounshell, 1984; Sloan, 1964). Ohno believed that GM had not abandoned Ford's mass production system, since the objective was still to use standard components enabling large batch sizes, thus minimizing changeovers. So the management of Western vehicle manufacturers were striving for large scale production and economies of scale, as outlined in the 'Maxcy–Silberston curve' (Holweg, 2007; Oliver, 2008).

Ohno gradually extended his concept of small-lot production throughout TMC focusing on cost reduction through waste elimination as in his previous job in loom business (Cusumano, 1985). Ohno describes in his book ,the two basic pillars of TPS: a) autonomation and b) just-in-time (JIT) manufacturing (Ohno, 1988) which supports that the best way to work would be to have all the parts for assembly at the side of the line just in time for their use. For the development of such a system, it was essential to produce and receive components and parts in small lot sizes, a process that so far was considered as uneconomical. Ohno obviously had to make alternations and changes in the machine changeover procedures in order to make the production of growing variety in smaller lot sizes possible. The fact that most of the machinery purchased by TMC with Kiichiro as Head was simple, general purpose equipment that could be easily subjected to changes and adjustments (Holweg, 2007). In this entire process of change-over reduction, apart from Ohno, the new hired consultant Shigeo Shingo had a vital contribution which was highlighted by the development of the single-minute exchange of dies (SMED) system (Shingō, 1983).

Ohno strongly supported the idea that removing all waste in a production system is the best way to make the system more efficient. As he describes in his book: "All we are doing is looking at the time line from the moment the customer gives us an order to the point when we collect the cash. And we are reducing that timeline by removing the non-value-added wastes" (Ohno, 1988). Ohno had learned from his experiences walking the shop floor a very particular meaning of non-valued-added waste: it had little to do with running labor and equipment as hard as possible, and everything to do with the manner in which raw material is transformed into a saleable commodity. For Ohno, the purpose of his journey through the shop floor was to identify activities that added value to raw material, and get rid of everything else. He learned to map the value stream of the raw material moving to a finished product that the customer was willing to pay for. This was a radically different approach from the mass production thinking of merely identifying, enumerating, and eliminating the wasted time and effort in the existing production processes and eliminating waste was going to become the heart of TPS (Liker, 2004).

He detected 7 main types of wastes inside TMC's production system, the so-called "7 deadly wastes or mudas (the Japanese word for waste)" (Ohno, 1988), which are the following:

1) Overproduction: The most serious of all of the seven wastes; the waste of overproduction is making too much or too early, before it is truly needed. This is usually because of working with oversize batches, long lead times, poor supplier relations and a host of other reasons. Overproduction leads to high levels of inventory which mask other underlying problems and inefficiencies.
2) Waiting (time-on-hand): The waste of waiting is any idle time produced when two interdependent processes are not completely synchronized resulting in wasted time because of slowed or halted production in one step of the production chain while the previous step is completed. If one task along the production chain takes longer than another, then any time the employee in charge of the next task spends waiting is wasted.
3) Transportation: The waste of transportation is the movement of materials from one location to another, without adding any value to the product. This unnecessary movement involves raw materials, work-in-process or finished products. Resources and time are used in handling material, employing staff to operate transportation, training, implement safety precautions, and using extra space. Transport can also cause the waste of waiting, as one part of the production chain must wait for material to arrive.
4) Over-processing or incorrect processing: One of the most difficult wastes to detect and eliminate; The waste of over-processing refers to any component of the production process that is unnecessary. Essentially, it refers to adding more value to produce than the customer requires.
5) Motion: The waste of motion refers to unnecessary movement of people, movement that does not add any value. Excessive travel between work stations, excessive machine movements from start point to work start point are all examples of the waste of Motion that create additional costs and cause stress to staff and machines.
6) Inventory: The waste of inventory refers to the waste produced by unprocessed inventory. Inventory includes all the product (raw materials, work-in-process, or finished products) quantities that go beyond supporting the immediate need. This waste includes the waste of storage, the waste of capital tied up in

unprocessed inventory, the waste of transporting the inventory, the containers used to hold inventory, the lighting of the storage space, etc.

7) Making Defective Parts: The waste of defects refers to the waste caused by the production of products that deviate from the predefined standards or from the customer's expectation. Every defective item requires rework or replacement, it wastes resources and materials, it creates paperwork, it can lead to lost customers.

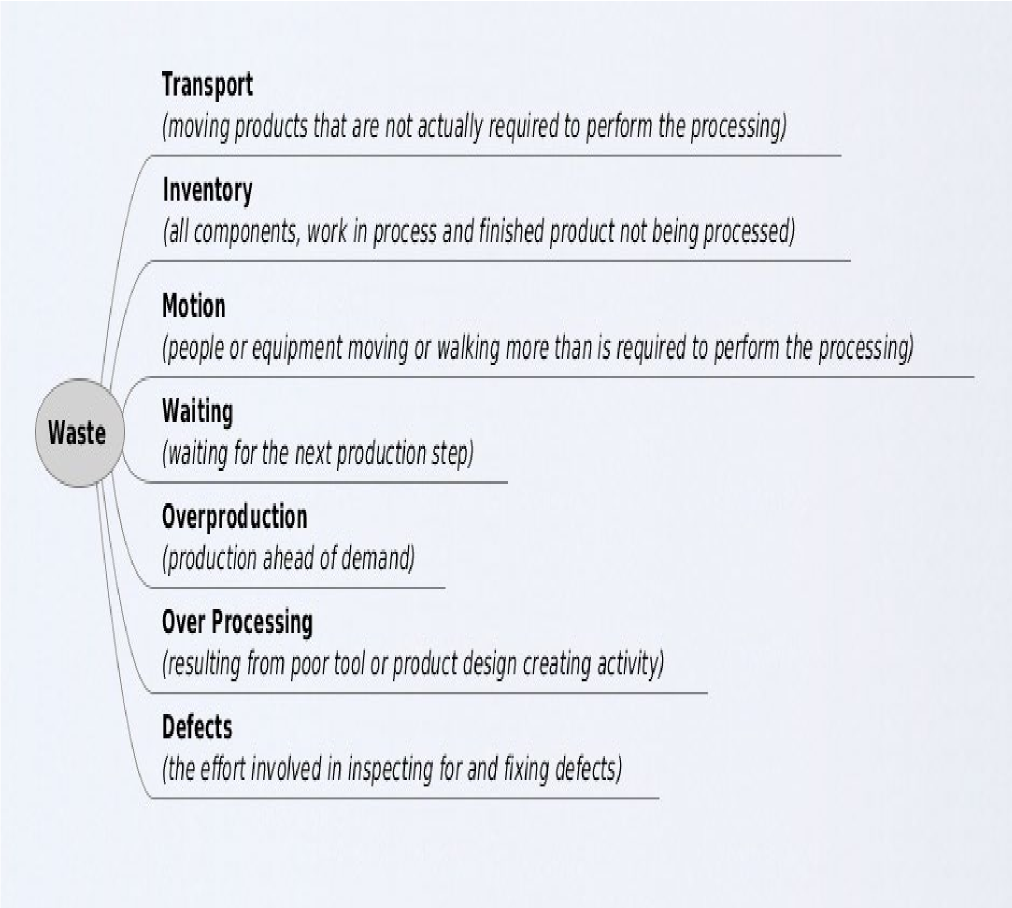

Figure 1. Toyota's (Ohno's) Seven Forms of Waste

Source: (Ōhno, 1988)

Later, an eight waste was added called "People". The waste of people refers to the under-utilization of the involved staff's skills and unused employee creativity. Losing time, ideas, skills, improvements, and learning opportunities by not engaging or listening to your employees (Liker, 2004).

With the development of TPS system, TMC became able to produce a great variety of automobiles in comparatively low volumes at a competitive cost, going against the conventional logic of mass production that was established from Ford and GM. The key to their operations was flexibility. This helped Toyota make a critical discovery: when you make lead times short and focus on keeping production lines flexible, you actually get higher quality, better customer responsiveness, better productivity, and better utilization of equipment and space. While Ford's traditional mass production looks good when you measure the cost per piece on an individual machine, what customers want is a much greater variety of choices than traditional manufacturing can offer cost-effectively. TMC focused on eliminating wasted time and material from every step of the production process from raw material to finished goods was designed to address the same conditions most companies face today: the need for fast, flexible processes that give customers what they want, when they want it, at the highest quality and affordable cost (Liker, 2004). By 1950, the entire Japanese auto industry was producing an annual output equivalent to less than 3 days' of the U.S. car production at the time (Holweg, 2007; Oliver, 2008). TMC adopted various elements of the Ford and GM production system and combined them with their ingenious system and original ideas and gradually become able to combine the advantages of small-lot production with economies of scale in manufacturing and procurement. The development of TPS by Ohno in 1948 was not a static but a dynamic event since the TPS was gradually improving and changing though continuously iterating learning cycle that spanned decades (Fujimoto, 1999).

2.1.2 The "Toyota Way"

In 2001, Toyota was unveiling its own internal document, the so-called "The Toyota Way" for training purposes. The Toyota Way is a set of principles and behaviors that underlie the TMC's managerial approach and TPS. This document summarized the entire philosophy, values and manufacturing ideals of TMC in four high-level principles:

1) Genchi Genbutsu
2) Kaizen
3) Respect and Teamwork
4) Challenge

which J. Liker correlated to four principle categories of **P**hilosophy, **P**rocess, **P**eople/Partners, and **P**roblem Solving (4P-model of the Toyota Way) in his book "The Toyota Way" (Liker, 2004) where he mentioned that "The Toyota Way and the TPS are the double helix of Toyota's DNA; they define its management style and what is unique about the company" (Liker, 2004). The 14 Principles of Toyota Way that are described in this book are the following (Liker, 2004):

Section I — Long-Term Philosophy

1) Principle 1: "**Base your management decisions on a long-term philosophy, even at the expense of short-term financial goals**".

   Have a philosophical sense of purpose that supersedes any short-term decision making. Work, grow, and align the whole organization toward a common purpose that is bigger than making money. Understand your place in the history of the company and work to bring the company to the next level. Your philosophical mission is the foundation for all the other principles. Generate value for the customer, society, and the economy it is your starting point. Evaluate every function in the company in terms of its ability to achieve this. Be responsible. Strive to decide your own fate. You must act with self-reliance and trust in your own abilities. Accept responsibility for your conduct and maintain and improve the skills that enable you to produce added value. Conclusively people need a purpose to find motivation and establish goals.

Section II — The Right Process Will Produce the Right Results

2) Principle 2: "**Create a continuous process flow to bring problems to the surface**".

   Redesign work processes to achieve high value-added, continuous flow. Strive to cut back to zero the amount of time that any work project is sitting idle or waiting for someone to work on it. Create flow to move material and information fast as well as to link processes and people together so that problems surface right away. Make flow evident throughout your organizational culture. It is the key to a true continuous improvement process and to developing people. In other words, work processes are redesigned to eliminate waste through the process of continuous improvement (kaizen), which is the core of Toyota Way.

   Kaizen is the Japanese word for " change for the best" or "improvement" and it consists of the word kai that means "do" and the word zen that means "good". The word refers to any improvement, one-time or continuous, large or small. Hence, Kaizen is the ability to make a change for the better (Abdulmouti, 2018; Imai, 1986, 2012; Liker, 2004).

   It refers to a Japanese philosophy aiming at continuous improvement of processes in manufacturing, engineering, the healthcare sector etc. Kaizen has its origins in the history of TMC which is described previously. Ohno identified an important aspect of the Kaizen Spirit when he said, "Despite knowing the outcome if I do it this way, I am compelled to do otherwise" (Lander & Liker, 2007; Liker, 2004; Ohno, 1988). Kaizen refers to the ability to step back from all activities, observe current processes and to propose solutions to problems. Kaizen spirit refers to an innate sense of continuous improvement in daily life in any place (in the workplace and even at home) and a continuous drive to improve. From TMC, Kaizen has been gradually adopted worldwide and it has become the central pillar for process improvement in business world (Abdulmouti, 2018; Imai, 1986, 2012).

Kaizen is a philosophy that involves a collective effort (including all employees of any degree) and defines management's role in continuously encouraging the implementation of small adjustments that make the production process more efficient, effective, manageable, and adaptable usually by using simple inexpensive techniques. Kaizen focuses on simplification by breaking down complex processes into their sub-processes and then improving them. Usually, Kaizen starts with how to produce efficiently with limited resources (manpower, materials, equipment). This means that it is not necessary to utilize all the available resources and manpower. On the contrary, it should be a focus on savings in manpower, space, equipment, materials, and time and an elimination of unnecessary processes. If something is found to be unused, it is better not to try to use it, but to remove it at once. If some employees are underutilized, they can be asked to help with Kaizen (Abdulmouti, 2018). By improving standardized programs and processes, kaizen aims to eliminate waste. It has since spread throughout the world and has been applied to environments outside business and productivity (Imai, 1986, 2012; Lander & Liker, 2007; Liker, 2004; Liker, J.K., & Meier, 2007; Pardi, 2007; Yuichi Sakai Toshihiko Sugano V Tomohiko Maeda, 2007).

Kaizen implementation consists of 3 distinct phases (Imai, 1986, 2012):

Phase 1 - Planning and Preparation: This phase involves the initial identification of an appropriate target area for a rapid improvement event. Once a suitable production process, administrative process, or area is selected, possible problems that need to be addressed are selected. Once the problem area is chosen, managers prepare a cross-functional team of employees that will later get involved with problem-solving process.

Phase 2 – Implementation: In this phase, the assigned team first tries to develop a clear understanding of the "current state" of the targeted process so that all team members have a similar understanding of the problem they are working to. This phase requires collection of data associated with the targeted process (measurements, rates, indicators, other metrics) and the assignment of specific roles for research and analysis to all involved team members. Once data is gathered, it is analyzed and assessed to find areas for improvement. Team members then brainstorm improvement options for their own assigned project and possibly for other projects related to the joint effort. Ideas are often tested on the shop floor or in process "mock-ups". Ideas that are evaluated as the most promising are selected and implemented. To fully realize the benefits of the kaizen, team members should observe and record new cycle times, and calculate overall savings from eliminated waste, operator motion, part conveyance, square footage utilized, and throughput time.

Phase 3 -Follow-up: This phase involves the follow-up activity that aims to ensure that the improvements applied in Phase 2 are sustained after the implementation process, and were not just temporary. Phase 3 is a crucial for Kaizen since it ensures the effectiveness of the entire process. Team members routinely track key performance measures and review metrics in order to verify the improvement and evaluate the improvement gains. Follow-up events are sometimes scheduled at 30 and 90-days following the initial kaizen event to assess performance and identify follow-up modifications that may be necessary to sustain the improvements.

3) Principle 3: "**Use pull systems to avoid overproduction**".

   Provide your downline customers in the production process with what they want, when they want it, and in the amount they want. Material replenishment initiated by consumption is the basic principle of just-in-time. Minimize your work in process and warehousing of inventory by stocking small amounts of each product and frequently restocking based on what the customer actually takes away. Be responsive to the day-by-day shifts in customer demand rather than relying on computer schedules and systems to track wasteful inventory. In other words, <u>develop a pull system in order to produce only the required material after the subsequent operation signals a need for it</u>.

4) Principle 4: "**Level out the workload (heijunka). (Work like the tortoise, not the hare)**".

   Heijunka is a Japanese word that means "leveling." When implemented correctly, heijunka elegantly – and without haste – helps organizations meet demand while reducing while reducing wastes in production and interpersonal processes. Eliminating waste is just one-third of the equation for making lean successful. Eliminating overburden to people and equipment and eliminating unevenness in the production schedule are just as important yet generally not understood at companies attempting to implement lean principles. Work to level out the workload of all manufacturing and service processes as an alternative to the stop/start approach of working on projects in batches that is typical at most companies. In other words, try to minimize waste and avoid creating uneven production levels while not overburdening people or/and equipment.

5) Principle 5: "**Build a culture of stopping to fix problems, to get quality right the first time**".
   Quality for the customer drives your value proposition. Use all the modern quality assurance methods available. Build into your equipment the capability of detecting problems and stopping itself. Develop a visual system to alert team or project leaders that a machine or process needs assistance. Jidoka (machines with human intelligence) is the foundation for building in quality. Build into your organization support systems to quickly solve problems and put in place countermeasures. Build into your culture the philosophy of stopping or slowing down to get quality right the first time to enhance productivity in the long run. In other words, quality takes precedence (Jidoka). Any employee has the authority to stop the process to signal a quality issue.
6) Principle 6: "**Standardized tasks and processes are the foundation for continuous improvement and employee empowerment**".
   Use stable, repeatable methods everywhere to maintain the predictability, regular timing, and regular output of your processes. It is the foundation for flow and pull. Capture the accumulated learning about a process up to a point in time by standardizing today s best practices. Allow creative and individual expression to improve upon the standard; then incorporate it into the new standard so that when a person moves on you can hand off the learning to the next person. In other words, find ways for continuous improvement (kaizen) from the people affected by that system. It empowers the employee to aid in the growth and improvement of the company.
7) Principle 7: "**Use visual control so no problems are hidden**".
   Use simple visual indicators to help people determine immediately whether they are in a standard condition or deviating from it. Avoid using a computer screen

when it moves the worker's focus away from the workplace. Design simple visual systems at the place where the work is done, to support flow and pull. Reduce your reports to one piece of paper whenever possible, even for your most important financial decisions.

Included in this principle is the **5S Program:** steps that are used to make all work spaces efficient and productive, help people share work stations, reduce time looking for needed tools and improve the work environment.

Sort: Sort out unneeded items

Straighten: Have a place for everything

Shine: Keep the area clean

Standardize: Create rules and standard operating procedures

Sustain: Maintain the system and continue to improve it

8) Principle 8: "**Use only reliable, thoroughly tested technology that serves your people and processes**".

   Use technology to support people, not to replace people. Often it is best to work out a process manually before adding technology to support the process. New technology is often unreliable and difficult to standardize and therefore endangers flow. A proven process that works generally takes precedence over new and untested technology. Conduct actual tests before adopting new technology in business processes, manufacturing systems, or products. Reject or modify technologies that conflict with your culture or that might disrupt stability, reliability, and predictability. Nevertheless, encourage your people to consider new technologies when looking into new approaches to work. Quickly implement a thoroughly considered technology if it has been proven in trials and it can improve flow in your processes. In other words, <u>technology is pulled by manufacturing, not pushed to manufacturing</u>.

Section III — Add Value to the Organization by Developing Your People

9) Principle 9: "**Grow leaders who thoroughly understand the work, live the philosophy, and teach it to others**".

   Grow leaders from within, rather than buying them from outside the organization. Do not view the leader's job as simply accomplishing tasks and having good people skills. Leaders must be role models of the company's philosophy and way of doing business. A good leader must understand the daily work in great detail so they can be the best teacher of the company's philosophy.

In other words, without constant attention, the principles will fade. The principles have to be ingrained; it must be the way one thinks. Employees must be educated and trained: they have to maintain a learning organization.

10) Principle 10: "**Develop exceptional people and teams who follow your company's philosophy**".

    Create a strong, stable culture in which company values and beliefs are widely shared and lived out over a period of many years. Train exceptional individuals and teams to work within the corporate philosophy to achieve exceptional results. Work very hard to reinforce the culture continually. Use cross-functional teams to improve quality and productivity and enhance flow by solving difficult technical problems. Empowerment occurs when people use the company's tools to improve the company. Make an ongoing effort to teach individuals how to work together as teams toward common goals. In other words, teamwork is something that has to be learned. Success is based on the team, not the individual.

11) Principle 11: "**Respect your extended network of partners and suppliers by challenging them and helping them improve**".

    Have respect for your partners and suppliers and treat them as an extension of your business. Challenge your outside business partners to grow and develop. It shows that you value them. Set challenging targets and assist your partners in achieving them. In other words, suppliers should be treated much like company's employees, challenging them to do better and helping them to achieve it.

Section IV — Continuously Solving Root Problems Drives Organizational Learning

12) Principle 12: "**Go and see for yourself to thoroughly understand the situation (Genchi Genbutsu)**".

Solve problems and improve processes by going to the source and personally observing and verifying data rather than theorizing on the basis of what other people or the computer screen tell you. Think and speak based on personally verified data. Even high-level managers and executives should go and see things for themselves, so they will have more than a superficial understanding of the situation. In other words, without experiencing the situation firsthand ("go-and-see"), managers will not have an understanding of how it can be improved.

13) Principle 13: "**Make decisions slowly by consensus, thoroughly considering all options; implement decisions rapidly (nemawashi)**".

Do not pick a single direction and go down that one path until you have thoroughly considered alternatives. When you have picked, move quickly but cautiously down the path. Nemawashi is the process of discussing problems and potential solutions with all of those affected, to collect their ideas and get agreement on a path forward. This consensus process, though time-consuming, helps broaden the search for solutions, and once a decision is made, the stage is set for rapid implementation. In other words, after determining the underlying cause and considering a broad range of alternatives, build consensus on the resolution and use efficient communication tools.

14) Principle 14: "**Become a learning organization through relentless reflection (hansei) and continuous improvement (kaizen)**".

Once you have established a stable process, use continuous improvement tools to determine the root cause of inefficiencies and apply effective countermeasures. Design processes that require almost no inventory. This will make wasted time and resources visible for all to see. Once waste is exposed, have employees use a continuous improvement process (kaizen) to eliminate it. Protect the organizational knowledge base by developing stable personnel, slow promotion, and very careful succession systems. Use hansei (reflection) at key milestones and after you finish a project to openly identify all the shortcomings of the project. Develop countermeasures to avoid the same mistakes again. Learn by standardizing the best practices, rather than reinventing the wheel with each new project and each new manager. In other words, the process of becoming a learning organization involves criticizing every aspect of what one does (investigate-countermeasure-evaluate-standardize).

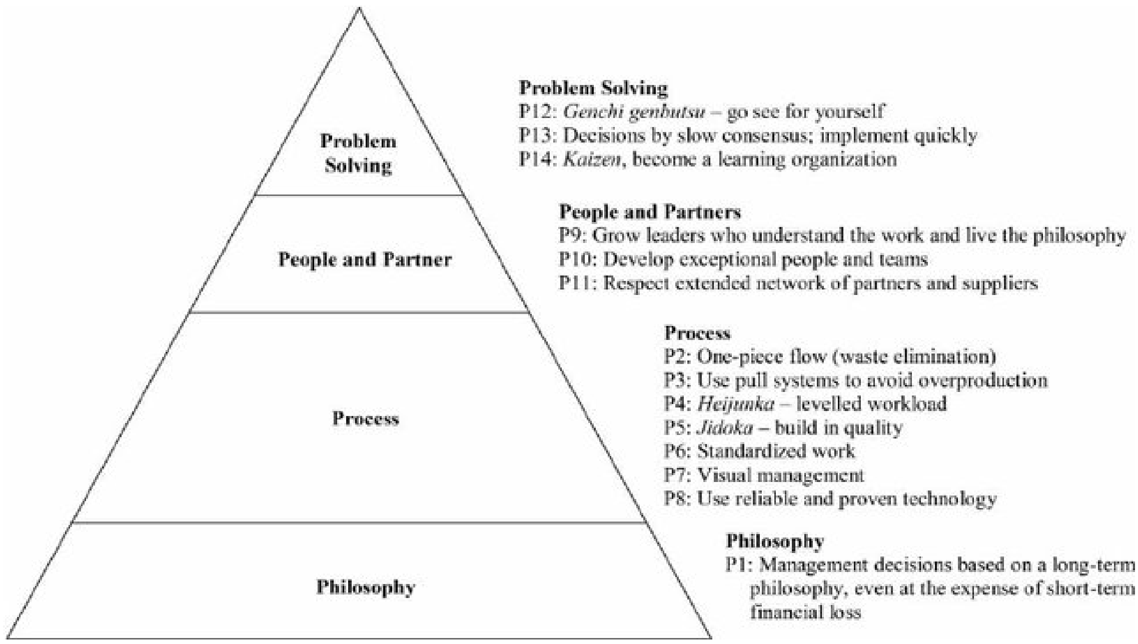

Figure 2. A 4 P model of the Toyota Way

Source: (Liker, 2004)

Toyota has been remarkably open in sharing its source of competitive advantage with the rest of the world. A milestone was Eiji Toyoda s decision in 1982 when, as chairman, he, along with Shoichiro Toyoda, President, approved the agreement with GM to create NUMMI, a joint auto manufacturing venture specifically intended to teach the Toyota Way to GM. That meant sharing Toyota's famous Production System, with its principal global competitor. Another milestone in opening up TPS to the world was the decision to create the Toyota Supplier Support Center in 1992 for the purpose of teaching the Toyota Production System to U.S. companies by setting up working models in plants across industries (Liker, 2004).

2.1.3 From TPS to Lean Thinking

The most visible product of TMC's quest for excellence is its manufacturing philosophy, THE previously described TPS. TPS is the next major evolution in efficient business processes after the mass production system invented by Henry Ford, and it has been documented, analyzed, and exported to companies across industries throughout the world (Liker, 2004). The Toyota Way was the first book to introduce this kind of company management thinking outside of Japan. It explains to the managers in any environment blue-collar, white-collar, manufacturing, or service industry how managers can dramatically improve their business processes by: eliminating wasted time and resources, building quality into workplace systems, finding low-cost but reliable alternatives to expensive new technology, perfecting business processes and building a learning culture for continuous improvement (Liker, 2004).

Outside of TMC, the Toyota Way and especially TPS are often known as lean or lean thinking, since these were the terms that was used in two best-selling books: "The Machine That Changed the World" (Womack, Jones, & Roos, 2007) and "Lean Thinking: Banish Waste and Create Wealth in Your Corporation" (Womack & Jones, 2006). The authors make it clear, however, that the foundation of their research on lean thinking is TPS and the Toyota Way.

In the first part of the book "Lean Thinking: Banish Waste and Create Wealth in Your Corporation", the authors James P. Womack and Daniel T. Jones argue that a lean way of thinking allows companies to "specify value, line up value creating actions in the best sequence, conduct these activities without interruption whenever someone requests them, and perform them more and more effectively" (Womack & Jones, 2006). This is why the 2 authors described in their book the five basic principles of LM: 1)Value 2)Value Stream 3)Flow 4)Pull and 5)Perfection (Womack & Jones, 2006).

1) <u>Value</u>: is defined in page 311 as a "capability provided to customer at the right time at an appropriate price, as defined in each case by the customer". Value is the critical starting point for LT, and can only be defined by the ultimate end-customer. The ultimate end customer (or the end-user of the product), is contrasted with all the interim customers, such sales, marketing, distribution, suppliers, etc. Value also is a product-specific term, and the authors argue it is only meaningful when expressed in terms of a specific product. The definition of Value is the initial step in LT process and it is not an easy task to accomplish.
2) <u>Value Stream</u>: is defined in page 311 as the set of all the "specific activities required to design, order, and provide a specific product, from concept to launch (problem solving task), order to delivery (information management task), and raw materials to the final product into the hands of the customer (finish material task)". In order to create a value stream, all activities that occur to a product at every production step, from design to order to raw material to delivery, have to be described. The concept of value-added and non-value-added work that is introduced with the value stream perspective is the essence of lean thinking, based on the TPS.

   There are 3 main types of activities in the Value Stream:

a) Value-Added activities: It includes all the activities that unambiguously add/create value.

b) Type-1 Muda activities: It includes all the activities that, despite the fact that they do not add/create value, they seem to be unavoidable and unrestrained based on current technologies and/or production assets.

c) Type-2 Muda activities: It includes all the activities that do not add/create value, but are immediately avoidable or at least restrained.

Muda activities are mistakes which require rectification, groups of people in a downstream activity waiting on an upstream activity, or goods which don't meet the needs of the customer.

3) Flow: is defined in page 306 as the "progressive achievement of tasks along the value stream so that a product proceeds from design to launch, order to delivery and raw materials to the final product into the hands of the customer with no stoppages, scrap or backflows". This basically implies the need to move away from the traditional and widely accepted "batch-and-queue" thinking to new ways to foster flow such as quick changes of tools in manufacturing, rightsizing machines and locating sequential steps adjacent to one another. Ideally, each step in the flow has to be always available and adjustable to the changing needs of the customers.

4) Pull: is defined in page 309 as a "system of cascading production and delivery instructions from downstream to upstream in which nothing is produced by the upstream supplier until the downstream customer signals a need". The concept of Pull avoids pushing products through a system, which is unresponsive to the customer resulting this way in unnecessary inventory buildup (waste).

5) Perfection: is defined in page 308 as the "complete elimination of muda so that all activities along a value stream create value". The concept of Perfection idealizes the LT as a never-ending dynamic process since there will be always muda in the value stream and so its complete elimination is more of a desired end-state rather than a feasible and achievable target. Basically, the implementation of the concept for continuous improvement leads to the emergence of new innovative approaches and methods to improve the Value Stream, Flow and Pull making the organization more efficient while bringing the target of Perfection a step closer.

In summary, to be a lean manufacturer requires a way of thinking that focuses on making the product flow through value-adding processes without interruption (one-piece flow), a pull system that cascades back from customer demand by replenishing only what the next operation takes away at short intervals, and a culture in which everyone is striving continuously to improve (Womack & Jones, 2006).

2.1.4 Lean Thinking Toolbox

Emergency departments (EDs) face problems with overcrowding, access block, cost containment, and increasing demand from patients. In order to resolve these problems, there is rising interest to an approach called "lean" management.

2.1.4.1 Value Stream Mapping (VSM)

Value-stream mapping is a primary lean-thinking tool that focuses on the analysis of two distinct states: a) the current state which is carried out until now and b) the future state in which the transition has to be made after proper improvements and corrective action is applied (de Koning, Verver, van den Heuvel, Bisgaard, & Does, 2006; Rother & Shook, 2003). The entire process is basically the visualization of the two states in form of value stream maps that show the flow of materials and information as they progress from the beginning of the specific process until it reaches the customer in the form of a service or product with detailed display of all the critical steps, the time and volume taken at each specific step (Rother & Shook, 2003). The current state value stream map depicts what the process currently looks like while the future state value stream map shows how the process will ideally look like after process improvements will be implemented (Mascitelli, 2011). VSM is a Lean practice that maps the current product development process (current state map), identifies value adding and non-value adding activities and steps, and helps to create an action plan for achieving an improved future state of the process (future state map) (Khurum, Petersen, & Gorschek, 2014).

As mentioned, the first step is mapping the current state with its entire processes. Collection and analysis of data is vital for the correct and precise creation of the current state map. VSM analyzes both material and information flow (Rother & Shook, 2003). The aim of this process is to see the entire process and detect possible wastes and non-value-added processes that should be removed or minimized (Machado & Leitner, 2010). Once the collected data is analyzed, the VSM can start. Any VSM can be drawn using simple symbols or icons. Also, the time duration associated with each process and step are included in the map both the actual time that is usually spent and the ideally required time that is enough for the process. It is obvious that the aim is to reduce the time spent in non-adding-value processes since the time spent in value-adding processes cannot be reduced in most cases (Mascitelli, 2011).

Shigeo Shingo, the consultant of Toyota, colleague of Ohno and father of the SMED system, in his book (Shingō, 1983) suggests a way of VSM where the value-adding steps are drawn across the center of the map and the non–value-adding steps in vertical lines at right angles to the value stream making it easier to distinguish the value stream from the waste steps. The thinking here is that the non–value-adding steps are often preparatory or tidying up to the value-adding step and are closely associated with the person or machine/workstation that executes that value-adding step. Therefore, each vertical line is the "story" of a person or workstation whilst the horizontal line represents the "story" of the product being created (Shingō, 1983).

Once the current state map is complete, the design of the future state map follows. In order to better define the perquisites of the future state, the assigned staff should be experienced with lean principles. Also, some series of questions can be used as a guide during the mapping process aiming to cause a creative brainstorming concerning potential improvements and corrective action whose implementation will lead to the transition from current to future state. As an outcome, a future state map that reflects how operations should change in the near future. The proposed improvements should be achievable and suitable for the company with definite positive value added vs. non-value-added ratio (Machado & Leitner, 2010).

A basic VSM procedures involves the following steps (Bicheno, 2004):

1. Sponsor selection: The sponsor is the individual responsible for making decisions, arbitrating solutions, and planning the project. The sponsor is the one who selects the processes that will be mapped and will define what achievement is being targeted.
2. Team selection: Team selection is very important and should be done in a way that every step of the process is represented in the assigned team.
3. Selection of Process for mapping: The process that will be mapped is defined.
4. Mapping of the Process Flow: All the steps have to be included within an organization from raw material supplier to the final customer of the product/service. The process steps are the various operations that are performed on the product/service and are generally located in a single place with one point that inventory enters and then leaves. Breaking down each operation into specific tasks and sub-tasks is not recommended.

5. Adding of Information Flows in the map: All the necessary information associated with the customers, the suppliers and the workers are included.
6. Collection of Process Data: Collection of data associated with the performance of each step of the process is carried out including inventories, batches, timings and any other metric suitable to the organization for which VSM is done.
7. Creation of the Time Line of the Process Flow: The time line is necessary in order to calculate the total process times and lead times for inventory through process flow. Having high lead times and short processing times indicates the amount of waste there is in the mapped production flow.

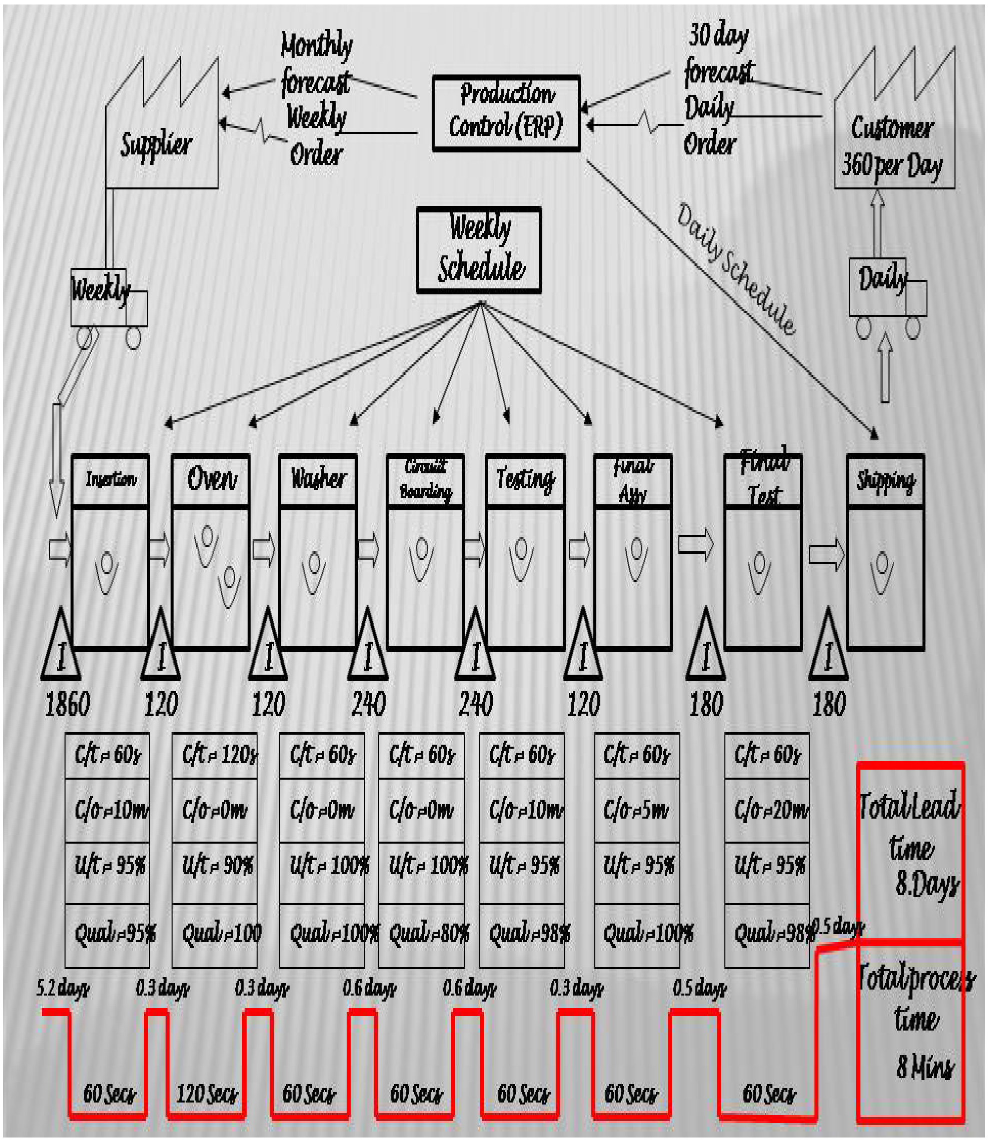

Figure 3. An example of Value-stream mapping

Source: https://leanmanufacturingtools.org/

2.1.4.2 The A3 Report

A3 is derived from one of the standard European paper sizes (A3 paper is also known as 11” x 17” or B-sized paper). The A3 Report is based upon the Plan, Do, Check, Act (PDCA) Method. The PDCA process is sometimes referred to as the Deming Wheel or Deming Circle. The A3 Report incorporates this basic premise to problem solving and continuous improvement (Bassuk & Washington, 2013; Mangelsdorf et al., 1995; Matthews, 2011; Sobek & Smalley, 2008).

Some problem-solving tools involve numerous pages of information, multiple charts and graphs and lengthy reports. The A3 process allows groups of people to actively collaborate on the purpose, goals, and strategy of a project. It encourages in-depth problem solving throughout the process and adjusting as needed to ensure that the project most accurately meets its intended goal. The A3 Report format can be used to more effectively communicate all of the necessary information with greater visual impact. While the A3 Report is an effective communication tool, it is actually much more valuable as a problem-solving and critical thinking tool that can be used to drive continuous improvement. The A3 Report fosters a problem solving / continuous improvement mindset within the participating team members. It is an excellent tool for managers and supervisors to share problem solving techniques with their teams. With resources being limited, completion of a formal A3 Report may not be applicable to every problem. Its use should be determined based upon the size of the problem and its impact on the business or organization (Mangelsdorf et al., 1995; Matthews, 2011; Sobek & Smalley, 2008).

The A3 Report usually consists of multiple steps following a PDCA structure of Plan, Do, Check, Act. The number of steps can vary due to the different formats being used for the A3 Report. The exact number of steps used is not as important as the end result. The A3 Report can utilize various forms depending upon the organizations needs and preferences. The basic steps and where they fall into the PDCA structure are listed below (Bassuk & Washington, 2013; Mangelsdorf et al., 1995; Matthews, 2011; Sobek & Smalley, 2008).

<u>Plan</u>

1. Definition of the Problem:

The first step is to define the problem or identify the need for improvement. Also, the ideal state, the operational standard or the desired condition should be defined as well as the current situation or status. Then, the gap between the current status and the desired state/ operational standard has to be described. The final goals have to be set as well as the reasons how performing the A3 and closing the gap would benefit the organization (A3 value)

2. Containment:

   In some A3 formats, a section is included for immediate counter-measures or containment actions aiming to prevent further problems from occurring or prevent the current problem from causing negative effects to other processes, products or departments.

3. Breakdown of the Problem:

   The problem has to be further analyzed according 5W (What, When, Where, Who, Why) and 2H (How, How many / How often) questions. There also may be more than one issue contributing to the problem or more detail required to properly address the problem, in case prioritization of the issues is necessary as well as the identification of the occurrence point or escape point.

4. Definition of goals:

   Setting goals for the desired improvement is essential. The goals could include a percentage of improvement in process throughput, reduction in number of defects per unit or processing time. In any case, the goals should be specific, measurable, realistic, achievable and time-efficient.

5. Root Cause Analysis:

   A Root Cause Analysis (RCA) of the problem should be carried out using, among others, data analysis or completing a Cause and Effect or Ishikawa diagram followed by a 5 Why exercise. Whatever method selected, it is important to identify the symptoms of the problem and the root cause.

6. Countermeasures:

   Design and application of permanent counter-measures or/and corrective actions are vital to address the root cause and should be clearly defined, achievable by the assigned individuals and have a due date.

Do

7. Implementation:

   Design and application of an implementation plan for the corrective actions should be developed. The plan should define the team members, resources and time required to complete each task. In some cases, support from outside resources or test facilities may be included. In some cases, certain levels of management should be kept informed throughout the process to assure adequate resources are available for the execution of the implementation plan.

Check

8. Monitoring and Validation:

   The effectiveness of the applied counter-measures and corrective actions has to be evaluated and confirmed. This can be accomplished in many ways, including but not limited to additional quality checks, Statistical Process Control (SPC) data, process or product audits and customer feedback.

Act

9. Standardization and Improvement:

   During this phase of the A3, the process changes or improvements are subjected to standardization including all standard work, work instructions and process control plans, etc. In addition, it is a good practice to perform a short Things Gone Right / Things Gone Wrong (TGR/TGW) exercise and document in the A3 report what went well during the process and what could use improvement. The management team should also promote continuous improvement of the A3 tool within the organization.

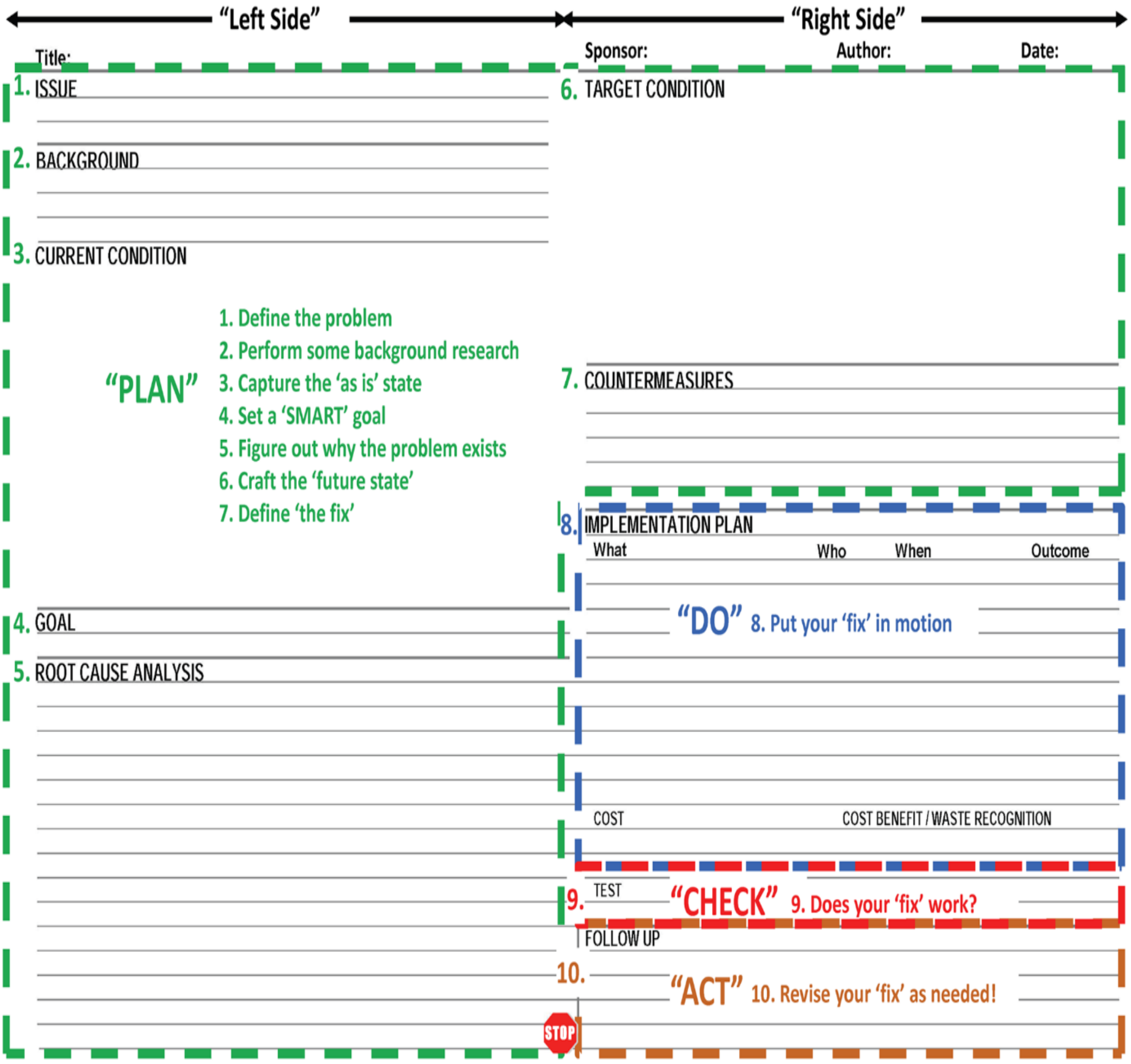

Figure 4. The A3 report

Source: (Bassuk & Washington, 2013)

The A3 Report is an effective visual tool for driving improvement and promoting a problem-solving way of thinking. The format can and does vary depending upon the company or organization. The format you select is not as important as the results. As long as the form contains the basic steps for problem identification, root cause analysis, corrective action and monitoring improvement or performance, it will be a very effective tool.

2.1.4.3 The 5S Method

5S is a Japanese methodology introduced by Takashi Osada in 1980s for the improvement of working environment, human capabilities and productivity in a clean, efficient and soft way (Machado & Leitner, 2010). 5S correspond to 5 disciplines for maintaining ideal workplace while reducing the unnecessary movements and wastes (Goswami, Gupta, & Choudhary, 2019). The 5S principle for workplace organization which is a philosophy of good housekeeping. It is a practical concept that means to realize the smoothest flow and a synchronization in processes (Abdulmouti, 2018). It increases the worth value of the industry. There are the steps which can reduce the timings and improve the quality and manufacturing cost along with the target of reduction in the cost. From small scale industries to large scale industries this method can be implemented successfully by applying the 5 principles that compose the 5S Method which are the following ones:

1. **SEIRI = (SORT)**

It includes sorting and removing the unwanted things that are not needed, while working in terms of tools, machines, equipment, materials etc. The first step includes identification of the items that are required and the items which are not required and then sorting out the wanted and unwanted ones that should be placed, if they cannot be removed immediately, in a 'red tag area' so that they are easy to remove later on. The removal of unwanted items makes crystal clear to the workers at the time of machining / operations of what to use while making the workplace more. Thus, making the workplace neat and clean leads to more efficiently working in the workplace (Patel & Thakkar, 2014). The goals are the reduction of time loss looking for an item by reducing the number of items and of the chance of distraction by unnecessary items together with the increase in the amount of available, useful space and of safety by eliminating obstacles.

2. **SEITON = (SET-IN-ORDER)**

After sorting, the next step is setting in order the wanted items by placing them in the optimal places from which they will be obtained while performing operations. Optimal placing is crucial, so that unwanted movements can be minimized. The arrangement of work stations should be done in such a way that all tools and equipment are in close proximity, in an easy to reach spot and in a logical order adapted to the work performed.

This second phase is vital since it aims basically at the implementation of **Just-in-time (JIT)** methodology, is a management philosophy that "activates" the production process, when there is customer need, only in the quantities requested while reducing times within the production system as well as response times from suppliers and to customers and eliminating any delays in the inventory. JIT is a powerful method to reduce costs and increase efficiency (Pinto, Matias, Pimentel, Garrido Azevedo, & Govindan, 2018).

The involved workers also play an important role, which results in saving time and increasing the efficiency and that helps in lowering the risk of important items getting lost, found missing or searching during the operation performing time (Wilson, 2010).The goal is to make the workflow smooth and easy.

3. **SEISO = (SHINE)**

The next step is to make the workplace shine by inspecting the workplace, tools and machinery on a regular basis and periodic scheduling of cleaning activities, equipment maintenance, equipment calibration and facilities maintenance. Cleaning must be performed after the completion of every cycle in order to remove the unwanted scrap and leftovers. By doing so the hygiene is maintained in the workplace which leads to a healthy friendly-working environment for the workers. This increases the motivation of the workers and improves the production process efficiency and safety, reduces waste, prevents errors and defects. A rule in seiso is that when it's done right, an individual not familiar with the workplace should be able to detect any problems within 50 feet in 5 sec. (Khedkar, Thakre, Mahantare, & Gondne, 2012).

4. **SEIKETSU = (STANDARDIZE)**

The most important of the 5S is standardization of the operations are to be carried out (Ghodrati & Zulkifli, 2013). Discipline is the main goal of standardization. It monitors the 3 previously described S in proper decorum and establishes procedures and schedules to ensure the repetition of the first three 'S' practices. Standardization increases the safety concerns of the workers, who can work without any types of confusion or deviation from the standardized operating procedures and working instructions. The goal is to develop a work structure that will support the new practices and make it part of the daily working routine.

5. **SHUTSUKE = (SUSTAIN)**

Generally known as self-discipline that all involved personnel (managers and workers) have to ensure that the 5S approach is followed constantly and properly maintained. For this, regular audits have to be scheduled to ensure that all defined standards are being implemented and followed and if not, proper corrective action is necessary to be applied.

In the bibliography, in some case, 5S has become 6S, with the sixth element being safety (Safe) (Gapp, Fisher, & Kobayashi, 2008).

Figure 5. 5S methodology

Source: www.projectcubible.com

2.1.4.4 Ishikawa/Fishbone diagrams

Ishikawa diagrams (also called fishbone diagrams, herringbone diagrams, cause-and-effect diagrams, or Fishikawa) are cause-and-effect diagrams, introduced by Dr. Kaoru Ishikawa, one of the founding fathers of modern management, at the University of Tokyo in 1943, showing the potential causes of a specific event or problem (Ishikawa, 1986). As illustrated below, a completed Fishbone diagram includes a central "spine" and several branches reminiscent of a fish skeleton with the problem at its head/mouth, facing to the right, and the possible contributing causes for the problem are listed on the smaller “bones” feeding into the spine extending to the left. The “ribs” branch off the backbone for major causes, with sub-branches for root-causes, to as many levels as required (Ishikawa, 1986).

Ishikawa diagrams consist a highly visual tool that can help in brainstorming to identify possible causes of a problem and in sorting ideas into useful categories. A fishbone diagram can be helpful in identifying possible causes for a problem that might not otherwise be considered by directing the team to look at the categories and think of alternative causes and track down the reasons for imperfections, variations, defects, or failures. It promotes "System Thinking" through visual linkages, helping in prioritizing further analysis and corrective actions. It is an easy-to-use tool that allows the assigned team to see all causes simultaneously while verifying if a root cause appears multiple times in the same or different causal tree (Ishikawa, 1986; Tague, 2004). However, due its visual structure, it is not suitable for complex problems with numerous root causes. Also, in some cases, the possible interrelationships between root causes may not be easily detected due the diagram’s “bone” arrangement (Tague, 2004).

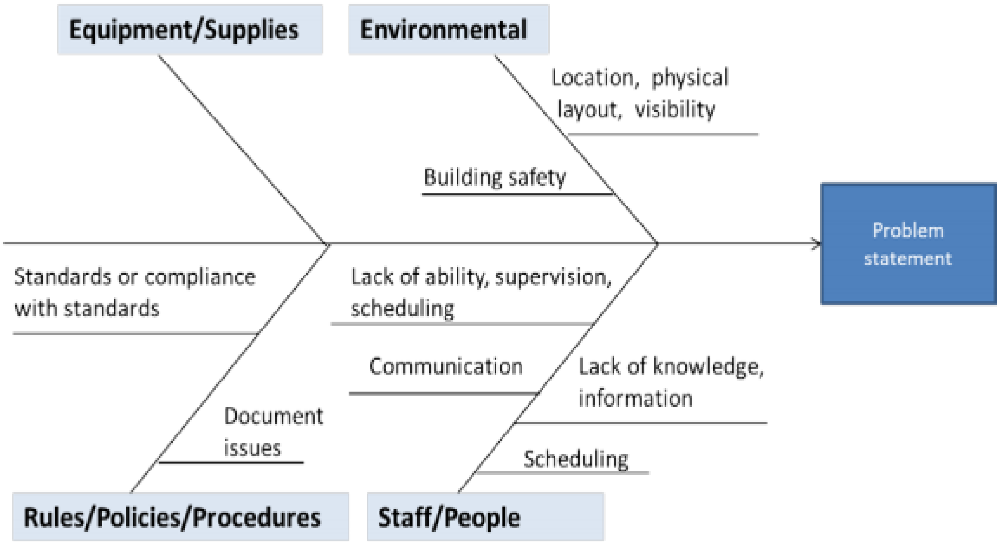

Figure 6. Example of Ishikawa diagram

2.1.4.5 Time metrics

Takt Time (TT): Takt time is the rate at which the production process needs to be completed in order to meet the customer's demand. Takt is the German word meaning "pulse" and it was named in order to show that by establishing a correct, steady heartbeat across all production processes, it can be ensured that the consumers get the right products of the right quality at the right time, meaning that TK helps find the delicate balance between production and customer demand. Managers measure takt time to identify and eliminate wasteful over- and underproduction. They use this metric to synchronize interdependent processes and increase quality control standards. They optimize systems by matching takt time with customer demand to ensure teams and machines waste neither resources nor time. In other words, TK is the calculated duration of optimal production (George, 2002, 2003; George, Rowlands, & Kastle, 2004; Pyzdek & Keller, 2018).

$TT = T_a \div D$

In this equation, TT represents Takt time, Ta represents the total available production time, and D represents the rate of customer demand. In an ideal world, Takt time should remain relatively static. If an organization's TT is growing, more time is being dedicated to production than should be necessary to meet customer demand. If it's instead shrinking, customer demand has outstripped production time. In either case, processes should be reevaluated to ensure that production time properly aligns with overall demand for a product. Calculating TT is vital in order to estimate service delivery processes, maintain a constant production flow and standardize work processes while gradually increasing efficiency and quality and decreasing training times, overtime and errors. By calculating TT and setting the work flow at this pace (determined by consumer demand), it becomes easier to detect glitches in the production system, to notice overworked teams sacrificing quality to meet unreasonable demands and/or idle teams with nothing to do, due to capacity and synchronization issues (George, 2002, 2003; George et al., 2004; Pyzdek & Keller, 2018).

Cycle Time (CT): Cycle time is the time it takes to complete the production of one unit (product/service) from production (start of production) to finish (end of production). Takt time is based on customer demand whereas CT is work process based. CT starts when the actual work begins on the unit and ends when it is ready for delivery, measuring the completion rate or, in other words, actual rate of work. Ct managing is important for matching demand with inventory and improving the CT will ultimately result in a shorter LT (George, 2002, 2003; George et al., 2004; Pyzdek & Keller, 2018).

$CT = 1 \div TR$

In this equation, CT represents Cycle time and TR represents the Throughput Rate which is the number of Units Produced or Tasks Completed / Time. The calculation of cycle time is a continuous process. There is a large number of products or services being processed at a given moment. Therefore, the formula of cycle time has been reworked: CT = the average of the time between the completion of units (George, 2002, 2003; George et al., 2004; Pyzdek & Keller, 2018).

Lead Time (LT): Lead time is the time it takes for one unit (product/service) to make its way through the entire operation from front (receiving the order) to end (receiving the final payment for the unit). This includes any time taken to manufacture materials for the finished product or the time it takes to receive the materials. All activities, wasteful or not, add up to the lead time. LT measures the time elapsed between order and delivery, thus measuring the production process from the customer's perspective or, in other words, the arrival rate. When a consumer places an order, their concern is the time it takes until they get their product (LT) but are not necessarily concerned with how long it takes for the product to be processed (George, 2002, 2003; George et al., 2004; Pyzdek & Keller, 2018).

LT = CT * WIP or LT=WIP / TR

In this equation, LT represents Lean time, CT represents Cycle time, WIP represents Work in Progress and TR represents the Throughput Rate (George, 2002, 2003; George et al., 2004; Pyzdek & Keller, 2018).

2.1.4.6 Plan-Do-Check-Act (PDCA) Cycle

PDCA or Deming or Shewhart Cycle is a four-step management tool for the quality control and continuous improvement of processes and products (Tague, 2004).

Shewhart's "Statistical Method from the Viewpoint of Quality Control", published in 1939, first introduced the concept of a straight-line, three-step scientific process of specification, production and inspection that was later turned into a cycle-line process. Shewhart's concept eventually evolved into what became known as the Shewhart cycle (Shewhart, 1986).

Deming had a front-row seat for Shewhart's thinking: At the age of 39, Deming edited a series of lectures Shewhart delivered to the U.S. Department of Agriculture into what eventually became the basis of Shewhart's 1939 book. Deming built off Shewhart's cycle and modified the concept. He got the chance to present the new version of the cycle in 1950 during an eight-day seminar in Japan sponsored by the Japanese Union of Scientists and Engineers (JUSE). In his new version of the cycle, Deming stressed the importance of constant interaction among the four steps of design, production, sales and research. He emphasized that these steps should be rotated constantly, with quality of product and service as the aim, as shown in Figure 7. This new version is referred to as the Deming wheel, the Deming cycle or the Deming circle (Imai, 1986; Moen & Norman, 2010).

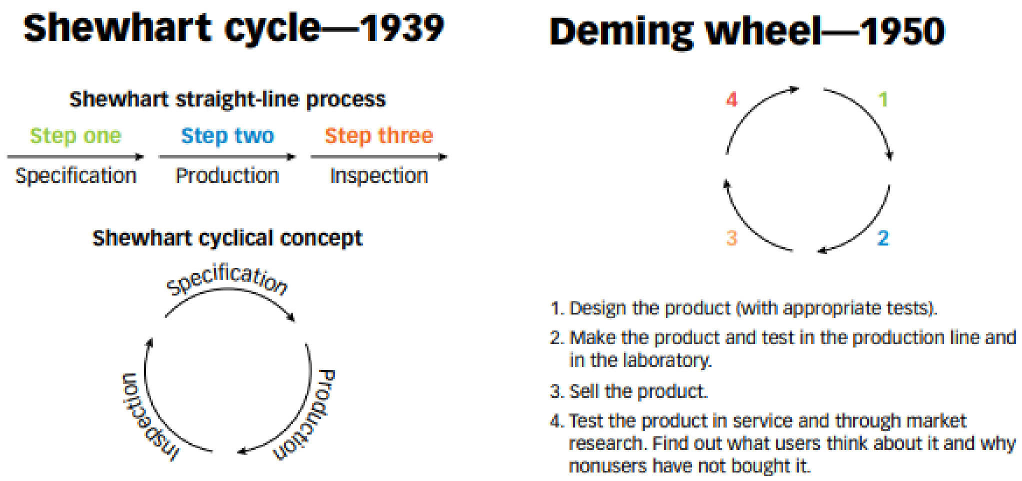

Figure 7. Shewhart cycle & Deming wheel

Japanese executives recast the Deming wheel presented in the 1950 JUSE into the PDCA cycle (Imai, 1986). In Figure 8 the relationship between the Deming wheel and the PDCA cycle is depicted.

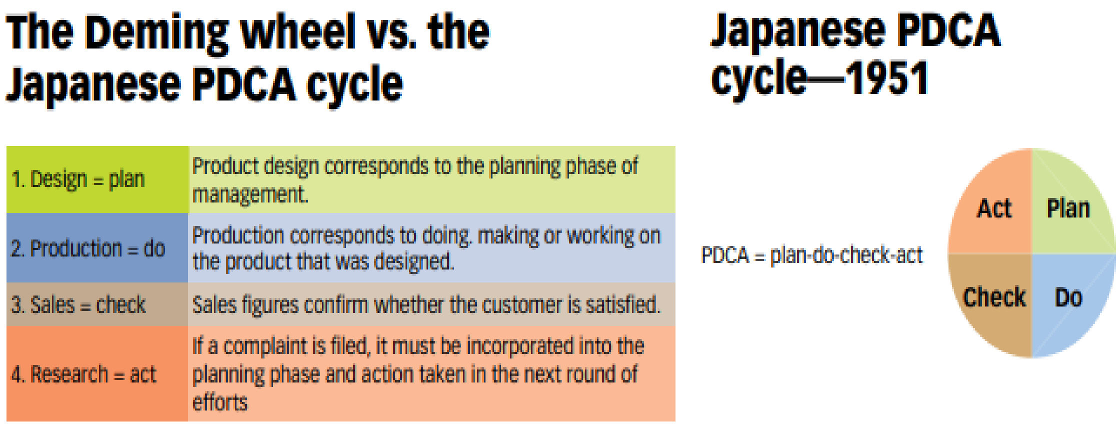

Figure 8. Deming wheel & Japanese PDCA cycle

The resulting PDCA cycle, shows the four-step cycle for problem solving as follows (Imai, 1986):

1. Plan: Define a problem and hypothesize possible causes and solutions.
2. Do: Implement a solution.
3. Check: Evaluate the results
4. Act: Return to the plan step if the results are unsatisfactory, or standardize the solution if the results are satisfactory.

The PDCA cycle also emphasized the prevention of error recurrence by establishing standards and the ongoing modification of those standards.

Later, Kaoru Ishikawa redefined the PDCA cycle to include more in the planning step: determining goals and targets, and formulating methods to reach those goals. In the do step, Ishikawa also included training and education to go along with implementation. Ishikawa said good control meant allowing standards to be revised constantly to reflect the voices of consumers and their complaints, as well as the requirements of the next process. The concept behind the term “control” (kanri) would be deployed throughout the organization (Suckow, 2012). Ishikawa’s changes gave rise to a revised cycle as shown in Figure 9.

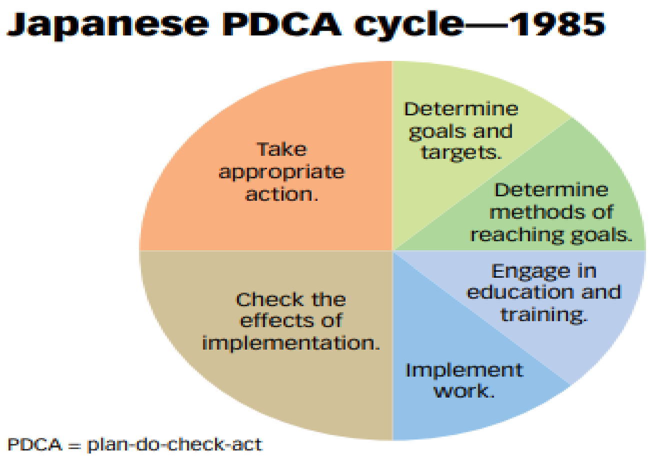

Figure 9. Japanese PDCA cycle

A fundamental principle of the scientific method and PDCA is iteration—once a hypothesis is confirmed (or negated), executing the cycle again will extend the knowledge further. Repeating the PDCA cycle can bring its users closer to the goal, usually a perfect operation and output.

In 1993, Deming modified the Shewhart cycle and named it the Shewhart Cycle for Learning and Improvement, which is also known as the PDSA (Plan-Do-Study-Adopt) cycle, as shown in Figure 10, since it is basically a circular flow diagram for learning and improvement of a product or a process.

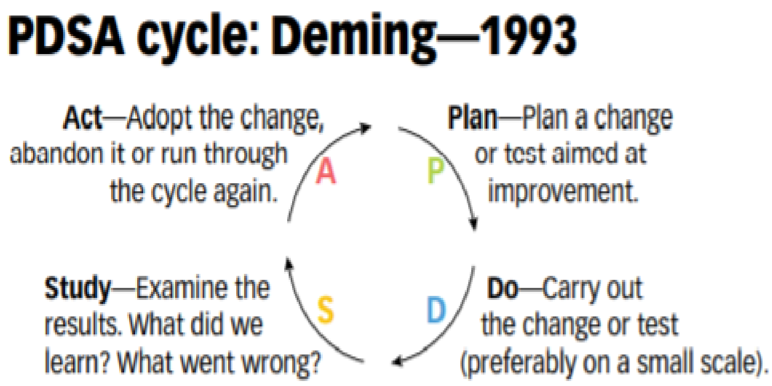

Figure 10. PDSA cycle

In 1994, G. Langley, K. Nolan and T. Nolan added three basic questions to the PDSA flow diagram which was further evolved as shown in Figure 11. This improved version of PDSA cycle provides a basic framework for developing, testing and implementing changes to the way things are done leading to any kind of improvement from minor to crucial and complex one (Langley et al., 2009)

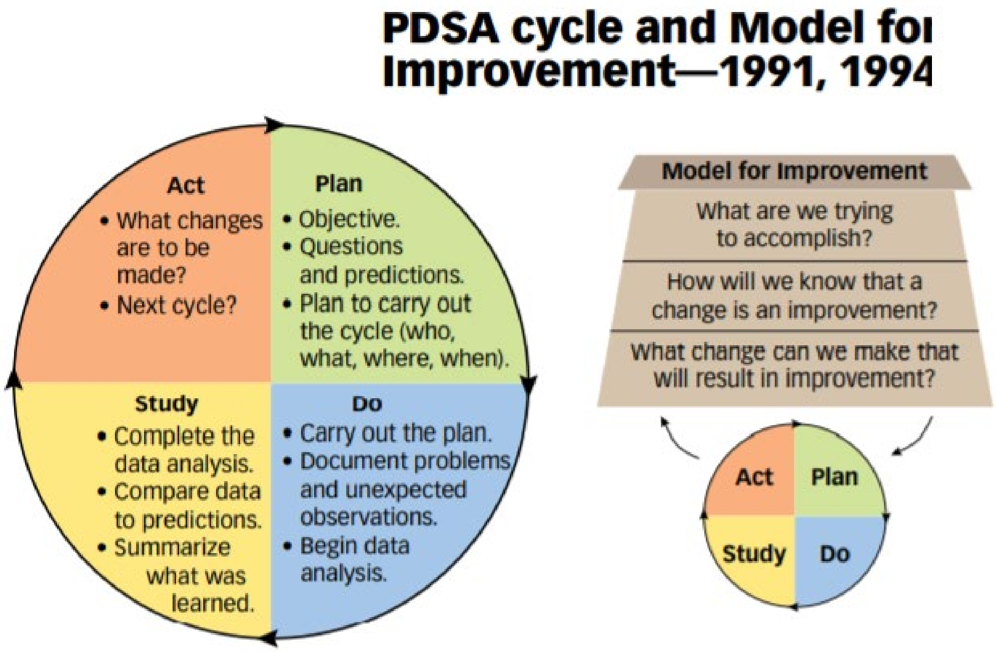

Figure 11. PDSA cycle and Improvement Model

2.1.4.7 Stopping the line

Every worker in the Toyota plant has the power and the obligation to stop the assembly line when a defect or error is identified or even suspected. Workers pull a cord, a light goes on, music plays as a signal for supervisors to come and help, and the entire assembly line either slows or stops (depending on the degree of the defect resolution time) while line workers and supervisors assess and fix the problem, often preventing an error from becoming embedded in the final product. This typically happens many times a day. The theory behind stopping the line is that mistakes are inevitable, but reversible. Defects are mistakes that were not fixed at the source, passed on to another process, or not detected soon enough and are now relatively permanent. If you fix mistakes early enough in the process, your product will have zero defects. Mistakes are least harmful and easiest to fix the closer you get to the time and place they arise. The reverse is also true.

2.1.5 Lean Management in healthcare organizations

Today, lean has become the standard for efficiency and excellence in the manufacturing industry. However, during the last decades, the healthcare industry has succeeded in deploying lean principles to achieve quality in its operations and processes. Although operations in the manufacturing and healthcare industries may differ in various ways, the requirements necessary for change are quite similar. Both industries demonstrate a commitment to the projects from senior management, engage practitioners and recognize shop floor expertise in identifying necessary improvements. Healthcare organizations are complex in nature. All the previously described lean operating philosophies and methods can be applied not only in production lines and industries but also in healthcare organizations aiming to create a maximum value for patients by reducing waste and waits. The main difference here is that the implemented learning cycle is driven not by workers and managers but the "true" experts in the processes of health care, being the patients/families, health care providers and support staff (de Souza, 2009). Also, lean in the manufacturing industry focuses more on identifying value-adding processes and removing waste from the system while the healthcare industry involves high specialist influence, the variability of patient presentations and geographical protection of healthcare delivery. Although lean is of utmost benefit to the patients, it is not meant for patients alone. Lean is beneficial to other stakeholders in healthcare like nurses, physicians, healthcare organizations as well as the community.

It has been suggested that for lean management in healthcare, the patient has to be the center of the initiative, while time and comfort should be added as key performance measures in the system. Defining the patient as the primary customer requires a conceptual leap because usually the customer pays directly, whereas in healthcare third-party indirect fees depending on the level of insurance are the usual way of payment (Kollberg, Dahlgaard, & Brehmer, 2006). However, if it is understood that value is related to customer requirements and it will be the customer that ultimately determines what constitutes waste, it becomes evident that patients' demands may require changes even in processes that may not be directly related to patient care (Teich & Faddoul, 2013).

2.1.5.1 History and Examples of Lean Management in healthcare organizations

Initial approaches for implementation of lean principles in healthcare were basically nothing more than an exercise to transfer manufacturing principles in order to reduce physical inventories in hospitals (Heinbuch, 1995). However, later various types of implementation efforts in healthcare were reported including, among others, manufacturing-like studies, managerial and support case studies, patient-flow case studies as well as organizational case studies as mentioned in the effort of de Souza et al aiming to provide a taxonomy for classification of existent studies associated with lean principles application in healthcare (de Souza, 2009). Most of these studies (57%) were applied in the USA. According to de Souza et al the levels of implementation can be defined at three levels (de Souza, 2009):

- Micro—operational level outcomes represented by manufacturing-like, managerial and support, and patient-flow cases
- Meso—strategic level that focuses on financial health of organizations, with potential outcomes being financial, staff morale, and involvement
- Macro—outcomes of national initiatives such as the National Health Service plan in the UK

Guimaraes et al noticed that as implementation of lean principles in healthcare was becoming more popular in the USA and Europe, a shift from manufacturing-like to organizational cases emerged gradually in the literature (Guimarães & Crespo De Carvalho, 2012). Despite that, as already described, TMC was the founder of Lean Management, there were not any publications concerning lean implementation in Japanese healthcare organizations possibly due to either lack of Japanese case publishing tradition or the fact that lean is naturally embedded in the Japanese culture and only outstanding cases were reported (Guimarães & Crespo De Carvalho, 2012).

2.1.5.2 Virginia Mason Medical Center

Virginia Mason Medical Center (VMMC) in Seattle, Washington is an integrated health care system that includes a 336-bed hospital, 9 locations, 400 physicians and 5,000 employees. In 2000, after a period of economic stress and a general malaise in the organizational culture with a-two year straight negative balance, the Board of Directors issued a broad mandate for change. Under new leadership, VMMC developed a new strategic plan that called for, among other things, a sharper business focus and more accountability. The leadership's vision was VMMC to become the quality leader in health care and to make this come true the Virginia Mason Production System (VMPS) was designed upon the principles of TPS and gradually applied in VMMC (Edwards & Saltman, 2017; Kim, Spahlinger, Kin, & Billi, 2006; Teich & Faddoul, 2013) as shown in Figure 12.

VMPS, with its unequivocal focus on the patient, was the first step in changing the culture at VMMC when it was initially introduced in late 2001. VMMC leadership sought to clarify expectations, responsibilities, and accountabilities in order to make specific roles and expectations explicit. To do so, "compacts" were created for everyone involved in VMMC (leaders, Board of Directors, medical personnel), spelling out expectations and responsibilities for each, as well as what they can expect from the organization. This is another way that Virginia Mason laid the cultural foundation for lean (Edwards & Saltman, 2017; Kim et al., 2006; Teich & Faddoul, 2013).

Another important action VMMC took in order to promote lean principles was sending in 2002 all its senior executives to Japan to get familiar with how lean management works and harmonize with lean principles and methods. Thirty executives were sent to work on the production line in the Hitachi Air Conditioning plant where they recorded workflow, measured cycle times, and documented process flow and soon realized that healthcare has many steps and concepts in common with the industrial production lines since both involve concepts of quality, safety, customer satisfaction, staff satisfaction, and cost-effectiveness. The completion of the product involves thousands of processes, many of them very complex while as in health care, the stakes are high since a potential failure can cause fatalities. Since then and until 2008, more than 200 employees have toured production plants in Japan.(Edwards & Saltman, 2017; Kim et al., 2006; Teich & Faddoul, 2013).

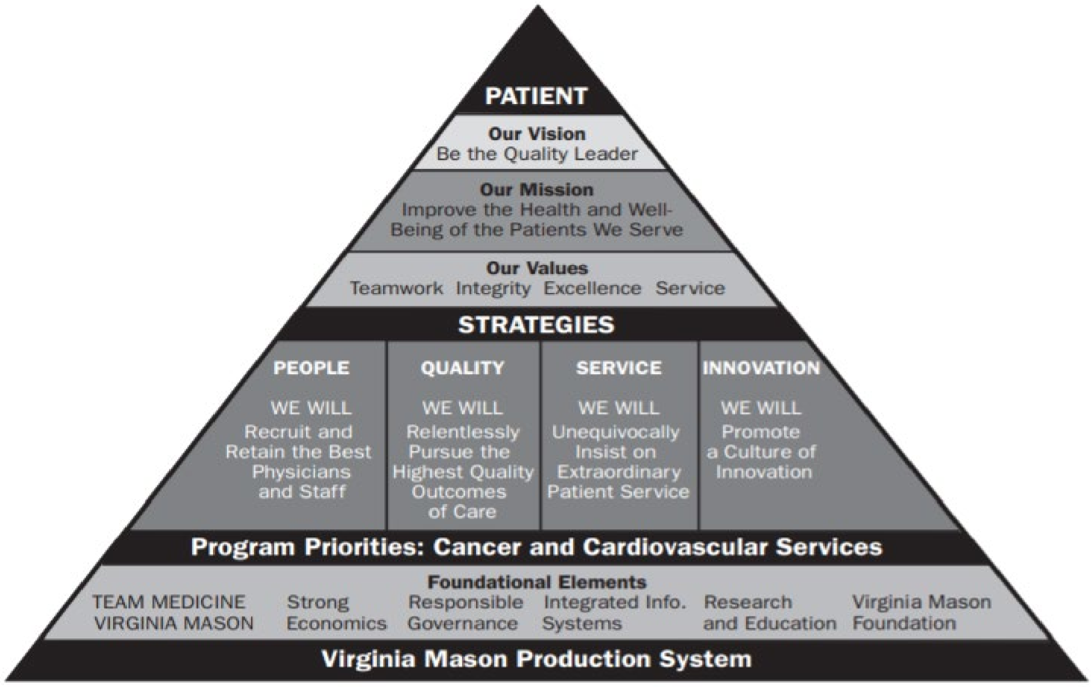

Figure 12. Virginia Mason Production System

When they returned from Japan, those executives gradually designed the VMP), based on the principles of TPS. The basic aim was to achieve continuous improvement by adding value without adding money, people, large machines, space or inventory, all toward a single overarching goal which was the complete elimination of all wastes. VMPS has six areas of focus (Edwards & Saltman, 2017; Kim et al., 2006; Teich & Faddoul, 2013):

1. “Patient First” as the driver for all processes
2. The creation of a safe and free working environment in which people could seek improvement, including the adoption of a “No-Layoff Policy”. In fact, the No-Layoff Policy is critical to the success of implementing lean management. People will more fully commit and engage in improvement work if they are not worried about improving themselves out of a job. Attrition, typically steady in health care, will enable most organizations to reassign staff to other necessary work. A culture shift is important here as well: Staff, especially in health care, do not typically view themselves as working for the organization, but for their individual department and/or care team. In lean thinking, the patient/customer drives all processes, and staff/providers must come to understand that they work for the patient. This means they may be reassigned depending on the needs of the patients.

3. Implementation of a company-wide defect alert system called “The Patient Safety Alert System”. In fact, The Patient Safety Alert System is based on the TPS principle “stopping the line.” At VMMC, the Patient Safety Alert System is part of a culture in which anyone can, and indeed must, “stop the line,” or stop the care process if they feel something is not right. The person who activates the alert informs the patient safety department and an administrator or other relevant manager and the appropriate process stakeholders come immediately to assess the situation and conduct a root cause analysis. In 2002, there were an average of three alerts per month at Virginia Mason; by the end of 2004 that number had risen to 17. The alerts predominately identify systems issues, medication errors, and problems with equipment and/or facilities.
4. Encouragement of innovation and “trystorming”, a new term combining trying and brainstorming meaning quickly trying new ideas or models of new ideas
5. Creating a prosperous economic organization primarily by eliminating waste
6. Accountable leadership

The VMPS is an integrated system of processes and approaches that tie together, and must be thought of in an integrated way. A major component of the system is value stream mapping. Nearly every area in the medical center has a high-level value stream map and a detailed process flow diagram. Kaizen events, or Rapid Process Improvement Workshops at Virginia Mason, are held weekly, bringing people together to use the tools of lean to achieve immediate results in the elimination of waste. Other tools of VMPS include 5-S and 3-P, shorthand for organizing frameworks. 5-S (sort, simplify, standardize, sweep and self-discipline) is a method for organizing work areas to maximize smooth and efficient flow of activities and reduce wasted time and effort. 3-P (production, preparation, process) focuses on the design of new processes or workspaces (Edwards & Saltman, 2017; Kim et al., 2006; Teich & Faddoul, 2013).

With the implementation of VMPS, VMMC created more capacity in existing programs and practices so that planned expansions were scrapped, saving significant capital expenses: $1 million for an additional hyperbaric chamber that was no longer needed; $1 to $3 million for endoscopy suites that no longer needed to be relocated; $6 million for new surgery suites that were no longer necessary. VMMC reported increased profit margins, decrease in deaths, and decrease in the number of medication errors. Other reported benefits are an 85% reduction in how long patients wait for a lab result, increased productivity by 93%, and lowering inventory costs by $1 million (Edwards & Saltman, 2017; Kim et al., 2006; Teich & Faddoul, 2013).

In addition to the financial and efficiency gains, the lean culture has also advanced clinical improvements at VMMC. For example, because lean promotes the consistent and reliable use of standardized processes, the groundwork was laid for introduction of the “ventilator bundle,” a set of specific steps proven to reduce the incidence of ventilator-associated pneumonia (VAP). In 2002, VMMC had 34 cases of VAP, at an estimated cost of $500,000. In 2004, after implementing the ventilator bundle, there were only four cases of VAP, at an estimated cost of $60,000 (Edwards & Saltman, 2017; Kim et al., 2006; Teich & Faddoul, 2013).

However, even with these successes, work of implementing lean thinking throughout the organization is not static but dynamic, requiring considerable focus and commitment to achieve defect-free care. For instance, in November 2004, a patient died due to a medical error in VMMC. Senior management, then in the process of setting its executive leadership goals for the coming year used the tragedy as a guide in its work and reduced the proposed five executive leadership goals to just one: Ensure Patient Safety (Edwards & Saltman, 2017; Kim et al., 2006; Teich & Faddoul, 2013).

2.1.5.3 ThedaCare Inc

ThedaCare Inc is a community health system with three hospitals, 27 physician clinics, 6,300 employees and a 300,000-member health plan, located in northeast Wisconsin. It recognized nationally for its quality performance results while at the same time is considered one of the biggest employers in Wisconsin (Barnas, 2011).

In 2003, ThedaCare leaders decided that their cooperate culture should change by applying lean manufacturing tools to some of their healthcare processes. So, they set highly ambitious goals for their firm including, among others, improving the quality of their services to superior levels (95th percentile or greater), increasing annual productivity by 10%, becoming the health care employer of choice and one of the best employers nationally, lowering their costs in order to lower the price paid for services aiming to gain $10 million a year through cost savings and increased productivity while keeping the patient at the center of these goals (Figure 13). To achieve these goals, they consulted with a nearby business, Ariens Outdoor Power Equipment Company, that has very successfully employed lean management for several years. ThedaCare gradually achieved significant improvements in quality of their provided services and the elimination of waste through the development of the ThedaCare Improvement System

(TIS), which included Value Stream analysis, rapid improvement events, and projects applied to specific processes. However, goals for continuous daily improvement and increasing productivity by 10% annually were not accomplished (Barnas, 2011, 2014; Toussaint & Gerald, 2010).

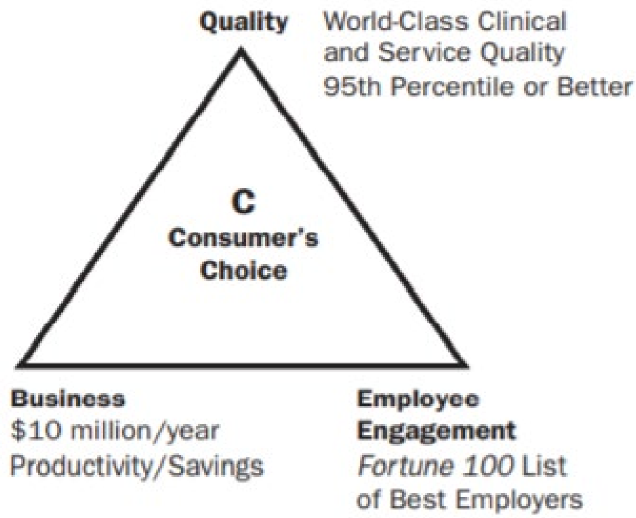

Figure 13. Thedacare's lean management goals

ThedaCare leadership concluded that changes in the way their managers were conducting and managing their daily work should be applied. So, they changed the way we manage so that it is commensurate with Lean thinking by developing what ThedaCare's Business Performance System (BPS) to achieve and sustain continuous daily improvement. Before an organization embarks on the process of developing its own BPS, however, it first needs one or two years of experience in Value Stream and rapid improvement work to be able to understand the need for management work. The culture change that ThedaCare's leadership designed and applied was based on the brainpower of its staff aiming to continuous improvement of the firm. Furthermore, they realized that a significant waste was the total time the staff was spending on "putting out fires" and that designing processes that work better reduces waste and helps the involved staff in meeting easier and to greater extent the needs of patients. Like VMMC, ThedaCare leadership encouraged staff in participating in periods of intensive process improvement efforts, which they call Event Weeks. Participation in at least one Event Week is now mandatory for all staff members who have the option to choose from six different Event Week topics each week. The groups that come together for Event Weeks use the ThedaCare Improvement System, which includes three tenets for change, as a framework for their work (Barnas, 2011, 2014; Toussaint & Gerald, 2010).

These tenets are:

1. Respect for people
2. Teaching through experience
3. Focus on world-class performance

The details of these tenets are spelled out so that everyone in ThedaCare can use them in their process improvement work. An example is shown in Figure 14 where the way the organization defines the first tenet “Respect for people” is presented.

What It Is:	What It Isn't:
Error-free practice	Long wait times
Timely service	Creating/doing non-value-added work
No waste	Wasted time
No-layoff philosophy	Wasted materials
Professionals who work together to improve performance	People focused on tasks rather than patient outcomes

Figure 14. ThedaCare's first tenet for change: Respect for people

The second tenet “Teaching through experience” is important because people learn best when they are directly involved. The rapid results of the work demonstrate for participants the power of their work and helps to build momentum. The three goals of the ThedaCare Improvement System are:

1. Improved staff morale
2. Improved quality (reduction of defects)
3. Improved productivity

Every Event Week must focus specifically on these three goals. ThedaCare leaders have acknowledged to staff that the new culture of lean will feel counter-intuitive for a while, with its emphasis on reducing waste and non-value-added work, as opposed to adding technology, buildings, or manpower. Lean also has a penchant for redeploying the best employees when productivity improves, not the poor or marginal performers; moving an accomplished lean thinker to a new department is an effective way to spread change. The new culture requires new behaviors, including the use of smaller, “right-sized” groups of workers or technologies in “cells” rather than large, cumbersome processes; strong, sometimes directive leadership, augmenting more traditional team approaches; and less batching of work in favor of “right now” real-time action. The new culture of lean also involved roles’ change. Managers became teachers, mentors, and facilitators rather than simply directors or controllers (Barnas, 2011, 2014; Toussaint & Gerald, 2010).

On a monthly basis, ThedaCare tracks a range of outcomes related to lean management, including number of Event Weeks, number of employees who have participated in at least one Event Week, significant quality improvements, and financial measures. With about six rapid improvement Event Week topics every week, by the end of 2004, ThedaCare had involved more than 600 employees directly in learning about lean thinking. Between 2004 and 2009, using their system of training facilitators and teachers, 6 to 10 rapid improvement events each week were carried out. In that time, significant, breakthrough improvements were achieved.

The implementation of lean thinking in ThedaCare resulted, only for 2004, in $3.3 million estimated cost savings, saving of $154,000 in the Catheterization Lab supply procurement processes, reducing accounts receivable from 56 to 44 days equating to about $12 million in cash flow and redeploying staff in several areas saving the equivalent of 33 FTEs. ThedaCare achieved bottom-line savings of $25 million by 2009 directly attributed to the TIS. These savings were accomplished with their no-layoff philosophy intact. Furthermore, the firm achieved to improve the Physicians phone triage times by 35%, to reduce hold time from 89 to 58 seconds, physicians phone triage abandonment rates by 48% and the time it takes to complete clinical paperwork on admission by 50%. Finally, their Med/Surg decreased medication distribution time from 15 minute/medication pass (the amount of time it takes to pass one medication to one patient) to 8 min/ medication pass impacting 4.1 FTEs of staff time (Barnas, 2011, 2014; Toussaint & Gerald, 2010).

2.1.5.4 Flinders Medical Hospital

The Flinders Medical Centre (FMC) is a 500-bed teaching general hospital in the southern suburbs of Adelaide, Australia. FMC is a “cradle-to-grave” institution, providing a complete range of secondary and tertiary services to a population of ~300000. It is the largest member of a de-facto consortium of hospital and community health service providers that also includes a smaller general hospital and a community hospital. FMC is the primary regional provider of time urgent, complex care of all kinds, with its Emergency Department (ED) seeing more than 50.000 patients per year(Ben-Tovim, Bassham, et al., 2008).

During 2003, FMC ED saw around 45.000 patients, 40% of whom were admitted to hospital. In that same year, the number of patients seen per day peaked at around 140 once or twice per week during the winter period. At this time, ED had become so congested that patients were regularly overflowing into the nearby recovery area of the operating theatre suite, disrupting the work of both the ED and the Division of Surgery. Cancellations of elective work were pervasive, surgical training schemes were under scrutiny, the safety of care in the ED was becoming compromised, and high levels of staff turnover were undermining the viability of key clinical services. There was bitter conflict between staff, key senior clinicians were prepared to leave, the “blame game” was pervasive, and surgical and medical programs were proving hard to sustain. Despite having implemented a range of strategies to relieve congestion, the capacity to provide safe care was under threat (Bartlett, Cameron, & Cisera, 2002; Ben-Tovim, Bassham, et al., 2008).

These difficulties had not arisen suddenly; nor were they a consequence of unusual levels of demand. FMC was struggling to fulfil the predictable demands of the population served. What was needed was to do something that the staff did not yet know how to do. The United Kingdom National Health Service Modernization Agency advised that sustainable change requires as much care in developing an improvement team, as in the improvement interventions themselves. The hospital board agreed to provide non-operational funds to support a program of hospital redesign. Consequently, the Redesigning Care team — comprising of experienced clinicians as clinical facilitators was formed. The hospital management executive was the authorizing body for all redesign activities at FMC. The Redesigning Care program itself was managed by a reference group of the most senior hospital executives, plus the redesign team. Clinical leaders from the major clinical divisions take leadership roles in their own areas, and each major work program involved an executive sponsor from outside the relevant operational division(Ben-Tovim, Bassham, et al., 2008).

The members of the team first got familiar with “the technical knowledge” for redesign with the aid of a lean thinking expert from Lean Enterprise Australia and the scientific staff of the School of Management at the University of South Australia. This way, they all realized the complexity of other service and manufacturing industries, and the seriousness with which quality control is approached outside health care. Knowledge of lean thinking principles and practices helped them in moving away from a craft-group skill base (e.g., medical care, nursing) or a body system orientation (e.g., cardiovascular, respiratory) to a process view where the care was recognized as the outcome of a sequential series of steps through a sectional and hierarchically organized institution or service (Ben-Tovim, Dougherty, O’Connell, & McGrath, 2008) where the patient’s symptoms were considered as the “raw material” and the patients journey from arrival through to exit from the ED as the “product”.

The Redesigning Care Team started mapping the journeys of patients who were either discharged directly from the ED, or who needed admitting to hospital. The care processes involved were described as the staff saw them. Several sessions were needed to document the steps involved in the patient journey through the ED. The mappings brought together large numbers of staff from each service who plotted out the end-to-end journeys taken by typical patients. The mapping sessions had a profound impact on all involved creating a shared awareness of how chaotic the care processes had become, and generated support to change processes within the ED irrespective of what was being done elsewhere in the hospital.

The ED Director proposed a radical restructuring of the way patients flowed through the FMC ED. The mapping had demonstrated that attempting to prioritize care by means of the Australasian Triage Scale, a 5-point measure of patient acuity, materially contributed to the complexity of patient allocations within the department. The staff were continually attempting to respond to the distress of patients who were “bumped” out of order from their place in the notional queue when a patient who arrived after them was seen before them because they were in a different triage category. Ad hoc and hard to manage strategies were being used to try to push patients through when the build-up of “bumped” patients became excessive. The new flows involved breaking away from using the triage score as a method for prioritizing care within the ED. Instead, patients would be assessed by a triage nurse who, while allocating a triage score, would also indicate whether in his or her judgment the patient was likely to be admitted to hospital or to return home directly from the department. Each stream of patients (likely to be discharged/short-care stream, likely to be admitted/long-care team) was to be aligned with a separate team of nurses and doctors in specific areas of the ED . In the absence of a threat to life and limb, patients were to be seen in order of arrival. Initially, this was only if they were likely to go home, but subsequently, the proposal was widened to include all adult patients. (Ben-Tovim, Bassham, et al., 2008; Ben-Tovim, Dougherty, et al., 2008; King, Ben-Tovim, & Bassham, 2006).

Furthermore, a short-stay (less than 72 hours) medical/surgical emergency inpatient ward within the body of the hospital was designed and implemented. Patients continued to be discharged in a timely manner from that ward no matter how congested the rest of the hospital becomes, thus aiding patient flows. Indeed, at times, up to a quarter of all adult inpatient emergency admissions were managed through this one ward of 26 beds (Cooke, Higgins, & Kidd, 2003).

In terms of long-care patients, they tried to minimize the time patients spend as outliers in wards other than the home ward of the treatment team. A multiyear, multigroup program balancing workloads and bed capacities between highly specialist and generalist medical teams set the scene for a major practice change. The new system involved patients either being allocated directly to a highly specialized unit, or, if a period of further clinical "sorting" was required over and above that undertaken in the ED, patients were referred to an acute medical assessment unit for the first 12 hours of their care. From there, medical emergency patients were assigned to home teams at a consultant team meeting every morning, where allocations were balanced so as to keep numbers relatively even between teams. All the above changed impressively the bed management system, moving away from a central bed manager "pushing" patients into any available bed(Ben-Tovim, Bassham, et al., 2008).

Also, the Redesigning Care Team identified opportunities for redesign and make the necessary changes by means of a series of plan-do-study-act cycles as shown in Figure 15, each of which is evaluated according to relevant measures identified in the diagnostic phase. The key measurement issue is: how can we tell if what we have done has made things any better? As far as possible, the processes and outcomes measured need to be important to both the patients cared for by the institution and the practitioners. Separate measures may be required to capture these different concerns. The facilitators also worked on developing widespread understanding of lean thinking principles and practices. They communicated them in a variety of ways, including lean thinking education days for large numbers of staff, open staff meetings, newsletters and an intranet site(Ben-Tovim, Bassham, et al., 2008; Berwick, 1998).

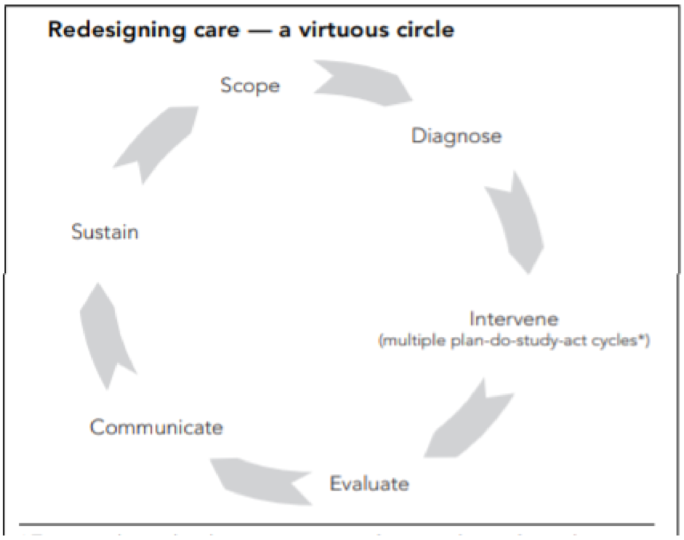

Figure 15. Redesigning care - a virtuous circle

Source:(Ben-Tovim, Bassham, et al., 2008)

Staff received brief orientation to “streaming”, as the new processes came to be described, and it was initiated towards the end of November 2003. The impact was immediate. At the end of the first day, there was a discernible lessening of the chaos within the department, and this sense of increased control has continued. Streaming has been well supported by the staff and has been maintained continuously since its introduction. A clear indication of the increased acceptability of the care provided was the immediate halving of the numbers of patients leaving the department without completing their care. “Did-not-waits” as a percentage of arrivals fell from 7% of all arrivals to just over 3% and have been maintained at that level. Streaming also decreased congestion by decreasing the overall time patients spent in the department. The average time that patients spend in the department was reduced by 48 minutes in the first year after implementation (bringing the average time spent in the department from 5.7 hours down to 5 hours). The next year saw a 10% increase in the numbers of patients attending the department, but the decrease in average time in the department was not only maintained, it was further reduced by 6 minutes (Ben-Tovim, Bassham, et al., 2008; Ben-Tovim, Dougherty, et al., 2008).

3. Methodology

The methodology in this study was a case-report study which evaluated lean management application in a complex real healthcare organization. The case study methodology was selected because of its great flexibility since it can be conducted at various points in the research process while offering researchers a way to develop ideas for more extensive research. They are also effective conduits for a broad range of research methods from focus groups to questionnaires or participant observation. Furthermore, case studies offer great concept of "lived reality" representing more of the "noise" of real life than many other types of research (Hodkinson, P. Hodkinson, 2001).

The selected organization of the study was the Emergency Department (ED) of Hippokration General Hospital of Thessaloniki, one of the largest hospitals in Greece. The hospital is in General Call every 4 days according to the Call Schedule of the 4th National Healthcare Distinct. The emergency cases are taken care by the ED of the hospital which is responsible for:

- the triage of patients
- the diagnosis and management of threatening for life health situations
- the instant revitalization, support, stabilization and further final treatment of patients
- the short-term hospitalization of patients
- the operation of minor surgical interventions την διεκπεραίωση μικρών χειρουργικών και ορθοπεδικών επεμβάσεων.

The field in which lean management was applied was the patient flow and times in terms of patients visits at the ED. For this purpose, 644 patients who visited the ED from January 2020 to June 2020 where included in this study and statistically analyzed for time metrics and averages calculation. For this purpose, a well-structured self-administered anonymous questionnaire was provided to every patient during their visit asking to answer multiple-choice questions.

This questionnaire was initially developed by our research team from ED who firstly mapped (process mapping) the 7 consecutive procedures that a patient has to pass through during their visit at the ED:

a) Secretarial registry

b) Patient triage

c) Clinical assessment

d) Laboratory testing

e) Imaging analysis

f) Final Diagnosis

g) Patient discharge or hospitalization

The process mapping is shown in Figure 16.

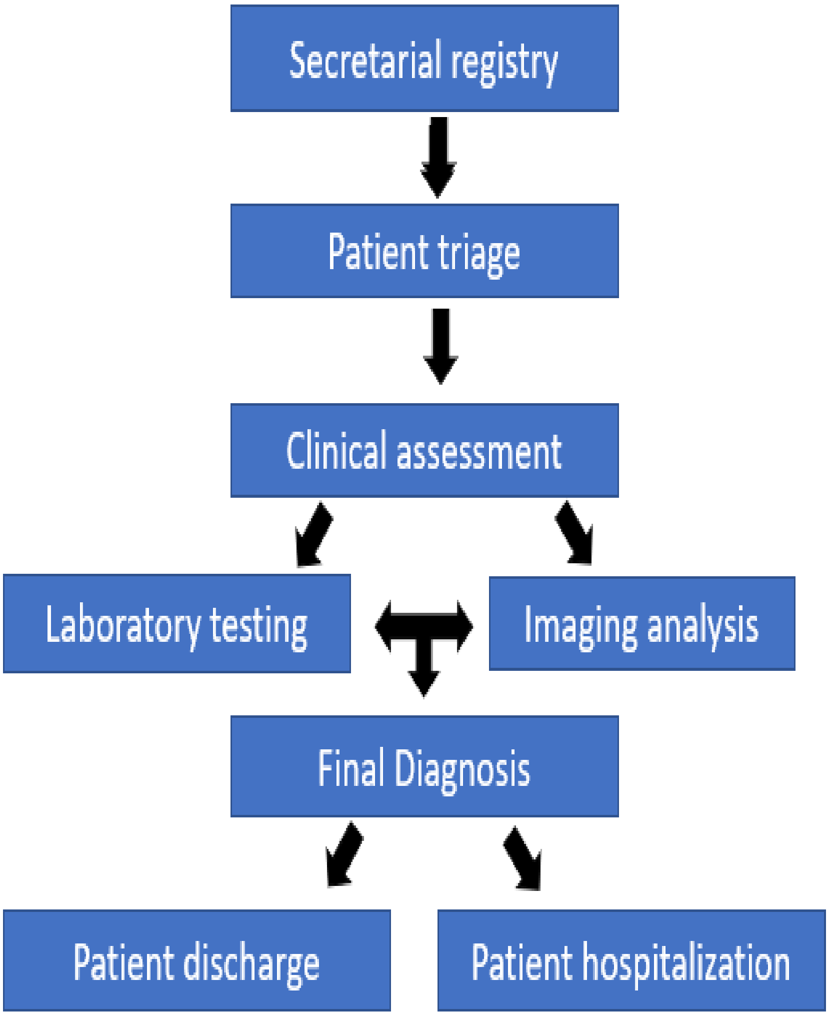

Figure 16. Process Mapping of Patient Flow in ED

The introductory part of the questionnaire explored demographic characteristics of the respondents. In detail, participants were questioned about their age, sex, educational and employment status. The core part of the questionnaire was consisted of one question asking patients if they have visited this ED before and eight questions asking the patients to estimate their total waiting time during each of the previously described procedures from Secretarial registry to Patient discharge or hospitalization as well as the actual time spent for the process itself.

After calculating all the patient metrics, opinions and beliefs concerning the entire patient flow procedures from entering the hospital to final discharge or hospitalization were collected from 34 healthcare professionals including midwifes, physicians and administrative personnel, who were asked about the procedures, practices, policies and methods that are applied and followed in their ED concerning patient care as well as what they think could be done to improve the entire patient flow making it more effective and efficient with smaller time metrics. This was achieved through personal interviews, with a duration of 10-20 minutes, focusing on was what was according to them the ideal time that each of these 7 procedures should last and what they believe should be done to further improve patient flow. The interviews took place from Jan 2020 to March 2020.

The data obtained from the responses of the participants with the form of questionnaires and interviews were collected and analyzed with the Statistical Package for the Social Sciences (SPSS) Version 24.

4. Results and Discussion

4.1 Patients

The questionnaire was administered to a total of 689 patients. From this initial group of 689 participants, a total of 644 agreed to answer (93.46% response rate) the questionnaire of the study. Their detailed demographics are shown in Table 1.

Table 1. Patient demographics

Demographic characteristics		%	(n=644)
Sex			
Male		37.1	239
Female		62.9	405
Age (years)			
<20		5.3	34
20-29		8.7	56
30-39		21.9	141
40-49		18.3	118
50-59		19.6	126
>60		26.2	169
Educational level			
Elementary		10.2	66
Gymnasium		22.5	145
Lyceum		14.9	96

Bachelor's Degree		23.4	151
Master's Degree		22.7	146
PhD		6.3	40

Demographic characteristics		**%**	**(n=644)**
Employment			
Unemployed		10.4	67
House keeping		17.4	112
Private sector employed		14.9	96
Public sector employed		8.2	53
Self employed		25.3	163
Military/Police/Firearms		3.7	24
Retirement		20.1	129
First time visitor			
Yes		46.0	296
No		54.0	348

Most of the participating patients were women (62.9%). Regarding the age of the study group, more than half of the respondents were between 30 and 59 years old (59.8%), one quarter of them were older than 60 years old (26.2%) and only 14 were younger than 30 years old. Regarding educational level and status, there was almost a balance between the patients with basic school education (until lyceum) and those with academic studies (47.6% and 52.4% respectively). The vast majority of the basic school education group had either completed gymnasium or lyceum (145 and 96 respectively) while most of the academic education group had attended obtained at least a Bachelor's

Degree or/and a Master's Degree (151 and 146 respectively) and only 40 had obtained a PhD. Concerning employment, more than half the patients were working (52.1%) with most of them being self-employed (163) or private-sector employees (96). More than 200 patients stated either "housekeeping" or "retirement" as their employment status (112 and 129 respectively) while 67 were unemployed. Finally, the number of patients visiting this ED for their first-time was slightly less than those that have visited the same ED in the past (296 and 348 respectively).

4.2 Patients towards patient flow in the ED

The remaining questions asked the participating patients to estimate the waiting time they spent for each of the following procedures during their visit at the ED as well as the actual duration of each procedure itself:

a) Secretarial registry

b) Patient triage

c) Clinical assessment

d) Laboratory testing

e) Imaging analysis

f) Final Diagnosis

g) Patient discharge or hospitalization

The estimated waiting and actual times were analyzed and their average values (as well as the minimum and maximum values are presented in Table 2.

Table 2. Average waiting time and actual time spend per procedure of the patient flow and minimum/maximum values

It seems that the process of Laboratory Testing was the one with the higher patient times both in terms of waiting (28.1 minutes) and actual duration (125.4 minutes) corresponding to 23.47% and 43.67% of the total waiting time and actual time spent respectively. For the processes of Clinical assessment, Patient triage, Secretarial registry and Patient discharge or hospitalization, the patients had to wait for at least 15 minutes for each one before they were serviced. Although Imaging analysis has the second lower waiting time (10.2 minutes), it is however characterized by the second higher actual time (98.4 minutes). On the other hand, the process of Final Diagnosis is the one with the least waiting time (5.5 minutes) while the process of Secretarial registry is the one with the smaller actual duration (2.1 minutes) followed a 5.3 minutes duration of the Patient Triage.

The percentage of the total waiting time and total actual time for each separate process during the patient flow is depicted in Figures 17 and 18 respectively.

Figure 17. Total waiting time for each process during patient flow

Procedure	Waiting Time (minutes)
Secretarial registry	15.3 (1 to 44)
Patient triage	20.2 (3 to 48)
Clinical assessment	22.3 (5 to 75)
Laboratory testing	28.1 (8 to 60)
Imaging analysis **Final Diagnosis**	10.2 (3 to 24) 5.5 (4 to 10)
Patient discharge or hospitalization	18.1 (8 to 32)
TOTAL TIME	**119.7**

Figure 18. Total actual time for each process during patient flow

Procedure	Actual Time Spent (minutes)
Secretarial registry	2.1 (1 to 4)

Patient triage	5.3 (2 to 9)
Clinical assessment	20.4 (12 to 30)
Laboratory testing	125.4 (120 to 150)
Imaging analysis **Final Diagnosis**	98.4 (30 to 120) 15.3 (10 to 30)
Patient discharge or hospitalization	20.2 (12 to 60)
TOTAL TIME	**287.1**

Based on the above time metrics, value stream mapping was used to visualize the time metrics for each procedure during patient flow. In detail, all the waiting times were considered as procedures that add no value (no-value added time) while the actual duration of each procedure was considered to be of high value (value-added time). Minimum, maximum and average time metrics during patient flow were included in the value stream mapping. The result is presented in Figure 19 with no-added-value time metrics colored red and the value-added time metrics colored blue.

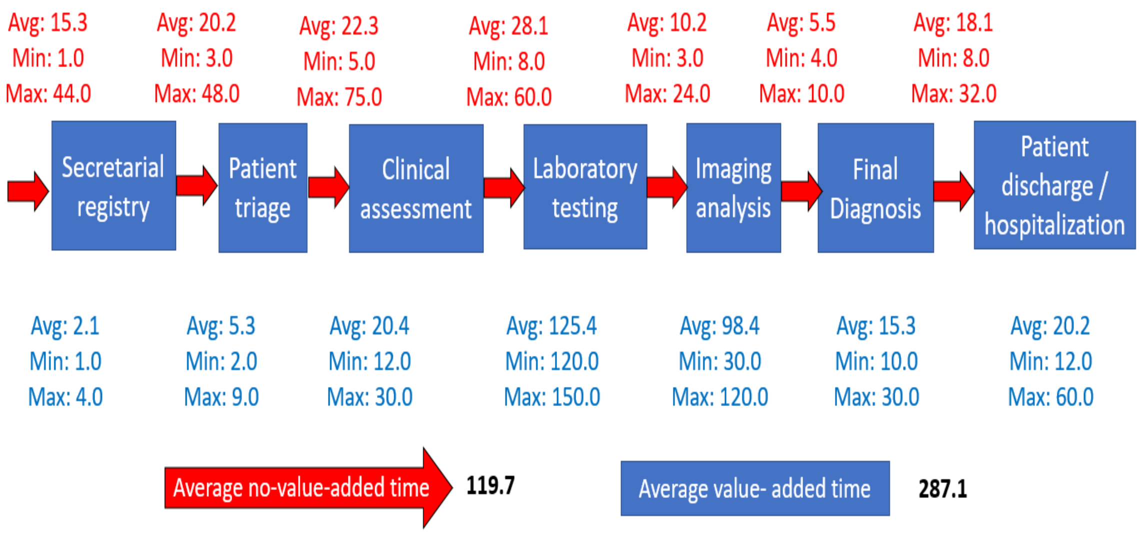

Figure 19. Value stream mapping of patient flow in the ED

As shown in Figure 19, the total lead time of an average patient visit at the ED is 406.6 minutes with the average no-value-added time being 119.7 and the value-added time being 287.1 corresponding to 29.43% and 70.57% respectively of the average total lead time during patient flow.

4.3 Healthcare professionals

After all the patient time metrics were calculated, opinions and beliefs concerning the entire patient flow procedures from entering the hospital to final discharge or hospitalization were collected from 34 healthcare professionals including midwifes, physicians and administrative personnel, who were asked about the procedures, practices, policies and methods that are applied and followed in their ED concerning patient care as well as what they think could be done to improve the entire patient flow making it more effective and efficient with smaller time metrics. The demographics of this study group are shown in Table 3.

Table 3. Demographics of healthcare professionals

Demographic characteristics	%	(n=34)
Sex		
Male	41.2	14
Female	58.8	20
Age (years)		
20-29	8.8	3
30-39	23.6	8
40-49	41.2	14

50-59	17.6	6
>60	8.8	3
Working Position		
Administrative staff	14.8	5
Nursing staff	23.5	8
Midwife	17.6	6
Clinician	20.6	7
Laboratory staff	23.5	8

Our group of 34 healthcare professionals consisted of 8 nurses, 6 midwifes, 7 clinicians, 8 lab-techs and 5 secretaries all working at the ED of Hippokration General Hospital. Most of them were female (58.8%) with an age between 30-49 yrs (64.8%).

4.4 Healthcare professionals towards patient flow in the ED

All of them assessed the 7 procedures during patient flow in the ED and estimated the ideal duration of each procedure according to their own view. The results are shown in Table 4.

Table 4. Average ideal duration per procedure of the patient flow and minimum/maximum values

Procedure	Ideal duration (minutes)
Secretarial registry	1.5 (1 to 3)
Patient triage	3.5 (3 to 8)
Clinical assessment	10.2 (8 to 20)
Laboratory testing	60 (60 to 90)
Imaging analysis	40.6 (30 to 45)
Final Diagnosis	8.4 (5 to 20)
Patient discharge or hospitalization	10.8 (7 to 20)
TOTAL IDEAL TIME	135

Then, we revealed to them the real actual duration each procedure required in their ED in order to make the comparison with what they considered as ideal duration. A comparison between them is depicted in Table 5.

Table 5. Comparison between ideal duration and actual time spent per process

Procedure	Ideal duration (minutes)	Actual Time Spent (minutes)	Discrepancy from ideal state
Secretarial registry	1.5 (1 to 3)	2.1 (1 to 4)	-40%
Patient triage	3.5 (3 to 8)	5.3 (2 to 9)	-51.4%
Clinical assessment	10.2 (8 to 20)	20.4 (12 to 30)	-100%
Laboratory testing	60 (60 to 90)	125.4 (120 to 150)	-109%
Imaging analysis	40.6 (30 to 45)	98.4 (30 to 120)	-142.3%
Final Diagnosis	8.4 (5 to 20)	15.3 (10 to 30)	-82.1%
Patient discharge or hospitalization	10.8 (7 to 20)	20.2 (12 to 60)	-87%
TOTAL IDEAL TIME	**135**	**287.1**	**-112.6%**

The closing question of each interview was what they considered should be done to improve the time metrics. However, due to the different working positions, each staff category focused mainly in their own field and expertise.

In detail, the administrative personnel agreed that additional personnel should be used for registry as well as most of them pointed out the fact that the used outdated computer hardware with many often failures while the internet connection was quite slow most of the times.

The nursing and medical staff were of the opinion that they are outnumbered for their duties since most of the times they are at most 3 professionals for Clinical Assessment. Also, they mentioned an important delay in receiving the results from laboratory testing and imaging analysis due to often reboots of the hospital cloud service and internet speed, delaying this way the Final Diagnosis process, together with the fact that ED supervisor who has to sign the results is busy most of the time with other patients.

The laboratory staff highlighted that additional personnel should be assigned to use the analyzers and imagers. Also, they mentioned that there were only 2 laboratory analyzers with an analytic run testing of 90 minutes that could not be shortened somehow.

In terms of patient waiting times it was generally agreed that increasing the number of healthcare professionals will shorten the patient waiting times in most procedures. Additionally, it was brought to attention that most patients preferred to wait for the laboratory sampling to take place before moving to imaging analysis. This resulted in alarmingly long waiting line in front of the laboratory even if there were no one waiting in front of radiology department next door. Then, if 2 or 3 individuals have completed their blood or urine sampling then they would all together move to radiology department creating a new waiting line there.

Based on the previous opinions and notices from the healthcare professionals, a Fishbone diagram was designed as shown in Figure 20.

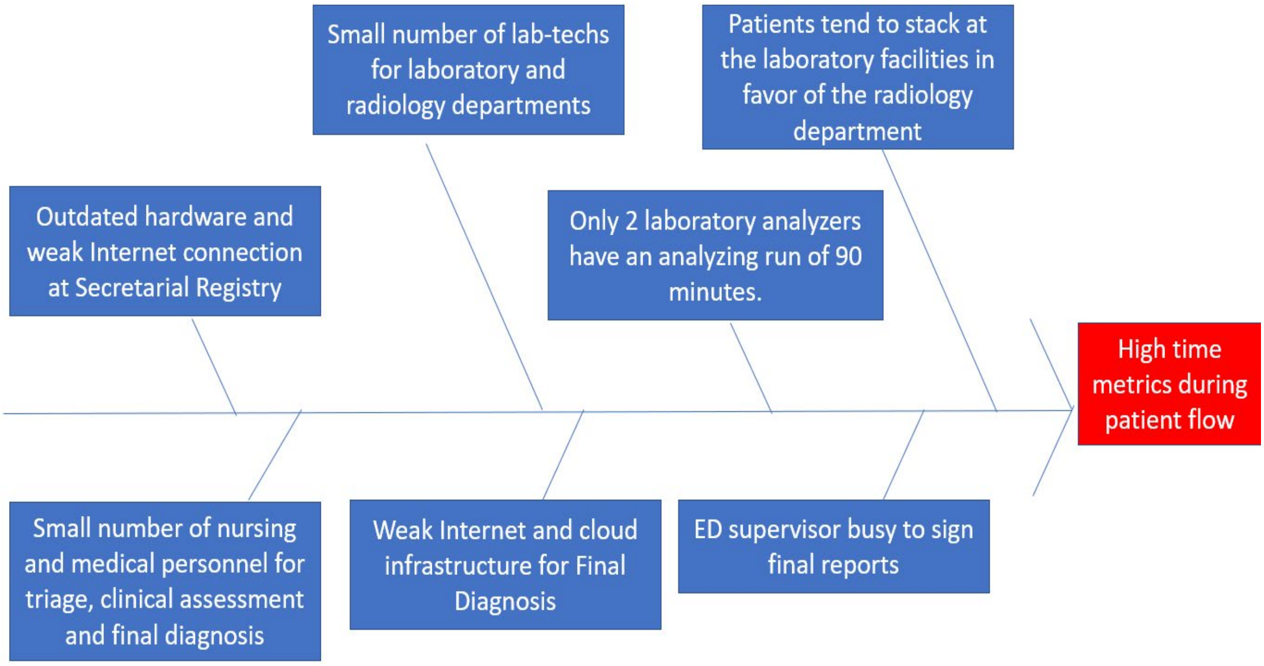

Figure 20. Fishbone diagram of current problems in ED

Having identified potential causes of delayed patient flow, we decided to design and implement countermeasures in order to improve the current patient flow in the ED. The proposed action plan is summarized in the A3 report in Fig 21.

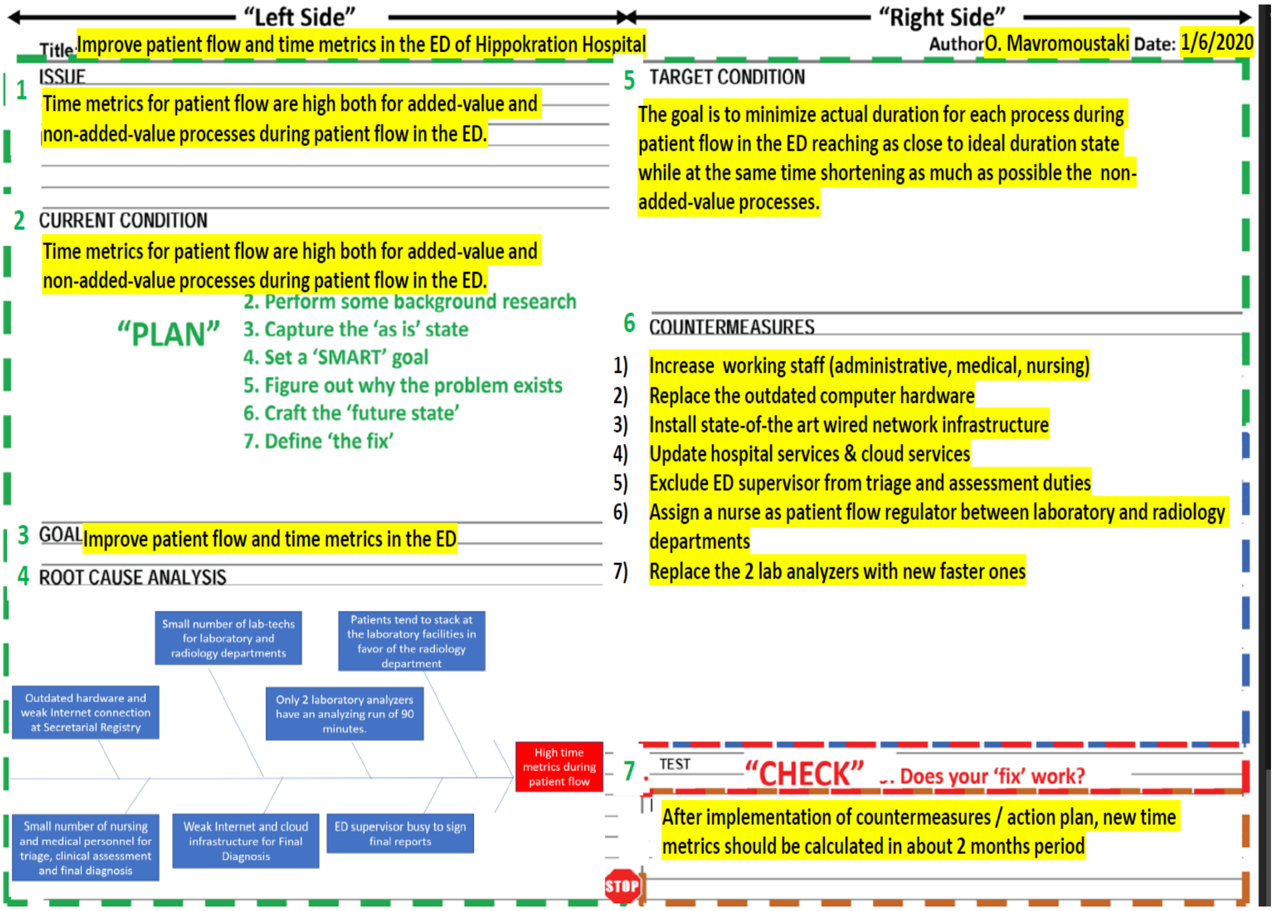

Figure 21. A3 Report "how to improve patient flow and time metrics in ED"

In detail, the following countermeasures were applied:

a) With an official request to the Board of the Hospital, the ED asked for more working personnel (administrative, nursing and medical). In fact, 1 secretary, 1 doctor and 1 lab-tech were assigned to work in the ED.

b) In collaboration with the laboratory administration, the manufacturer of the laboratory analyzers was requested to replace the existing analyzers with new ones with a run-time of 60 minutes.

c) In collaboration with the hospital IT unit, all the outdated computer hardware was replaced with new one and the old internet connection cables were replaced with new optic ones. Furthermore, most hospital servers were updated with faster hardware to improve cloud services.

d) The ED supervisor was released from examination and assessment duties in order to be available to sign final reports anytime.

e) In collaboration with the ED Director, a nurse was assigned as "patient flow regulator" between laboratory and radiology department organizing the waiting lines in both departments.

All the countermeasures were applied on 1 June 2020.

4.5 Verification of applied countermeasures

After implementation of the action plan, from 30 July to 10 August 2020, 345 patients were asked to estimate their total waiting time during each of the previously described procedures from Secretarial registry to Patient discharge or hospitalization as well as the actual time spent for the process itself. The results are summarized in Table 6.

Table 6. Average waiting time and actual time spend per procedure of the patient flow and minimum/maximum values after countermeasures implementation

The percentage of the total waiting time and total actual time for each separate process during the patient flow are depicted in Figures 22 and 23 respectively.

Procedure	Ideal duration (minutes)	Actual Time Spent (minutes)	Discrepancy from ideal state
Secretarial registry	1.5 (1 to 3)	2.1 (1 to 4)	-40%
Patient triage	3.5 (3 to 8)	5.3 (2 to 9)	-51.4%
Clinical assessment	10.2 (8 to 20)	20.4 (12 to 30)	-100%
Laboratory testing	60 (60 to 90)	125.4 (120 to 150)	-109%
Imaging analysis	40.6 (30 to 45)	98.4 (30 to 120)	-142.3%
Final Diagnosis	8.4 (5 to 20)	15.3 (10 to 30)	-82.1%
Patient discharge or hospitalization	10.8 (7 to 20)	20.2 (12 to 60)	-87%
TOTAL IDEAL TIME	135	287.1	-112.6%

Figure 22. Total waiting time for each process during patient flow after the countermeasures

Procedure	Waiting Time (minutes)	Actual Time Spent (minutes)
Secretarial registry	8.3 (1 to 20)	1.5 (1 to 3)
Patient triage	15.3 (3 to 34)	4.1 (2 to 7)
Clinical assessment	17.6 (5 to 75)	18.4 (8 to 20)
Laboratory testing	17.4 (8 to 32)	90.2 (65 to 130)
Imaging analysis **Final Diagnosis**	5.2 (3 to 11) 2.5 (2 to 8)	84.4 (19 to 105) 10.3 (7 to 20)
Patient discharge or hospitalization	12.4 (8 to 24)	15.5 (9 to 45)
TOTAL TIME	78.7	224.4

Figure 23. Total actual time for each process during patient flow after the countermeasures

The improved time metrics are presented in Figure 24 with no-added-value time metrics colored red and the value-added time metrics colored blue.

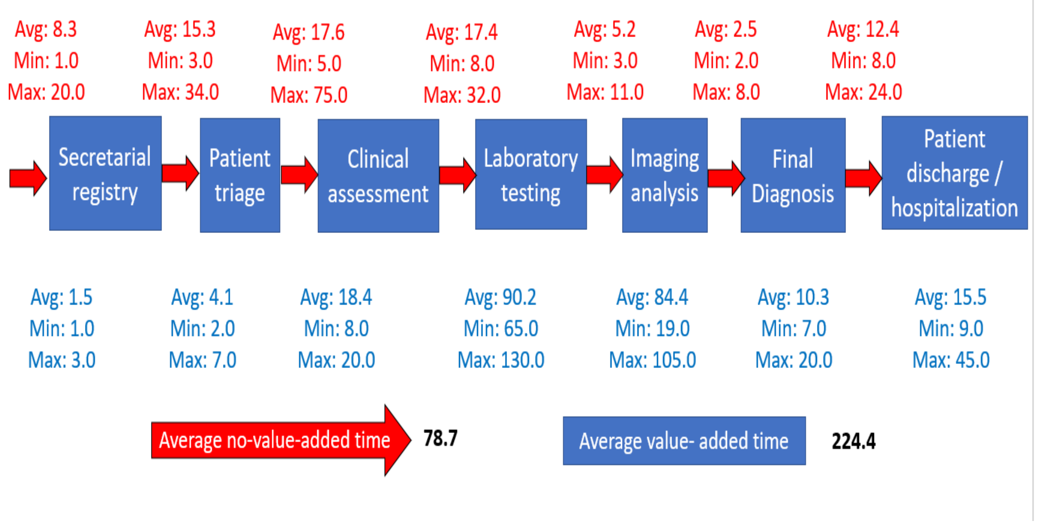

Figure 24. Value stream mapping of patient flow in the ED after countermeasure implementation

As shown in Figure 24, the total lead time of an average patient visit at the ED is 303.1 minutes with the average no-value-added time being 78.7 and the value-added time being 224.4 corresponding to 25.96% and 74.04% respectively of the average total lead time during patient flow.

A comparison between time metrics before and after countermeasures is shown in Table 7 while Figure 25 compares the two value stream maps of patient flow before and after countermeasure implementation.

Table 7. Time metrics comparison before and after countermeasures

Procedure	Waiting Time before countermeasures (minutes)	Waiting Time after countermeasures (minutes)	Improvement index
Secretarial registry	15.3 (1 to 44)	8.3 (1 to 20)	+45.7%
Patient triage	20.2 (3 to 48)	15.3 (3 to 34)	+24.2%
Clinical assessment	22.3 (5 to 75)	17.6 (5 to 75)	+21%
Laboratory testing	28.1 (8 to 60)	17.4 (8 to 32)	+38.1%
Imaging analysis	10.2 (3 to 24)	5.2 (3 to 11)	+49%
Final Diagnosis	5.5 (4 to 10)	2.5 (2 to 8)	+54.5%
Patient discharge or hospitalization	18.1 (8 to 32)	12.4 (8 to 24)	+31.5%
TOTAL TIME	**119.7**	**78.7**	**+34.2%**
Procedure	**Actual Time Spent before countermeasures (minutes)**	**Actual Time Spent after countermeasures (minutes)**	**Improvement index**
Secretarial registry	2.1 (1 to 4)	1.5 (1 to 3)	+28.5%
Patient triage	5.3 (2 to 9)	4.1 (2 to 7)	+22.6%
Clinical assessment	20.4 (12 to 30)	18.4 (8 to 20)	+9.8%
Laboratory testing	125.4 (120 to 150)	90.2 (65 to 130)	+28.1%
Imaging analysis	98.4 (30 to 120)	84.4 (19 to 105)	+14.2%
Final Diagnosis	15.3 (10 to 30)	10.3 (7 to 20)	+32.6%
Patient discharge or hospitalization	20.2 (12 to 60)	15.5 (9 to 45)	+23.2%

TOTAL TIME	**287.1**	**224.4**	**+21.3%**

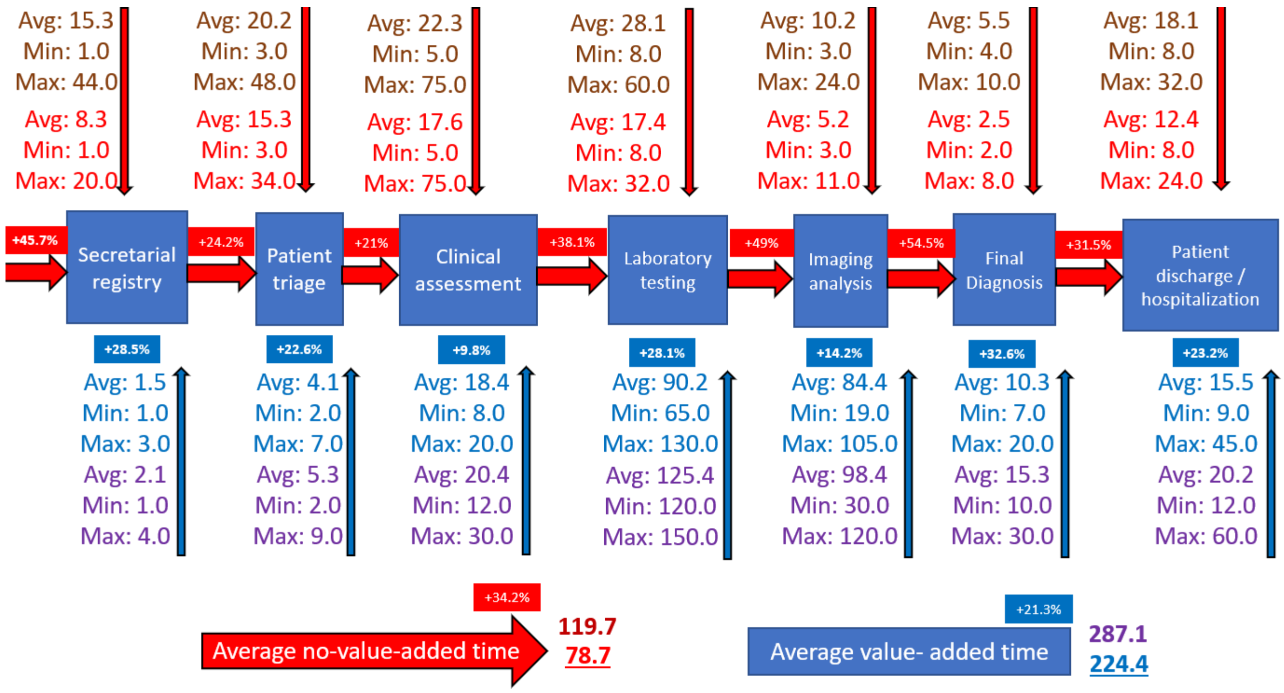

Figure 25. Comparison between the two value stream maps of patient flow before and after countermeasure implementation

It seems that every time metric parameter has significantly improved after the countermeasure implementation. In terms of patient waiting times, the procedures of Final Diagnosis, Imaging Analysis and Secretary Registry were the ones that showed the greatest improvement having a time improvement index of 54.5%, 49% and 45.7%. It is important that all the other procedures benefited from the countermeasure implementation as well with improved waiting times ranging from 21% to 38.1%. The overall average waiting time was decreased from 119.7 minutes to 78.7 minutes showing an improvement by 34.2%. In terms of actual duration, all the procedures had improvement indices from 9.8% to 32.6% with Final Diagnosis being the most improved one (32.6%) followed by Laboratory Testing and Secretarial registry (28.1% and 28.5% respectively). The total average actual duration was decreased by over 60 minutes (from 287.1 minutes to 224.4 minutes) showing an improvement of 21.3%.

Table 8. Comparison between ideal duration and actual time spent per process

Procedure	Ideal duration (minutes)	Actual Time Spent (minutes)	Discrepancy from ideal state
Secretarial registry	1.5 (1 to 3)	1.5 (1 to 3)	0%
Patient triage	3.5 (3 to 8)	4.1 (2 to 7)	-17.1%
Clinical assessment	10.2 (8 to 20)	18.4 (8 to 20)	-80.4%
Laboratory testing	60 (60 to 90)	90.2 (65 to 130)	-50.3%
Imaging analysis	40.6 (30 to 45)	84.4 (19 to 105)	-107.3%
Final Diagnosis	8.4 (5 to 20)	10.3 (7 to 20)	-22.6%
Patient discharge or hospitalization	10.8 (7 to 20)	15.5 (9 to 45)	-43.5%
TOTAL IDEAL TIME	**135**	**224.4**	**-66.2%**

5. Discussion

Healthcare organizations are complicated structures where implementation of lean management tools can be challenging. However, the growing numbers of patients visiting hospitals and clinics have made Hospital Managers to focus on their “patients/clients” and to satisfy them by providing high-quality medical services and a pleasant smooth experience to them.

In this study, an effort was made to apply lean management principles and tools in the ED of the Hippokration General Hospital of Thessaloniki. The basic aim was to improve the entire patient workflow during visits in the ED while minimizing the waiting times and actual duration of all related procedures during patient flow which were mapped with process mapping and were the following: a) Secretarial registry b) Patient triage c) Clinical assessment d) Laboratory testing e) Imaging analysis f) Final Diagnosis and g) Patient discharge or hospitalization.

At first, an assessment of the waiting times and actual durations of all 7 procedures was made by asking 644 patients who visited the ED from January 2020 to June 2020 to full in a well-structured self-administered anonymous with multiple-choice questions. It was shown that Laboratory Testing was the one with the higher patient times both in terms of waiting (28.1 minutes) and actual duration (125.4 minutes) while for Clinical assessment, Patient triage, Secretarial registry and Patient discharge or hospitalization, the patients had to wait for at least 15 minutes for each process. Although Imaging analysis has the second lower waiting time (10.2 minutes), it is however characterized by the second higher actual time (98.4 minutes). The total lead time of an average patient visit at the ED was 406.6 minutes with the average no-value-added time being 119.7 and the value-added time being 287.1 corresponding to 29.43% and 70.57% respectively of the average total lead time during patient flow.

After all the patient time metrics were calculated, 34 healthcare professionals consisted of 8 nurses, 6 midwifes, 7 clinicians, 8 lab-techs and 5 secretaries all working at the ED of Hippokration General Hospital, were asked about the procedures, practices, policies and methods that are applied and followed in their ED concerning patient care as well as what they think could be done to improve the entire patient flow making it more effective and efficient with smaller time metrics. The ideal average actual duration for all procedures was estimated to be 135 minutes according to the healthcare professionals while the actual duration according to participating patients was more than double reaching 287 minutes. Then, the healthcare professionals were asked what should be done to improve the situation. A number of problems were revealed including the outnumbered personnel in all working positions, outdated computer hardware, old and unstable internet connection, old laboratory analyzers and problem with patient flow between laboratory and radiology departments and ED supervisor's lack of time to sign the final results.

An A3 report was created based on the above observations and as a result a number of proper countermeasures were applied in order to improve the entire patient flow and minimize the time metrics both waiting times and actual durations. In detail, the following countermeasures were applied:

a) Additional secretary, doctor and lab-tech were assigned to work in the ED.

b) The existing analyzers with a run-time of 90 minutes were replaced with new ones with a run-time of 60 minutes.

c) All the outdated computer hardware was replaced with new one and the old internet connection cables were replaced with new optic ones while at the same time, most hospital servers were updated with faster hardware to improve cloud services.

d) The ED supervisor was released from examination and assessment duties in order to be available to sign final reports anytime.

e) A nurse was assigned as "patient flow regulator" between laboratory and radiology department to organize the waiting lines in both departments.

Almost two months after implementation of the countermeasures, from 30 July to 10 August 2020, 345 patients were asked to estimate their total waiting time during each of the previously described procedures from Secretarial registry to Patient discharge or hospitalization as well as the actual time spent for the process itself, in order to evaluate the effectiveness of the applied measures. It was revealed that every time metric parameter was significantly improved. In terms of patient waiting times, the procedures of Final Diagnosis, Imaging Analysis and Secretary Registry were the ones that showed the greatest improvement having a time improvement index of 54.5%, 49% and 45.7%. with the improvement index in the remaining procedures ranging 21% to 38.1%. The overall average waiting time was decreased from 119.7 minutes to 78.7 minutes showing an improvement by 34.2%. In terms of actual duration, all the procedures had improvement indices from 9.8% to 32.6% with Final Diagnosis being the most improved one (32.6%) followed by Laboratory Testing and Secretarial registry (28.1% and 28.5% respectively). The total average actual duration was decreased by over 60 minutes (from 287.1 minutes to 224.4 minutes) showing an improvement of 21.3%.

It is obvious that the applied countermeasures significantly improved the patient flow in the ED while minimized all the time metrics, which was the aim of this study which is a basic lean thinking implementation and by no means is considered as a total lean management project which is far more complicated and does not focus only on patient time metrics as in this study. For a total lean management project, more than one researcher is required with different backgrounds and expertise. Furthermore, apart from patients, other parameters are analyzed such as inventory, facilities etc.

Despite all that, the way lean management was designed and applied in terms of the ED of Hippokration Hospital revealed promising results with significant improvement indices in patient time metrics which is representative of how much could the hospital benefit from the implementation of total lean management in this working structure.

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