A Study of Lean Principles Implementation in the Libyan Healthcare and Industry Sectors

Nasser M. Amaitik, Ngwan F. Elsagzli

Abstract**—**Lean technique is very important in the service and industrial fields. It is defined as an effective tool to eliminate the wastes. In lean the wastes are defined as anything which does not add value to the end product. There are wastes that can be avoided, but some are unavoidable for many reasons.

The present study aims to apply the principles of lean in two different sectors, healthcare and industry. Two case studies have been selected to apply the experimental work. The first case was Al-Jalaa Hospital, while the second case study was the Technical Company of Aluminum Sections in Benghazi, LIBYA. In both case studies the Value Stream Map (VSM) of the current state has been constructed. The proposed plans have been implemented by merging or eliminating procedures or processes.

The results obtained from both case studies showed improvement in Capacity, Idle time and Utilized time.

Keywords**—**Healthcare service delivery, Idle time, Lean principles, Utilized time, Value stream mapping, Wastes.

I. Introduction

THERE were many people who just tried to use the tools in lean without understanding the meaning of them. But there are a number of places this system is working well. The complete elimination of waste is the target of the system. This concept is vitally important today since in today's highly competitive world there is nothing we can waste.

Understanding some of the basic lean principles is very important in the success. Lean defines the value of a product or a service with the customer point of view. Customers do not mind how hard you work or what is the technology you used to create the product or service you are selling to them [1].

Customers do not need to pay for the quality defects you have removed from your production lines. They also do not need to pay for the huge amounts of Over Head costs you have back in your facility. They will pay for the fulfillment of their requirements with the product or service you are providing to them. This is why should be a good quality product always said too costly than a lower quality one.

Quality products are chosen among the average or bad quality products. Therefore it is obvious that the customers will define the value differently to the manufacturer. It does not matter how much valuable the product or service to the manufacturer/provider.

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In lean the wastes are defined as anything which does not add value to the end product. If a customer sees the value with the end product, it is very much fair to define a waste in this way. Customers do not mind how much it costs you to repair damage, cost for your huge stocks and stores or other overheads. There are wastes that can be avoided, but some are unavoidable for many reasons.

When identifying the wastes and categorize them into avoidable and unavoidable, you have to think about removing the wastes from the system. However, lean always talks about removing, not minimizing. The wastes are everywhere in many different forms. Every organization wastes the majority of their resources. Therefore it is worthier to have a closer look at these wastes. These wastes are categorized into eight categories [1], as follows.

- Over production
- Waiting, including time in queue.
- Work In Progress (WIP)
- Transportation between workstations or between suppliers and customers.
- Inappropriate processing
- Excess motion or ergonomic problems
- Defected products
- Underutilization of employees

Although in different groups, each one of these is interconnected. Therefore one change will affect the total system.

We shall look into some quantified benefits of lean techniques where principles of lean are implemented successfully. Lean technique is normally known to reduce [4];

- Lead time by 50% at least
- Reduced WIP up to 80%
- Floor space savings around 30% (sometimes more than 50%)
- Increased productivity at least by 30% (even more than 100% in some cases)
- Quality improvement
- Overall cost reduction

The above are only the quantified and most common advantages. But there are more other advantages come with lean implementation. Among them are:

- Good team spirit which will drive the organization to the excellence
- Innovative culture in the organization
- Self driven people
- Pleasant working conditions

- Worker involvement and improved worker satisfaction
- Longer machine life
- Systematic approach to work
- Improved flexibility
- Environmentally friendly
- Built in quality

There are many definitions related to the lean techniques, these are listed below [2].

- ***Available Process Time***

Net production time available for processing products based on current resource availability.

- ***Capacity***

The maximum theoretical amount produced by a production process over a standard time period.

- ***Non-Value Added Time***

An operation or activity that takes time and resources but does not add value to the product sold to the customer. Non-value adding activities include work-in-process, inspection, defects, waiting and inefficiency.

- ***Set-up Time***

The entire time it takes a process or operation to switch from producing one part or assembly to another. It is defined as the time from the moment the last "good" part / assembly A was produces to the completion of the first "good" part / assembly B.

- ***Takt Time***

Is the rate at which the end product must be produced in order to meet customer demand how frequently a sold unit must be produced. Takt time is calculated, not measured and may be longer or shorter than cycle time. Takt time is usually expressed in seconds.

- ***Value Added Time***

Time during which an action or process changes the size, shape, form, fit or function of the product.

- ***Value Stream Map (VSM)***

VSM is a lean tool that illustrates the material flow, information flow and manufacturing & processing data to identify improvement opportunity.

There are important equations used when implementing lean principles, these equations include:

- ***Takt Time***

The Takt time is calculated using the formula below:

Takt time = time available/customer requirement

- ***Production Capacity***

It defined as the maximum rate of output that a production facility (or production line) is able to produce under a given set of assumed operation. Conditions the production facilities usually refer to plant of factory and so the term plant capacity is often used for this measure. The number of hours of plant operation per week is critical issue in defining plant capacity. Quantitative measures of plant capacity can be developed based on the production rate models derived earlier [3].

Where:

The measure of capacity= the number of units produced per week

$$Pc = N*S*H*Rp$$

Pc = the production capacity of given facilities under consideration (output unit/wk).
N = number of machines or work centers in facilities
S = the number of shifts per period (shift/wk).
H = (hr/shift).
Rp = the hourly production rate of each work center (output unit/hr).

- ***Wastage of Time***

The wastage of time/worker/day has been calculated using the formula below:

Wastage of time/worker/day = available time of worker (sec)-(capacity*cycletime)

- ***Idle Time***

The idle time/worker/day has been calculated using the formula below:

Idle time/worker/day = available time of worker-utilized time

Implementation of lean techniques present efficient solutions to many of the problems associated with manufacturing and services sectors. There are many studies and researches recently conducted for using Lean techniques in different fields of manufacturing and services management. The following sections present brief review of selected ones.

Reference [4] described the effects of Lean, a process improvement strategy pioneered by Toyota, on quality of care in 4 emergency departments (EDs). Participants in 2 academic and 2 community EDs that instituted Lean as their single process improvement strategy made observations of their behavioral changes over time. They also measured the following metrics related to patient flow, service, and growth from before and after implementation: time from ED arrival to ED departure (length of stay), patient satisfaction, percentage of patients who left without being seen by a physician, the time from ordering to reading radiographs, and changes in patient volume. The results showed that length of stay was reduced in 3 of the EDs despite an increase in patient volume in all 4. Each observed an increase of patient satisfaction lagging behind by at least a year. The narratives indicate that the closer Lean implementation was to the original Toyota principles, the better the initial outcomes. The immediate results were also greater in the EDs in which the frontline workers were actively participating in the Lean-driven process changes. In conclusion, Lean principles adapted to the local culture of care delivery can lead to behavioral changes and sustainable improvements in quality of care metrics in the ED. These improvements are not universal and are affected by leadership and frontline workforce engagement.

Reference [5] investigated the adoption of lean manufacturing in the electrical and electronics industry in Malaysia. A questionnaire survey was used to explore 14 key areas of lean manufacturing namely, scheduling, inventory, material handling, equipment, work processes, quality, employees, layout, suppliers, customers, safety and ergonomics, product design, management and culture, and tools and techniques. The respondents were asked to rate the extent of implementation for each of these areas. The average mean score for each area was calculated and some statistical analyses were then performed. In addition, the survey also examined various issues associated with lean manufacturing such as its understanding among the respondent companies, its benefits and obstacles, the tools and techniques used etc. The survey results show that many companies in the electrical and electronics industry are committed to implement lean manufacturing. Generally, most of them are “moderate–to–extensive” implementers. All the 14 key areas investigated serve as a useful guide for organizations when they are adopting lean manufacturing. This was the first study that investigates the actual implementation of lean manufacturing in the Malaysian electrical and electronics industry.

Reference [6] presented a brief history of lean manufacturing and discussed different facets that are components of an effective lean culture and programs. Specific impact of each of lean manufacturing tools on bottom line and performance of a company was examined.

Reference [7] presented several actual case studies of firms that the Missouri Enterprise has been involved as facilitator and consultant. These case studies are used to illustrate the steps in the implementation of lean manufacturing and providing actual, very positive results.

Several case stories on Lean thinking initiatives in the healthcare sector can be found in [8], [9]. In a recent publication by the Institute of Healthcare Improvement, two health care organizations in the US showed positive impact on productivity, cost, quality, and timely delivery of services after having applied Lean principles throughout the Measuring Lean Initiatives organization.

Reference [10] was concerned with the applicability of lean production principles, currently being implemented in manufacturing, to the construction industry. The manufacturing industry has seen dramatic improvements in productivity and quality, while reducing cost and lead times. The construction industry has not seen such positive results. Improvement opportunities are in demand. However, both of these industries involve the management of complex operations and strive to deliver a quality product in the shortest feasible time possible. The primary question in this study that the authors seek to answer is, “Does lean practice hold potential for improving construction?”. The authors developed the study by presenting to the readers the theory behind lean thinking. They state a set of research questions, create a lean assessment instrument, and conduct six case studies. They finally present a set of conclusions and recommendations in support of this assumption that lean practices do indeed hold potential for improving construction. The reader is initially introduced to “lean” and lean theory from the perspective of the manufacturing industry. The Toyota Motor Company, the founder of lean production principles, is integral to this background. These principles or goals include reducing lead times, eliminating non-value adding activities, and reducing variability and are facilitated by methods such as pull scheduling, simplified operations, and buffer reduction. The tools mentioned in the report that have been created to aid these methods include Value Stream Mapping, Just-in-Time, and Continuous Improvement. It was evident that a major problem in construction involves the area of supply chain management and design information. These are bottlenecks that are inhibiting the flow in the construction process, causing road blocks for further value generation.

Reference [11] sees an obvious application of Lean thinking in healthcare in eliminating delay, repeated encounters, errors and inappropriate procedures. Similarly, reference [12] advocate Lean thinking in healthcare and give an example of how Lean management principles can be applied to health care processes through the use of the Six Sigma methodology, which in many ways resemble the Lean production techniques.

Reference [13] advocates the application of Lean thinking in the medical systems. They argue that the first step in implementing Lean thinking in medical care is to put the patient in the foreground and include time and comfort as key performance measures of the system. Having multi-skilled teams taking care of the patient and an active involvement of the patient in the process is emphasized.

Reference [14] examined the effects of three contextual factors, plant size, plant age and unionization status, on the likelihood of implementing twenty-two manufacturing practices that are key facets of lean production systems. Further, they postulate four “bundles” of interrelated and internally consistent practices; these are Just-in-Time, Total Quality Management, Total Preventive Maintenance, and Human Resource Management. They empirically validated and investigated their effects on operational performance. The study sample uses data from the Industry Week’s Census of Manufacturers. The evidence provides strong support for the influence of plant size on lean implementation, whereas the influence of unionization and plant age is less pervasive than conventional wisdom suggests. The results also indicate that lean bundles contribute substantially to the operating performance of plants, and explain about 23 percent of the variation in operational performance after accounting for the effects of industry and contextual factors.

Reference [15] argues that Lean product development, supply chain management, and Lean manufacturing are important areas also in healthcare. The focus on zero defects, continuous improvements and JIT in healthcare makes Lean concepts especially applicable. The establishment of customer interaction is equally important in the manufacturing industry as it is in the healthcare sector.

The present study attempts to apply the principles of lean in two different sectors; service and industrial. The service sector is the Emergency Department in Al-Jalaa Hospital for Surgery and Accidents, and the industrial sector is the production of aluminum sections in the Technical Company of Aluminum Industry in Benghazi, LIBYA.

II. Application of Lean Techniques in Emergency Department at Al-Jalaa Hospital for Surgery and Accidents

The Emergency Departments play a vital role in providing care to patients and they are recognized for their contribution that they make to the society. The available statistics make it clear about the indispensability of this healthcare service operations that the country relies upon to provide medical services to the patients on a 24/7 basis. The ED healthcare service delivery system represents one of the most visible service sectors where the effects are very stark. Poor service delivery can often make the difference between life and death.

On at least few occasions in their lifetime, an individual is very likely to visit a hospital. The serious issue concerning healthcare in hospitals' ED is that they are very crowded and waiting times are so long that it is rarely smooth and satisfying experience. Causes for ED overcrowding are well known and include hospital bed shortage, high medical acuity of patients, increasing patient volume, shortage of examination space and shortage of medical staff. Even though these issues are well recognized, alleviation of these problems in ED is not trivial and requires addressing complex systems issues. This study concentrates on exploration of improving effectiveness of ED operations by creating framework for eliminating waste in healthcare front-end processes, significant long term benefits can be gained (e.g. shorter lead times), less personnel required, more satisfied patients etc.

A. Introduction to Al-Jalaa Hospital

The Al-Jalaa hospital is a teaching hospital opened on 1968 and improved on 1974, with a 460-bed facility. It serves the entire population of the eastern region of LIBYA. Table I below shows average annual statistics obtained from Statistics and Documentation Unit of the hospital.

TABLE I
HOSPITAL'S STATISTICS

Description	Number
Admission cases	19,500
Minor operations	6,100
Major operations	5,000
ED visits	35,000

B. Description of Current ED Service Delivery Process

In the ED procedures patients are categorized according to the severity level of their medical condition. Walk-in patients are categorized as being the least emergent. Most emergent patients that require immediate care from a physician are served first, while other patients are expected to see a physician upon a number of visits to the ED, however, they have been witnessed to be waiting over an hour in the waiting room. The ED provides medical service to the patients on a 24/7 basis of two shifts. Each shift includes one main physician at examination room. The ED also contains one observation room of 16 beds.

The ED service delivery process can be represented by the following set of core activities. These activities occur in a sequential manner; some of the steps are either rearranged or are omitted for different patient types. Fig. 1 below shows general process flowchart and patient flow through the system.

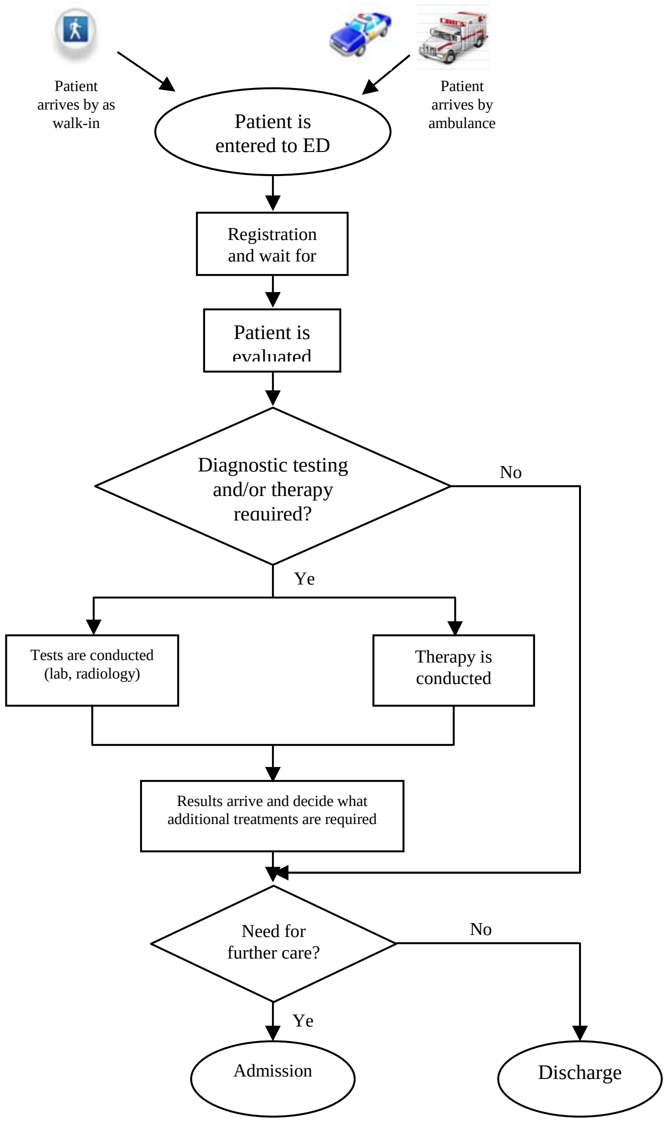

Fig. 1 ED Service Delivery Process Flowchart

C. Data Collection and Development of the VSM for Current ED State

VSM is defined as all the actions (both value added and none value added) required to bring a specific product, service or a combination of products and services, to a customer. It is an enterprise wide improvement technique that help visualize the entire process, representing material and information flow, to improve production and service processes by identifying point of weakness, waste and its sources. Then it can help to prevent such weakness and wastes in the future design.

The VSM of the ED is created by using a predefined set of icons as shown in Fig. 2 below.

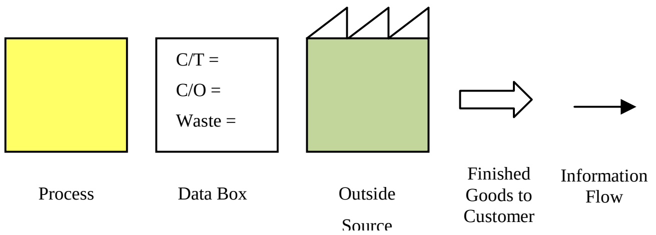

Fig. 2 Value Stream Mapping Icons

The operations to be carried out per cycle are shown in Table II. The VSM of current ED state is presented in Fig. 5. The service commences with registration by taking patient information. Following the registration, patient is ready to be assessed by a physician. Following the assessment by the physician the patient undergoes the diagnostic testing and/or therapy, and after evaluation of diagnostic reports and/or medical assessment, a decision to admit or discharge the patient is made. Entries in data box underneath the process icon include entries for cycle time, change over time and waste time. As discussed previously, cycle time is the time it takes to service a patient. Cycle time includes issues like face to face contact with the patient and physical examination. Value of cycle times shown for each process was obtained from the relevant people and has been included as the cycle time for each stage in the service delivery process. Change over time included in data box accounts for cleaning and preparation for the next patient. Wasting time is the time the patient takes until they start serving him/her in each process. For the purpose of service control there are weekly schedules for physicians, nurses and other clinical staff. Utilizing all these concepts VSM for current state of the process is shown below.

D. Analysis of Service Details of Current ED State

It is important at this stage to take a look to the overall flow of the service through the current process, in order to find out the lead time, which is the time spent within the process–from beginning to finishing–but it does not add any value to the product. It is not even the type of non-adding value time that is unavoidable in the process. This time is what restrains the organization's competitiveness ability and it must be reduced.

From the data presented in the case, the capacity of the individual unit per hour has been calculated. This value is not uniform. It indicates that there will be lot of idle time for the staff as well as in the process. It is observed that, in the present system only 48 patients can be served per day. So it is decided to improve the service capability by applying lean manufacturing philosophy. At this stage, the total number of relevant clinical staff required is equal to 5. The idle time for each operation is calculated and shown in Table III. The total idle time is calculated as (201600 sec). This idle time must be utilized in order to increase service capability. The main objectives of applying lean principles are to reduce wastages, idle time of operators and to increase the production/service capability by combining some of the operations or adding new ones. These analyses are discussed in the subsequent sections.

To show the current state more clearly, an analysis has been carried out using Ms-Excel. Fig. 3 shows the relationship between cycle time and their respective operations. Bottleneck problems within the processes are seen very clearly, represented in diagnostic testing and/or therapy operations, which have largest cycle times respectively.

Similarly, Fig. 4 shows the relationship between capacity per day and their respective operations. It can be clearly seen that the bottleneck problems are in the diagnostic testing and/or Therapy operations, where their capacity per day is clearly low compared to other operations.

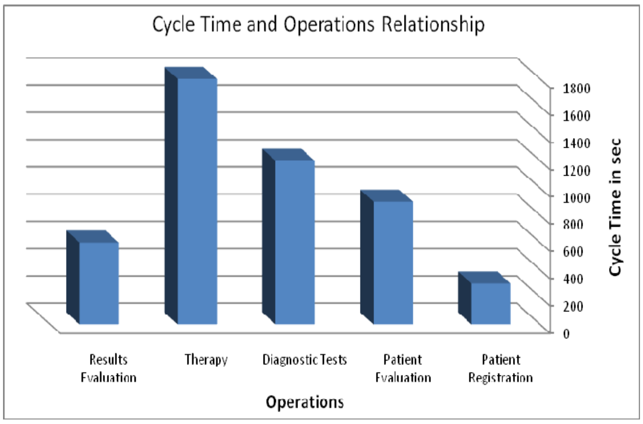

Fig. 3 Cycle Time Vs ED Operations

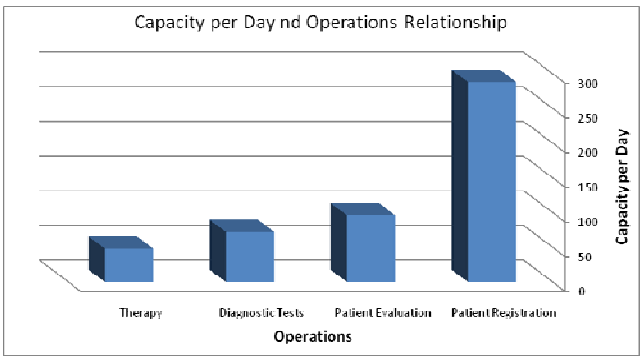

Fig. 4 Capacity per Day Vs ED Operations

TABLE II
DATA COLLECTIONS OF ED OPERATIONS

No	Description	Cycle Time (C/T) in (sec)	Available Time of Related Clinical Staff (sec)
1	*Patient Registration*	300	86400
2	*Patient Evaluation*	900	86400
3	*Diagnostic Tests*	1200	86400
4	*Therapy*	1800	86400
5	*Results Evaluation*	600	86400
	Total	**4800**	**345600**

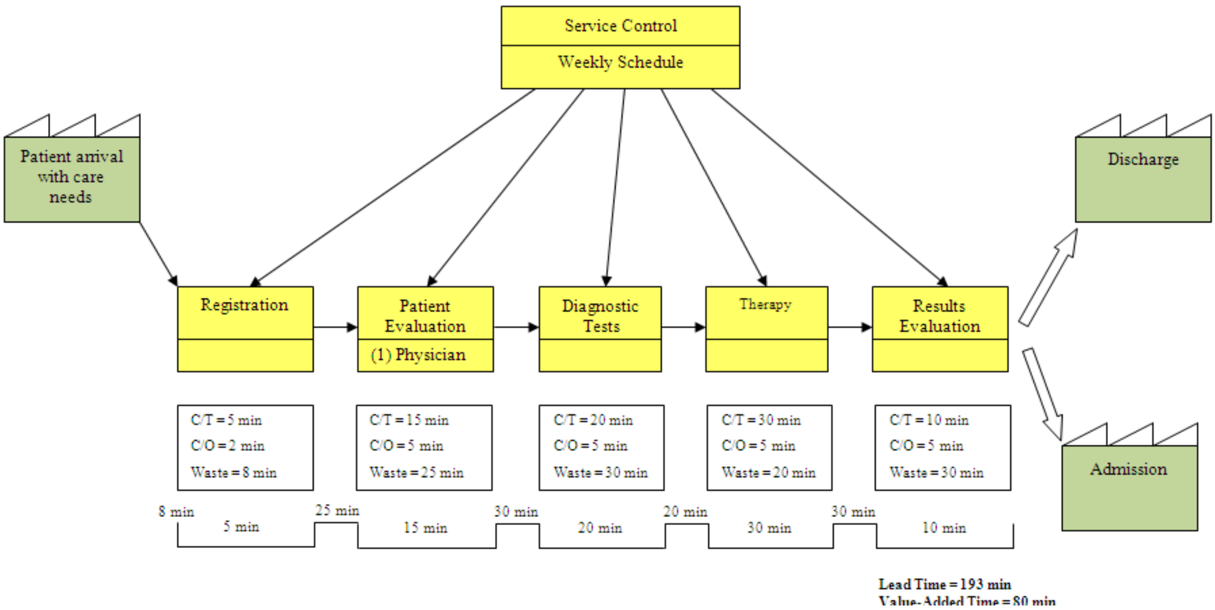

Fig. 5 VSM for the Current State

TABLE III
SERVICE DETAILS OF CURRENT ED STATE

No	Operation Description	Cycle Time (C/T) in (sec)	Number of Related Clinical Staff	Available Time of Related Clinical Staff (sec)	Capacity per Clinical Staff/Day	Utilized Time = 48 x C/T	Idle Time per Clinical Staff/Day	Capacity /Hour
1	*Patient Registration*	300	1	86400	288	14400	72000	12
2	*Patient Evaluation*	900	1	86400	96	43200	43200	4
3	*Diagnostic Tests*	1200	1	86400	72	57600	28800	3
4	*Therapy*	1800	1	86400	**48**	**86400**	**0**	**2**
5	*Results Evaluation*	600	1	86400	144	28800	57600	6
	Total	**4800**	**5**	**432000**	**-**	**230400**	**201600**	**-**

TABLE IV
SERVICE DETAILS OF FUTURE ED STATE

No	Operation Description	Cycle Time (C/T) in (sec)	Number of Related Clinical Staff	Available Time of Related Clinical Staff (sec)	Capacity per Clinical Staff/Day	Utilized Time = 72 x C/T	Idle Time per Clinical Staff/Day	Capacity/Hour
1	*Patient Registration*	300	1	86400	288	21600	64800	12
2	*Patient Evaluation*	900	1	86400	96	64800	21600	4
3	*Diagnostic Tests and Results Evaluation*	1200	1	86400	**72**	**86400**	**0**	**3**
4	*Therapy and Results Evaluation*	1800	2	172800	96	129600	43200	4
	Total	**4800**	**5**	**432000**	**-**	**302400**	**129600**	**-**

E. The Proposed Plan

This section introduces proposed plan for improving the services capability and reducing the idle time of the related clinical staff for ED.

In the proposed plan, the patient evaluation operation has been combined with each of diagnostic testing and therapy operations so that the same clinical staff doing diagnostic tests or therapy can read the reports and evaluate the results, and then make decision either for continuing service (admission) or leaving the ED (discharge). Also, another new physician was suggested to be added at the combined operation (Therapy and Results Evaluation). This will reduce the waiting time, increase the serviceability and patient flow at the observation room, as illustrated below.

Next, changes that could be done to the current system and how it will affect the overall performance and the improvement in service capability has been illustrated. These improvements mentioned above led to increasing the patients served (capacity) from 48 to 72 (50%), reducing idle time from 201600 sec to 129600 sec (36%) and increasing utilized time from 230400 sec to 302400 sec (31%), while the number of clinical staff remains the same with 5. The detailed results of these improvements are shown in Table IV.

Initially diagnostic testing/therapy and patient evaluation operations are carried out by three clinical staff, which led to an idle time of 86400 sec per day. In proposed plan after combining the operations idle time has been reduced to 43200.

In the proposed methodology, one clinical staff is engaged in the Diagnostic Testing and Patient Evaluation operation. So the capacity of the operation has been improved to 72, but the maximum capacity of the system is 288 which is higher than the capacity of the diagnostic testing and patient evaluation operation. The difference can be eliminated by reducing waste time and change over time of operations and adding more units especially for diagnostic testing. In this way, the service capability has been improved. The improvement in service provided, idle time and utilized time are plotted and shown in Figs. 6-8 below.

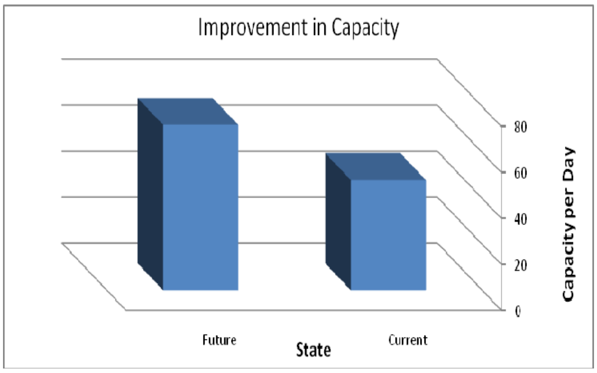

Fig. 6 Improvement in Capacity

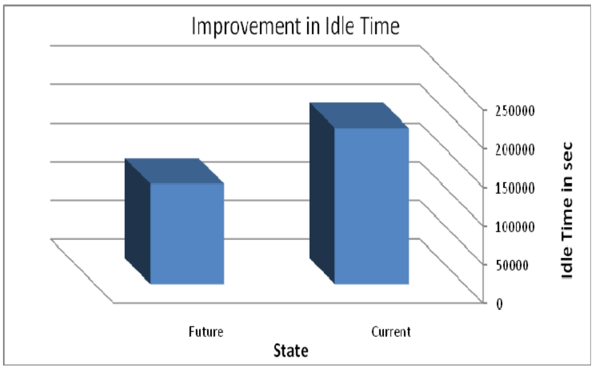

Fig. 7 Improvement in Idle Time

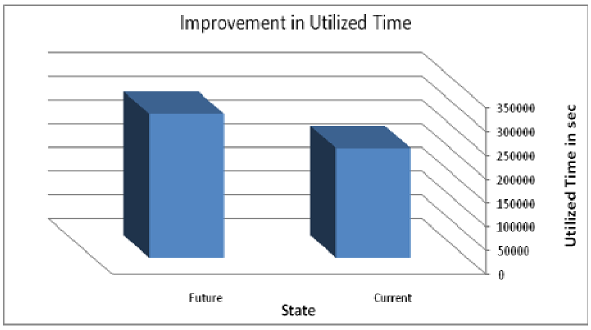

Fig. 8 Improvement in Utilized Time

F. Value Stream Mapping for Future ED State

The future stream map is a method of showing the desired achieved future goals. It also shows service delivery processes after using lean tools to improve it. The future stream map is similar to the current stream map, where both give visual representation of the material, information and time flow, and it is used to show the level of successes and changes.

The future stream map will be used to demonstrate how the product flows, eliminating all the wastes shown in the current state and achieve lean manufacturing. It is a powerful tool, it provides a clear statement of a vision for where the organization is going, however if the ideas are not implemented within a short time, it will lose its force and it will become another "has been" of manufacturing technique. The future stream map (or VSM) in this case study, which represents the future vision of the ED, is shown in Fig. 9.

The results achieved in the future stream map resulted from using some of the lean manufacturing; these techniques are helping the ED to be more productive, flexible, smooth and with high quality output. This will enhance the ED overall performance, lead time, changeover time and the delivery time to patients. It can be seen that the lead time of the service at ED has been reduced from 193 sec to 153 sec (20.7%).

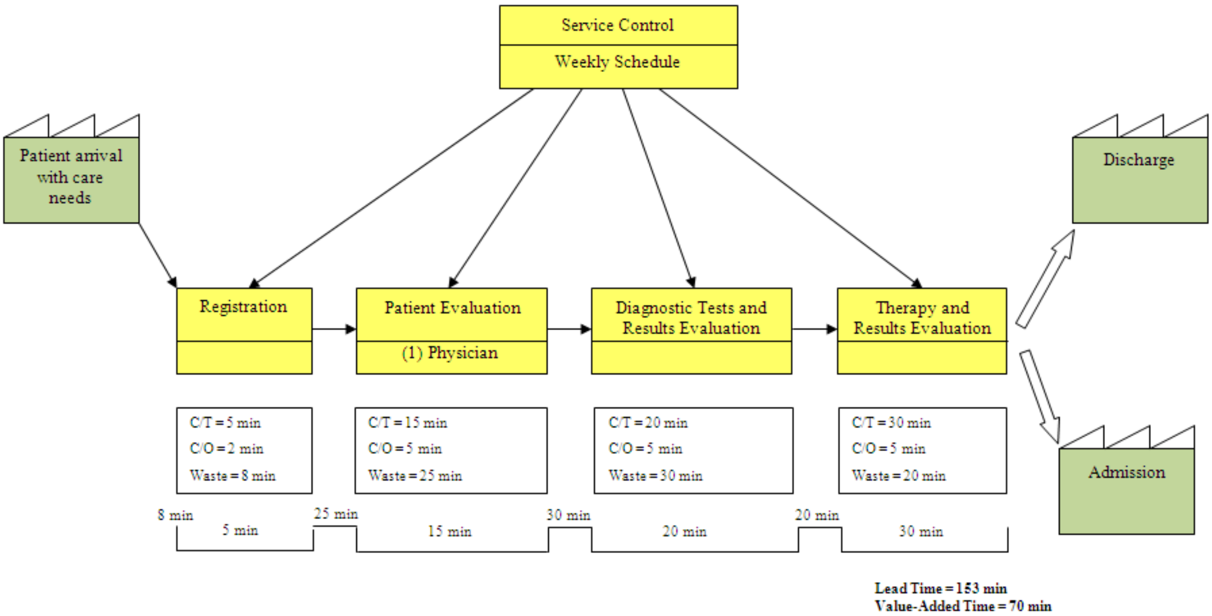

Fig. 9 VSM for the Future State

G. Benefits of Implementing Lean Techniques at ED

By implementing the lean manufacturing techniques, ED at Al-Jalaa Hospital for Surgery and Accidents will gain lots of benefits with regard to its healthcare services provided to the patients. Some of these advantages can be seen directly from the future stream map and can be considered as long term advantages. Table V below shows the differences in results between the current state and the future state.

TABLE V
DATA COLLECTIONS OF ED OPERATIONS

Item	Current State	Future State	% of Improvement
Capacity	48	72	50
Idle Time	201600 sec	129600 sec	36
Utilized Time	230400 sec	302400 sec	31
Number of Operations	5	4	20

The benefits that may consider as long term benefits are:

- Patients served increased from 48 to 72
- Total idle time is reduced from 201600sec to 129600sec
- Total utilized time is increased from 230400sec to 302400sec

III. Application of Lean Techniques in Technical Company of Aluminum Industry

Global society faces a great challenge to shift human economic activity and lifestyles on to a sustainable path in the 21st century, including meeting threats from climate change. The story of the Aluminum industry over the decades ahead must be one of how it is part of the solution for a sustainable future [16].

This century began with an estimated 6 billion people on the planet, up six-fold in just 200 years from 1 billion in the year 1800. The United Nations currently expects global population to peak around 2050 at about 9 billion.

Aluminum is a young material, and in the little more than a century since its first commercial production, it has become the world's second most used metal after steel. Aluminum is the metal of choice for leading designers, architects and engineers, all of whom are looking for a material which combines functionality and cost-effectiveness with forward looking form and design potential.

Aluminum is an extraordinarily versatile material. The range of forms it can take (castings, extrusions and tubes, sheet & plate, foil, powder, forgings, etc) and variety of surface finishes available (coatings, anodizing, polishing etc) means it lends itself to a wide range of products, many of which we use every day of our lives. Its strength, combined with low density, make it ideal for transport and packaging applications. Aluminum is a unique metal: strong, durable, flexible, impermeable, lightweight, corrosion-resistant, and 100 percent recyclable.

Aluminum is the third most abundant element in the earth's crust and constitutes 7.3% by mass. In nature however it only exists in very stable combinations with other materials (particularly as silicates and oxides). While there were some historical mentions of Aluminum use, it was not until 1808 that its existence was first established. It then took many years of painstaking research to "unlock" the metal from its ore - the hard, reddish and clay-like bauxite. Further years of experimentation finally, in 1854, saw the development of a viable, commercial production process.

The global Aluminum industry has therefore developed a four-pronged voluntary strategy to meet the challenges of climate change, which encompasses the full lifecycle of Aluminum from production, to primary use, to recycling and reuse [16]:

1. Reduce greenhouse gas emissions from Aluminum

production;
2. Increase energy efficiency in Aluminum production;
3. Maximize used-product collection, recycling and reuse;
4. Promote the light-weighting of vehicles.

A. Intro. to Technical Company of Aluminum Industry

Technical Company of Aluminum Industry is a LIBYAN company concerned with the Aluminum trade and industry. The company conducted a study about the use of Aluminum in the local market, which showed that the small business companies and workshops of Aluminum worked on the local market depending 100% on importing the necessary material for its operating (Aluminum sections and bars) from the border countries. The amount imported is estimated by 380 Ton per month (12.67 Ton/day).

Because of the raw material (Aluminum scrap) is available in good quantities in the local market, as well as the need for such industry near to the local market, the Company decided to build a plant for producing Aluminum sections and bars that can feed the local market with this vital product with a good quantities, competing quality and price to the imported product. The plant was established on 07/11/2007, and located on Sidi-Khalifa region east of Benghazi. The designed capacity of the plant is 10 Tons per day.

Fig. 10 shows a flowchart illustrating the manufacturing process of the Aluminum sections, from raw material (scrap collecting) to the final product.

These manufacturing processes are controlled and followed by the Department of Production Planning and Follow-up. A Quality Control Division is responsible for maintaining and keeping the product within the specification limits during all manufacturing process.

B. Data Collection

The Plant works in two shifts with 8 hours per shift. Each shift includes one hour lunch and half-hour break. So, in this way the available time for work is 13 hours per day which equal to 46800 sec.

The operations to be carried out per production cycle are shown in Table VI below.

TABLE VI
DATA COLLECTION OF PRODUCTION OPERATIONS

No	Description	Cycle Time (C/T) in (sec)	Available Time of Station/Unit (sec)
1	Scrap Collecting	5040	46800
2	Casting Furnace	5400	46800
3	Homogenizing Furnace	2880	46800
4	Cooling Furnace	1080	46800
5	Press Unit	9180	46800
6	Extrusion Aging Oven (Hardness)	3600	46800
7	Powder Coloring	5400	46800
8	Anodizing	5400	46800
9	Packaging	4320	46800
10	Final Product (Store)	3600	46800
	Total	**4800**	**345600**

C. The Current Plan

From the data collected and presented in the case, the capacity of the individual operation has been calculated. This value is not uniform. It indicates that there will be lot of idle time for both staff and machines. It is observed that, in the present system only 7.22 Tons of final product can be produced per day. Achieving the design capacity of the plant is not possible at the moment because the frequent interruption in the electricity, lack of skilled manpower and the machines breakdown and maintenance, however they were used before installing them in the Plant. So, it is decided to improve the production capability by applying lean philosophy. At this stage, the total number of operations/units is equal to 10. The idle time for each operation is calculated and shown in Table VII. The total idle time is calculated as (156081.6 sec). This idle time must be utilized in order to increase the production capability. The main objectives of applying lean principles are to reduce wastages, idle time of operators/machines and to increase the production capability by combining some of the operations or adding new ones. These analyses are discussed in the subsequent sections.

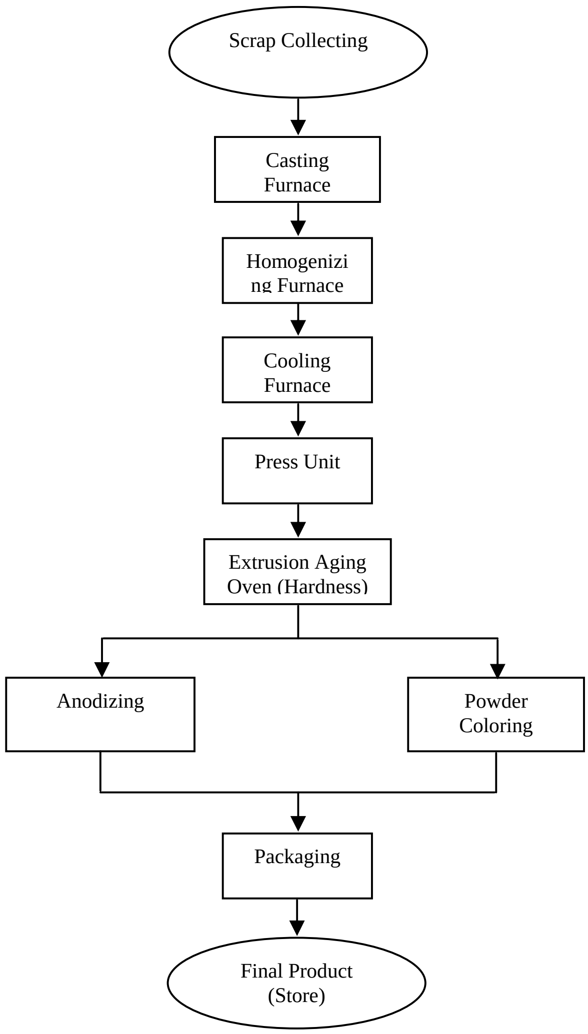

Fig. 10 Manufacturing Processes of Aluminum Sections

TABLE VII
OPERATION DETAILS OF THE CURRENT PLAN (CASE STUDY II)

No	Operation Description	Cycle Time (C/T) in (sec)	Number of Stations (Units)	Number of Workers	Available Time of Stations (sec)	Capacity per Station/Day	Utilized Time = 7.22 x C/T	Idle Time per Station/Day	Capacity /Hour
1	*Scrap Collecting*	5040	1	24	46800	9.30	36388.8	10411.2	0.72
2	*Casting Furnace*	5400	1	11	46800	8.67	38988	7812	0.67
3	*Homogenizing Furnace*	2880	1	1	46800	16.25	20793.6	26006.4	1.25
4	*Cooling Furnace*	1080	1	1	46800	43.33	7797.6	39002.4	3.33
5	*Press Unit*	6480	1	16	46800	**7.22**	**46800**	**0**	**0.56**
6	*Extrusion Aging Oven (Hardness)*	3600	1	1	46800	13	25992	20808	1
7	*Powder Coloring*	5400	1	12	46800	8.67	38988	7812	0.67
8	*Anodizing*	5400	1	25	46800	8.67	38988	7812	0.67
9	*Packaging*	4320	1	26	46800	10.83	31190.4	15609.6	0.83
10	*Final Product (Store)*	3600	1	11	46800	13	25992	20808	1
	Total	**43200**	**10**	**128**	**468000**	-	**311918.4**	**156081.6**	-

Fig. 11 shows the relationship between cycle time and their respective operations. Bottleneck problems within the processes are seen very clearly especially represented in Press Unit, which have largest cycle time.

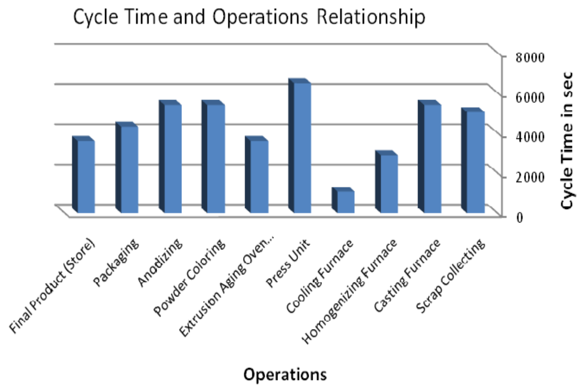

Fig. 11 Cycle Time vs. Operations

Similarly, Fig. 12 shows the relationship between capacity per day and their respective operations. It can be clearly seen that the bottleneck problems is in the Press Unit, where its capacity per day is clearly low compared to other operations.

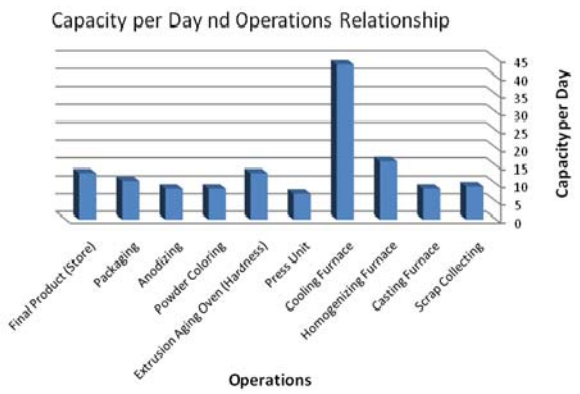

Fig. 12 Capacity per Day vs. Operations

D. The Proposed Plan

This section introduces proposed plan for improving the production capability and reducing the idle time of the operations.

As the layout and arrangement of the machines inside the plant were done in a good way, and the shortage of the production is due to other factors, which the main of them discussed earlier. In the proposed plan, it is suggested to add another Press machine to the Press Unit in order to increase the rate of the production and reduce the waiting time. It is suggested to add electric Press machine which has cycle time (approx. 2700 sec per 1 Ton) much better than the existed one (operates by Gas and has cycle time of 6480 sec per 1 Ton). So the new cycle time will be 9180 sec. The operators needed to operate the two Press machines are 25, adding only 9 operators to carry out the basic activates. Adding this new Press machine will be very beneficial on the long term as the demand is in increase.

Next, changes that could be done to the current system and how it will affect the overall performance and the improvement in production capability has been illustrated. These improvements mentioned above led to increasing the production (capacity) from 7.22 Tons to 8.67 Tons (20%), reducing idle time from 156081.6 sec to 116901 sec (25%) and increasing utilized time from 311918 sec to 397899 sec (21.5%), while the number of operations remains the same with 10. The detailed results of these improvements are shown in Table VIII.

The improvement in production, idle time and utilized time are plotted and shown in Figs. 13-15 below.

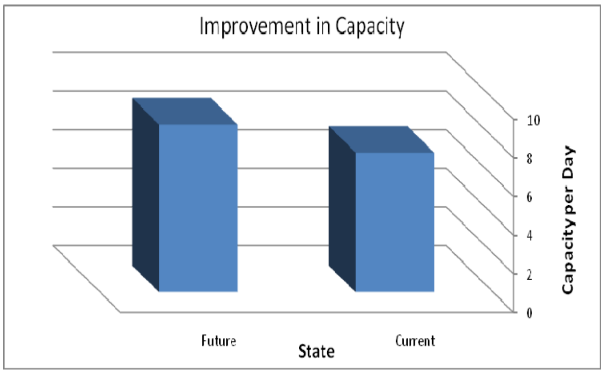

Fig. 13 Improvement in Capacity

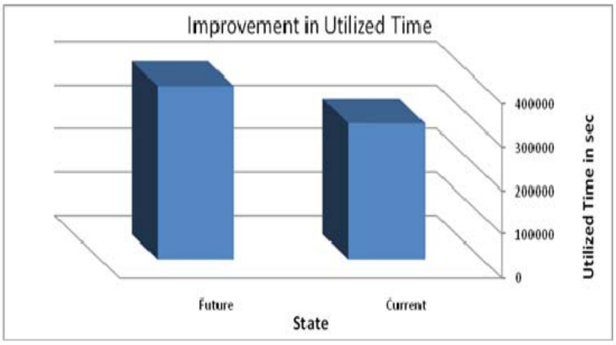

Fig. 14 Improvement in Idle Time

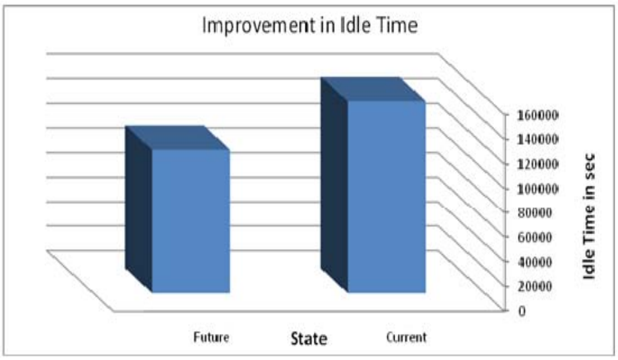

Fig. 15 Improvement in Utilized Time

TABLE VIII
OPERATION DETAILS OF THE FUTURE PLAN (CASE STUDY II)

No	Operation Description	Cycle Time (C/T) in (sec)	Number of Stations (Units)	Number of Workers	Available Time of Stations (sec)	Capacity per Station/Day	Utilized Time = 8.67 x C/T	Idle Time per Station/Day	Capacity / Hour
1	*Scrap Collecting*	5040	1	24	46800	9.30	43696.8	3103.2	0.72
2	*Casting Furnace*	5400	1	11	46800	**8.67**	**46800**	**0**	0.67
3	*Homogenizing Furnace*	2880	1	1	46800	16.25	24969.6	21830.4	1.25
4	*Cooling Furnace*	1080	1	1	46800	43.33	9363.6	37436.4	3.33
5	*Press Unit*	9180	2	25	93600	10.20	79590.6	14009.4	0.78
6	*Extrusion Aging Oven (Hardness)*	3600	1	1	46800	13	31212	15588	1
7	*Powder Coloring*	5400	1	12	46800	**8.67**	**46800**	**0**	0.67
8	*Anodizing*	5400	1	25	46800	**8.67**	**46800**	**0**	0.67
9	*Packaging*	4320	1	26	46800	10.83	37454.4	9345.6	0.83
10	*Final Product (Store)*	3600	1	11	N	13	31212	15588	1
	Total	**45900**	**11**	**137**	**514800**	-	**397899**	**116901**	-

E. Benefits of Implementing Lean Techniques at Technical Company of Aluminum Industry

Lots of benefits such as increasing productivity and reducing idle time have been achieved in this study. Table IX below shows the differences in results between the current state and the future state.

TABLE IX
COMPARISON OF RESULTS BETWEEN CURRENT STATE AND FUTURE STATE

Item	Current State	Future State	% of Improvement
Capacity	7.22 tons	8.67 tons	20
Idle Time	156081 sec	116901 sec	25
Utilized Time	311918 sec	397899 sec	21.5
Number of Operations	10	10	0

The benefits that may consider as long term benefits are:

- Aluminum sections produced increased from 7.22 to 8.67 tons
- Total idle time is reduced from 156081sec to 116901sec
- Total utilized time is increased from 311918sec to

397899sec

IV. Conclusions

The present work studied the implementation of lean principles in two different sectors, healthcare and industry, with the purpose of eliminating wastes and increasing capacity. Two case studies have been selected to apply the experimental work. The first case was the Emergency Department at Al-Jalaa Hospital, and the second case was the Aluminum sections plant at Technical Company of Aluminum Industry in Benghazi, LIBYA.

In general, it was shown that the Value Stream Mapping is an ideal tool to expose the waste in a value stream and to identify tools for improvement. The development of the future state map is not the end of a set of value stream activities. It should be stressed that the value stream should be revisited until the future becomes the present. The idea is to keep the cycle going because if sources of waste are reduced during a cycle, other wastes are uncovered in the next cycle.

In the first case study, the results achieved in the proposed plan showed significant improvements in the overall performance of the ED, which allowed it to be more productive, flexible, smooth and with high quality service. These improvements include reducing the lead time of the service at ED from 193 sec to 153 sec (20.7%), which increased the patients served (capacity) from 48 to 72 (50%), reducing idle time from 201600 sec to 129600 sec (36%) and increasing utilized time from 230400 sec to 302400 sec (31%).

In the second case study, significant improvements have also been achieved from implementing lean principles. These improvements include increasing in production (capacity) from 7.22 Tons to 8.67 Tons (20%), reducing idle time from 156081.6 sec to 116901 sec (25%) and increasing utilized time from 311918 sec to 397899 sec (21.5%).

The complexities of the healthcare environment present unique challenges that do not exist in most manufacturing systems. Healthcare professionals and interested researchers are increasingly use VSM new knowledge regarding its effective use and it will continue to emerge, however the tool is still in its infancy in healthcare.

A logical continuation (extension) of the work done in the first case study would be to elevate the level of work to the hospital level (mapping other departments of the hospital), rather than keeping it at the departmental level (ED level). The reason for the long delays in the ED is not necessarily an internal flaw, the bottleneck might lie elsewhere. Some other processes down the line might be experiencing difficulties in admitting patients, automatically leading to an overcrowded ED.

Finally, it is concluded that an improvement in Capacity, Idle time and Utilized time has been achieved as a result of implementing lean principles in both case studies.

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