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Applying Management Principles of Lean Manufacturing for Enhancing Efficiency and Effectiveness of Emergency Department Rooms

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Abstract

The lean manufacturing approach plays a vital role in reducing waste and enhancing productivity in the production environment and service setups. Lean manufacturing-based techniques might be employed in evaluating the efficiencies of different rooms in emergency departments (EDs) and hospitals. A lean thinking approach may be used in testing the usage of the existing facilities planned and constructed for patients' use. In the present study, the management principles of lean manufacturing-based methodology have been used to test the usage of the ED services. Two vital rooms of the ED viz. rapid response trauma (RR-Trauma) and rapid response medical (RR-Medical) are studied in terms of crowding and bed occupancy. Using the concept of takt time (TT), an individual department's efficiency and relative efficiency have been calculated to judge the effectiveness of the ED services. A case of a governmental, non-profit and teaching hospital in the southern region of Saudi Arabia has been studied to see the effect of staffed bed redistribution based on lean manufacturing concept. It has been revealed that ED is facing crowding and frequent critical ambulance diversion problems which require a management intervention to go for staffed bed redistribution to accommodate all of the patients' arrivals. Furthermore, the optimal allocation of resources is essentially be achieved to enhance the efficiency and effectiveness of ED rooms. Based on the lean manufacturing concept, the acceptable TT and efficiency for ED rooms are recommended.

Keywords: Cycle time (CT); Efficiency; Emergency department (ED); Lean manufacturing; Takt Time (TT).

1. Introduction

The emergency department (ED) plays a powerful function in a human being's risk management. There is an increasing risk of a sudden outbreak in the present age and an increased rate of injuries which places the burden on ED. To counteract the various natural diseases, scientists have developed remedies to cure most of the diseases in the present age. However new diseases are erupting from time to time thus makes everybody on their toes to develop a strategy to protect humanity. Also, man-made or natural disasters, injuries, epidemics of infectious diseases caused by viruses, etc. are the main reasons why emergency departments are crowded. The accidents are considered to be a major man-made threat to human beings around the globe. According to the World Health Organization (WHO), road traffic injuries caused an estimated 1.24 million deaths worldwide annually, which amounts to the accidental death of one person every 25 seconds. Furthermore, according to figures from statistics of Saudi Arabia, every second a car accident happens and on average 17 people are killed in accidents every day [1].

The epidemic eruption and increased accident rate pose great challenges to ED. The EDs are facing many challenges, some of which are very critical. The overcrowding problem in the ED is a major threat therefore, ambulance diversion problems can be faced due to the crowding problem in ED and boarding takes place which may put the patients in great danger. Also, in the case of accidents, sometimes the patients are brought in the critical situation warrants the medical aids in time, if not tackled quickly the patient may lose precious life.

One of the major problems faced by ED is overcrowding of patients and consequently ambulance diversion. Ambulance diversion is defined as the process of turning away the ambulance from the ED to another hospital due to insufficient staffed bed capacities or deficiency in the ED management process. Ambulance diversion poses a risk to any patient and endangers his or her life when needs immediate medical care.

The ED under study is part of a governmental, teaching and non – profit hospital located in Saudi Arabia. The ED in this hospital faces a serious overcrowding problem and ambulance diversion in the rapid response trauma (RR-Trauma) room and rapid response medical (RR-Medical) room. Therefore; ambulances are redirected to private

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hospitals in the city due to the agreement between the Saudi Ministry of Health (MOH) and the private health sector. According to this agreement, the Ministry of Health is responsible for all the patients' care expenses in private hospitals. Hence, this situation will increase the cost of the provided healthcare services by the MOH. Furthermore, ambulance diversion is only taking place at RR-Trauma and RR-Medical. There is no ambulance diversion is taking place at the other ED rooms. The patients in such rooms have to wait or leave and seek services in other private hospitals at their expenses.

The lean management principles have gone far in the last decade and covered almost every field of production and service organizations. The vary introduction and implementation of the comparison analysis lean production system in Toyota has now a great impact on different areas of production and services. The various lean practices have shown that lean production methods are equally applicable to ED. Thus, lean management based concepts have been applied in ED rooms to resolve various issues faced regularly.

Looking at the ample potential and opportunities of lean implementations in services, the present research has been carried out with the following objectives:

1. To use the lean management based methodology in the service improvement of ED rooms of a governmental hospital.
2. To calculate the various efficiency of ED rooms and provide optimal redistribution of staffed bed to enhance efficiency and effectiveness

The paper is further organized as follows. Section 2 reviews the available literature on ED services and efficiency. Section 3 highlights the significance of cycle time (CT) and Takt Time (TT). Section 4 is about revisiting ED services of a government hospital. Section 5 discusses the results of the study, it also provides a comparative analysis of various ED rooms and staffed bed redistribution strategy. Section 6 provides a discussion on the present research. The paper ends with a conclusion in section 7.

2. Literature Review

In recent years, several researchers have studied the problem of patients' long waiting times in the healthcare sector in general and ED rooms in particular. The reduced waiting time and crowding in ED rooms will enhance service time effectiveness to improve the quality of delivered care services [2 – 7]. Keith et al. [8] researched on achieving wait time reduction in the ED. Their quality improvement team was able to achieve a large reduction in waiting time in the ED. Thereafter; Oredsson et al. [9] studied the worldwide problem of overcrowding in the ED. They used a scientific approach to explore the right intervention to improve patient flow in the ED.

Lean thinking principles have found its origin in the production area [10]. It has been applied to production and service management to enhance the productivity of resource utilization and many lean thinking studies have been carried out in a production environment. Braglia et al. [11] and Vendan and Sakthidhasan [12] used value stream mapping (VSM) lean tool in complex production systems. Matt and Rauch [13] studied the implementation of lean production principles in small-sized enterprises and Mandahawi et al. [14] assessed printing and cutting machines performance on the bases of customized Lean Six Sigma approaches at a paper manufacturing company. Marodina and Saurina [15] highlighted research areas and opportunities in lean production systems.

However, the applications of lean thinking principles have been extended to the healthcare sector. Many studies explored the application of these principles in healthcare organizations and ED to reduce waiting time and improve patients' flow [16 – 21]. Murrell et al. [22] applied lean thinking principles to develop a rapid triage and treatment (RTT) system in ED of community hospital and Holden [23] critically reviewed lean thinking in ED for understanding the effects of lean on ED work structures and processes, patient care, and employees, as well as the factors on which lean's success is contingent. Later on, Gill [24] used the application of VSM to eliminate waste in an emergency room.

In a process of ED services improvement, many researchers attempted to reduce the waiting times in the ED [25]. Mandahawiet al. [26] attempted to reduce waiting time in the ED using design for six sigma and discrete event simulation. Also,Vermeulen et al. [27] evaluated an ED using a lean process improvement program to reduce the length of stay (LOS).

The staffed bed redistribution has been an important research area for the researchers attempting to enhance the efficiency and effectiveness of the ED room. Akkerman and Knip [28] applied Markov chain theory and simulation experiments to carry out the staffed bed reallocation. Mehrolhasani et al. [29] applied a goal programming model for staffed bed reallocation. Khare et al. [30] applied computer simulation to decide the number of staffed beds in the ED. Diane et al. [31] used the application of lean thinking to redesign the ED. Teng-Kuan et al. [32] applied lean principles and simulation for the optimization for ED layout design

From the in-depth literature review, it has been found that using a lean thinking approach; efficiency can be calculated for various rooms of EDs for useful comparison. Thus, the present research attempts to bridge this gap.

3. Significance of CT and TT

As soon as the patient rushes in ED, the staff on duty takes due care in managing the existing emergency. The CT and TT are crucial in managing the number of patients rushing to ED. The increase in CT will increase the length of stay (LOS) and affect staffed bed availability. Thus, CT and TT become the important process analysis parameters required in determining the system efficiency and effective service rate. CT is the exact time required to serve a patient in ED, whereas a TT is the new time required to serve the increased demand of patients for the services. In the present study, TT is selected as a quantitative tool to measure the efficiency of the ED.

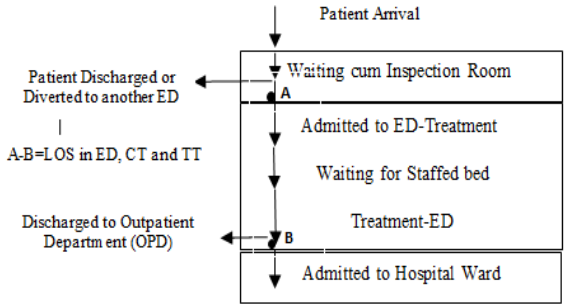

Figure 1. Patient Treatment in ED

Figure 1 shows the various parameters for the patients stay in ED for instance LOS, CT, TT, waiting for staffed bed, treatment time etc. These parameters are also presented in mathematical form in Equation (1-4) for calculating efficiency and effectiveness of ED rooms.

$$CT = \frac{Net\ Operation\ Time\ Period}{No\ of\ Patients\ treated} \quad (1)$$

$$TT = \frac{Net\ Operation\ Time\ Period}{Required\ number\ of\ patients\ to\ be\ treated\ per\ period} \quad (2)$$

Where:

$Net\ Operation\ Time\ Period$= Total available service time – Breaks (3)

Required service rate = Number of patients to be served

$$= \frac{Services\ provided\ to\ total\ patients}{Working\ periods\ per\ period} \quad (4)$$

Two different rooms of ED like RR – Trauma and RR – Medical rooms are considered for the present study. The TT in ED has been calculated by dividing operational time per period by the required number of patients to be treated per period. The TT can be used for all units in the value stream to adjust served patients to actual demand to serve more patients during peak hours.

3.1. Comparison of CT and TT

The crowd management in the ED is crucial and influenced by CT and TT. Cycle time is how long it should take to serve a patient in the ED. Thus CT includes value-added activities and non-value added activities hence warrants careful attention to achieve the desired service rate. The CT time depends on many parameters like number of activities to be performed, kind of medical procedure, the complexity of the task in various rooms, for instance, RR – Trauma and RR – Medical rooms. It also depends upon the availability of the doctor, nurse, technician, staffed bed, dressing room, body parameter measuring equipment etc. The TT is affected by patients' crowding requiring emergency services.

Various scenarios that can be found with their leading effects are listed in Table 1.

Table 1. Various scenario for CT and TT

Scenarios	Interpretation
CT=TT	The service line/production line is smooth and considered flawless and efficient.
CT<TT	The service capacity/production capacity is underutilized leading to waste and inefficiencies.
CT>TT	The presence of bottleneck in the service line/ production line cannot be ruled out.

4. Revisiting ED services of a government hospital

The ED under study is part of a governmental hospital based in the southern region of Saudi Arabia with a population of more than 350000. The ED consists of several rooms and this study is only concerned with RR – Trauma and RR – Medical rooms.

The study that conducted by Shakoor et.al. [33] has been further explored and results are further compared for the useful conclusion. Both RR – Trauma and RR – Medical rooms consist of 6 staffed beds for emergency patients and there is an extra staffed bed reserved for very critical cases that couldn't be diverted to other hospitals. It is noticed that the rooms under study facing a serious overcrowding problem and ambulance diversion.

In the present research, to determine and compare the efficiency of rooms under study, actual data for the length of stay (LOS), the maximum number of staffed beds occupied simultaneously each day and the total number of admitted patients are required. The required data is retrieved from the log book of the hospital. LOS represents the time that the patient reserves the staffed bed from the moment he or she admitted to the department until discharged. The collected data for RR-Trauma and RR-Medical rooms is summarized and tabulated in Table 2. The ED staffed bed occupancy rate is the ratio of the sum of the number of patients occupying staffed beds and the number of patients discharged in a day to the total number of staffed beds. The probability of ambulance diversion for RR–Trauma is 62.2% on day to day basis whereas the probability of ambulance diversion for RR-Medical is 9.58% on day to day basis. The RR-Trauma has high bed occupancy rate thus effects the ambulance diversion more as compared to RR-Medical.

Table 2: Number of Patients and LOS for RR-Trauma and RR-Medical rooms of ED

ED Rooms	Total No of Patients	LOS	Available Time (minutes)	Staffed bed Occupancy/year	Probability of ambulance diversion
RR – Trauma	1436	2123724	3153600	227	62.2%
RR – Medical	309	1173084	3153600	24	9.58%

Table 3. The Probability of the Bed Occupancy in the ED Rooms

Room	Maximum No of Staffed beds	The Probability of the Staffed bed Occupancy in the ED Rooms						
		4 or less	5	6	7	8	9	10
FOR	**9**	99.95%	0.05%	0.00%	0.00%	0.00%	0.00%	
FTR	**10**	99.17%	0.23%	0.14%	0.05%	0.14%	0.00%	0.28%
MOR	**9**	99.91%	0.00%	0.09%	0.00%	0.00%	0.00%	
MTR	**10**	98.29%	0.28%	0.19%	0.14%	0.14%	0.32%	0.65%
POR	**5**	97.78%	2.22%					
PTR	**5**	83.98%	16.02%					
RR MEDICAL	**6**	91.11%	2.22%	6.67%				
RR TRUMA	**6**	24.44%	13.33%	62.22%				

Table 4. Probability for a patient waiting or ambulance diversion upon arrival in the ED rooms.

Room	PTR	POR	MTR	FTR	MOR	FOR	RR-Medical	RR-Trauma
Probability	16.02%	2.22%	0.65%	0.28%	0.00%	0.00%	9.68%	62.22%

Table 3 shows the probability of staffed bed occupancy in ED rooms on day to day basis. The ED is equipped with Male Treatment Room (MTR), Female Treatment Room (FTR), Male Observation Room (MOR), and Female Observation Room (FOR), Pediatric Observation Room (POR), Pediatric Treatment Room (PTR), RR-Medical and RR-Trauma. The maximum number of staffed beds available for patients arriving in various rooms is different. The number of staffed beds ranges from 6 to 10 in ED rooms hence it is vital to know the staffed bed availability. The staffed bed availability maybe understood from the probability of the staffed bed occupancy rate on day to day basis. The staffed bed availability will be critically important to avert last-minute hustle and unnecessary ambulance diversion. Looking to the staffed bed usage of FOR, it has been revealed that the available 9 staffed beds have never been occupied at the same time during the whole year study period. Further, it has been seen the staffed bed utilization never been more that 5 staffed beds at the same time. If the utilization of staffed beds in the FOR, FTR and MOR rooms is compared with POR and PTR for example, it has been noted that the staffed beds in POR and PTR are continuously occupied as compared to the other rooms during the same period. Hence, distribution of the staffed bed must be revisited to enhance the efficiency and effectiveness of these staffed beds in the ED. Similar observations are also made for non-use of staffed bed during the study period so that the same can be reshuffled among the various ED rooms to enhance the efficiency and effectiveness. Table 4 provides the probability for a patient waiting or ambulance diversion in the ED rooms. The probability is ranging from 0.0% to a maximum of 62.22% for various rooms in the ED.

5. Results and Data Analysis

Based on the data collected from the hospital database for the two rooms of ED i.e. RR-Trauma and RR-Medical rooms, the actual available time/day was calculated for each room using the available facilities as shown in Table 2. Later on, the CT and TT were calculated for each room to compare the efficiency of each room with the other rooms. Cycle time is calculated as the ratio of the total actual time it takes the patients to get served to the total number of patients in a given time whereas the TT is calculated as the ratio of total available time to serve to the total number of patients in a given time. The CT and TT thus obtained are further used to calculate the efficiency of each room.

5.1. RR-Trauma Room vs. RR-Medical Room

- For the RR- Trauma room:

  CT = $\frac{2123724}{1436}$ = 1478.92 min / patient

  TT = $\frac{3416400}{1436}$ = 2379.11 min / patient

$Efficiency = E_{RR-Trauma} = \frac{\text{CT}}{\text{TT}} = \frac{1478.92 \text{ min./ patient}}{2379.11 \text{ min./ patient}} =$ 0.6216 i.e. 62.16%

- For the RR-Medical:

  CT = $\frac{1173084}{309}$ = 3796.39 min. / patient

  TT = $\frac{3416400}{309}$ = 11056.31 min. / patient

$Efficiency = E_{RR-Medical} = \frac{\text{CT}}{\text{TT}} = \frac{3796.39 \text{ min./ patient}}{11056.31 \text{ min./ patient}} =$ 0.3434 i.e. 34.34%

The CT, TT and calculated efficiency are represented for easy understanding in Figure2 and Figure3 respectively.

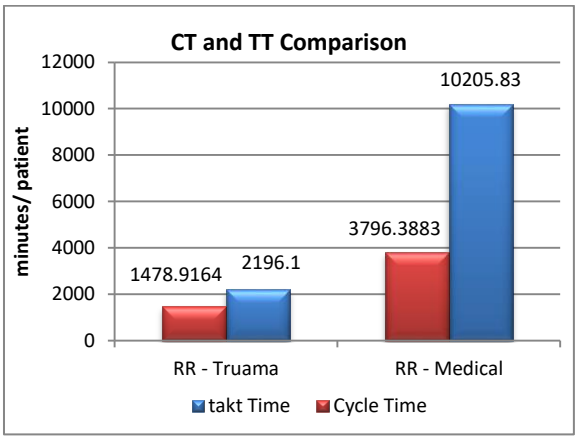

Figure 2. Comparing CT and TT of RR-Trauma and RR-Medical of ED Rooms

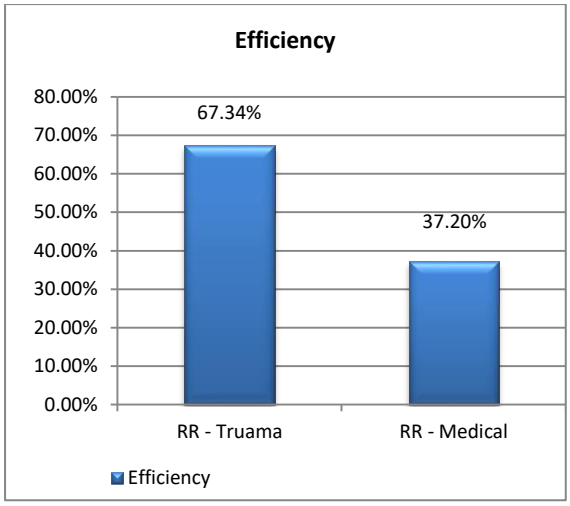

Figure 3. Efficiency Comparison of RR-Trauma and RR -Medical

A concept of relative efficiency $RE_{X/Y}$ as shown in Equation (5) is used to compare the efficiency between the two rooms X and Y as follows:

$$RE_{X/Y} = \frac{E_X}{E_Y} \quad (5)$$

Thus the $RE_{RR-\frac{Truama}{RR}-Medical}$ can be calculated as follow:

$$RE_{RR-Trauma/RR-Medical} = \frac{E_{RR-Trauma}}{E_{RR-Medical}} = \frac{0.6216}{0.3434} = 1.81,$$

The relative efficiency implies that RR-Trauma room is 1.81 times more efficient than the RR- Medical room.

5.2. Comparison Analysis of the RR-Trauma Room and RR-Medical Room with the Other Rooms at the ED

On analyzing the data shown in Table 2 for LOS and staffed bed occupancy documented from the hospital log sheet, it has been observed that the staffed bed occupancy is more in RR-Trauma as compared to RR-Medical. Hence, it is more difficult to handle the patient's arrival in RR-Trauma as compared to RR-Medical. The probability of ambulance diversion is 62.2% which indicates that the ambulance has to be diverted considerably for more occasions as compared to RR-Medical. From Table 2, it is also evident that the number of patients handled in RR-Trauma are more as compared to RR-Medical. The CT and TT of RR-Trauma and RR-Medical maybe compared to understand the burden on the system. It has been seen that CT is less than the TT for both the Trauma rooms. It can be concluded that the ED room will be able to cope with the pressure of the arriving patients. Figure 2 shows the CT and TT for both RR-Trauma and RR-Medical and it may be compared to identify for the higher probability of ambulance diversion. The efficiency of RR-Trauma and RR-Medical maybe calculated and further compared for optimal resource utilization. It has been found that the RR-Trauma has higher efficiency i.e. 67.34% whereas the efficiency of RR-Medical is 37.20%. Figure 3 shows the efficiency comparison of RR-Trauma and RR-Medical.

Table 3 shows the probability of the staffed bed occupancy in the ED Rooms. The staffed beds' availability is ranging from 5 staffed beds to 10 staffed beds. Based on the hospital log sheet, it can be seen that 4 or less patients might be accommodated easily in all the ED rooms. Table 4 provides the probability of patient waiting or probable ambulance diversion in the ED rooms. The probability of waiting is more in Pediatric Treatment Room (PTR) and Pediatric Observation Room (POR) due to less number of staffed bed availability. Similarly, the treatment room occupancy is more compare to the observation room hence Male Treatment Room (MTR), and Female Treatment Room (FTR) show more patient waiting. The waiting time is minimum in Male Observation Room (MOR) and Female Observation Room (FOR). It has been observed that the observation rooms in male and female rooms can handle maximum 4 patients without any waiting. There is less ambulance diversion for RR-Medical as compared to RR-Trauma. Table 5 shows the efficiency, CT and TT of the ED rooms. The efficiency is maximum for PTR followed by POR. The efficiency of MTR and FTR are 50.32% and 41.45%.The efficiency of observation room for male and female is comparatively low. The efficiency of MOR is 18.97% and whereas efficiency of FOR is 17.73%. RR-Medical and RR-Trauma has the efficiency of 67.34% and 67.34% respectively.

The CT and TT for various ED rooms maybe calculated for comparison purposes as shown in Figure 4. It has been observed that CT is comparatively less than the TT in all the ED rooms. It has also been observed that the CT and TT of RR-Trauma and RR-Medical are the maximum. Whereas, the CT and TT are less in case of PTR.

Table 5: Efficiency, CT and TT of the different rooms of the ED

Room	Present Staffed beds	Available Time (minutes)	LOS (minutes)	No of Patients	CT	TT	Efficiency
PTR	5	2628000	2462436	25856	95.24	101.64	93.70%
POR	5	2628000	2065608	7981	258.82	329.28	78.60%
MTR	10	5256000	2645060	8274	319.68	635.24	50.32%
FTR	10	5256000	2178826	5816	374.62	903.71	41.45%
MOR	9	4730400	897556	1512	593.62	3128.57	18.97%
FOR	9	4730400	838482	1547	542.01	3057.8	17.73%
RR MEDICAL	6	3153600	1173084	309	3796.39	10205.83	37.20%
RR TRAUMA	6	3153600	2123724	1436	1478.92	2196.1	67.34%

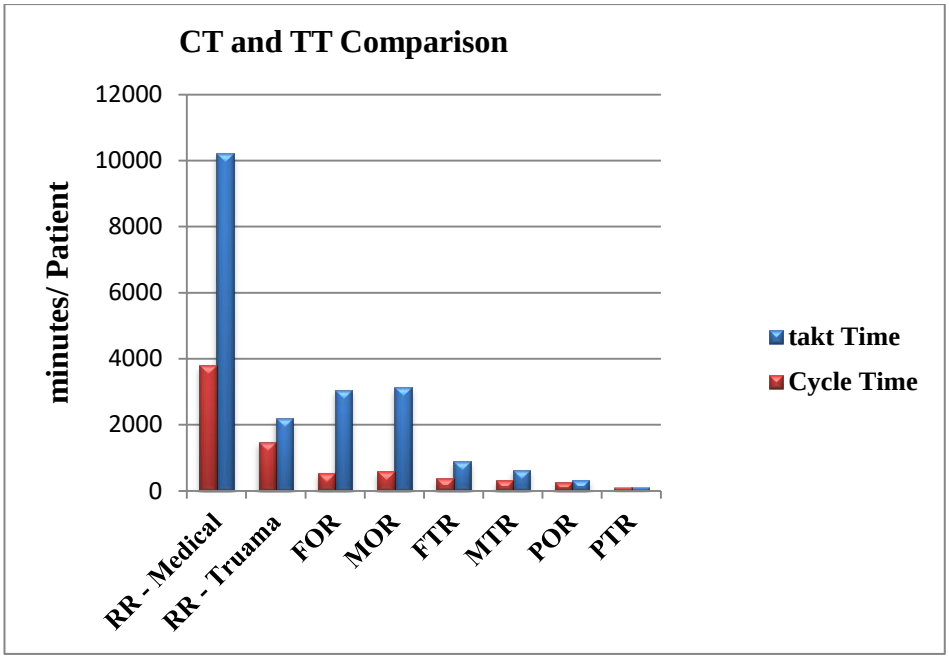

Figure 4: Comparison of CT and TT for the different rooms of the ED

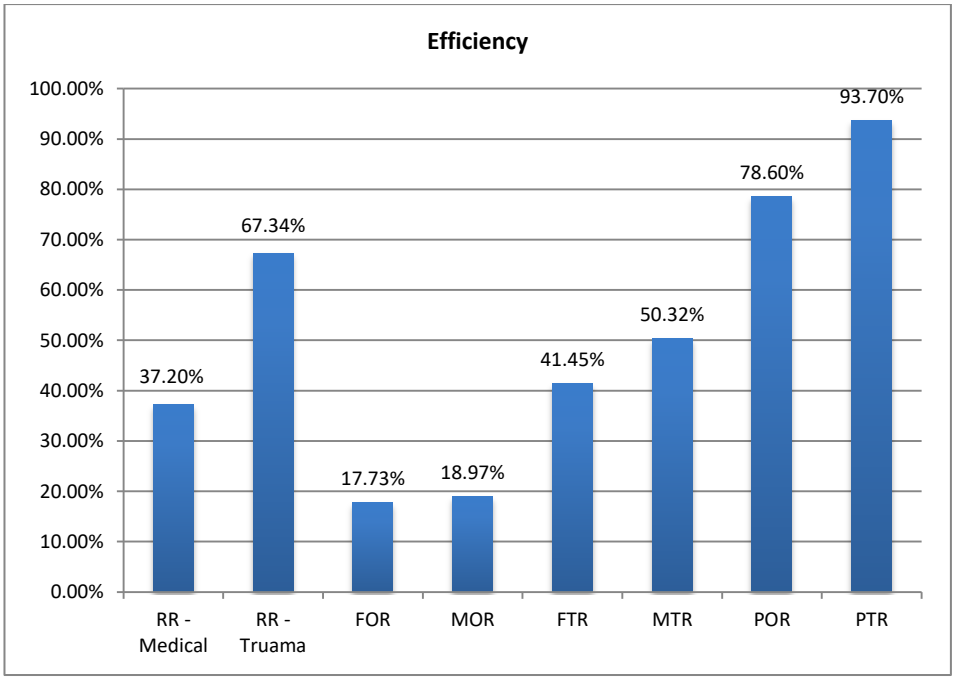

Figure 5: Efficiency comparison for the different ED rooms

5.3. Analysis of staffed Beds Redistribution in the ED Rooms

Looking to the underutilization of some rooms in the ED, the staffed bed redistribution is essential for the enhancement of efficiency and effectiveness. Based on the utilization probability as shown in Table 2 and Table 3, the staffed beds maybe redistributed for the optimal utilization. Based on the probabilities shown in Table 3 and Table 4, the allocated staffed beds maybe changed to enhance efficiency and effectiveness of ED room. As per Table 5, the number of staffed beds allocated for the MOR is 9 and proposed beds are reduced to 5, thus 4 staffed beds are transferred to other ED room to strengthen the resource utilization. Similarly FOR has 9 staffed beds, PTR and POR has 5 staffed beds, MTR and FTR has 10 staffed beds, RR medical and RR Trauma has 6 staffed beds, can be redistributed. The new proposed staffed beds distribution is shown in Table 5. Due to the proposed staffed bed redistribution, the TT and efficiency can be determined. The new proposed staffed beds along with TT and efficiency are shown in Table 6.

Table 5: Staffed bed redistribution with probabilities of accommodating more patients in the ED rooms

Room	Proposed Staffed beds for the Room	4 or less	5	6	7	8	9	10	11
FOR	5	99.95%	0.05%						
FTR	8	99.17%	0.23%	0.14%	0.05%	0.42%			
MOR	5	99.91%	0.09%						
MTR	10	98.29%	0.28%	0.19%	0.14%	0.14%	0.32%	0.65%	
POR	5	97.78%	2.22%						
PTR	7	83.98%	3.38%	2.50%	10.14%				
RR MEDICAL	9	91.11%	2.22%	3.34%	1.11%	2.22%	0.00%		
RR TRUMA	11	24.44%	13.33%	12.22%	28.90%	14.44%	4.44%	2.22%	0.00%

Table 6: Effects redistribution of staffed beds on the parameters of ED rooms

Room		FOR	FTR	MOR	MTR	POR	PTR	RR - Medical	RR - Trauma
ED Parameters	Proposed staffed beds	5	8	5	10	5	7	9	11
	TT	1698.77	722.97	1738.1	635.24	329.28	142.3	16159.22	4209.19
	Efficiency	31.91%	51.82%	34.15%	50.32%	78.60%	93.70%	23.49%	35.14%

Based on the staffed bed redistribution, the FOR and MOR rooms at ED will face a reduced crowding. Both ED rooms will be able to negotiate the patients' arriving flow. The staff at ED will be able to deliver quality care by timely assessing patients and providing treatment without unnecessary patient waiting. From Table 6, it is revealed that the arriving patients at FOR and MOR rooms at ED will have to face a low probability of waiting. Therefore, it maybe recommend the acceptable TT and efficiency for ED rooms preferably below 1700 minutes/ patient and 30% respectively.

6. Discussion

As it is well understood that lean at ED helps in establishing value-added activities (for example wound cleaning and repair) by eliminating non-value-added activities (for example triage) in accomplishing immense patients' care. It also strives to remove *Muda* (waste) from the process by smoothly balancing *Mura* (un-level workload) among ED staff and *Muri* (unreasonable burden) on equipment thus lean management methodologies may prove to be useful for the managers in ascertaining the required efficiency, reduce waiting time for patients seeking quality care and predicting ambulance diversion to meet the patients' expanded population. The knowledge of lean management in general and TT in particular will enable managers to revisit the ED activities at *Gemba* (workplace) to ensure a new framework, implement suitable changes, develop methods and time standards for smooth workflow (staff and patient movement) to implement for continuous improvement at ED. The knowledge of CT, TT will also help managers to handle the work pressure which will help in negotiating the error and service quality. The probability of ambulance diversion is an important parameter to decide the crowding in the ED rooms. The ambulance diversion may also be controlled by managing the TT. Thus, based on the staffed bed occupancy during the year a probability of non-availability of staffed bed and TT will decide the ambulance diversion to another ED of other private hospitals. The probability patients' arrival and TT at the ED rooms will also ensure the minimum staffed bed to handle the patients rush at the ED rooms. By calculating the TT and probability of staffed bed occupancy in ED rooms, a decision making policy concerning the minimum number of staffed beds maybe useful in maintaining the balance between the quality care services to ailing patient and optimum resource utilization.

It has been noticed that the ED rooms are not optimally utilized throughout the year due to the variation in the patients' arrival. Hence based on the logbook data of the hospital, the redistribution of staffed bed has been carried out to enhance the efficiency and effectiveness of ED rooms. Based on the lean principles, it has been proposed that the number of staffed beds maybe 5 for optimal resource utilization. Similarly, the FTR may have 8 staffed beds, MOR may have 5 staffed beds, MTR may have 10 staffed beds, POR may have 5 staffed beds, PTR may have 7 staffed beds, RR Medical may have 9 staffed beds, and RR Trauma may have 11 staffed beds. This staffed bed redistribution will enhance the efficiency and effectiveness of ED rooms. It will also help in saving the precious life of ailing patients seeking immediate care. The frequent ambulance diversion will also affect the breakeven point of the hospital operation which will make hospital service most costly. It will also pose a hurdle in becoming a competitive healthcare services provider. Using management principles of lean manufacturing the TT management is feasible. The reduced TT will further help in reducing the cycle time. On managing TT within a controllable limit, it is also further possible to enhance the efficiency and effectiveness of ED rooms. The patient arrival rate maybe accurately forecasted to take complete control of ED rooms.

6.1. Case of RR- Trauma Room

Retrieved data from the hospital database revealed that in 62.22% of the year days, there was a probability of ambulance diversion from the RR-trauma room due to the occupancy of all staffed beds simultaneously by patients in

this room. Also, in 27% of the year days, there was a probability of not accommodating very critical cases because the seventh staffed bed that reserved for these cases is occupied. This situation surfaced out the serious and critical problem in managing the patients' crowd in this room of the ED. Therefore, this situation requires an urgent intervention to increase the number of staffed beds in this room in order to accommodate all arrived patients and save their lives.

In this room, the CT<TT (i.e. 1478.92<2379.11), cycle time is 1478.92 minutes/ patient, whereas TT is 2379.11 minutes/ patient. Also, the RR-Trauma's room efficiency ($E_{RR-Trauma}$)is calculated as the ratio of CT to TT, and found to be $E_{RR-Trauma}$= 62.16% which is considered to be a high value for healthcare facilities as in ED.

6.2. Case of RR-Medical Room

Also, the retrieved data revealed that in 9.58% of the year days, there was a probability of ambulance diversion from the RR-medical room. In addition to that, in 27% of the year days, there was a probability of not accommodating very critical cases. It is evident that the RR-medical room has a crowding and ambulance diversion problems but the situation in this room still much better than the situation in the RR-trauma room. The RR-medical room requires an increase in the number of staffed beds in order to reach the conclusion of a zero ambulance diversion.

Furthermore, in this room, the CT<TT (i.e. 3796.39 <11056.31), cycle time is 3796.39 minutes per patient, whereas TT is 11066.31 minutes per patient. Also, the efficiency of the RR-Medical room ($E_{RR-Medical}$) has been found as 34.34% which is considered to be an acceptable value but still need to be reduced in order to reach a zero ambulance diversion. Looking at the efficiency calculations, it has been observed that the efficiency of the RR-Trauma room is 81% greater than the RR- Medical room.

7. Conclusion

It is very essential to understand the role of CT and TT in order to increase the efficiency and effectiveness and to reduce crowding at the ED rooms. In the ideal situation for ED services, the CT should equal the TT. It may be interpreted as service warranted does not show any exigency nor need any additional action as there is no pressure on its administration and management. However, this situation is hardly prevailing in the ED rooms. When CT is more than the TT, it results in severe crowding at ED rooms. It is observed that on frequent crowding the patients have to wait in receiving the critical care services in ED. In the present case, it was revealed that there was a shortage of staffed beds in ED rooms. In such a scenario, the patient's life is put to great danger. The decision-making becomes crucial in a patient's movement and subsequent ambulance diversion. Frequent crowding and ambulance diversion may threaten to lose customer faith and loyalty. Thus, private healthcare organizations may face losing customers and market share in the end. The frequent ambulance diversion will be a costly affair as it will put pressure on the hospital overhead. The government may also face extra burdens due to added liability. On the other hand, the TT and probability-based staffed bed distribution will further reduce the number of totals diverged patients to other hospitals in a year which will help in saving lives and cost. From the present case study, it may be recommended that the acceptable TT and efficiency for ED rooms preferably should be below 1700 minutes/ patient and 30% respectively. The practicing managers at ED may follow this benchmarking in managing patients' flow to avert crowding. Finally, CT and TT must be considered as the top priority in ED services. The ED staffed beds maybe redistributed using the lean concepts to enhance patient's flow and to optimize the resource utilization to offer world-class services.

Compliance with Ethics Requirements

Mwafak Shakoor declares that he has no conflict of interest.

Also, this article does not contain any studies with human or animal subjects.

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