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Efficiency Assessment in Emergency Department Using Lean Thinking Approach

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Abstract

Lean thinking approach plays a vital role in reducing waste and enhancing productivity in production environment and service setups. Lean thinking approach may be employed in cutting down the patients' waiting time in emergency departments and hospitals. Also, lean thinking approach may be used in testing the usage of the existing facilities planned and constructed for customers' use. In the present study, lean manufacturing approach has been used to test the usage of the emergency department's services. Four vital sections of the hospital emergency department viz. Male Treatment Room (MTR), Female Treatment Room (FTR), Male Observation Room (MOR), and Female Observation Room (FOR), are studied in terms of bed occupancy. Using the concept of takt time, an individual department efficiency and relative efficiency have been calculated to find the waiting time of customers intending to use the emergency services. A case of a governmental, non-profit and teaching hospital in the southern region of Saudi Arabia has been used to present the methodology based on lean manufacturing approach systematically. In conclusion, the present study revealed that extra equipped beds have been used in these four rooms in the emergency department that can be allocated to the other crowding witnessed rooms of the same department.

Keywords: *Efficiency, lean thinking, emergency department, length of stay, cycle time, takt time, waiting time, Saudi Arabia*.

1. Introduction

Emergency Department (ED) plays a vital role in risk management of a mankind. In the present age, there is a growing risk of sudden epidemic and increased accident rate that put burden on ED. Natural or man-made disasters, accidents, sudden surge of infectious virus borne diseases, etc. are the major reasons for crowding the ED. According to Saudi Arabia statistics, a car accident happens every second and 17 people are being killed in crashes every day on an average [1].

Nowadays Emergency Departments (EDs) face major problems and some of them are very critical, such as overcrowding of patients, deterioration of quality of care, patients leaving without being seen, ambulance diversion due to crowding in ED, shortages of staff, cost containment, patient safety, etc. [2, 3]. The emergency system has become increasingly crowded during the past decade and hence the patients' waiting times are prolonged, which in turn has a detrimental effect on the patients' morbidity and mortality [4, 5, 6] and staff performance [7]. In addition to that, increased waiting time to discharge medical aids to the patient brought in and length of stay are the major worries to a common man. Therefore, emergency departments crowding in a large number of countries all over the world is started to be considered as a major threat and common health concern. Unfortunately, this crowding problem in ED continues to be more badly and hence threatens the quality and efficiency of the delivered healthcare services.

Lean thinking (also known as lean manufacturing, Toyota Production System (TPS), or simply lean) is a continuous quality improvement technique and management philosophy which is originated within Toyota corporation boundaries and thereafter widely applied across many fields, such as healthcare systems, manufacturing systems, and service facilities. Lean thinking methodology focuses on continual process improvement, worker partnership, problem solving, and the elimination of seven types of waste that defined by Taiicho Ohno [8-12]. Lean thinking has already been widely utilized across many healthcare facilities and organization in order to eliminate unnecessary waste, improve patients flow, reduce waiting times, maximize value to the customer, improve quality and increase efficiency [13-19]. Consequently, it is a tool of quality improvement that can considerably enhance efficiency and service quality [20, 21].

Dart [16] stated that lean thinking principles have gone far in the last decade and applied in manufacturing, production and service organization for thousands of times and the application of this approach in emergency departments will not be an exception. As a result, lean

thinking can be considered as a different method for achieving efficiency in the ED. Therefore, lean thinking has been applied in healthcare systems and emergency departments for reducing waste and improving patient flow. However, the application of lean thinking to measure and improve the efficiency in ED did not receive enough attention in research and, hence, the relationship between lean thinking and efficiency enhancement in ED is still vague and requires a thorough study and investigation.

Efficiency is a significant factor for the estimation of both system and resources performance in the emergency department. It is defined by the Institute of Medicine (IOM) as "avoiding waste, including waste of equipment, supplies, ideas, and energy" [22-24] and it is indicated to be as one of six main objectives for enhancing the twenty first century healthcare systems in United States [25]. The IOM report mentioned that the healthcare systems should be efficient, effective, safe, timely, patient – centered and equitable in order to be of high quality [26, 27]. Also; the Institute of Medicine defined the aims of efficiency for quality improvement as "resources are used to get the best value for the money spent." The IOM and the National Academy of Engineering (NAE) published a joint report indicating that healthcare systems in US losing 30 to 40 cents of every single dollar spent due to inefficiency and waste [28].

Expanding the EDs capacity is not enough to tackle the crowding issue or improve the quality and efficiency of the provided services [29] yet the EDs should enhance patient flow, resources and processes efficiency. Therefore, establishing efficient and effective strategies to increase the emergency departments' efficiency should receive higher priority from hospitals management. Abdelhadi and Shakoor [30] reported that improving efficiency within the healthcare system or emergency department is the key component for increasing quality and sustainability of the provided services to patients. Also, reducing wastes and enhancing service efficiency of the process leads to a significant decrease in the operating cost [31]. Thus, several researchers and scientists paid an attention to efficiency issue in healthcare systems and deeply investigated the factors that affect this problem and proposed suggestions for improving efficiencies in healthcare facilities and organization [32, 33].

Obviously, the research effort on healthcare efficiency and particularly attempts to improve efficiency in emergency departments is still in the infancy stage. Different and inconsistent criterions for estimating efficiency in the emergency departments were investigated and tested, such as patient Length of Stay (LOS) [34-36] ratio-based measures [37] frontier techniques [38], etc. This inconsistency in standards for measuring the efficiency in EDs have stimulated various agencies to support the efforts for the development of new techniques to measure the EDs efficiency

Thus, looking at the ample potential and opportunities of lean implementations in services, the present research has been carried out to use lean methodology in emergency department of a governmental hospital in the southern region of Saudi Arabia. The present study is aimed at using beds efficiency in various rooms of ED as a measure of ED efficiency because a significant number of free beds or unavailable beds for most of the time may give a clear image about the ED department effectiveness. Hence, using lean thinking approach, the efficiency of resources (equipped beds) in various rooms of ED will be assessed so that a useful comparison and improvement can be suggested if needed. Also, it has been noticed that inventory waste in terms of extra equipped beds in various rooms of the EDs can be reduced by applying lean thinking. Thus, the present work attempts to bridge this gap.

2. Methodology

2.1. Study Design and Setting

This is a retrospective cohort study carried out in ED of a governmental, teaching and general hospital providing medical care to the residents of Abha region in the southern part of Saudi Arabia with a population of more than 350 000. The medical services provided in the ED during 24 hours per day and 7 days per week. The emergency department consist of the following rooms: Male Treatment Room (MTR), Female Treatment Room (FTR), Male Observation Room (MOR), Female Observation Room (FOR), Pediatric treatment room, pediatric observation room, Urgent (cold cases) room, and the Rapid Response medical and Rapid Response trauma room (RR – medical and RR - trauma). In the present research, 38 beds are assigned out of 67 beds for the rooms under study. Out of 38 beds, 20 beds are allocated equally for MTR, FTR whereas 18 beds allocated equally for MOR, FOR.

The admitted cases to the rooms under study were adult patients of ages greater than 12 years old who arrived at the ED between November 1, 2013 and October 31, 2014 and the data were collected from the ED database.

The hospital management noticed that some rooms in the ED are suffering from patients overcrowding and ambulance diversion; whereas, others have a portion of beds that are not been utilized for most of the time.

2.2. Data Collection and Study Outcome

The nurses at the ED reception desk record the required information for every patient arrives at the ED. The information includes personal details, arrival time, triage category, entry date and time to room, room classification and departure time. This information is saved in the hospital data collection database and the required data for the present study were retrieved from this database.

The three outcomes that determined every day are the number of occupied beds by patients, the maximum number of beds occupied simultaneously in every room of the four different rooms and the total time a bed reserved by patients. The estimated period of the occupied bed by a patient was specified from the time a bed assigned to the patient till the time of departure from the ED. The total available times for beds in each room were calculated during a one year study period and all time units were in minutes.

2.3. Results

During the study period (November 1, 2013 till October 31, 2014), 17149 patients were admitted to the four rooms under study, as shown in Table 1. All patients admitted to the four rooms were included in the study and there were no exclusion criteria. The following data were extracted from the database: date and time of arrival to the ED, date and time of entry to the room, age, sex, the date and time of departure from ED.

The specified time that the patient reserves the bed from the moment he or she admitted to the room until discharged from the emergency department is defined as the length of stay (LOS). In the present study, to compare the efficiencies of various rooms in the ED, actual data for the length of stay are required. Therefore, the collected data for MTR, FTR, MOR, and FOR are tabulated in Table 1.

Table 1: Summary of total number of patients admitted and the patients LOS time for MTR, FTR, MOR, and FOR in ED of emergency department

ED Rooms	Total No of Patients	LOS time in bed in minutes	Available Time in minutes
MTR	8274	2645060	5256000*
FTR	5816	2178826	5256000*
MOR	1512	897556	4730400**
FOR	1547	838482	4730400**

*Available time (Monday to Sunday for 24 hours/ day) =10*24*60*365=5256000 min

**Available time (Monday to Sunday for 24 hours/ day) =9*24*60*365=4730400 min

3. Data Analysis

Cycle time and takt time are the important process analysis parameters required in determining the system efficiency and effective service rate. Cycle time is how long it should take to serve a patient in ED and it includes value added activities and non-value added activities thus warrants a careful attention to achieve the desired service rate. In the ideal situation, cycle time equals the takt time. Thus, service doesn't warrant any additional attention.

In the present study, takt time is selected as a quantitative tool to measure the efficiency of the ED. Various rooms of ED, like MTR, FTR, MOR and FOR, are considered for the present study. Takt time in ED has been calculated by dividing operational time per period by required number of patients to be treated per period.

$$\text{Takt time} = \frac{\textit{Operational time per period}}{\textit{Required number of patients to be treated per period}} \quad (1)$$

Where:

$$\text{Operational time} = \text{Total available service time} - \text{Breaks} \quad (2)$$

$$\text{Required service rate} = \text{Number of patients to be served} = \frac{\text{Services provided to total patients}}{\text{Working periods per period}} \quad (3)$$

Takt time can be used for all units in the value stream to adjust served patients to actual demand in order to serve more patients during crowding.

Cycle Time and Takt Time Comparison

Based on the actual data collected from the hospital for four rooms of ED, i.e., MTR, FTR, MOR, and FOR rooms, the actual available time/year was calculated for each room using the available facilities as shown in Table 1. Later on cycle time and takt time were calculated for each room in order to compare the efficiency of each room with others. 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 time period whereas the takt time is calculated as the ratio of total available time to serve to the total number of patients in a time period. The cycle time and takt time thus obtained are further used to calculate the efficiency of each room. The efficiency of the different rooms in the emergency department will be estimated on the bases of a ratio based measure.

MTR vs. FTR

- For the MTR:

Cycle time = $\frac{2645060}{8274}$ = 319.68 min / patient

Takt time = $\frac{5256000}{8274}$ = 635.24 min / patient

Efficiency = $E_{MTR}=\frac{\text{Cycle time}}{\text{Takt time}}=\frac{319.68 \text{ min./ patient}}{635.24 \text{ min./ patient}}$ = 0.50,

i.e., 50.00%

- For the FTR:

Cycle time = $\frac{2178826}{5816}$ = 374.63 min. / patient

Takt time = $\frac{5256000}{5816}$ = 903.7 min. / patient

Efficiency = $E_{FTR}=\frac{\text{Cycle time}}{\text{Takt time}}=\frac{374.63 \text{ min. / patient}}{903.7 \text{ min./ patient}}$ = 0.42,

i.e., 42.00%

Cycle time and takt time for MTR and FTR are carried out and compared in Table 2. The cycle time, takt time and calculated efficiency are represented for easy understanding in Figure 1 and Figure 2.

Table 2: Cycle Time, takt time and efficiency of MTR and FTR of ED

Description	**MTR**	**FTR**
Cycle time	= $\frac{2645060}{8274}$ = 319.68 min / patient	= $\frac{2178826}{5816}$ = 374.63 min. / patient
Takt Time	= $\frac{5256000}{8274}$ = 635.24 min / patient	= $\frac{5256000}{5816}$ = 903.7 min. / patient
Efficiency	$\frac{319.68 \text{ min./ patient}}{635.24 \text{ min./ patient}}$ = 0.50 i.e. 50.00%	$\frac{374.63 \text{ min. / patient}}{903.7 \text{ min./ patient}}$ = 0.42 i.e. 42%

Cycle time and takt time for MOR and FOR are calculated and compared as shown in Table 3. The results of cycle time, takt time and calculated efficiency are graphically represented for easy understanding in Figure 3 and Figure 4.

MOR vs. FOR

- For the MOR:

Cycle time = $\frac{897556}{1512}$ = 593.62 min. / patient

Takt time = $\frac{4730400}{1512}$ = 3128.57 min. / patient

EMOR=$\frac{\text{Cycle time}}{\text{Takt time}}$= $\frac{593.62 \text{ min./ patient}}{3128.57 \text{ min./ patient}}$ = 0.19, i.e., 19.00%

- For the FOR:

Cycle time = $\frac{838482}{1547}$ = 542.0 min / patient

Takt time = $\frac{4730400}{1547}$ = 3057.8 min / patient

EFOR=$\frac{\text{Cycle time}}{\text{Takt time}}$= $\frac{542.0 \text{ min./ patient}}{3057.8 \text{ min./ patient}}$ = 0.177, i.e., 17.7%

The various results obtained for MOR, and FOR are tabulated in Table 3.

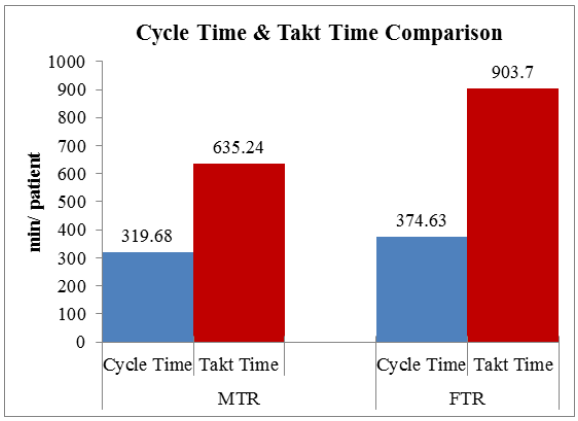

Figure 1: Comparing cycle time and takt time of MTR and FTR of emergency department

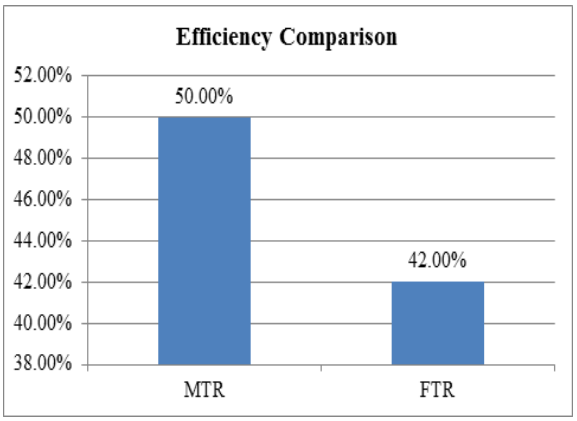

Figure 2: Comparing efficiency of MTR and FTR of emergency department

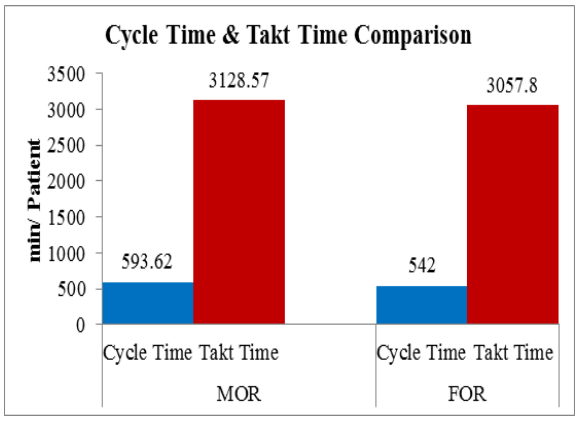

Figure 3: Comparing cycle time and takt time of MOR and FOR of ED

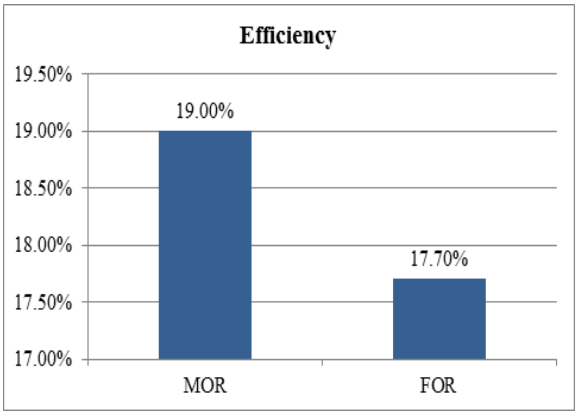

Figure 4: Comparing efficiency of MOR and FOR of ED

Table 3: Cycle time, takt time and efficiency of MOR and FOR of ED

Description	MOR	FOR
Cycle time	= $\frac{897556}{1512}$ = 593.62 min. / patient	= $\frac{838482}{1547}$ = 542.0 min / patient
Takt Time	= $\frac{4730400}{1512}$ = 3128.57 min. / patient	= $\frac{4730400}{1547}$ = 3057.8 min / patient
Efficiency	$\frac{593.62 \text{ min./ patient}}{3128.57 \text{ min./ patient}}$ = 0.19 i.e. 19.00%	$\frac{542.0 \text{ min./ patient}}{3057.8 \text{ min./ patient}}$= 0.177 i.e. 17.7%

The efficiency of the four rooms of ED are compared and depicted graphically in Figure 5 for clear understanding.

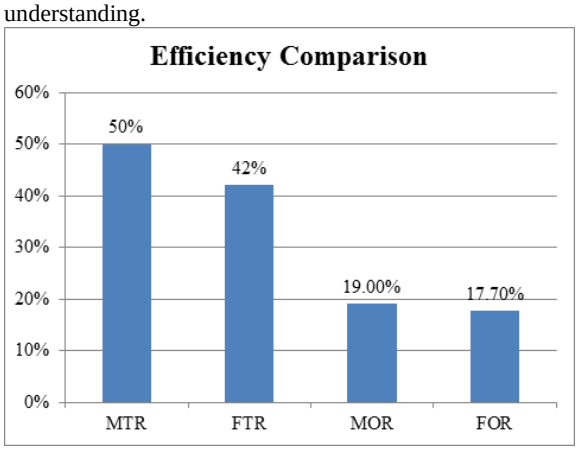

Figure 5: Comparing efficiency of MTR, FTR, MOR and FOR of emergency department

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

$$RE_{X/Y} = \frac{E_X}{E_Y}$$

Thus, the $RE_{MTR/FTR}$ i.e. relative efficiency between MTR and FTR can be calculated as follows:

$$RE_{MTR/FTR} = \frac{E_{MTR}}{E_{FTR}} = \frac{0.50}{0.42} = 1.19,$$

This figure implies that MTR is 1.19 times more efficient than the FTR. Likewise, all the relative efficiency among MTR, FTR, MOR and FOR were calculated and tabulated in Table 4.

Table 4: The relative efficiency among MTR, FTR, MOR, and FOR of emergency department

	MTR	FTR	MOR	FOR
MTR	-	1.19	2.63	2.83
FTR	-	-	2.21	2.37
MOR	-	-	-	1.07
FOR	-	-	-	-

4. Discussion and Conclusions

Cycle time deals with the time needed to complete the operations whereas the takt time deals with the time needed to complete the operations with respect to patients' demand and the available time. In the present study, cycle time and takt time of four rooms of ED, i.e., MTR, FTR, MOR and FOR were calculated and compared for meaningful inferences as follows:

- Case of MTR

The cycle time < takt time (i.e., 319.68 < 635.24), cycle time is 319.68 minutes, whereas takt time is 635.24 minutes. Therefore, it is obvious in this case that there is an extra equipped beds used in the MTR room which is a type of inventory waste as defined in lean thinking and doesn't add a value to the patients. Whereas the service is smooth and considered to be efficient when cycle time = takt time which is the ideal case.

In this case, MTR's inefficiency in managing patient in the ED has been surfaced out. MTR has been underutilizing the capacity to serve the patients in more efficient ways. The efficiency of MTR (E_{MTR}) is calculated as ratio of cycle time to takt time, and found to be E_{MTR}= 0.50 i.e 50%. The efficiency so obtained may also be compared with ideal case. It is evident from the calculation that wasted resources (extra beds) are used in the MTR room which incurs enormous costs and reduces the department efficiency. Hence, this waste requires a management action to eliminate it by cutting down the number of beds to improve the efficiency, quality of provided services, and reduce cost. Eliminated beds can be utilized in other rooms were overcrowding and ambulance diversion problems exist.

- Case of FTR

The cycle time < takt time (i.e., 374.63 < 903.7), cycle time is 374.63 minutes, whereas takt time is 903.7 minutes. In this case, the FTR's is also having a problem in managing the patients. FTR has been underutilizing the capacity to serve the patients in more efficient ways. The efficiency of FTR (E_{FTR}) has been found as E_{FTR}= 0.42 i.e. 42%. From the results, it can be said that wasted resources are used in the FTR room which requires a management action to eliminate it for improving the efficiency, quality, and cost reduction purposes.

- Case of MOR

The cycle time < takt time (i.e., 593.62 < 3128.57), cycle time is 593.62 minutes, whereas takt time is 3128.57 minutes. In this case, the MOR's is also having enormous problems in managing the patients' crowd in the ED. The efficiency of MOR (E_{MOR}) has been found as E_{MOR}= 0.19, i.e., 19%. Therefore, more inventory waste (extra beds) exists in the MOR room according to lean thinking principles.

- Case of FOR

The cycle time < takt time (i.e., 542.0 < 3057.80), cycle time is 542.0 minutes, whereas takt time is 3057.80 minutes. In this case, the FOR's is also having a problem in managing the patients rushing into the ED. The efficiency of FOR (E_{FOR}) has been found as E_{FOR}= 0.177, i.e., 17.7% and it is obvious that more inventory waste exists in this room.

The MTR, FTR, MOR and FOR rooms of the emergency department are underutilizing the capacity to serve the patients, thus warrants the implementation of lean principles so that rooms can operate in an efficient ways. From the above results, it is evident that efficiency in FOR and MOR rooms is less hence non effective time has to be curtailed. In case of MTR and FTR rooms, the efficiency obtained are reasonably good but still can be improved by reducing the number of beds thus it can be assumed that the patients' services are managed effectively. From calculation, the following relations can be established:

$$E_{MTR} > E_{FTR} > E_{MOR} > E_{FOR},$$

i.e., 50.00% > 42.00% > 19.00% > 17.70%

Looking at the efficiency calculations, it has been observed that efficiencies of MOR and FOR are 50% less that MTR and FTR, respectively. Hence, there is a crowding witnessed at two rooms of ED i.e. Rapid Response – medical (RR – medical) and Rapid Response –

trauma (RR – trauma). Owing to this excess crowding, there are many ambulance diversions taking place to private hospitals. In order to reduce ambulance diversions to private hospitals, ED management should implement lean thinking principles to increase the efficiency of MOR and FOR at par with MTR and FTR, respectively. In some cases, management can transfer number of beds from these rooms to RR – medical and RR – trauma room in the ED. Also, hospital management may go ahead to redesign the layout of the emergency department in order to accommodate the beds transfer.

4.1. Forecasting Analysis and Efficiency Improvement

A forecasting analysis has been done using the artificial neural network tool to determine the maximum number of occupied beds simultaneously in each room. It revealed that for the next three years, there will be a demand of 6, 5, 3, and 3 beds for MTR, FTR, MOR and FOR, respectively. Consequently, on the bases of these figures, an improvement strategy is suggested to reduce the number of beds in the rooms under study as 14 beds are allocated equally for MTR, FTR whereas 10 beds allocated equally for MOR, and FOR. This reduction in the number of beds will reduce the inventory waste and improve the efficiency by 21.6%, 17.8%, 15.2%, and 14.2% for MTR, FTR, MOR, and FOR, respectively. Figure 6 and Figure 7 represent the efficiency improvement versus the number of beds in the room under study.

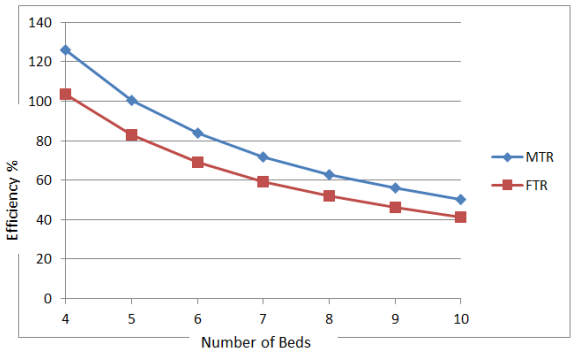

Figure 6: Efficiency improvement for MTR and FTR rooms

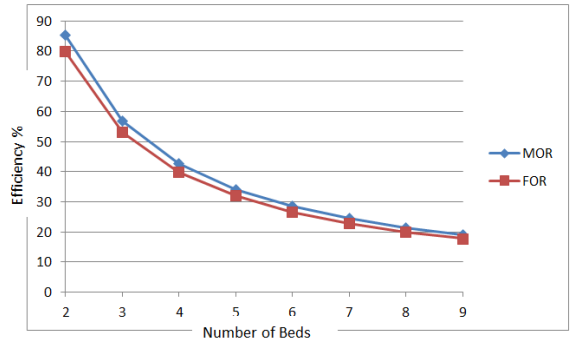

Figure 7: Efficiency improvement for MOR and FOR rooms

4.2. Managerial Implications and Future Research Directions

Using lean practices, the efficiency of a room can be measured and may be compared with other rooms to take precautionary measures to stream line patients' flow and services of the department. Also, applying lean practices, waste and waiting time of the patients can be curtailed and more effective services may be offered to needy patients in EDs. Health Maintenance Organizations (HMO) managers need to re-devise their strategies to incorporate lean practices in every room of health care system so that rapid and effective improvement can be made in the system. Many researchers observed in their studies that patient care usually improved after implementation of lean principles in health care services [15]. Also, it has been observed that many EDs have reported decreases in LOS, waiting times, and proportion of patients leaving the ED without being seen. Moreover, lean manufacturing principles can reduce waste and improve the patients' flow through the ED, resulting in greater patient satisfaction along with reduced time spent by the patient in the ED [39].

The lean approach may be applied to benchmark each and every room of the ED. It may also be applied to benchmark each service being served in every room so as to compare at global level. The present relative efficiency approach may be used to determine the number of beds, doctors, nurses and medical instruments in ED. The present approach may also be used to forecast the demand and supply rate of medical hospitals to make the service available to curb accidental death rate. A Decision Support System (DSS) may be developed to help HMO managers in critical decision making in different scenarios with increased or decreased strength of patients. Using laser aided digital camera, the patients rushing into the ED may be gauged well in time and system goes on updating and calculating the change in takt time and available time. Manager may get help from system about possible increase or decrease of medical services to offer. In such cases, manager will be well informed and more comfortable in managerial decision making.

References

[1] Health Statistics Annual Book. Ministry of Health, Saudi Arabia, http://www.moh.gov.sa/en/Ministry/Statistics/book/flash/1433/MOH_Report_1433.html, accessed on 1 – 12 – 2014, 2012.

[2] M. Kennedy, "Equitable emergency access: rhetoric or reality?", Emergency Medicine Australasia, Vol. 17 (2005), 392–6.

[3] R. Forero, K.M. Hillman, S. McCarthy, D.M. Fatovich, A.P. Joseph, D.B. Richardson, "Access block and ED overcrowding", Emergency Medicine Australasia, Vol. 22 (2010), pp. 119–35.

[4] D.B. Richardson, "Increase in patient mortality at 10 days associated with emergency department overcrowding", Medical Journal of Australia, Vol. 184 (2006), 213–16.

[5] P.C. Sprivulis, J.A. Da Silva, I.G. Jacobs, A.R. Frazer, G.A. Jelinek, "The association between hospital overcrowding and mortality among patients admitted via Western Australian emergency departments", Medical Journal of Australia, Vol. 184 (2006), 208–12.

[6] S.R. Morgan, A.M. Chang, M. Alqatari, J.M. Pines, "Non-emergency department interventions to reduce ED utilization: a systematic review", Academic Emergency Medicine, Vol. 20 (2013), 969–85.

[7] Higginson, J. Whyatt, K. Silvester, "Demand and capacity planning in the emergency department: how to do it", Emergency Medicine Journal, Vol. 28 (2011), 128– 35.

[8] J.P. Womack, D.T. Jones, "Lean Thinking: Banish Waste and Create Wealth in Your Corporation", Free Press, 2003, 2nd Edition.

[9] J.K. Liker, "The Toyota Way", McGraw-Hill, New York, NY, 2004.

[10] S. P. Vendan, K. Sakthidhasan, "Reduction of Wastages in Motor Manufacturing Industry", Jordan Journal of Mechanical and Industrial Engineering, Vol. 4 (2010), No. 5, 579 – 590

[11] N. Mandahawi, R.H. Fouad, S. Obeidat, "An Application of Customized Lean Six Sigma to Enhance Productivity at a Paper Manufacturing Company", Jordan Journal of Mechanical and Industrial Engineering, Vol. 6 (2012), No. 1, 103 – 109

[12] C. Andrea, "Waste savings in patient transportation inside large hospitals using lean thinking tools and logistic solutions", Leadership in Health Services, Vol. 26 (2013), No. 4, 356 – 367

[13] D.L. King, D.I. Ben-Tovim, J. Bassham, "Redesigning emergency department patient flows: Application of Lean Thinking to health care", Emergency Medicine Australasia, Vol. 18 (2006), 391–397

[14] J.J. Kelly, E. Thallner, R.I. Broida, D. Cheung, H. Meisl, A.G. Hamedani, K. Klauer, S.J. Welch, C. Beach, "Emergency Medicine Quality Improvement and Patient Safety Curriculum", Academic Emergency Medicine, Vol. 17 (2010) No. s2, e110 – e129.

[15] R.J. Holden, "Lean thinking in emergency departments: a critical review", Annals of Emergency Medicine, Vol. 57 (2011), 265–278.

[16] R.C. Dart, "Can Lean Thinking Transform American Health Care?", Annals of Emergency Medicine, Vol. 57 (2011), No. 3, 279 – 281

[17] N. Burgess, "Evaluating Lean in healthcare", International Journal of Health Care Quality Assurance, Vol. 26 (2013), No. 3, 220 – 235

[18] P. Dannapfel, B. Poksinska, K. Thomas, "Dissemination strategy for Lean thinking in health care", International Journal of Health Care Quality Assurance, Vol. 27 (2014), No. 5, 391 – 404

[19] M.J. Vermeulen, T.A. Stukel, A. Guttmann, B.H. Rowe, M. Zwarenstein, B. Golden, A. Nigam, G. Anderson, R.S. Bell, M.J. Schull, "Evaluation of an Emergency Department Lean Process Improvement Program to Reduce Length of Stay", Annals of Emergency Medicine, Vol. 64 (2014), No. 5, 427 – 438

[20] L.B. de Souza, "Trends and approaches in lean healthcare", Leadership in Health Services, Vol. 22 (2009), No. 2, 121-139.

[21] T. Papadopoulos, Z. Radnor, Y. Merali, "The role of actor associations in understanding the implementation of Lean thinking in healthcare", International Journal of Operations & Production Management, Vol. 31 (2011), No. 2, 167 – 191

[22] V. Fuchs, ‘‘Health Care Expenditures Reexamined’’, Annals of Internal Medicine, Vol. 143 (2005), No. 1, 76–78.

[23] R.W. Bush, "Reducing Waste in US Health Care Systems", Journal of the American Medical Association, Vol. 297 (2007), No. 8, 871–874.

[24] P.S. Hussey, H. de Vries, J. Romley, M.C. Wang, S.S. Chen, P.G. Shekelle, E.A. McGlynn, "A Systematic Review of Health Care Efficiency Measures", Health Services Research. Vol. 44 (2009), No. 3, 784 – 805

[25] M.J. Ward, H. Farley, R.K. Khare, E. Kulstad, R.L. Mutter, R. Shesser, S. Stone-Griffith, "Achieving Efficiency in Crowded Emergency Departments: A Research Agenda", Academic Emergency Medicine, Vol. 18 (2011), No. 12, 1303 – 1312.

[26] L. Graff, C. Stevens, D. Spaite, J. Foody, "Measuring and Improving Quality in Emergency Medicine", Academic Emergency Medicine, Vol. 9 (2002), No. 11, 1091 – 1107.

[27] S. Smallbane, "Lean thinking redesign: A weighty matter", Emergency Medicine Australasia, Vol. 19 (2007), No. 1, 79.

[28] P.P. Reid, W.D. Compton, J.H. Grossman, G. Fanjiang, National Academy of Engineering, Institute of Medicine (U.S.), and National Academies Press (U.S.), Building a Better Delivery System: A New Engineering⁄ Health Care Partnership, Washington, DC, National Academies Press, 2005.

[29] V.G. Valdmanis, M.D. Rosko, R.L. Mutter, "Hospital Quality, Efficiency, and Input Slack Differentials", Health Services Research, Vol. 43 (2008), No. 5, 1830 – 1848

[30] Abdelhadi, M. Shakoor, "Studying the efficiency of inpatient and outpatient pharmacies using lean manufacturing", Leadership in Health Services, Vol. 27 (2014), No. 3, 255 – 267

[31] B.L. Hintzen, S.J. Knoer, C.J. Van Dyke, B.S. Milavitz, "Effect of lean process improvement techniques on a university hospital inpatient pharmacy", American Journal of Health-System Pharmacy, Vol. 66 (2009), No. 22, 2042-2047.

[32] T.L. Newell, L.L. Steinmetz-Malato, D.L. Van Dyke, "Applying Toyota production system techniques for medication delivery: improving hospital safety and efficiency", Journal for Healthcare Quality, Vol. 33 (2011), No. 2, 15-22.

[33] R.L. Mutter, M.D. Rosko, H.S. Wong, "Measuring Hospital Inefficiency: The Effects of Controlling for Quality and Patient Burden of Illness", Health Services Research, Vol. 43 (2008), No. 6, 1992 – 2013

[34] L. Chan, L.E. Kass, "Impact of medical student preceptorship on ED patient throughput time", American Journal of Emergency Medicine, Vol. 17 (1999), 41–43.

[35] D.N. Kyriacou, V. Ricketts, P.L. Dyne, M.D. McCollough, D.A. Talan, "A5-Year Time Study Analysis of Emergency Department Patient Care Efficiency", Annals of Emergency Medicine, Vol. 34 (1999), No. 3, 326 – 335

[36] R.L. Lammers, M. Roiger, L. Rice, D.T. Overton, D. Cucos, "The Effect of a New Emergency Medicine Residency Program on Patient Length of Stay in a Community Hospital Emergency Department", Academic Emergency Medicine, Vol. 10 (2003), No. 7, 725 – 730

[37] R.L. Mutter, M.D. Rosko, "The impact of ownership on the cost-efficiency of U.S. hospitals", Advances in Health Economics and Health Services Research, Vol. 18 (2008), 113–38.

[38] A.C. Worthington, "Frontier Efficiency Measurement in Healthcare: A Review of Empirical Techniques and Selected Applications", Medical Care Research and Review, Vol. 61 (2004), No. 2, 1-36.

[39] D. Ng, G. Vail, S. Thomas, N. Schmidt, "Applying the lean principles of the Toyota production system to reduce wait times in the emergency department", Canadian Journal of Emergency Medicine, Vol. 12 (2010), No. 1, 50–57.