Abstract - Escalating cost in health care industry and increasing demand of patients’ satisfaction triggers hospitals in general to improve their performance. Emergency department is an important area where hospital management needs to increase its efficiency. This is due to the emergency nature of the patients and also the position of emergency department as the biggest contribution to the hospital nature of the patients and also the position of emergency department as the biggest contribution to the hospital needs to increase its efficiency. This is due to the emergency department is an important area where hospital management needs to increase its efficiency. One way to yield higher efficiency is by applying Business Process Reengineering (BPR) which focuses on understanding the current processes before proposing relevant changes. This paper discusses a case study conducted at a Singaporean Hospital and investigates deeper on the current situation including characteristics of emergency department.

Keywords – BPR, simulation, waiting time

I. INTRODUCTION

Achieving higher business performance is a definite choice of every organization. In this highly competitive era, one needs to improve its organizational performance in as many aspects as possible, from efficiency to productivity with ultimate goal of both customers’ satisfaction and high company’s profit margin. Business Process Reengineering (BPR) is arguably one of the best methods to achieve significant improvement in business performance (Kumar and Shim, 2005, 2006). It defines an organization as a set of business processes. By identifying each business process, bottlenecks of the overall process can be identified and subsequently necessary changes can be made.

One of the most challenging organizations for BPR concept to be applied is hospital. Hospital, as an organization which could be found almost everywhere in the world due to the needs from the society, consists of many complex business processes. The business processes range from its medical procurement, high technology equipment, and services provided to its customers, patients by doctors and nurses which could be classified into many groups. At the same time, the position of hospital is unique or probably difficult as it is pressured from two sides: low cost, and high service quality. Thus, in order to survive, hospitals must look into their business processes and do necessary follow up on the problems hindering the organization’s growth.

One of the processes which influence patients’ satisfaction on the service offered by the hospital is waiting time. Often patients have to wait quite long either in seeing a physician in specialist outpatient’s clinics or in emergency department. As patients’ satisfaction which correlates closely with patient care efficiency is reduced due to the prolonged waiting time; it is necessary to apply the BPR concept.

Long waiting time will most likely cause dissatisfaction or even complaints from patients. There are around half a million patients in five public sector EDs in Singapore (MOH, 2004). The hospital having the largest volume of ED patient visits also has the longest waiting time both for major and minor emergency cases. There have been several efforts to investigate how to optimize the waiting time of patients at ED. However, as the solution of cases in other hospital is not simply suitable to be implemented in other place, a study in optimizing the waiting time of EDs will stay relevant. Moreover, the approach provided in this paper is rather unique where quantifiable solutions become the main achievement. The usage of simulation modeling in relation to BPR concept is highly relevant. The paper also evaluates the model built and assesses the effectiveness of proposed changes to the process in relation with the waiting time reduction.

II. LITERATURE REVIEW

Glasson et al (1995) defined BPR as an integrated approach to dealing with business problems and opportunities through a fundamental re-thinking of its key processes in order to achieve sustainable effects and major business. Chow-Chua (2000) and Motwani et al (1998) explained clearly the difference between BPR and Total Quality Management (TQM). Maull et al (1995) discussed that there is a set of fundamental issues which companies have to face at certain point of the BPR implementation. They also mentioned that Information Technology (IT) has a key role in the context of a BPR approach. Chan (2000) agreed that the impact of IT on business process had been growing. Further, Greasley (2003) mentioned Business Process Simulation (BPS) as a tool used to assist in management of change in various settings. The simulation has two roles in implementing BPR: it assesses the “as-is” state in order to fully understand the process, and it predicts the performance of the “to-be” design before the real implementation.

In the healthcare industry, Caccia-Bava (2005) argued that hospital’s BPR implementations were more successful than before. In addition, they carried out empirical testing to investigate further the implications of theoretical success’ factors. Another consideration in hospital management is the status of the hospital. Kumar et al (2005) developed a performance measurement system to improve the inefficiencies found in the healthcare supply chain. Heinbuch (1995) also investigated ways to improve efficiency in healthcare supply chain. Francis and Alley (1996) defined three possible areas of BPR solutions: IT solutions, human resources, and physical space. Furthermore, Probert et al (1999) re-introduced the term of
PPR (Patient Process Re-engineering) as the interpretation of BPR in the healthcare environment.

Most EDs all over the world face similar challenges on limited resources with huge demands shown by the overcrowding patients. This has led many research investigations done with the objective to improve the performance of ED including the waiting time experienced by its patients. Kyriacou et al (1999) summarized the issue based on previous studies that prolonged waiting times is the main factor of patient dissatisfaction and the most frequent reason patients leave before medical evaluation. Further, Tahan et al (2005) suggested that one common area of waiting time is the time when patient gets hospitalized in emergency conditions.

Coats and Michalis (2001) tried to apply mathematical modeling concept on the patient flow in an Accident and Emergency (A&E) department. Kilmer et al (1995) argued that there were drawbacks to the use of simulation. This is especially true in the environments where decisions are made frequently and under tight time constraints.

III. EMERGENCY DEPARTMENT (ED) AT TAN TOCK SENG HOSPITAL

Tan Tock Seng Hospital, the second largest in Singapore has 1400 beds with 17 clinical disciplines. The Accident and Emergency (A&E) Department also called ED occupies the highest portion (27.5%) of ED patients among the public hospitals, which are 376 patients daily. Any patient coming to the ED has to pass the screening which determines which part of the ED the patient should go. After the screening, the patient has to register followed by first triage done by the nurse. The patient would then wait to see the doctor who will decide the appropriate treatment. Should a patient be discharged upon ED treatment, the patient will have to make payment before leaving ED.

The ED of Tan Hospital has already been computerized where all data are keyed into the computer. The data are divided into two categories: healthcare data is kept by the healthcare team of ED while non health-related data are duplicated for a separate system used by the Operations Quality Management (OQM). Inside ED, there are various roles within the healthcare provider teams. The doctors are clustered into two categories based on the qualification and experience: Senior Doctors and the Medical Officers. For the nurses, there are five different roles: Senior Staff Nurse (SSN), Staff Nurse (SN), Assistant Nurse (AN), Nurse Officer (NO) and Healthcare Assistant (HCA).

The ED classifies its patients into four different priority levels based on acuity: PAC 1, PAC 2, PAC 3 and PAC 4. PAC 1 patients are attended immediately whereas PAC 2 are seen before PAC 3. PAC 4 patients will only be served after PAC 1 to PAC 3 cases are cleared. As PAC 1 is served immediately, there should be no waiting time for PAC 1. For PAC 2 and PAC 3, the targeted waiting time set by Ministry of Health (MOH), are 20 and 30 minutes (median) respectively. However, the waiting time experienced at Tan Tock Seng Hospital by PAC 2 patients is 47 minutes. In addition, the PAC 3 median waiting time is 54 minutes. The long waiting time seems to be explained by the more number of patients this hospital has. However, as the goal of reasonable maximum waiting time is still to be achieved, it is necessary to investigate the causes of the long waiting time and improve it.

IV. APPLICATION OF STATISTICAL DATA ANALYSIS AND SIMULATION

Computerized data collection has been possible as Tan Hospital has implemented computerized record of their patients’ data. This information system normally supports the various analyses done by the OQM of hospital. The usage of Radio Frequency Identification (RFID) at this hospital has also increased the accuracy of the data. This allows much better tracking of the movement of patients from one station to another station. After the collection of data, a statistical analysis was conducted using SPSS software.

An accurate definition of the real process flow was obtained by a direct visit to the ED at Tan hospital to ensure that the process modeled is close enough with the actual flow. Once the process flow was available, the model was built in SIMUL8 software. SIMUL8 software is mainly designed for BPR to improve customer service and widely used in the industry. It integrates easily with third-party software enabling customers to build it into their own solutions. The various parameters obtained by statistical data analysis such as inter-arrival time and service time were incorporated into the system. A certain value of warm-up interval was specified. A multiple run of 100 trials were selected in this project.

V. RESULTS AND DISCUSSION

The findings on Emergency Department's characteristics based on the statistical analysis and various perspectives on ED such as the number of patients' arrival, how the parameters such as day of the week affect the characteristic, and the capacity of different stations in ED are some of the highlights discussed below. To see the changes clearly, simulation is used. The models before (“as-is”) and after the changes are re-engineered, are shown for further discussion. In addition, the existence of the health care resources and their relationship with patient demands are also discussed.

A. Characteristics of Emergency Department

Most of Emergency Department patients fall under the PAC 2 and PAC 3 levels where PAC 3 patients are always higher than PAC 2. The number of very urgent cases namely PAC 1 is considerably low, being always less than 10% of the total number of ED patients. In addition, unlike PAC 2 and PAC 3 which vary in different months, PAC 1 stays at a stable level. Fig. 1 tries to capture the pattern of
the patient arrival by comparing the number of patient arrivals for the period from July 2005 to January 2006.

PAC 1 has the highest percentage of volume of patients with PAC 3 the lowest among all. PAC 4 patients, due to its nature, do not show any record of being hospitalized after the ED process. More than 70% of PAC 1 patients are hospitalized followed by PAC 2 patients (40 to 50%). Finally, the PAC 3 only contributes little more than 10% to the hospital admission. PAC 1 contributes 709 patients; PAC 2 contributes 2,425 patients; and PAC 3 contributes 771 patients. In other words, PAC 2 and PAC 3 levels contribute 3,196 out of 3,904 or 81.8% of ED patients; PAC 2 contributes 2,425 patients; and PAC 3 contributes 771 patients. In other words, PAC 2 and PAC 3 levels contribute 3,196 out of 3,904 or 81.8% of ED contribution. Tan hospital faced long waiting time for PAC 2 and PAC 3 levels which have the top three specialties as General Medicine (GMD), General Surgery Day (GSD), and Orthopedic (ORT). On the other hand, there are many PAC 1 cases under the specialty of Cardiovascular (CVM) and Respiratory Medicine (RES) such as difficulties in breathing.

B. Analysis of Patients’ Waiting Time in Emergency Department

Fig. 2 proves that PAC 1 patients do not experience long waiting time. The patients under PAC 2 and PAC 3 levels wait considerably long as MOH targeted waiting time for PAC 2 and PAC 3 levels are 0.33 hour and 0.5 hour in median respectively. In terms of time hour slot, a relationship between the long waiting time for PAC 2 and PAC 3 levels with respect to time of arrival is also found out.

There is a special waiting room for pre and post-admission patients. The waiting times for different classes requested are significantly different. The higher the class with increment in the hospital fee, the shorter the waiting time of the patients.

C. Re-engineering of Counter Payment Flow

The ED process initially allocated its payment counter towards the end of the process. This choice of location of payment counter is common in any healthcare flow which starts with registration followed by consultation and ends with payment. On the other hand, this choice would result in non-standard payment system where some patients pay more according to their additional service provided. Ultimately, it takes more time to finish one patient’s payment process and thus creates longer queue. One way to improve is by having two counters for payment. According to the ED practice, all patients have to pay $70 for the standard service and medication provided by ED. For this standard payment, one counter is set up between registration and triage. Two objectives of this measure are: to increase the speed of payment process by having a standard amount of payment, and to fill in the gap created by the waiting time between registration and triage, therefore, patients are occupied instead of just asked to wait for triage. For special cases where additional payment is necessary, a payment counter is still available at the end of ED process.

Adding Short-stay Ward: As patients for whom status are not yet clear, it would take more hours of observation before their status could be finalized. These long hours of observation occupy some spaces inside the waiting room resulting into longer queue to the waiting area. Therefore, an alternative to have a special ward called EDTC for this type of patient was implemented. This special ward is designed for short-stay for long hours but less than one day for patients requiring additional treatment or observation. If the patient’s condition is improved, the patient could be discharged.

D. Simulation Model Built

For a better representation of the system, a simulation model of the process flow as depicted in Fig. 3 is developed using SIMUL8 software. The process flow of ED is expressed into four possible terms called work stations are: input of the system, queue (storage bin), work station (service station), and exit. This includes any part of the process flow which has health care manpower resources from screening to the counter payment.

The result generated by the simulator only yields the average, standard deviation, lower and upper limits for 95% interval of the information. Thus, in order to validate the simulated results, one way is to make a comparison between the 95% interval of simulated result and the actual value. Table 1 shows the comparison between the values of queuing time from registration to the point of consultation as it is the time most concerned by the patients.
Fig. 4 shows the model after changing of the payment counter system and the addition of EDTC acting as a short-stay ward. The simulation model was run. The results generated are shown in Table 2 and indicate that there are improvement in terms of the queuing time of PAC 2 and the total time in the system. The PAC 2, the biggest contribution to the hospital admission shows a decrease in the waiting time of patients to be seen by the doctor. In addition, the length of stay inside ED, represented by the total time in the system has decreased.

Another observation made was the capacity of the Emergency Department together with its resources in terms of the health care team. It provides the information on the capacity of each major station in serving the people. In addition, the graph is structured in such a way that the cumulative number of people making the upper most graph to be the total number of people inside ED. The total number of ED patients in a particular hour could be as high as 85 and as low as 19 in a day. It is shown that the supply does not match the demand for the period from 10 a.m. to 1 p.m. This probably contributes to the long waiting hours experienced by PAC 2 and PAC 3 patients between 11 a.m. and 3 p.m. based on the analysis made earlier.

Table 2 – Simulation Results for the Model after Implementation of Changes

<table>
<thead>
<tr>
<th>Simulation Object</th>
<th>Performance Measure</th>
<th>Low 95% Range</th>
<th>Average</th>
<th>High 95% Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Queue for Screening</td>
<td>Average Queuing Time</td>
<td>0.1460</td>
<td>0.1503</td>
<td>0.154</td>
</tr>
<tr>
<td>Queue for registration</td>
<td>Average Queuing Time</td>
<td>3.1137</td>
<td>3.3153</td>
<td>3.516</td>
</tr>
<tr>
<td>Queue for payment</td>
<td>Average Queuing Time</td>
<td>0.9321</td>
<td>0.9676</td>
<td>1.003</td>
</tr>
<tr>
<td>Queue for triage</td>
<td>Average Queuing Time</td>
<td>0.0905</td>
<td>0.0931</td>
<td>0.0956</td>
</tr>
<tr>
<td>Queue for Counter Payment</td>
<td>Average Queuing Time</td>
<td>0.457</td>
<td>0.483</td>
<td>0.5082</td>
</tr>
<tr>
<td>Pac 1</td>
<td>Average Queuing Time</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Pac 2</td>
<td>Average Queuing Time</td>
<td>44.730</td>
<td>56.081</td>
<td>67.432</td>
</tr>
<tr>
<td>Pac 3 and 4</td>
<td>Average Queuing Time</td>
<td>68.151</td>
<td>70.564</td>
<td>72.976</td>
</tr>
<tr>
<td>upgraded P3 and P4</td>
<td>Average Queuing Time</td>
<td>95.872</td>
<td>95.986</td>
<td>96.10</td>
</tr>
<tr>
<td>Medication and Discharged</td>
<td>Average Time in System</td>
<td>123.33</td>
<td>135.53</td>
<td></td>
</tr>
</tbody>
</table>

Table 1 – Comparison between Simulation Results and Actual Value SPSS data

<table>
<thead>
<tr>
<th>Average Queuing Time</th>
<th>95% Interval of Simulated Value</th>
<th>Actual Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pac 1</td>
<td>(0.17856, 0.36844)</td>
<td>0.3502</td>
</tr>
<tr>
<td>Pac 2</td>
<td>(60.24215, 67.52391)</td>
<td>61.514</td>
</tr>
<tr>
<td>Pac 3 and 4</td>
<td>(63.81505, 65.29309)</td>
<td>65.0103</td>
</tr>
</tbody>
</table>

VI. CONCLUSIONS

Good business process re-engineering (BPR) requires in depth understanding of the current business processes. This study shows that there is a need for BPR inside the ED. The efforts were supported by the advantage of Tan Tock Hospital having computerized record of time-based
data of the patients. In order to re-engineer the existing processes in ED for shorter patients’ waiting time, the process flow of the real system was studied by collecting and analyzing the large data. Table 3 summarizes the findings of the attributes of all four patient acuity levels.

**TABLE 3 - Summary of ED Characteristics**

<table>
<thead>
<tr>
<th>% of Total Number of Patients</th>
<th>PAC 1</th>
<th>PAC 2</th>
<th>PAC 3</th>
<th>PAC 4</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of Total Number of Patients</td>
<td>8.02%</td>
<td>42.79%</td>
<td>48.40%</td>
<td>0.79%</td>
<td></td>
</tr>
<tr>
<td>Average Daily No. of Patients</td>
<td>31 patients</td>
<td>166 patients</td>
<td>188 patients</td>
<td>3 patients</td>
<td>388 patients</td>
</tr>
<tr>
<td>Average of Monthly Median of Waiting Time from Registration to Start of Consultation</td>
<td>0 hour</td>
<td>0.79 hour</td>
<td>1.03 hour</td>
<td>0.73 hour</td>
<td>0.84 hour</td>
</tr>
<tr>
<td>% of Contribution to Total ED patients being hospitalized</td>
<td>18% (75% of total PAC 1 patients)</td>
<td>62% (48% of total PAC 2 patients)</td>
<td>20% (13% of total PAC 3 patients)</td>
<td>N/A</td>
<td>127 patients daily</td>
</tr>
</tbody>
</table>

PAC 2 and PAC 3 were the areas where the BPR concepts need to be applied. Their median waiting times, 47.4 and 61.8 minutes respectively were far above the targeted median waiting time from MOH which is at the level of 20 and 30 minutes. The longest waiting time occurred in general from 1 to 2 p.m. with median value of 67.2 and 90 minutes. Thus, there is a need to re-engineer the existing process to reduce the peak waiting time between 11 a.m. and 3 p.m.

The simulation model was able to produce the similar value of waiting time compared to that in actual data. The basic requirement such as number of PAC 3 level being higher than PAC 2 and PAC 2 being higher than PAC 1 is fulfilled. It is also shown that the change of work flow of the payment counter and the addition of short-stay ward brings good impact to the ED. In addition, the average length of stay of patients in ED is significantly decreased.

There are several recommendations of possible changes to improve the waiting time in the Emergency Department. First recommendation is to try shifting the current manpower resources pattern few hours earlier. Another recommendation which is considered as qualitative solution is on the area of space. There is currently unused space in ED. It may not solve the problem directly as one of the bottlenecks is still the limited number of doctors for consultation. However, the space may be used for creative purpose, for example having few additional beds.

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**REFERENCES**


