Value Stream Mapping the Emergency Department

C.P. Koelling, PhD+
D. Eitel, MD*
S. Mahapatra+
K. Messner, MD
L. Grove*

+Grado Department of Industrial and Systems Engineering
Virginia Tech, Blacksburg, VA-24061
*Emergency Department
York Hospital, Wellspan Health, York, PA-17405

Abstract

Value stream mapping has become a valuable tool to model and evaluate work and process flow in industry. This tool can also be indispensable in the health care environment. One of the key elements in its use is the identification not only of process and flow, but of value added. This paper describes value stream map development in the large emergency department (ED) at York Hospital. An “as is” map was developed and reviewed by key personnel in the ED. Lean principles are now being applied to develop an appropriate “to be” map that will be reviewed for implementation.

Introduction

In the face of rising healthcare costs, various initiatives have been initiated to increase the operational efficiency and cost effectiveness of the healthcare delivery process. In particular, in the face of fixed capacity available to provide healthcare service to an ever increasing healthcare service demands, the area of healthcare service delivery operations needs to be seen in a new light. Several attempts have been made to address the issues that confront the health services industry. The most notable ones include piecemeal tweaking of a process or developing new analytics that are built on math or simulation models that have had limited success (Herlinger 1999). The need of today is to look at solutions that aim at revolutionizing the process and bring about an everlasting change to the industry.

Of the various areas in the healthcare industry that policy planners and change agents have focused their attention on, the Emergency Departments (ED) have received their fair share. The EDs play a vital role in the providing care to patients and are recognized for their contribution that they make to the society. The available statistics make it clear about the indispensability of this healthcare service operation that the country relies upon to provide medical services to the patients on a 24/7 basis. There were about 107.5 million ED visits in 2001, up 10% from 97.4 million visits in 1997, while the number of hospitals providing emergency care decreased (Heffler et al. 2003). Also, the ED health care 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. The legal consequences of failed services are immense in the U.S. (Griffith 1998). In light of the critically important ramifications of the quality of emergency health care rendered to patients presenting to a hospital seeking emergency services, the authors believe that it is necessary to look at the issue first from a systems perspective to identify root causes; and then propose and test potential solutions without perturbing real patients or real staff.

Lean Thinking

Lean production also called as lean manufacturing, or lean thinking, as popularized by Womack and Jones (1996) is increasingly being implemented as a potential solution for many organizations including various sectors in the manufacturing industry and recently being adopted by the healthcare services industry as well. The term lean thinking was introduced by Taichi Ohno. Lean thinking includes processes that are
flexible, reduce waste, optimize the process, improve process control and finally improves utilization of people resources. These areas of focus and principles can be operationalised using a specific set of tools and techniques. A number of authors have defined the portfolio of tools and techniques that assist implement Lean production. Some tools have focused on the entire organization as the unit of analysis while others as Value Stream Mapping (VSM) have focused on a product value stream.

A value stream is defined as all the actions (both value added and non value added) required to bring a specific product, service or a combination of products and services, to a customer. VSM is an enterprise wide improvement technique that helps visualize the entire process, representing material and information flow, to improve production or service processes by identifying waste and its sources (Rother & Shook, 1999). The value stream map is created by using a pre-defined set of icons (shown in Figure 1). VSM presents the big picture that encompasses the entire set of processes from start to finish that a product goes through in the manufacturing process or the customer experiences in a service delivery operation.

**Steps In Value Stream Mapping**

Rother & Shook (1999) define a structured approach for improving a value stream. The first step is to identify relevant product families and select one as the target. The second step is to construct a current state map for the product value stream, using information gathered from the actual production process. The third step in the VSM process is to map a future state. It is important to bear in mind that the steps and the icons are product specific that are more in tune with the manufacturing systems, nevertheless, the authors believe that the concepts can be employed to the services industry as well (McDonald et al. 2002). The abundance of success stories available in research and practitioner based papers and texts are directed towards the amelioration of manufacturing process but the authors believe that with minor tweaking and using the framework that has been suggested by Rother & Shook the success stories can be replicated in the services industry specifically the healthcare industry as well.

![Figure 1: Value Stream Mapping Icons (Rother & Shook, 1999)](image-url)
To develop the VSM of the Emergency Department the icons that will be utilized by us include the process icon, the data box, inventory icon, operator block icon, push arrow icon, finished goods to customers icon, manual information flow icon, electronic information flow icon and the schedule icon. The process icon captures the activity that unfolds at a specific station and addresses capacity constraints. The data box icon includes data about cycle time, change over time, uptime and the number of seconds available at the station. The definitions about the various entries in the data box require extra clarification. Cycle time is defined as the time that elapses between one part or customer entity coming off the process to the next customer or part coming off the process. Change over time is defined as the time to switch from producing one product or servicing one customer. The number of people required to operate the process or provide services indicated with an operator icon as shown inside the process boxes. Available working time per shift (in seconds) minus breaks, meeting and clean up times and machine or server uptime information are necessary. These issues are handled in greater detail in subsequent sections (Rather & Shook, 2003).

**Target System**

This research is a joint project of the Industrial and Systems Engineering Department at Virginia Tech and the ED of York Hospital in York Pennsylvania. York Hospital is part of the WellSpan Health System, an integrated health system provider serving the greater Adams-York county region of Pennsylvania. York Hospital has been actively engaged in performance improvement efforts for several years. Specifically, physicians and researchers at York Hospital and Virginia Tech have jointly developed simulation models of the York emergency department (ED), focusing on the impact of 5-level triage on elements of patient flow. One of the primary “missions” of the initial efforts has been to “turn the lights on” and help York staff see the tremendous potential in examining patient flow from an operations improvement standpoint. This joint work has naturally developed into other areas of performance management, one being a more detailed analysis of the workflow of the ED, and has expanded beyond the ED to include ancillary services.

York Hospital is dedicated to the highest-quality patient care, and has as a major initiative performance improvement in service delivery activities. Like most health care organizations the clinical performance of the system is paramount, as it should be, and has received the lion’s share of attention. Thinking and planning with respect to operations performance improvement has not been a focus, or perhaps even visible, until the past few years. Now York, and increasingly other health care institutions, have recognized the value of this type of performance improvement and are devoting time and resources to it.

York hospital has been recognized as one of the top 100 hospitals in the U.S. It is a 558-bed tertiary care community teaching hospital and serves a population of 350,000 in south central Pennsylvania (The web site of York Hospital). The ED sees, on average, 67,000 patients annually with yearly growth rates of 5-10% in the recent 3 years. It is an academic environment with emergency medicine residents, residents from other services, and medical students in its physician provider staff mix. It participates in the hospital’s trauma services response by supplying physician, nursing and other support staff for resuscitation and stabilization of trauma patients.

**ED Service delivery Process**

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

1. Arrival
2. Triage
3. RN assessment
4. MD assessment
5. Initial diagnosis and treatment
6. Diagnostic Testing
7. Junior Doctor Supervision/Teaching
8. Follow up/treatment planning
9. Discharge or admit
10. Access to In-patient Beds and Admitting Physicians
Functional analysis of the service delivery protocol listed above can be classified into the following areas of care delivery at the York Hospital ED.

1. Triage Station
2. Critical Care Unit
3. Intermediate Care Unit
4. Alterna Care Unit
5. Diagnostic Testing
6. Patient Discharge/Admit

**Triage Station**

Figure 2 represents patient flow through the system. Arriving patients check in and wait to be triaged by a triage nurse. At the triage station the nurse records patient signs and an ESI level (1 through 5) is assigned depending on both the acuity of the case and the predicted resource needs of the particular patient (Eitel et al. 2003). After the initial assessment by the triage nurse the patient waits (typically in a waiting room) for
an available bed. The ESI level governs the routing of the patient to one of the care delivery units, CCU or ICU/ACU. The low resource intensity patients are routed to the ACU, or the express care unit if it is open.

**Critical Care Unit (CCU)**

The CCU serves the most acute patient cases. ESI-1s, 2s and 3(geriatrics) are routed to the CCU unit for assessment by a CCU nurse and formal clinical assessment by an emergency physician or a senior resident. Depending on the initial assessment by the physician/resident one or more diagnostic tests are recommended. Based on the outcome of the diagnostic tests the patient is reassessed by the physician or the senior level resident. Finally, the patient is discharged or admitted to the hospital.

**Intermediate Care Unit (ICU)**

The ICU serves the less acute patient cases. ESI-3s (non geriatrics), 4s and 5s are routed to the ICU unit for initial assessment by an ICU nurse and formal clinical assessment by an emergency physician or a low level resident or a medical student. Any clinical assessment by a medical student is always followed by a repeat assessment by an emergency physician to confirm the assessment. Depending on the initial assessment none, one or many diagnostic tests are recommended. Based on the outcome of the diagnostic tests the patient is reassessed by the emergency physician. Finally the patient is discharged or admitted to the hospital.

**Alterna Care Unit (ACU)**

The ACU is a fast track patient unit operational from 11:00AM-11:00PM daily. The ACU handles low acuity patients, the ESI 4s and 5s. This alternative treatment route is one of the policy initiatives of the senior management of York ED to bring about reductions in the overall length of stay of low acuity case patients. An Alterna Care physician, in tandem with a physician extender(PE), with occasional availability of a emergency care technician, manages the patient disposition at the ACU. We use the term PE to refer to those professions (such as highly trained nurses) who can provide treatment normally associated with a doctor for low acuity patients.

**Diagnostic testing**

Patients from the CCU, ICU and the ACU may undergo diagnostic tests. The diagnostic testing unit may be viewed as a set of sub-systems within a larger system. Diagnostic tests can be categorized into two broad categories - phlebotomy and imaging. The phlebotomy section performs multiple types of blood assays on patient blood samples. The imaging section includes resources for CAT scans, plain film X-Rays and Ultrasounds. These tests help diagnose the nature of the clinical case and permit follow up remedial clinical steps.

**Patient Discharge/Admit**

Following any diagnostic tests, the patient is reviewed by the physician and or the senior level resident. The review process will result in a recommendation for admission to the hospital or discharge from the ED.

**Patient Transportation**

Patient wheeling is a critical component of the care delivery process. By patient wheeling the researchers refer to the physical transportation of the patient entity to the different units of the ED. The patient needs to be transported/wheeled to a bed (either in the CCU, the ICU or the ACU) from the waiting room, back and forth to the imaging diagnostic center and to the floor when admitted.

**Treatment Resources**

The ED service delivery process is accomplished through the services of both human and physical resources. The human resources include senior and lower level residents, emergency physicians (EP), nurses, physician extenders (PE) and emergency care technicians (ECT). Since the diagnostic testing center is shared by the hospital, the resources available at diagnostic testing are not considered a part of the ED. The processing times for all healthcare professionals with a particular set of competence working at a specific unit (CCU, ICU or ACU) was assumed to be uniform and constant. Factors pertaining to fatigue and exhaustion have not been included in the model.
Data collection and analysis

Fidelity of any process improvement study depends upon the quality of the data. York Hospital is a progressive, forward-looking institution that has had extensive data collection systems in place for a long period of time. These data proved invaluable for developing the ‘as-is’ state of the overall service delivery process. The data comprised the key service times that go into delivery of clinical service, including patient arrival times, waiting times at various stages of the service delivery process, and staff schedules of ED personnel. Interviews with emergency physicians, residents, nurse administrators, and technicians were conducted to gain valuable insights into the process of ED service delivery in this teaching environment. Direct observation and the judgment of staff directly involved in the service delivery operations were used to derive average processing times and to represent the fluid interactions between the different service delivery processes (Mahapatra, Koelling, Eitel et al. 2003). For the development of the VSM we are focusing only on the ICU of York Emergency Department. The service time at each stage for the ICU is indicated in table 1.

Table 1: Service delivery times in the ICU

<table>
<thead>
<tr>
<th>Activity</th>
<th>Service Time Distribution (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient evaluation by ICU nurse</td>
<td>Triangular (4,6,10)</td>
</tr>
<tr>
<td>Patient evaluation</td>
<td></td>
</tr>
<tr>
<td>- lower-level resident</td>
<td>Triangular (5,10,15)</td>
</tr>
<tr>
<td>- EP</td>
<td>Triangular(4,7,15)</td>
</tr>
<tr>
<td>Follow-up treatment by EP or senior-level resident and nurse after reviewing diagnostic reports</td>
<td>Uniform (4,12)</td>
</tr>
<tr>
<td>Additional time for admission/ discharge</td>
<td></td>
</tr>
<tr>
<td>- Admitted patient</td>
<td>Triangular (25,35,180)</td>
</tr>
<tr>
<td>- Discharged patient</td>
<td>Uniform (5,25)</td>
</tr>
</tbody>
</table>

Also, on the basis of the historical data the mean inter arrival time for the various patients were calculated. The results of such an analysis are indicated in Table 2. As per the ESI algorithm and the service structures at York hospital, level 3 patients are seen at the ICU. A thorough and rigorous process would require us to find the averages of the mean inter-arrival times for the weekdays and weekends for each of the time intervals ---12:00AM-12:00PM and 12:00PM-12:00AM. However, for matters of simplicity we assume the inter arrival time to be 30 minutes for ESI-3 patients.

Table 3.3: Mean Inter-Arrival times for 5 ESI levels

<table>
<thead>
<tr>
<th>ESI Level</th>
<th>12:00 AM – 12:00 PM</th>
<th>12:00 PM – 12:00 AM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weekdays</td>
<td>Weekends</td>
</tr>
<tr>
<td>ESI-1</td>
<td>323</td>
<td>289</td>
</tr>
<tr>
<td>ESI-2</td>
<td>93.2</td>
<td>96.4</td>
</tr>
<tr>
<td>ESI-3</td>
<td>38</td>
<td>34.1</td>
</tr>
<tr>
<td>ESI-4</td>
<td>88.8</td>
<td>69.5</td>
</tr>
<tr>
<td>ESI-5</td>
<td>199</td>
<td>171</td>
</tr>
</tbody>
</table>

Development of Value Stream for the Intermediate Care Unit

The value stream for the Intermediate Care Unit is presented in Figure 3. The service commences with triage followed by nurse assessment. Following the assessment by the nurse the patient is ready to be assessed by the physician. Following the assessment by the physician the patient undergoes diagnostic testing and after evaluation of the diagnostic reports, a decision to admit or discharge the patient is made. Entries in the data box underneath the process icon include entries for cycle time, change over time, available time per shift and uptime. 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, reading the charts and also entering the patient information into relevant information systems. The average value for the cycle times
from Table 1 have been included as the Cycle time for each stage of the service delivery process. The uptime and the change over time included in the data box are some what debatable and we need to look at it more closely to depict reality. Uptime needs to account for issues like shift changes and scheduled breaks. Change over time accounts for cleaning and preparation for the next patient. The inventory at each stage as the patient transitions from one procedure to another is governed by the total bed capacity in the ICU. For the ICU at York Hospital this capacity is 16. Finally, there are material flows and also information flow between the various stations. The information input at the triage station resides in a hospital wide information system and is utilized by the nurses, physicians at the down stream stages. Also, any additional information entered at the down stream stages is also made available to all the upstream processes. For the purpose of service control there are weekly schedules of physicians, nurses and other clinical staff. The inventory icon (triangle) indicates the number of patients waiting to move from one stage of service processing to another. The number inside the triangle indicates the total number of beds that are meant for the intermediate care patients. Utilizing all these concepts the VSM for the current state of the process is shown below.

**Discussion**

The complexities of the health care environment present unique challenges that do not exist in most manufacturing systems. As health care professionals increasingly use VSM new knowledge regarding its effective use will continue to emerge—the tool is still in its infancy in health care.
References


