Facets of operational performance in an emergency room (ER)

Taco van der Vaart a, Gyula Vastag b,*, Jacob Wijngaard a

a University of Groningen, Faculty of Management and Organisation, P.O. Box 800, 9700 AV Groningen, The Netherlands
b Corvinus University of Budapest, Faculty of Business Administration, Budapest, Fővám tér 13-15 (Sóha), H-1093 Budapest, Hungary

1. Introduction

Emergency medical care is the most visible part of the health care system where process failures (excess time spent in waiting rooms or misdiagnoses, for example) are widely publicized and subjected to public scrutiny and debate. According to Reinberg (2006), “Emergency care in the United States only deserves a C-.” The study, conducted by the American College of Emergency Physicians, found that “the emergency care system is overcrowded, provides limited access to care, and is hampered by soaring liability costs and a poor capacity to deal with public health or terrorist disasters.” The root of the problem, writes Neergaard (2006), is that “demand for emergency care is surging, even as the capacity for hospitals, ambulance services and other emergency workers to provide it is dropping.”

Dykstra (1997) describes the two major models of emergency medicine. In the “Anglo-American Model,” emergency care takes place in the hospital (emergency medicine) and pre-hospital (emergency medical services [EMS]) settings but the emphasis is on bringing the patients to the hospital. Emergency care in these systems has achieved clinical, academic and professional recognition and accreditation in the United States, Canada, Australia, New Zealand and more recently, in the United Kingdom. In the “Franco-German Model,” emergency medicine practiced in the pre-hospital setting (that is, physicians and technology are sent to the scene), with medical leadership and direction generally provided by anesthetists. Physicians with certain clinical skills (or experience) and after completing an emergency care course become eligible providers within this system. These physicians are either assigned to an advanced life support (ALS) ambulance or travel to the scene separately with the other members of the ALS crew (“rendezvous” system). Basic life support (BLS) calls are generally responded to by a team of paramedics and/or emergency medical technicians [EMTs] without the on-site presence of physicians. Inside the hospital, the “Franco-German model” considers emergency medicine an interdisciplinary activity that does not require specialty status. Barring a few exceptions, the equivalent of an emergency department does not exist. As a result, there is no clinical or academic recognition for emergency medicine in these countries, no career track for physicians, and circumstances obviously restrict the resources available for research. The Franco-German model can be found in Austria, Finland, France, Germany, Latvia, Norway, Poland, Portugal, Russia, Slovenia, Sweden and Switzerland (Holliman and Čevik, 2000). The Hungarian system of emergency medicine represents a unique combination of the Franco-German and Anglo-American models: it has ERs with medical doctors specialized in ER but,
unlike in the USA, their work is complemented with the Hungarian Ambulance System with assigned medical doctors.

The Dutch EMS system, although many of its features are similar to the various American models, takes an alternate approach to pre-hospital health care delivery. It is a nurse-driven triage system, both at the dispatch level and at the treatment level. The Dutch EMS system utilizes these highly trained personnel to effect judicial use of emergency pre-hospital resources (Dib et al., 2006).

Each emergency department (ED) or emergency room (ER), we use these terms as synonyms, must have treatment-related functions that are very often accompanied with teaching and research responsibilities. First and foremost, emergency departments have to be available to receive patients in urgent need of treatment at any time. Considering that there is a great deal of uncertainty regarding the timing and volume of patients' arrival and the amount of resources needed to treat them, resource utilization of the ER and waiting times of the patients are the two most critical and conflicting issues hospital emergency departments are facing. A related and important issue is that most of the patients attending ER do not require real emergency care (Steinbrook, 1996).

A patient's time in the ER is either spent with using a resource (attended by a nurse or physician and/or receiving treatment, undergoing testing) or waiting for a resource (which might be a release note, an administrative action). It has been well-established that ER waiting times are the major determinant of patient satisfaction or dissatisfaction (Holden and Smart, 1999; McMillan et al., 1986). Increasing budget pressures, however, limit the resources (e.g., number of beds, number of physicians and nurses) made available to ER. Consequently, facing more and more public scrutiny and resource limitations, hospitals have to increase patient satisfaction while making better use of their resources (see Chan et al., 1997, for an illustrative analysis).

The next two functions of ER are stabilization and disposition. After treating and stabilizing the patients, they either go home or referred to further treatment that may take place in the hospital or in a non-hospital location immediately or at a later, scheduled time. Additionally, many emergency departments play a key role in medical education and research; they may serve as crucial training grounds for residents, for example.

Because of the highly stochastic nature of emergency care, rules were developed for situations where demand exceeds available resources. Triage in general, and the Manchester Triage System (MTS) in particular, was the first formalized system for managing clinical risks (Manchester Triage Group, 1997; Derlet, 2004; Windle and Mackway-Jones, 2003). The word “triage” is derived from the French “trier” meaning “sort” and much of the credit for the development of a method for quickly evaluating and categorizing the wounded in the battlefield goes to Dominique Jean Larrey, a surgeon in Napoleon's army. Now, triage means a brief clinical assessment that determines the time and sequence in which patients should be seen in the ER. These decisions generally are based on a short evaluation of the patient and an assessment of vital signs. The patient's overall appearance, history of illness and/or injury and mental status also are important in the triage decision (McMahon, 2003). The question of determining priority scores and the reliability of these scores have been discussed in several papers (for example, George et al., 1993; Jelinek and Little, 1996). The triage system became widely accepted in the second half of the 20th century when organized departments with on-duty physicians became standard. For a literature review of emergency department triage, please see McDonald et al. (1995) and FitzGerald et al. (2010).

There are many reported cases of triage misclassifications with occasional dire consequences. The two illustrative cases and the following evaluation are from Derlet (2004). These cases also illustrate the influence and critical role of the dynamically changing ER load (the number of patients in ER).

"Case 2: A 43-year-old woman presented to the ED, complaining of headache. The patient had normal vital signs except for temperature of 101.2 °F. The ED was very busy and crowded. Since the triage nurse had seen many patients that day whose symptoms included headache and because this patient seemed no worse than the others, she sent the patient to the waiting room. Four hours later, another patient came to the triage desk stating that the woman, who was still in the waiting room, was having a seizure. A repeat temperature 5 h after initial presentation was 104.5 °F, and she was admitted to the hospital with a diagnosis of meningitis.

Case 4: A 55-year-old man presented to the ED complaining of abdominal pain. He stated that he thought his condition was secondary to eating too much greasy fast food too rapidly. His vital signs were blood pressure, 150/100 mmHg; pulse, 100 bpm; respiration, 22 bpm and temperature, 98 °F. As the ED was busy, the patient was sent to the waiting room. Two hours later, the patient's friend complained that he looked pale and had increasing weakness. The patient's friend was told, that the ED was overcrowded. Three hours after triage, the patient collapsed in the ED waiting room. He was brought into the ED hypotensive and was taken to surgery, where he died of a ruptured aortic aneurysm.

While the outcomes of some of the above cases may not have changed had the patients been seen directly in the ED and immediately evaluated by a physician, these cases do illustrate that patients' medical conditions are constantly changing, and that triage is an active and dynamic process. If there are long lines to see a physician in the ED, continually reassess patients."

From an operations management perspective, MTS has two interrelated functions. First, the system supports the triage nurse in sequencing, that is, the decision on the order in which the patients will be treated. Second, the system incorporates performance norms through the time frames defined per triage code. Many ERs in the USA initially used a three-level approach, and now follow the lead of the United Kingdom, Australia and Canada to develop and implement five-level triage classification systems (McMahon, 2003; Cook and Jinks, 1999; McDonald et al., 1995; Pearson et al., 1995; Considine et al., 2004; Beveridge et al., 1999; Cooke and Jinks, 1999; Zimmerman, 2001).

This paper, using detailed time measurements of patients, examines three facets of an emergency room's (ER) operational performance: (1) effectiveness of the triage system in rationing patient treatment; (2) factors influencing ER's operational performance in general and the trade-offs in flow times, inventory levels (that is the number of patients waiting in the system) and resource utilization and (3) the impacts of potential process and staffing changes to improve the ER's performance.

Specifically, four proposals, rooted in and linked to the theoretical underpinnings of Operations Management and Supply Chain Science (Hopp, 2008), for streamlining the patient flow are discussed:

1. Establishing designated tracks (“fast track,” “diagnostic track”), like in focused factories.
2. Creating a “holding” area for certain type of patients; an equivalent of positioning and establishing buffers that could reduce interarrival variability.
3. Job design and deskilling by introducing a protocol that would reduce the load on physicians by allowing a registered nurse to order testing and treatment for some patients and thus could contribute to reducing process variation.
4. Potentially, and in the longer term, moving from non-ER specialist physicians to ER specialists that, in principle, would also reduce process variation.

The paper's findings are based on analyzing the paths of 1095 patients between November 8 and 28, 2004 and 798 patients between March 13 and 26, 2006 in the emergency room of the Medical Center of Leeuwarden (MCL), The Netherlands. These observations were complemented by interviews with hospital management and staff that also validated the findings presented here. Using exploratory data analysis the paper presents generalizable findings about the impacts of various factors on ER's lead-time performance and shows how the proposals fit with well-documented process improvement theories. The two main lines of inquiry of this exploratory research are focused on the influence of triage and the necessity for and ways of reducing variability in an ER setting.

The paper is organized as follows. Section 2 introduces the emergency room of MCL (Medical Center of Leeuwarden, The Netherlands) and data collected there. Section 3 presents the results of our analysis. Section 4 deals with suggestions for improvement. The paper ends with conclusions and suggestions for future research (Section 5).

2. The ER at the Medical Center of Leeuwarden (MCL)

MCL is a large, regional teaching hospital in Friesland; a province in the north of the Netherlands. In 2005, Friesland had about 643,000 inhabitants; Leeuwarden, its capital with about 91,000 inhabitants, is in the center of the province. MCL had 914 beds, employed over 180 medical specialists (physicians) and a number of medical residents. The hospital handled about 26,500 admissions, administered 16,000 one-day treatments and 132,000 outpatient visits per year.

The current ER facility at MCL was recently upgraded and, since 2001, it has been the sole provider of emergency care at the hospital (prior 2001, there were two facilities). Since 2004, after the development of a new information and computer system, the emergency room uses the Manchester Triage System (MTS).

Table 1 shows the number of patients in the ER annually and the average lead-time per patient (time between registration and departure from ER).

<table>
<thead>
<tr>
<th>Year</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006*</th>
</tr>
</thead>
<tbody>
<tr>
<td>ER Patients per year</td>
<td>19,826</td>
<td>19,454</td>
<td>19,610</td>
<td>19,422</td>
<td>20,223</td>
<td>6773</td>
</tr>
<tr>
<td>Average flow time per patient (min)*</td>
<td>95</td>
<td>91</td>
<td>101</td>
<td>111</td>
<td>115</td>
<td>121</td>
</tr>
</tbody>
</table>

* For January, February, March and April.
<table>
<thead>
<tr>
<th>Room 9 (X-ray)</th>
<th>Room 10 (family)</th>
<th>Room 11 (standard)</th>
<th>Room 12 (standard)</th>
<th>Dressing room</th>
<th>Room 13 (X-ray)</th>
<th>Room 14 (observation)</th>
<th>Room 15 (standard)</th>
<th>Room 16 (standard)</th>
<th>Room 17 (stitching)</th>
<th>Storage</th>
<th>Garden with terrace</th>
</tr>
</thead>
</table>

Fig. 1. ER Layout of MCL.
The trend of relatively constant number of ER patients per year with increase in lead-time per patient visit continued in 2006: in the first four months, the average length of an ER visit was 121 min.

Fig. 1 shows the layout and the patient flow at the ER at MCL. Patients can arrive by any of three modes of transportation: ambulance or helicopter (in extreme emergencies), through a hospital department (e.g., X-ray or outpatient clinic), and other (by car or walk-in). With the exception of extreme cases, patients are registered at the reception desk and their identifiers are entered into the computer system. Data were also collected about the reason for the visit (ini.arr: calling the Dutch emergency number, physician referral, patient’s initiative and other) and the potential cause behind the visit (cause: illness with unknown cause, home accident, mutilation, not feeling well, workplace accident, violence, sport accident, traffic accident, disaster and other). Urgent patients (arriving by ambulance, for example) are delivered directly to ER and their data are entered later. Registration processing is very quick (a couple minutes) and the patient’s data are automatically transferred to the ER by computer. The patient’s card with a bar code is printed in the central station of the ER. In the March 2006 data, each patient, in addition to our assigned unique code, has a seven-digit unique code; the same code is assigned to the same person (it is not true for November 2004), so multiple visits in the research period can also be accounted for.

From the reception desk patients proceed to the waiting room where they are called from by the triage nurse. In the triage, an experienced nurse uses a computer program and a set of questions to assign one of the five color codes of the Manchester Triage System (blue = non-urgent, green = standard, yellow = urgent, orange = very urgent, red = immediate) to the patient. MTS (Manchester, 1997) consists of five steps: (1) Identify the complaint voiced, and pick an appropriate flow chart. (2) Gather and analyze information using six general key discriminators (like life threat, pain and conscious level) to determine a level of priority. (3) Evaluate and select alternatives, using discriminators within the flow chart to identify the patient’s general acuity. (4) Implementation and simplified documentation. (5) Evaluation.

In addition to the triage code, the triage nurse also assigns a specialty code to the patient. If the ER visit was initiated by the patient then the triage nurse decides about the code assigned. Otherwise, if the patient was sent by a physician (e.g., family doctor), she uses the code assigned previously.

MTS also provides limits to the waiting time before a physician sees the patient. These norms are on display in the ER waiting room (see Fig. 2): 4 h for blue patients, 2 h for green, 1 h for yellow, 10 min for orange, and 0 min for red patients.

Depending on the patient’s condition and on the load in the ER, the patient is either sent back to the waiting room or transferred to the ER immediately for treatment. The ER, in addition to the triage room, consists of eight standard rooms and eight specialized rooms that are listed in Fig. 1. All rooms have sliding doors and curtains to provide the level of privacy needed. In the experience of ER personnel, patients prefer to leave the doors open, so they do not feel isolated even when the curtain is closed. Each room is, largely, customizable by carts of supplies and equipment. Some rooms, however, are more specialized with expensive equipment (trauma room with X-ray, for example) or with specific supplies (casting, burns).

Fig. 2. Time norms of the Manchester Triage System (MTS).

Fig. 3. Schedule of nurses (number of nurses in the ER).
All 26 nurses in the ER’s nurse-pool are trained in triage; in every shift, one nurse works in the triage, the others are in the ER. The nurses can work in one of five shifts: Night, A, C, D, and F where the F shift is used sporadically to address high demand situations. Fig. 3 shows the total number of nurses on duty (including the triage nurse) by the hour of the day. It should be noted that between 15:30 and 16:00 hours, there is a planned half-an-hour overlap between A and D shifts to discuss and hand over patients. In this period, eight (if there is no F shift) or nine (in case of an F shift) nurses are present, but based on our discussions with ER personnel, we showed the effective capacity of the ER as six and five nurses, respectively.

There are two resident physicians on duty all the time. Typically, one of them is a surgical resident, the other one is an internist and each treats patients with complaints related to their specialty. The residents are supervised by attending MCL physicians in their specialties and both the residents and the supervisors can request consultation with other doctors from other fields (cardiology, plastic surgery, gynecology, pediatrics, etc.). Consequently, the flow of patients served by the internal medicine residents and the flow served by the surgery residents are independent to a certain degree. Before triage, there is one queue of patients and the two groups of patients are served with the same resources, i.e. nurses and ER cubicles. Especially at busy times, the two lines for the two specialties become more mixed strengthening the conclusion that there are no separate streams for different groups of patients. If needed, the residents consult with the attending physician and other physicians at MCL. In each

![Fig. 4. Timeline (t.xxx) and related measurements (variables).](image-url)
research period, 20–25 residents, supervised by more than 60 attending physicians, treated patients in the ER.

The nurses and residents are assisted by a secretary (24-h position) who collects patient information and create patient files, does the electronic registration, makes notes on the plan board for residents and physicians, has contact with the reception (it is also a 24-h post) about arriving helicopters, notifies trauma teams, sends blood samples to the lab, provides administrative support (patient phone, fax, etc.), keeps the valubles of patients in a safe, takes care of the patient’s family and sets additional appointments for casting and outpatient clinic.

Additionally, the ER shares the following resources with MCL: laboratory, VP-scan, CT-scan, ultrasound and additional physicians (residents, attending and consulting doctors).

Patient data was obtained from the ER’s computer system to which, during the time periods examined, a research assistant added additional measurements. Patient lead-times were measured in detail including arrival time, triage time, start treatment, contact moments with physician, lead times of tests conducted by the hospital’s laboratory and departure time (admission to the hospital or discharge). The most important departure from the computer system was that the research assistant, with help from the nurses, recorded the time when the patient had contact with physicians. In the first test week, the nurses got instructions every day, to guarantee good registration. Fig. 4 shows the timeline and lists variables measured in the process. Additionally, we have used several derived variables in the analysis (e.g., number of patients in the ER at any given moment with a specific triage code) that we will discuss later in the paper.

In November 2004, there were records for 1103 patients. From the 1103 patients eight observations were removed because crucial data (like triage code and triage time) were missing; leaving us with 1095 patient records. For most measures, the completeness of the data was very good. These observations were complemented with 804 records collected in March of 2006; six of them were missing crucial data, so we used 798 records.

3. Analyses and results

In this section, using exploratory data analysis we examine three facets of MCL ER operational performance: (1) effectiveness of the triage system in rationing patient treatment; (2) factors influencing ER’s operational performance in general and the trade-offs in flow times, inventory levels (that is the number of patients waiting in the system) and resource utilization. In the next section, we will review the planned process and staffing changes to improve the ER’s performance.

Table 2 shows some aggregate statistics for the total time spent in MCL ER (the time elapsed between the start of triage (registering with the triage nurse) and being released from ER) by triage code.

In the table, both the mean and the median of the total flow time per patient are shown because these distributions are significantly and positively skewed (there is an asymmetric tail extending to the positive values). Skewness statistics are in the neighborhood or in excess of three standard errors of skewness; the standard errors of skewness were estimated using the formula suggested by Tabachnick and Fidell (1996). The flow times are also, to a lesser extent, leptokurtic (too tall or peaked); in case of the “Green” and “Red” codes, we can speak of significant positive kurtosis (they are leptokurtic) as the shown statistics are 3.5 times greater than the estimated standard error of kurtosis (Tabachnik and Fidell, 1996).

Fig. 5, by showing data for individual patients, confirms that flow times for codes 2, 3 and 4 (green, yellow and orange) are surprisingly close to each other.

MTS standards set upper limits for patient waiting times. Fig. 6, on the horizontal axis, shows the time elapsed between triage and an ER nurse seeing the patient (lt.nurse). The vertical axis of the same graph shows the time difference between triage and the resident physician’s first meeting with the patient (lt.resid). The conclusion seems to be that in the overwhelming majority of the cases a nurse sees the patient within the time limit set. However, the waiting time for doctors is much longer; often they see patients later than required. For triage code yellow (code.tr: 3), for example, the norm is 60 min. There are only five cases that the nurses attended to more than an hour after triage but there are numerous instances with doctors’ lead time longer than an hour.

However, we must use some caution in interpreting this finding. In the dynamically changing environment of the ER where physicians and nurses are working in close proximity of each other, the patients’ conditions are frequently and routinely communicated. Consequently, even though the physician may have been “late” to see the patient (as the record shows), he/she may have been aware of the patient’s condition and the treatment administered.

We used regression tree analysis (Brieman et al., 1984; Vastag et al., 1996) to classify the patients into more homogenous groups; see Fig. 7. This method looks at all possible splits for all variables included in the analysis, and it conducts searches through all of them. The process is considerably simplified.
because the method always asks questions that have a yes or no answer. The next step is to rank each splitting rule on the basis of a goodness-of-split criterion. One criterion commonly used is a measure of how well the splitting rule separates the classes contained in the parent node. Once a best split is found, the search process is repeated for each child node and continues recursively until further splitting is impossible or stopped for some other reason (e.g., the node has too few cases). We used the trimmed mean loss function (20% of the extreme observations are removed before computing the mean) that gave a PRE (proportional reduction in error) value of 0.334. The cutting variables were the specialty codes and the number of lab requests: if patients are assigned to general surgery (specialty code = 1) or plastic surgery (specialty code = 2) and have no lab requests (no_lab < 1) then, on average, these patients (there are 395 of them) spend 69.1 min in MCL ER. On the other hand, there were 392 patients (most of them assigned to internal medicine) who had at least one lab test; on average, their time in the ER was 151.9 min.

Historically, MCL ER tried to schedule the nurses to anticipate the demand, the number of patients in the system. Using a manufacturing term, patients represent work-in-process in inventory and they can be in two areas: either in triage (in the system and waiting for admission to the ER) or in the ER. Using 2004 data, the number of triage and ER patients by the minute from the midnight of the start of the week.

Putting it in a different way: a reduction in flow time cannot be achieved without a reduction in the average number of patients in the system (“where there is WIP, there is flow time,” Hopp, 2008) but the latter, inevitably, will lead to questions about resource utilization. This seemingly trivial but often overlooked insight is the direct consequence of Little’s Law: [Flow Time] = [WIP]/[Flow Rate]. If the average utilization of 40% (that is on average 40% of the beds are occupied) is raising eyebrows then reducing flow time, which is one of the stated goals of ERs, inevitably will lead to an even lower utilization level.

4. Suggestions for improvement

The four proposals considered by MCL ER management all aimed at reducing variability and thus fit nicely with process improvement literature. We will discuss these proposals one-by-one although they may have the best effect if used together.

4.1. Establish designated tracks (“fast track” and “diagnostic track”)

The basic idea here is to create more homogenous groups of processing times by removing the two ends of the distribution: the patient groups that either do not require major intervention (→ “fast track”) or those that spend more time in ER but their condition is stable (their triage code is either blue or green) and most of their time in the ER is spent with waiting for test results (→ “diagnostic track”). As an illustration, Fig. 9, using 2004 data, shows how much more time the non-urgent patients on the “diagnostic track” spend in the ER compared to others. Establishing a diagnostic track would also reduce the arrival variability, as these patients are not real ER patients: they can be scheduled in advance, so they could potentially free up treatment capacity for other patients.

The “fast track” approach is also known as a “see and treat” strategy (King et al., 2006) where patients are seen by senior decision-making staff who immediately discharge (at least this is the intention) a substantial number of patients. In MCL, after visiting the ER more than 40% of patients are admitted to the hospital. This high acuity level probably would not justify the establishment of the “fast track” or the application of the “see and treat” strategy.
4.2. Creating a holding area for certain type of patients

This proposal, very much like the bar in a Benihana restaurant, would reduce arrival variability by buffering non-urgent, schedulable patients (like the ones on the diagnostic track, for example) and thus achieving higher utilization on some critical resources.

4.3. New protocol that would allow registered nurses to order testing and treatment for some patients

Using a protocol for easy, standard cases would contribute to reducing the variation in processing times and at the same time would reduce the load on the doctors. This suggestion also fits well with the notion of deskilling where complex work processes are broken into smaller, simpler and unskilled tasks.

4.4. Moving from non-ER specialist physicians to ER specialists

Currently, there is a significant variation in processing times by specialty (internists, on average, take more time than surgeons; see Fig. 10) and by experience; inexperienced residents, on average, are associated with longer times in the ER than experienced ones.
Teaching and employing an ER specialist, like in the U.S.A., would mean greater standardization in procedures and approaches and would contribute to reduced variability in processing times.

These proposals individually, or taken together, would create more homogeneous patient subgroups and reduce both arrival and process variability in the ER.

5. Conclusions

In this paper, we outlined both production control (see for example Malakooti et al., 2004) type of improvements (Proposals 1 and 2) and ideas more related to organization and technology (Proposals 3 and 4). Our focus has been on the
former group, proposals that are directly related process improvement.

The problem with triage, as a prioritization tool, is that urgent patients will always override the less urgent ones (even though there are time limits for all triage classes) and, therefore, the average flow time will be approximately the same in all triage categories. As we found out, in predicting total flow times, specialty codes (surgery versus internal medicine, for example) and the number of lab requests were the key variables and they are not the control of an operations manager.

The diagnostic path, however, can free up capacity for the real urgent patients. The fact that the visits by these patients, to some extent, can be planned (within 24 h) means that it is possible to smooth the demand, which can have a positive effect on lead times during the busy hours.

King et al. (2006), in an environment similar to MCL, introduced a simple modification to the triage-based ER. In the first step, the triage nurse assigns the patient into one of two groups: (1) dischargeable or (2) admissible. This classification is based on her/his judgment of the patient's predicted outcome: the patient will either be discharged after the examination or be admitted to the hospital. The emphasis here is not so much on the accuracy of the prediction (triage nurses were accurate about 80% of the time) rather it is on the speed of the classification. In the dischargeable group, the priority rule is FIFO but patients could be re-classified to the other group. Triage is used only in the admissible group but even there the priority rule for the less serious categories can be changed to FIFO. These simple changes led to significantly shorter flow times in all patient groups and, consequently, the number of patients in the ER was also reduced.

While the ER system reported here is quite general and can be found in many countries, the study’s findings should further be validated with data from other ER models using approaches of causal modeling (e.g., Bayesian networks) and/or simulation.

References


Malakooti, B., Malakooti, N.R., Yang, Z. 2004. Integrated group technology, cell formation, process planning, and production planning with application