

PROCESS DESIGN IN A WALK-IN EMERGENCY DEPARTMENT

Decreasing a throughput time by re-designing a layout

Bachelor's Thesis
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Abstract

Overcrowding in emergency departments (EDs) is a highly reported phenomenon that burden both patients but also health care professionals. Length of stay (LOS) increases, health care professionals get frustrated, they make more errors and patients suffering from pain prolongs. The ED can be seen as a process where LOS is equal with throughput time (TPT). Patients are flowing from a phase to another and there can be waiting time between phases. Process type is then a job shop.

There are multiple reasons for overcrowding that can be divided into three categories: input, throughput and output factors. Health care professionals and the managers can have little if any power to change problems behind input and output factors. The thesis is then focussing on throughput factors.

Inadequate staffing and inappropriate layout of the ED are causing an increase in the TPT. For example, a new layout in a triage could be one solution for problem and especially a physician-lead triage has been studied. The triage is the part of the ED process that is evaluating need of care considering patient's medical condition. A physician in triage have decreased the LOS significantly.

Patients in the ED can be seen as work in process (WIP) and overcrowding changes the character of process caused by increased WIP. For instance, complexity and uncertainty of process increase. Industrial engineering process management has been utilized to the ED process. TPT has decreased after applying the principles of Lean management. Cost savings have not still achieved.

Based on my personal experience, the current system in EDs have problems in process design, communication and lack of collaboration between health care professionals. In this bachelor thesis, I aimed to decrease TPT by redesigning the layout of one walk-in ED in Uusimaa. The main idea was to highlight benefits of teamwork and to find a solution that reduces things unnecessarily repeated. Objective was an average throughput time (TPT) of a patient in the ED.

The re-design in this bachelor thesis led to 6.75 % reduction in TPT. The data was based on my empirical findings, so evaluating the significancy is not possible. However, similar findings have been described in the literature. To critically evaluate the layout of the ED, similar calculations should be done with real-life data.

Careful process design in the ED decreases TPT and helps with overcrowding problem. LOS of patients is only one objective to measure in real life. Population's life expectancy prolongs and need for medical care increases. To maintain current level of healthcare services, cost savings must be achieved. The effects of the process design on costs would be a relevant further topic of research.

Keywords emergency department, throughput time, length of stay

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1 Introduction

Overcrowding in emergency departments (EDs) is a phenomenon that has been recently discussed widely in the news. Indeed, overcrowding has multiple negative effects on patient care; length of stay (LOS) increases and patients suffering from pain are prolonged. Also, these factors can affect the mindset of the healthcare professionals negatively, leading to more malpractices. (Derlet & Richards, 2000; Salway et al., 2017)

In general, a patient visit in an ED can consist of a variety of actions. In addition to a patient seeing a nurse or doctor, some laboratory tests can be taken, radiologic examinations done and the patient may need evaluation from other professionals such as a physiotherapist. Each action takes time and there can be waiting times between actions (Kiran & Smith, 1984b). LOS is then consisting of various parts.

For example, the following causes for overcrowding have been described in the literature: overall increase in patient volume, professionals' time management problems, delays in providing supporting services such as laboratory and the shortage of staff (Derlet & Richards, 2000).

1.1 Research objectives and research questions

In this bachelor thesis I will focus on how to decrease throughput time (TPT) that equals with LOS in emergency departments. Further focus is on process layout changes in the ED. Without a doubt, resources of the EDs are limited. Based on that, the aim is to study how to get patient flow faster.

1.2 Scope of research

In this bachelor thesis I will study overcrowding in walk-in ED that is for minor traumas and for patients who are not coming to the ED by ambulance. There are no bed places for patients. The perspective is rather mechanistic, and the ED is modelled as a product line. Major-traumas and other more critical medical conditions need more experienced personnel and wider range of facilities, thus EDs that are handling critical patients are excluded from this study.

Bed place logistics operate differently. Remarkable cause for bed place overcrowding is boarding that refers to the practice of holding people in ED due to the lack of available places in follow-up care (American College of Emergency Physicians, 2018). Dealing with those problems exceed the purpose of this work.

1.3 Methodology

Firstly, I go through literature review on the topic of overcrowding in the ED. A perspective of industrial engineering is included to review. Main databases for the literature review were Scopus and Google Scholar. The aim was to find variety of different references, from textbook and review articles to original publications.

This bachelor thesis will include insights of working in the EDs based on my experiences as a physician role in several EDs. In this thesis my role as a participant is emphasized. If there is not any refer indicated for data, it is based on my experience from the work in the ED.

After the literature review, I set up an illustrative case for ED layout changes. Finally, I will discuss on the results and compare those to the previous literature.

1.4 Structure of the research

The rest of the thesis is structured as follows. Chapter 2 reviews the previous literature on overcrowding phenomenon and provides the theoretical framework for this study. Chapter 3 presents a case on layout design with an aim to reducing in TPT. Chapter 4 presents the results of the case In Chapter 5 I will discuss on implications, limitations and further steps of the bachelor thesis.

2 Theoretical background

In this section I will go through the general aspects of the EDs. The main focus is on the problems in ED that are causing overcrowding and possible solutions for such problems.

Firstly, I explain couple of main terms for thesis purpose (Cachon & Terwiesch, 2018):

- Throughput time (TPT) is referring to the total time that it takes a customer or a unit to go through whole process.
- Work in process (WIP) in referring to a number of customers or orders that are in a process or in a waiting line for process. The correlation between TPT and WIP is described in Little's law: $TPT = WIP * CT$ (CT; cycle time that is referring the average interval time that the process is outputting customers or orders).
- A bottleneck is the point of production system that stops or remarkably slows the system leading delays.
- Idle time refers to the working time for employee that is not used "productively" for production or services.

2.1 Emergency departments

In general, people can face acute medical conditions for which they want to be evaluated by medical professionals right away. EDs are for such purposes. The three most common disease spectrums in EDs are respiratory, cardiovascular, and gastrointestinal diseases (Liu et al., 2022). Typical symptoms are chest pain, breathing difficulties and stomach pain.

In Finland the basis of acute medicine is built on public sector EDs varying in size. Starting points for patients being evaluated for the first are health care centre EDs and if the condition might need hospital care, the patient is referred to nearest appropriate hospital. More critically ill patients are instructed straight to apply to the hospital ED.

Centralization of ED services have been a partial solution for utilizing limited health care resources (Beivers & Dodt, 2014) and many health care centre EDs are closed outside of office hours. Patients in those areas are now going to nearest hospital EDs that can be tens or hundreds of kilometres away.

EDs can be seen as dynamic job shops (Kiran & Smith, 1984b). Most often patients (= job) require several different operations from different health care professionals and diagnostic machines. Patients are arriving to the ED randomly over time.

2.1.1 Patient flow in ED

The ED is a process-rich environment. When arriving to ED, a walking patient is first encountering nurse-triage (Figure 1). Triage is a critical process in ED and it is ensuring clinical justice for patients taking the limited resources into account (FitzGerald et al., 2010). Large part of acute medical conditions happens outside of office hours. Even if a medical condition is acute for a patient, from the perspective of the health care system the problem can wait for the next day. Outside of official hours resources are narrower and the purpose is to diagnose and treat certain types of acute medical conditions. During office hours wider resources are available and a wider range of medical conditions can be evaluated. In the best scenario the appointment can be settled for the next day.

Based on patient's background, symptoms and clinical appearance triage is categorizing how fast a patient must be examined (FitzGerald et al., 2010). There are different methods to scale the urgency of patient. However, the main idea is to judge, if the need of examination and treatment is immediate, urgent or non-urgent. Most commonly, walk-in patients are categorized to either urgent or non-urgent.

If patient's condition needs evaluation from health care professionals, the next step in the ED flow depends on the situation and the condition of the patient (Figure 1). Some conditions can be examined and treated by nurse-practitioners or triage nurse can do referrals for laboratory tests or x-rays. These actions improve ED flow (Abdulwahid et al., 2016).

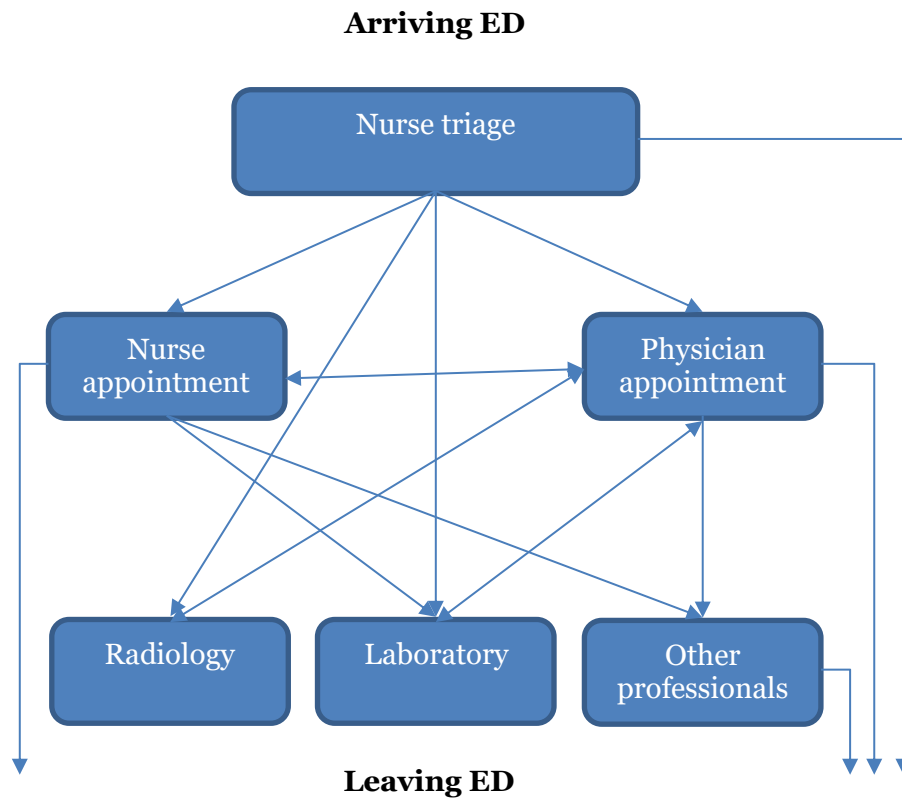


Figure 1. Patient flow in ED

Figure 1 is showing the mutual interaction between health care professionals:

1. Some conditions can firstly seem appropriate for nurse practitioner but then might appear something that needs action(s) from a physician. It is not necessity that a physician sees a patient but can also act as a consultant for nurse-practitioner.
2. Patient can have multiple problems and physician is not alone handling the whole situation. In that case patients can be referred from physician to nurses or other professionals as physiotherapists.

Often, a patient has visited the nurse-practitioner before physician's appointment (for example, blood pressure, pulse and blood saturation measurements are usually taken by a nurse) and further examinations have been in advance conducted, such as laboratory tests. Physician might still need to take more examinations before patient leaving from ED.

As shown in the Figure 1, a patient can flow through the ED various ways. In the ED a patient may have to wait in several different queues which is typical for a job shop (Kiran & Smith, 1984b).

2.2 Causes for overcrowding at ED

ED functions have been divided into input, throughput and output stages to identify issues causing overcrowding (Asplin et al., 2003). Then there are three categories of causes for overcrowding (Hoot & Aronsky, 2008):

- Input factors (for example nonurgent visits)
- Throughput factors (for example inadequate staffing)
- Output factors (for example hospital bed shortage)

Trying to control input and output factors is difficult if not impossible for ED staff or even for ED managers (Abdulwahid et al., 2016). For instance, an entry to follow-up care depends on resources of other departments than ED's. On the other hand, the politics affect the input of patients due to decisions considering EDs. Based on these, input and output factors are not discussed further in this thesis.

Throughput stage in the ED has two phases. The first includes functions from triage to the initial evaluation from medical professional and the second covers diagnostics and treatment provided by the ED. (Asplin et al., 2003)

The second phase is typically constituting the majority of throughput time (Asplin et al., 2003). Delays between different functions of the ED process accumulate and cause increase in LOS, for example waiting for radiological examinations, laboratory tests or medical consultation (Lindner & Weitok, 2021). Patients that need laboratory services, have been found to have longer LOS. Then again, longer LOS increases the risk for negative patient outcomes. (Yang et al., 2016)

Inadequate staffing is one of the main throughput factors. There can be imbalance between different medical professionals and especially lack of physicians and triad nurses cause longer LOS (Hoot & Aronsky, 2008). Bottle necks of ED process are easily formed in the phases where there are scarce resources. A layout design of the ED affect the efficiency (Ahmadpour et al., 2021). Several other factors affect also TPT during second phase, for example accessibility of medical information, quality of documentation and communication systems (Asplin et al., 2003).

2.3 Effect and consequences of overcrowding

From the perspective of process management, overcrowding means an increase in WIP. When returning to Little's law, TPT increases when WIP increases (if CT remains same as it is supposed to be with similar resources).

High levels of WIP change the process introducing an increase in the following characters (Cachon & Terwiesch, 2018):

- Complexity
- Vulnerability to error
- Uncertainty
- Delays in information transport

There are various consequences for overcrowding. To conclude, overcrowding results poor patient outcome (Carter et al., 2014).

2.4 Insights from perspective of a physician

TPTs are measured in the EDs. Most patient information systems contain a timer combined to each patients' data during their visit in the ED. The timer calculates TPTs, that are measured in hours even if the condition would need short evaluation from health care professionals. An average appointment time for nurse practitioner is 10-20 minutes and for physician 20-30 minutes and laboratory tests or radiologic examinations take approximately 30-45 minutes. TPT is relatively commonly around 4 hours, thus major part of the time is waiting for the next step in ED process and the process is then inefficient.

The following factors indicate that physicians are often the bottlenecks of ED:

- Average queueing time for physician is almost without an exception double compared to one for nurse-practitioners.
- Results from radiologic examinations and laboratory tests are analyzed a long before a physician sees the patient.
- Utilization of physician capacity is high and there is often more to do than could be done.

One of the main tasks of ED is to recognize life-threatening conditions. The triage is a key player in that (FitzGerald et al., 2010). However, in some cases more information, such

as laboratory tests, is needed before the condition can be reliably confirmed. Nurse-practitioners are capable to work independently or after a short discussion with the on-call physician. If the discussion between nurse and physician leads to additional laboratory tests or radiologic examination, patient often moves to a physician appointment queue.

Nurses and physicians have their own appointment rooms. Communicating is then more complicated because it requires a phone call or visiting the other room. Effort that communicating requires, leads to medical staff do same tasks twice rather than communicating about them. These factors indicate that the layout of the ED is often problematic and not supporting efficiency.

The effects of an increase in WIP can be seen in practical work. The more patients, the harder to remember details of each patient. This increases the complexity of work. The details including laboratory test results are stored in the patient information system. Anyway, it requires extra time checking them more than once. Health care professionals are also more vulnerable to errors because there is bigger possibility to mix information between patients.

It is natural that overloaded work leads to less time for a professional to inform others leading to delays in information transport. Health care professionals are also using shortcuts to deliver information, for example making a note somewhere in the system instead of calling about the results. Such shortcuts are easily missed by others causing uncertainty whether specific actions have been done.

2.5 Emergency department and industrial engineering management

ED can be seen as a product line in which the operations follow each other. As companies want their machines work efficiently, health care service provider would like to EDs operate efficiently. Due to the variation in demand, EDs must be flexible. Flexible system with an aim to low costs is complex to operate (Co et al., 1989). Industrial engineering management have been used to improve ED process. The 21st century medical technology is delivered with 19th century organization structures (Porter & Teisberg, 2004).

Dickson et al (2009) set up a 5-day Kaizen event to apply Lean manufacturing principles in the ED (Dickson et al., 2009). The authors made changes for example in room utilization, triage, timing of orders for laboratory tests or x-rays and signages directing

patients in the ED. LOS decreased around 8.07%. Similarly, the patient satisfaction increased. Significant changes in costs were not achieved.

Torkki et al (2006) managed urgent surgery as a process and made non-medical changes to that. The authors rearranged the patient flow in the wards, reorganized operating rooms and process guidance was simplified. Waiting time for operations and throughput time in the process were shorter (Torkki et al., 2006).

2.6 Solutions for overcrowding problems offered in literature

Overcrowding of the EDs have been studied widely and there have been many suggestions to tackle the problem. Most of them are dealing with larger EDs than is the perspective of this thesis. Most studies are considering are also bed places, not only walk-in patients.

Placing senior physician at the triage has widely implemented previously (Abdulwahid et al., 2016). If patients can be handled already in the triage, their TPT is minimal (Abdulwahid et al., 2016; Rowe et al., 2011). Then again, short TPT reduces a risk for accumulating WIP further in the process. Methods decreased LOS remarkably (Abdulwahid et al., 2016; Rowe et al., 2011). Additionally, they showed that fewer patients left the ED without seeing a physician (Abdulwahid et al., 2016). Physician have also leaded queueing process in ED with success in process time (DeFlicht et al., 2007).

Various advanced triage protocols are proposed to improve the triage process (Yang et al., 2016). Fry et al. studied safety and appropriateness of distal limb x-rays ordered by triage nurses (Fry, 2001). They found that triage nurses can asses the need for x-ray with structured education. This possibility would decrease TPT as patients would not need to wait first for a physician and then again after being in x-ray.

Triage Fast-track care lines have been created for minor health problems to offer quick and simple treatment (Yarmohammadian et al., 2017). The idea is to reduce the average number jobs and the overcrowding in the ED (= job shop) by processing small jobs first (Kiran & Smith, 1984a).

Hammer C et al. set up a multidisciplinary team to address barriers to patient flow in the ED (Hammer et al., 2022). The multidisciplinary team had meetings regularly. The method decreased LOS statistically significantly. However, the authors focused more on patients in bed places, thus these results can not be interpreted with the aim of this thesis.

Diagnostics, including laboratory tests and radiologic examinations, cause an increase in TPT as mentioned in chapter section 2.2. Point-of-care (POC) tests can be run in appointment room and result will take only couple to minutes to be ready. These applications reduce LOS (Lindner & Woitok, 2021).

There are obvious strategies to tackle problems in the process design of ED, such as increasing resources in ED but that is not reasonable choice when we are thinking optimizing of scarce resources. There have also been attempts to get input of EDs lower. Furhmann et al. guided non-urgent patients to walk-in clinics with lighter resources (Furhmann et al., 2021). Then again, patients with urgent conditions could have been treated more efficiently in the EDs. The total number of patients arriving to hospital was same but subspecialties were not overloaded.

3 Case

In this case, I describe a resource layout of a walk-in part in an ED located in Uusimaa. Objective is TPT. The aim is to decrease the objective by re-designing the layout of the walk-in ED. TPT is defined as the time from triage to time of discharge. Shorter TPT would help with overcrowding problem.

3.1 Original set up

During the nightshift with duration of 10 hours, resources are following (Figure 2):

- 2 triage nurses
- 3 nurse practitioners
- 2 physicians
- Laboratory with staff
- Radiology department with personnel

To make the process easier, other medical professionals are not considered in this case, including physiotherapists. Also, only few walk-in EDs have such professionals available during nighttime.

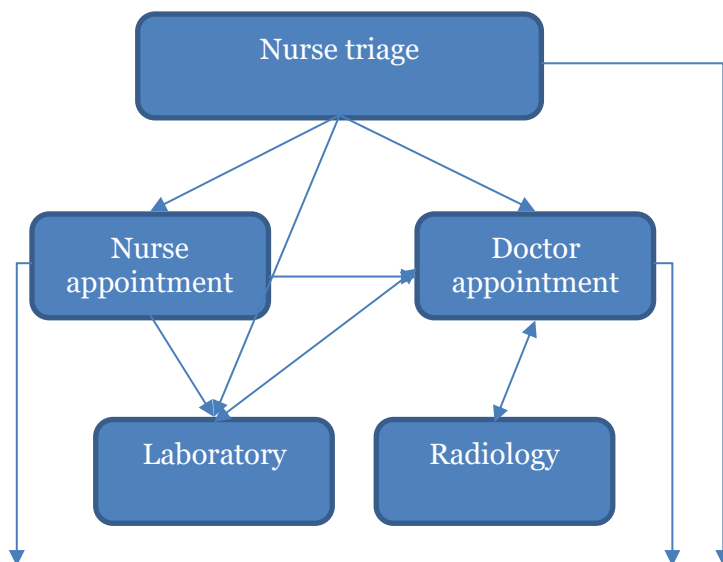


Figure 2. Case resources

3.1.1 Processing times and patients

Next, I will list the processing times of different phases in the ED process. There are variances in these processing times. To make calculations more practical, I will consider estimate values not including variance. The time spend in a phase is further spilt into smaller parts as described below. There can be alternatives for process times because of variety in medical condition. For example, other need further examinations and there must be referrals made.

- 10 min in triage
 - o 5 minutes for a medical history and 5 minutes for a plan
- 15-20 min in nurse appointment
 - o 5 minutes for a medical history and 5 minutes for a status
 - o 5-10 minutes for a treatment and a preliminary plan
 - 5 min, if not further examinations needed
 - 10 min, if there is need for laboratory tests because extra 2.5 min for referrals and 2.5 min for checking the results
- 20-30 min in physician appointment
 - o 5 minutes for medical history and 5 minutes for status
 - o 10-20 minutes for treatment and preliminary plan
 - 10 min, if not further examinations needed
 - 20 min, if there is need for laboratory tests or/and radiologic examinations; extra 5 min for referral(s) and then 5 min for checking the results
- 45 min for laboratory tests
 - o 15 min for taking the sample
 - o 30 minutes for analyzing
- 30 min for radiologic examinations
 - o 15 min for taking the imaging
 - o 15 minutes for analyzing

If a nurse practitioner asks medical history, a physician do not need to re-ask it. Status must be re-done always. Medical history asked by triage do not replace it in further phases.

In this case, it is assumed that there are no patients waiting before shift begins. Ten patients are arriving on average in an hour:

- 70 % of them need evaluating in the ED
 - o 40 % are guided for nurse-practitioner appointment
 - 20 % are leaving the ED after appointment
 - 10 % need laboratory tests and leave after those
 - 10 % of patients are re-guided for physician after nurse appointment and need laboratory tests
 - o 30 % are guided for physician appointment
 - 10 % are leaving the ED after appointment
 - 10 % need to see nurse before for examinations such as blood pressure or ECG measurements and laboratory tests referrals to be done
 - 10 % need radiologic examination

When nurses are taking blood pressures or other vital function measurements, they are using 10 minutes for “treatment”. They are not asking medical history or doing status. After nurse or physician sees the results from examinations, patients leave the ED.

3.1.2 Calculations

Capacities and amount of work for different phases are calculated:

- Triage
 - o Capacity: $2 \cdot 10 \text{ h} \cdot 60 \text{ min/h} = 1200 \text{ min}$
 - o Patient work: $10 \text{ patient/h} \cdot 10 \text{ h} \cdot 10 \text{ min/patient} = 1000 \text{ min}$
- Nurse appointment
 - o Capacity: $2 \cdot 10 \text{ h} \cdot 60 \text{ min/h} = 1200 \text{ min}$
 - o Patient work = 800 min
 - Own patient without laboratory tests: $0.2 \cdot 10 \text{ patient/h} \cdot 10 \text{ h} \cdot 15 \text{ min/patient} = 300 \text{ min}$
 - Own patient with laboratory tests: $0.1 \cdot 10 \text{ patient/h} \cdot 10 \text{ h} \cdot 20 \text{ min/patient} = 200 \text{ min}$
 - Re-guided patients: $0.1 \cdot 10 \text{ patient/h} \cdot 10 \text{ h} \cdot 20 \text{ min/patient} = 200 \text{ min}$
 - Measurements for physician appointment: $0.1 \cdot 10 \text{ patient/h} \cdot 10 \text{ h} \cdot 10 \text{ min/patient} = 100 \text{ min}$
- Physician appointment

- Capacity: $2 \cdot 10 \text{ h} \cdot 60 \text{ min/h} = 1200 \text{ min}$
- Patient work = 1150 min
 - Own patients without further examinations: $0.2 \cdot 10 \text{ patient/h} \cdot 10 \text{ h} \cdot 20 \text{ min/patient} = 400 \text{ min}$
 - Own patients without further examinations: $0.2 \cdot 10 \text{ patient/h} \cdot 10 \text{ h} \cdot 300 \text{ min/patient} = 600 \text{ min}$
 - Re-guided patients: $0.1 \cdot 10 \text{ patient/h} \cdot 10 \text{ h} \cdot 15 \text{ min/patient} = 150 \text{ min}$
- Laboratory:
 - Capacity: $1 \cdot 10 \cdot 60 \text{ min} = 600 \text{ min}$
 - Patient work: $0.3 \cdot 10 \text{ patient/h} \cdot 10 \text{ h} \cdot 15 \text{ min/patient} = 450 \text{ min}$
- Radiology department:
 - Capacity: $1 \cdot 10 \cdot 60 \text{ min} = 600 \text{ min}$
 - Patient work: $0.1 \cdot 10 \text{ patient/h} \cdot 10 \text{ h} \cdot 30 \text{ min/patient} = 300 \text{ min}$

People are not capable to work 100% of their time in a shift. Idle time is needed for eating, visiting toilet and having other necessary breaks. Idle time for physician is $50\text{min}/1200\text{min} = 4.17 \%$ that is rather low.

Physician are using only 15 minutes for re-guided patient, because they are doing status and then treatment/plan in 10 min. Laboratory tests have been taken in advance with referral form nurse. Medical history has been asked by the nurse.

3.1.3 Process flow



T = triage

W = waiting

N/P = nurse / physician appointment (or results checking)

L/R = laboratory tests / radiologic examinations

Figure 3. Process flow

All the patients face triage in the beginning of their flow. In the case they are taken into the ED, the patients move to a waiting room. Capacity is bigger than patient workload so patients should not wait more than process time of that phase.

- Waiting for appointment in phases 1 and 6: 0 – 20 minutes for nurse appointment and 0 – 30 minutes for physician appointment. Averages are 10 and 15 min because of linear probability.
- Waiting time for laboratory tests/radiologic examinations, phase 4: 0 – 15 min. An average is 7.5 min because of linear probability.

There are seven different phases for patient in the ED. All the patients are not passing through every phase. Percents are referring to total amount of patients arriving to the ED.

100 % of patients are facing triage in phase 1.

70 % of patients are taken in so they are at least in phases 2 and 3. In phase 3 50 % are in the nurse appointment and 20 % in the physician appointment. 10 % of nurse appointment patients are only there for checking blood pressure, ECG etc.

30 % (20 + 10 %) are leaving the ED after first appointments and 40 % of people go through phases 4 – 7.

In phase 5 30 % are in laboratory tests and 10 % in radiologic examinations.

In phase 7 10 % are in nurse appointment for laboratory result check, 10% are re-guided patient for physician appointment, 10% are patients with blood pressure, ECG and laboratory tests for physician appointment and 10% are radiologic result checks for physicians.

3.1.4 Throughput time

Summing up all previous information, average TPT for process is following:

$$\text{TPT} = \sum_{k=1}^7 \text{patients in phase } k * \text{duration of phase } k$$

$$= 1.0 * 10 \text{ min} + (0.5 * 10 \text{ min} + 0.2 * 20 \text{ min}) + (0.2 * 15 \text{ min} + 0.2 * 17.5 \text{ min} * 0.1 * 10 \text{ min} + 0.1 * 20 \text{ min} + 0.1 * 25 \text{ min}) + 0.4 * 7.5 \text{ min} + (0.3 * 45 \text{ min} + 0.1 * 30 \text{ min}) + (0.1 * 10 \text{ min} + 0.3 * 15 \text{ min}) + (0.1 * 2.5 \text{ min} + 0.1 * 15 \text{ min} + 0.1 * 20 \text{ min} + 0.1 * 5 \text{ min})$$

$$= 59.25 \text{ min}$$

3.2 New set up

The same actions could be done several times during the process. Medical history is partly taken in the triage, but the purpose is to decide whether a patient need to be taken in. That's why nurse practitioner or physician must revise the medical history of each patient from different point of view. Status is based on professionals' own findings, and every professional must do it individually. Some actions could be combined or be done concurrently.

Based on these findings and inspired by literature view, a new layout was built on the same resources.

3.2.1 New layout

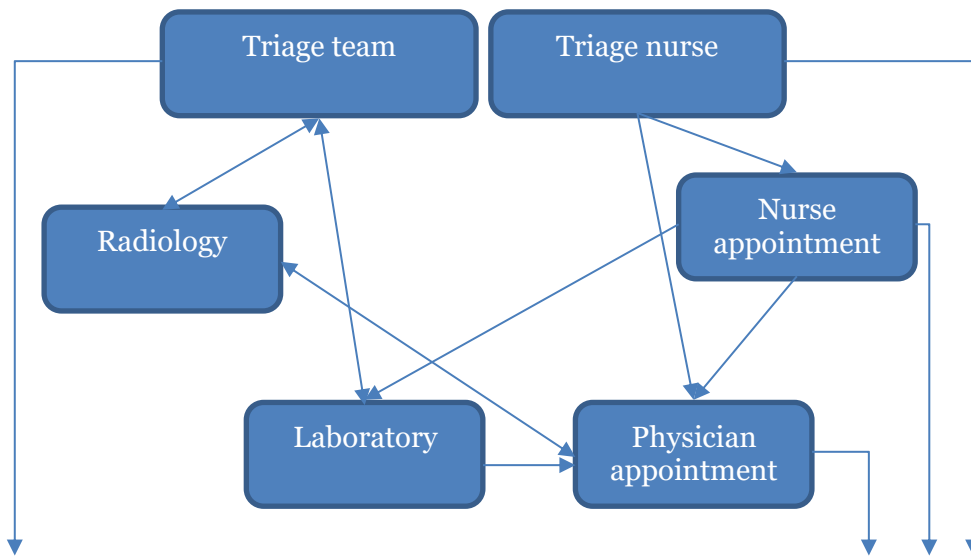


Figure 4. New layout

In the Figure 4 is new layout for ED process. Triage team is the main change compared to original layout (see Figure 2). The team consist of one nurse practitioner and one physician. They are cooperating with triage nurses and scan the incoming patients based on reasons why patients are in the ED. The triage team is focusing in the first place on patients that should be examined by nurse (blood pressure and ECG check etc.) before physician appointment. That allows nurse and physician work concurrently.

Triage team nurse and physician are working in the same room, and they can have also personal patients. Then the other party is scanning triage, checking results of patients or examining their own patients elsewhere. Physician tries to take all the patients that require radiologic examinations, as the results can be checked with collaboration of nurse. Indeed, it is more efficient to give instructions and for example crutches at the same time. Nurse asks physician to check re-guided patients before they are going to laboratory tests that after laboratory tests there it is only result check left.

The patients that triage team is not checking, are flowing normally to appointments. Straightforward conditions that need an appointment of one professional, are tried to guide for individual nurse practitioner and physician so there is not any unnecessary time spend from the other professional.

On average triage team is seeing 50 % of patients that need evaluation in the ED.

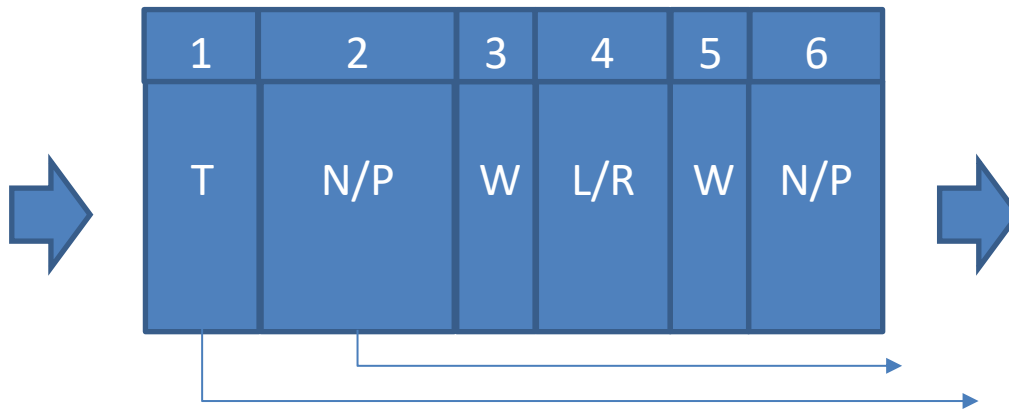


Figure 5. Process flow of triage team

Achieved benefits:

- If a patient is taken in, medical history is clear enough for the triage team.
- Re-guided patients need only one appointment before results check.
- Nurse and physician can operate concurrently

Appointment times:

- Pre-measured patients needed: triage phase 10 min, 10 min for measurements + status, 5 min for referral to laboratory tests and then 5 min to check results. In total those patients require 30 min.

Now there are two different process flows. 30 % are still leaving the ED from triage. Triage team take care on average:

- 10 % who need to examinations such as blood pressure or ECG measurements
- 10 % who need laboratory tests form nurse appointment and leave after those
- 10 % who need radiologic examination
- 5 % of patients who are re-guided for physician after nurse appointment and need laboratory tests

And “traditional line” operates on average:

- 20 % who are leaving the ED after nurse appointment
- 10 % who are leaving the ED after physician appointment
- 5 % of patients who are re-guided for physician after nurse appointment and need laboratory tests

Triage-team line, six phases (Figure 5):

- 50 % of all patients are facing triage phase 1.
- 35 % are taken in so they are at least in phase 2. 15 % are in the nurse appointment and 10 % in the physician appointment. 10 % of appointment are team appointments. All patients continue to phase 3-6.
- In phase 4 25 % are in laboratory tests and 10 % in radiologic examinations.
- In phase 6 10 % are in nurse appointment for laboratory result check, 15% laboratory checks for physicians and 10% are radiologic result checks for physicians.

In traditional line, seven phases (Figure 3):

50 % of patients are facing triage in phase 1.

35 % of those are taken in so they are at least in phases 2 and 3. In phase 3 25 % are in the nurse appointment and 10 % in the physician appointment.

30 % (20 + 10 %) are leaving the ED after first appointments so 5 % of people are in phases 4 – 7.

In phase 5 100 % are in laboratory tests.

In phase 7 5 % are laboratory result checks for physicians.

3.2.2 Throughput time

Throughput time is calculated with same principles:

$$\begin{aligned} \text{TPT} = & \sum_{k=1}^7 \text{patients in phase } k * \text{duration of phase } k \\ & + \sum_{k=1}^6 \text{patients in phase } k * \text{duration of phase } k \end{aligned}$$

$$= 0.5 * 10 \text{ min} + (0.25 * 10 \text{ min} + 0.1 * 20 \text{ min}) + (0.2 * 15 \text{ min} + 0.05 * 17.5 \text{ min} * 0.1 + 20 \text{ min}) + 0.05 * 7.5 \text{ min} + 0.05 * 45 \text{ min} + 0.05 * 20 \text{ min} + 0.05 * 5 \text{ min}$$

+

$$= 0.5 * 10 \text{ min} + (0.15 * 12.5 \text{ min} + 0.1 * 20 \text{ min} + 0.1 * 25 \text{ min}) + 0.35 * 7.5 \text{ min} + (0.25 * 45 \text{ min} + 0.1 * 30 \text{ min}) + (0.25 * 25 \text{ min} + 0.1 * 15 \text{ min})$$

$$= 55.25 \text{ min}$$

4 Results

TPT on average with original layout was 59.25 min and with new layout 55.25 min. An absolute reduction was $59,25 \text{ min} - 55,25 \text{ min} = 4 \text{ min}$. A relative reduction was $4 \text{ min} / 59,25 \text{ min} = 0.0675105\dots = 6.75 \%$.

5 Discussion and conclusions

The re-design led to decrease in TPT that equals with LOS. Similar changes in LOS have been found in previous studies with changes in a triage:

- 8 % (White et al., 2012)
- 7.4 % (Soremekun et al., 2012)

Besides, there are also controversial results with no significant decrease in LOS (Abdulwahid et al., 2016). The controversy could be due to that actions of triage are only one part of the actions executed in the ED, so it is logical to see that an influence is limited for LOS.

Because processing times were based on assumptions, the results cannot be interpreted in a clinic. But when considering other studies with similar results, possible decrease in the LOS could be achieved with suggested layout changes. However, before further changes will be done in real-life EDs, more calculations with data from real EDs should be done.

In chapter 2.2 were mentioned two phases of the ED process. The first is from triage to the initial evaluation and the second covers diagnostics and treatment (Asplin et al., 2003). In the case, LOS was mainly decreased in phase 1. Noticing that laboratory tests took 45 minutes to take and then comparing to average LOS being 55-60 minutes, laboratory tests were a major part of LOS. This is in the line with previous findings (Asplin et al., 2003).

It would have been possible to build two triage teams instead of one team with traditional workflow. However, effective actions of the team were based on selection of patients. It is not efficient to evaluate all patient in triage team because many professionals are using same amount of time to issue that can be handled by one professional.

In this case the benefits of teamwork gained reduction in LOS. Team-based working have been studied and both physician-nurse pair work and multi-teamwork have increased effectiveness and patient satisfaction (Farris, 1993; Powell & Biernacki, 2019).

5.1 Implications to research and practice

All values were assumptions; thus the reliability of the actual result is low. The layout of the case was real, and the result is showing that the ED should think there layout again. The aim of the thesis was to create a preliminary model to provide insight on the role of careful process planning. In a larger scale, the main goal is finally to improve the efficiency of EDs to reduce TPTs while providing high-quality treatment. Before the results can be interpreted into clinic, more advanced calculations with real-life data should be considered. However, similar results have previously been found with changes in triage.

5.2 Limitations and future research

As described in section 2, throughput factors are not the only causes for overcrowding. Input and output factors are playing a major role in a problem as well. Changes regarding those problems are more complex and require higher-level and multidisciplinary decisions that ED managers are not capable to do.

In many EDs the health care professionals are overloaded with work. Then in further calculations should also be considered effects on amount of work.

As mentioned also in section 2, POC tests have been used in the ED instead of traditional laboratory tests. In the case there was no use of those. POC tests take only couple of minutes to be ready versus traditional laboratory tests that take 30-60 minutes in the ED. Then actually implication of those would have had greater effect on TPT.

An effect of shorter TPT to costs in the ED would be interesting and current topic of research. It is speculated that a patient with longer TPT would need more nursing or physician time (Chan et al., 1997). Even if lean management have been used for the ED, cost savings have not occurred (Dickson et al., 2009). In the future cost savings are vital for health care sector because people´s life expectancy is higher and their need for health care increases.

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