

# Accident & Emergency Modelling

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## Abstract

This paper explores some of the dependencies involved in the operations of a typical hospital's Accident and Emergency ward, and how agents can help define the behaviour of processes involved in its operations. An attempt is made at agentification using the LSD notation. A model of the A&E ward built using *tkeden* is described and compared against a similar model built using SIMUL8, a popular modelling software.

## 1. Introduction

In today's businesses, computers are often used to make informed decisions when making changes pertaining to operations of the business such as staffing levels. Ill-informed changes often lead to the demise of the business as operations can be brought to a grinding halt.

There are plenty of modelling software available commercially, and most of these offer a high level of sophistication and accuracy in the modelling process. Often, one wants to define a business in terms of "stations" and "queues". This is particularly pertinent in a service-oriented business like a hospital, as time spent in the queue can have a direct effect on customer satisfaction levels and sometimes, mortality rate.

This paper discusses the applicability of Empirical Modelling (EM) concepts on an Accident and Emergency (A&E) ward and compares the use of EMtools for modelling it with conventional modelling software.

## 2. The Accident and Emergency Ward

When one visits an A&E ward, he usually has to take a number and wait for his turn to see a triage that will register him and take basic measurements such as blood pressure and temperature. Next, he waits for his turn to see the doctor before being discharged or warded as an in-patient. This is of course a simplistic view of the processes involved, as various auxiliary services such as x-ray often come in to play and may result in patients having to rejoin the queue to see the doctor.

From a patient's point of view, it is often not the time spent at the triage or doctor that constitutes the bulk of his time spent at the A&E ward. Rather, it is the time spent queuing

that is cause for concern (and often unhappiness).

### 2.1 The management point of view

From the management point of view, there is a fine balance to be struck between maintaining patient happiness and available resources. On one hand, it is desirable to minimize patient waiting times but on the other hand, there is a finite amount of resources to work with. Even if there were an infinite number of doctors and nurses, there are certain hard constraints that cannot be violated such as the number of rooms available.

For an application like the A&E ward, there is no magic formula that can correctly compute the staffing levels to cope with any given patient load (measured in terms of arrival rate). Managers often perform experiments on simulations before trying out new strategies in real life.

### 2.2 Applications of software for modeling

In a real life scenario like the A&E ward, modeling software offers an attractive solution to the difficulty of actually moving staff around to experiment to find an optimum staffing plan.

The use of software brings about a host of benefits:

1. The passage of time can be speeded up in a software model. This allows the user to rapidly model many scenarios in a short time.
2. There are no real world repercussions (usually) if the model turned out to be a failure.
3. Real world resource constraints do not apply to software, only computational resource restraints.

4. Experiments can be setup quickly be altering variables.

### 3. Empirical Modeling Concepts in the A&E Ward

This section of the paper looks at how Empirical Modeling concepts can be applied to the A&E ward model.

#### 3.1 Dependencies

Since the purpose of this modeling study is to find out average patient waiting time in relation to staffing levels, the concept of dependencies can be used. This is unlike statistical where consultation time (i.e. Time spent in the doctor's office or triage station) is usually expressed as a statistical distribution. As waiting time is very much dependent on the consultation times, an accurate statistical model needs accurate figures for its statistical distributions. For example, if one chooses to use a Normal distribution to model the time spent in the doctor's office, he needs to specify the mean and standard deviation before the model can be run. Suffice to say, to obtain these values is a major exercise in itself.

The modeller needs to be aware of various assumptions that need to be made when using any particular statistical distribution. With the Normal distribution example, one needs to assume that there is a very large number of samples, which is often not the case in real life. Also the modeller simply does not know if he has chosen the right distribution or not.

Empirical Modelling provides a simple way to avoid the tedious process of data collection. In a typical queue, it is usually the case that the amount of time spent in the consultation room diminishes when the size of the queue is big. In other words, it depends a lot on the current situation in the waiting room rather than some fixed distribution where individual samples are independent.

Movement of staff can also be considered a dependency as it is common practice for triage nurses to shut down a triage room and attend to patients in the queue so some patients can go straight to the doctors without having to wait twice. Since the purpose of this modeling study is to find out average patient waiting time in relation to staffing levels, the concept of dependencies can be used. This is unlike statistical where consultation time (i.e. Time spent in the doctor's office or triage station) is usually expressed as a statistical distribution. As waiting time is very much dependent on the consultation times, an accurate statistical model

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#### 3.2 Agents

In the A&E scenario, it was thought to be useful to look at the system from a broad context. As with most problems involving resource allocation, the modeler has to deal with many instances of the resource object, each of which can typically be thought of to be identical to every other instance of that resource in terms of its generic behaviour.

Triage stations can be thought to be agents in this context, as can doctor consultation rooms. For the purposes of this report, I shall talk about triage stations only as both are similar in terms of behaviour. The LSD notation can be used to specify these agents.

Beynon (1986) said that "in developing the LSD description, the first step is to identify the states, derivatives and oracles for the principal processes". Hence we need to specify the variables that are "subject to change beyond the user's direct control"(Beynon, 1986) (oracles) and the derivatives ("variables that are subject only to indirect changes of value"(W.M.Beynon and M.D.Slade, 1990)). The LSD specification for a triage stations is given:

```

agent triage_station (name){
  oracle triage_queue_size
  state staffed[name]
  derivate time_left[name]
  protocol
  staffed[name] ^ (time_left = 0) -> time_left(N)
}
staffed[name] ^ (time_left = 0) ^ (triage_queue_size > 20) -> ~staffed[name]
}

```

Figure 1: LSD specification for the triage station

The LSD specification for the doctor agent is similar.

## 4. Current Modelling Software

There are many modelling software tools available in the market these days, each with its own audience. This section of the paper compares the use of Empirical Modelling Tools (tkeden) against the use of a popular modelling software, SIMUL8 (Corporation, 2005) for the purposes of modelling an A&E ward.

### 4.1 SIMUL8

SIMUL8 is a popular modelling software used often in academia. In the University of Warwick, it is the software used in the Warwick Business School module, IB211 Simulation. In this 100% assessed module, students are required to build a software model of a business and conduct experiments on their models. Popular scenarios used for the assignment include service stations, airports, restaurants and hospitals.

This modelling software has a graphical user interface to allow users to build a process based model of a business. The four main components are entry and exit points of customers or products, queues and stops representing processes. The user can specify the time spent at each process in terms of a particular statistical distribution function and setup conditional routing algorithms for individual units.

The use of tkeden for modelling the A&E ward is compared against a similar model submitted by a student for the IB211 module built using SIMUL8.

#### 4.1.1 Strengths of SIMUL8

As a tool aimed at the business community, SIMUL8 “comes with everything you need to start building simulations straight away”(Corporation, 2005). With its simple user interface, users can build their model interactively using only the mouse. Processes can be linked to one another by simply clicking and dragging the mouse. Thus the process of building a simple model that is aesthetically

pleasing requires no programming knowledge at all. Simple animations can also be created to show the progress of the model during runtime.

Advanced features allow the user to use the various built in mathematical and statistical functions to model any aspect of the model that lends itself to such functions. Also the software provides a simple propriety declarative language to specify advanced behaviour of the model.

The biggest strength of the software is its ability to easily create runs of the model and collect data generated as a result of these runs for analysis.

### 4.2 SIMUL8 and tkeden

The greatest differences between the two approaches of modeling lie in the way variables (or observables in the EM context) are defined. Tkeden uses redefinition of observables which can have an “instantaneous side-effect[s] upon the values of other variables” (W.M.Beynon and M.D.Slade, 1990). When an observable changes value, any other observables depending on it changes value immediately as well. In the declarative approach used by SIMUL8, each and every other dependent variable needs to be manually updated by the modeller, resulting in the need to implement every dependency.

Tkeden is lacking in the mathematical faculties (to the best of the student’s knowledge) in that modeling complex functions like the Normal distribution is not entirely straightforward in tkeden. The use of statistical models often means that each sample is independent, so it would represent statements like:

“Doctors spend an average of x minutes with each patient”

with respect to the A&E context. This does not take into account the other factors affecting the time spent with patients by the doctor.

Tkeden on the other hand, is better suited for modeling behaviour such as:

“If the queue is long, I spend less time with each patient”

which means that the time spent by the doctor with each patient depends on the size of the queue at that time.

In light of the superior mathematical abilities of SIMUL8, the results produced by SIMUL8 should be more accurate than the corresponding data in a similar tkeden model. This is of course based on the premise that detailed studies have been conducted to justify the test data used in

the model. However, if it is a prototype model that one needs to build, then tkeden is likely to be more useful as dependencies can easily be defined in tkeden.

For this modelling study, it is expected that the model should be able to reflect behaviour described by the second statement above.

## 5. A&E Model

For this section, it will show the details of the model built by using tkeden tool. Due to the variety of using purposes and also the level of complexity to different types of users such as accitecures, doctors, nurses, etc, there are 4 models have been built. All of them will be explained in more details as follow.

### 5.1 Model 1

In all the models, the flow of serving patients is:

Arrival → Join the queue for triages service → Being served by Triage → Join the queue to see doctor → Being served by doctor → Discharged.

There are 5 triages and 5 doctors. There is option to change whether the triage/doctor is working today (or suddenly close, leave early) by using TOGGLE buttons. This will show in more accurate the statistic of service's performance in different time with varying amount of staffs. Working status: 'A' for available, 'B' for busy serving patient and 'O' for not working. These 3 statuses will be switched whenever using the TOGGLE button.

In this model, we use the uniform distribution in term of time for patient's treatment. It means the time treated by triage and doctor is set to be the same, saying 30 minutes per patient. It is set as the variable X on the screen. Whatever value of X change, it changes the serving time for the patient as well. The variable name of X is uniform\_time. About the arrival rate of the patients, the amount is also defined in term of value of X minutes, such as 7 patients in every 30 minutes.

Right after the patient is served by one of the triages, the patient will join the queue to see the doctor. The number of patients on the doctor queue is increased right after being released from the triage's room. But that number is also decreased if one of the doctor is available. Remember that the time treated by the doctor is the same as the time treated by the triage.

As described, the number of patients on the triage queue or on the doctor queue is updated every uniform\_time period by using the clock parameter,

The number of patients being served in A&E is increased everytime the uniform\_time period is finished.

### 5.2 Model 2

Since it's quite simple to assume that the time patient being served by the triage and the doctor are uniform and equal, the model 2 has improve the dependency of these two observables.

Therefore, two new dependencies are set up for 2 new observables: triage\_treatment\_time and doctor\_treatment\_time. Since as described in the previous section, the time for patient is very depended on the size of the queue. If the queue is too long, the triage needs to be more efficient in term of time checking the patient. And each patient will need the minimum time of treatment. For the case where the patient's health problem might take unusual long time, the model takes into account the extra random treatment time.

Hence, if the two observables are depended on the length of the queue, the minimum treatment time and the extra treatment time (due to different health problems).

Therefore, to be more accurate and make uses most of the new observable, two new clocks variables are created in order to keep eyes on when the patient is finished and when they are served etc. Everytime these clocks are incremented, it will update the triage/doctor treatment time for the patient due to the change of the patient queue.

By this model, it will produce a more realistic statistic in term of how wellthe service has performed, the queue situation at some period of the day and how busy the doctor or triage is if the treatment time is small in most of cases.

### 5.3 Model 3

This is the improved version of model 2, where it takes into account the arrival rate problem of new patients. We could not assume that the same number of patients will arrive at every fixed period of time such as 5 patients at every 30 minutes.

By using research and investigation, we decide that the number of new arrived patient can't be more than one specific number if the uniform\_time is less than certain number, say 60 minutes. And if the uniform\_time is set more than 60 minutes, then the new patients will be dependent on the preset arrival rate in each minute.

Hence, the new observable is defined that it is dependent on the value of the uniform\_time

and the arrival rate. Remember that the arrival rate, the minimum number of new patients and the `uniform_size` can be reset by the user.

This model give a more random impact on the behaviour of the triage queue and numbe of new patients. This helps to forseen the problem in organize the staff and manage the queue situation.

#### 5.4 Model 4

This is the final model where it takes into account the situation of the queue is too long. Since due to the fact that not every one need to see the triage before seeing the doctor, it will create the problem of long-waiting time for patient and crowded in the queue for those who don't need triage attention.

So the idea to reduce the queue size and reduce the average waiting time of patient, one of the triage will temporarily close their room after they finish serving the current patient. And he will go out to the triage queue and check the patients quickly to decide who still in the queue and who will skip this queue and join the doctor queue since their problem is not required triage attention.

Hence, saying if the queue size is more than 70, one of the triage will come out and help to reduce the queue. The model will take randomly up to 10 patients off the triage queue and join to the doctor queue. The checking activity is updated at every period of time to keep tracking on the queue size, by using `moved_clock` observable.

The new status 'C' of the triage indicates that the triage is temporarily out to check the queue and will get back when the queue size is less than the `max_queue_size` observable.

## 6. Conclusion

The A&E models have successful give the overview of the queuing system. It involves with several queue situation at both uniform time and also randomly behaviours of the staffs and also the arrival rates of new patients. There are several new improvements on the models such as keep eyes on the common medicine resource such as blood, water, sample tables etc or even the case when doing surgeon or people drops the queue after waiting at such specific long time.

### Acknowledgements

### References

Meurig Beynon. The lsd notation for communicating systems. *Computer Science Research Report 87, 1986.*

SIMUL8 Corporation. Simul8. ON-LINE, 2005. URL  
<http://www.simul8.com/products/>.

Ari-Pekka Hameri. Some simple models of scheduling and patient choice in accident and emergency (a&e) departments. ON-LINE, 11 2005. URL

<http://www.hec.unil.ch/>

[ahameri/cours3/](http://www.ahameri/cours3/)

[docscours3/DS Reading 2.pdf.](#)

R.A.Orr W.M.Beynon, M.T.Norris and M.D.Slade. Definitive specification of concurrent systems. In *IEE Conference Publications 316, 1990.*

Anthony Codrington-Virtue. Simulating Accident and Emergency Services with a generic process model. URL

<http://www.iol.ie/~rjtechne/millard/nsk56/acv56.htm>

Department of Health, How the EOR AE model works. URL:

<http://www.healthcareworkforce.org.uk/C12/Planning%20Tools/Project%20Documentation/how%20the%20EOR%20AE%20model%20works.doc>