

Strategic Emergency Department Design: From static estimation to dynamic capacity planning.

An experience report from a Swiss University Hospital emergency department

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Abstract

The ability of an emergency department to meet current demands is cause for increased concern amongst health care professionals and the public. Increased demand for emergency services, particularly throughout the United States of America, has reportedly reached crisis proportions. Numerous efforts have been made to explore the complex causes, because it is becoming more and more important to provide adequate health care within tight budgets. Optimisation of patient pathways in the emergency department is therefore an important factor.

This paper explores the possibilities offered by dynamic simulation tools to improve patient pathways using the emergency department of a busy university hospital in Switzerland as an example. Significant conclusions can be drawn from such simulations, resulting in more efficient processing of patients. Health professionals and administrative staff often have difficulties in seeing one common problem or goal. Our experience has showed that dynamic simulation stimulates staff with different backgrounds to discuss the challenge of rationalisation in a more objective and therefore more productive way.

Introduction

In both the USA and Europe, emergency departments (EDs) are confronted with overcrowding and budget restrictions. The profile of the patient population is also changing and is highly dependent on cultural context and developments. Furthermore, hospital management and the health authorities have an ever increasing need for more information for financial planning and health policymaking. These factors all provide a stimulus to analyze and improve internal processes in EDs. Traditionally, such design-relevant problems were solved by means of static (quantitative) estimates, but the use of a qualitative dynamic systems (DS) approach seems to be more appropriate. We used data from our department to map the system conceptually based on patient pathways from admission to discharge. Patterns of activity, demand, and system bottlenecks were simulated with this map and used to construct a quantitative DS model.

Dynamic planning tools have been well established for many years in aviation and other industries (i.e. reservation systems, technical and supply planning). In contrast, in the healthcare sector, planning has traditionally been based on static estimations with limited significance. EDs, with their numerous parallel and diverse processes, are ideal candidates for the quantitative DS model approach.

Currently, at the University Hospital in Berne, we are confronted with all the above problems, and also face the challenge of planning the future of our core processes in a new emergency department building. We have therefore been forced to find new ways of dealing with these problems.

We show here how a DS model approach can help to solve strategic design challenges in emergency department capacity planning, and demonstrate the significance of such a design feature in achieving strategic and political success.

Current situation, methods, project team, data set, software for simulation

Objectives:

The aim of this study was to highlight the possibilities offered by DS, by applying it to emergency department capacity planning and developing simulation scenarios.

Background:

The emergency department (ED) at the Inselspital in Berne, Switzerland, provides round-the-clock medical and surgical staff. The paediatrics and obstetrics/gynaecology divisions have separate emergency units at the hospital. We treat approximately 30,000 patients per year. An increasing patient volume has resulted in difficulty in reaching elective admission and bed occupancy targets. Computer simulation was selected to assist in meeting future objectives and targets.

Methods:

The goal was to solve complex problems within the framework of a process owner (the ED), a strategy owner (hospital management) and a model owner (systemic consultant) by implementing new ways of working together for all concerned in the hospital environment. It was also important to demonstrate the usefulness of the DS approach by collecting key data and transforming it from a static view into a dynamic understanding of a situation.

The collection of specific data and key information is strongly recommended in the context of ED design (1). Specific data, such as annual patient volumes, patient acuities, and patient age distribution give only a static system view. Only the DS approach described below enables capacity planning close to the real-life situation.

Our ED and the patient process are shown in figure 1. Contrary to the USA, European EDs are split into surgical and medical divisions or tracks, depending on the hospital. An incoming patient is first treated in the treatment berth. The patient then leaves the ED as an outpatient, or is transferred to the ward or stays within the ED and is relocated to a bed. Patients with non-urgent conditions or attending for follow-up examinations are treated in the fast track or ambulatory clinic. The different units can be considered as subsystems within the ED.

As shown in figure 1, the distribution of outpatients and inpatients, depending on the particular subsystem (ambulatory, treatment berth, bed), (1) differs between the medical (14.3% outpatients versus 19.3% inpatients) and surgical (36.7% outpatients versus 6.5% inpatients) track or unit. This is an important factor. Figure 2 depicts the acuity distribution for the same period: there are more medical patients with higher acuity than surgical patients. We therefore assumed that more inpatients than outpatients in the medical unit have a higher average acuity than in the surgical unit.

Acuity has 4 grades or levels of severity. Acuity is defined on admission and not after full medical evaluation. Discrepancies between the assessment of acuity by the patient and physician are especially common in the non-urgent category, particularly when variables such as environmental factors (i.e. waiting time) are taken into account.

Static System View

Precise definition of “simple” input parameters is the best means of obtaining comparable information in the long term. It is important that all stakeholders—such as health professionals, ED & hospital management, and politicians—agree on these definitions.

We used the following:

- The *ED patient* was defined (in the static sense where data is concerned) as a monthly ‘identity’ (i.e. one identity is at least one patient per month).
- The *ED case* was defined by its unique number.
- An *ED visit* was defined as any admission to the ED, regardless of patient identity or case-number (i.e. a patient can have one or more visits corresponding to the same or to a different case).

Similarly we have the ED subsystems (*EDS*) *visits* (including the ambulatory system [AS], the treatment berth system [TBS], and the bed system [BS]). Because incoming patients are initially difficult to categorize, they might, for example, first be an outpatient and then shift to be an inpatient, or vice versa. Hence, the statistic *EDS visits* provides an internal static view. Static data, such as totals and averages may be required for statistical analyses but they *do not provide sufficient information for capacity planning*. On the static level, hospitals and EDs often compare each other using the number of *ED visits* to represent the “number of patients”. However, static numbers cannot reflect the distribution of patient admissions over a certain period, which may differ considerably from hospital to hospital. Numbers are only comparable if the situations from which they are derived are also comparable (figure 3).

Dynamic System View

Unlike static information, such as system entry and exit rates within a certain period, a dynamic view allows peak volumes to be highlighted and can simulate capacity shortages as perceived by staff. Capacity planning is normally based on averages, but peak numbers of patients in the ED (or EDS) at key times per day and month (2) are also of great relevance.

Static information may be linked to qualitative parameters, e.g. acuity, which may influence relevant process variables such as length of stay (LOS) (2). Simulation 'activates' the simple static ED statistics, and ED visits become *dynamic*. In other words, the word "patient" (i.e. number of patients in the ED) in the following means the dynamic view with patients who actually appear (i.e. at key times) and is therefore based on the "activated" ED visit figure. The dynamic view gives a picture of increased complexity (individual LOS, non-linear distribution of entry and exit rates), but which is much closer to reality and provides relevant information for capacity planning.

Dynamic System Simulation

DS simulation offers decision-makers an accessible, cheaper, and timelier means of evaluation (3). Simulation is one of the most widely used methods to evaluate, improve and optimize many types of processes. It imitates an actual process over time (4). Simulation models imitate a system's behaviour, referred to as "baselining," and are then used to evaluate possible changes in its structure and environment, or by incorporating underlying assumptions in the form of a "what-if" analysis (4).

Non-healthcare organizations often use simulation for decision-making, and the advantages of simulation are how receiving increased attention within the healthcare sector. The literature consistently notes that simulation of patient flow provides valuable information for senior decision-makers in problem-solving activities (4).

We used *Ithink* software by *isee systems* (Lebanon, NH 03766, USA; formerly High Performance Systems, HPS) (5), which is used by major companies, government agencies and business schools in the USA. *isee systems* has become the world leader in Systems Thinking software based on the DS approach (6). It therefore seemed the right approach to assist us in answering our questions, as it is a method of studying and managing complex feedback systems, such as hospital environments. It offers state-of-the-art simulation of complex systems and is an integral part of the *Ithink* software. Real-time simulations are performed on this defined methodical base, and users have only to deal with modelling reality into processes.

What DS offers has been something of a minor technological revolution. Once a model has been built, it is easy to create a high-quality user interface and turn it into a business simulator. Anyone can run the business simulator, trying different decision scenarios and viewing the behaviours.

A computer is not a random device. If it were, programming would be as difficult as controlling human behaviour. Since the advent of the computer, mathematicians have developed algorithms capable of simulating randomness. Pseudo-randomisation is a standard functionality of all computer languages. The built-in RND function returns a single number, "randomly" chosen between 0 and 1 (in the language of probability, the number is uniformly distributed between the range of 0–1). A linear congruential

generator (LCG) is based on the formulae developed by Lehmer (1948): $\{rnd(i+1)=(rnd(i)*b+a) \bmod max\}$. *Ithink* is based on LCGs and currently used in almost all random number generators.

To simulate the different events, discrete simulations of patients use the following statistical methods: ED entrances are randomised by Poisson distribution, varying along the day line, as described in this article. For triage to different part of the E, normal distribution was extrapolated out of statistics. Duration of stays in berths or fast track beds are simulated by exponential distribution to simulate realistic behaviour, as recommended in standard literature and DS standards.

When developing a DS model with *Ithink* software the following five steps are important:

1. Goals and objectives of the simulation

The simulation should generate information that can be used by management to make appropriate decisions, solve capacity problems of the ED(S), install a planning process, and obtain a convincing and trusted “dynamic decision-making tool” for best practice.

It is also important to exclude goals that cannot be reached by simulation. Simulated scenarios cannot find the “best solution” by themselves. Simulation also cannot advise on the kind of scenarios to test. This is the responsibility of the team and decision-makers, and depends on the understanding of the whole complex process. What DS does is to provide answers, but sometimes only indicators, by testing ideas with different scenarios (7).

2. Describe the current system and development of the model

The framework for the ED(S) model was developed to map patient flow (figure 4). The process owners of the ED confirmed the patient flow diagram. This model was

developed to replicate current daily business and to communicate current bottlenecks in the ED(S). The level of detail chosen for a model is extremely important in achieving useful results. As the model becomes more complex, it requires additional data and continuous testing. It is necessary to understand the inverse relationship between model complexity and utility—or, in the words of Albert Einstein: “Make everything as simple as possible – but not simpler!”

3. Collecting Data

Simulation needs well-defined core data collected from the ED. The number of ED visits we used for the simulation was differentiated by the time of arrival of patients. The distribution of patient admissions over 24 hours as shown in figure 5 is important to simulate realistic daily fluctuation in combination with an average daily amount of patient arrivals.

Figure 5 assists in obtaining a realistic simulation of the bottlenecks, because the *patient flow* strongly fluctuates and defines the capacity needed, which cannot be achieved with statistical analysis of average estimates. The patient process analysis has to incorporate a description of key subprocesses during normal patient flow and in extreme daily behaviour (capacity and mean time). To arrive at solutions for problems with patient processes, e.g. decreasing patient waiting times and optimal resource utilization, we no longer describe capacity, the organization and quality management by using only statistics, and these aspects have to be reviewed by simulating different scenarios.

The dynamic effects of all subprocesses have to be reviewed, such as the sub-process “simulated pattern of use for ED treatment berth No. 7” hourly throughout one week, as shown in figure 6.

4. Testing the model

The key data are visualized in a “flight simulator” interface (figure 7), and graphic displays show the pattern of a week in the ED(S). The process owners are able to see at a glance whether the model will bring any advantages by comparison of the number of patients waiting in the ED(S) area or the fluctuations in the numbers of incoming patients.

5. Systems thinking—scenarios, analyses and solutions

Ideas and solutions for alternative approaches can be evaluated after testing the simulation model. Because simulation models evaluate outcomes without making changes to the real system, simulation modelling permits the evaluation of different alternatives before any resources are expended. The accountability for the variation of patient arrival times, utilization of infrastructure, queuing and treatment times are vital for results in a process that is dominated by interaction between human beings (8).

Scenario “Business as usual”—by annual growth + 5% and shift to more medical patients

The simulation depicted in figure 8 shows impressively how continuous growth of patient flow results in over-proportional growth in patient waiting times. The management of the TBS and BS loses all its flexibility: A simulation for 2002 (30,000 patients; 56% surgery/44% medicine) showed that there is sometimes a lack of available beds, but only for a short time. In contrast, the scenario for year 2008 (35,000 patients; 53% surgery/47% medicine) showed an increasing lack of beds in three comparative simulations. As mentioned above, the growing number of patients in our ED is mostly due to the more sensitive non-urgent patient. This may damage the image of an ED by causing long waiting times, which are well-recognized as detrimental: “Like it or not—it’s the key to your hospital’s reputation. Three times as many patients create their impressions of your hospital through the ED than by admissions—and 30% to 40% of admissions come through the ED.”(1)

The scenarios described above force management to act: if there are no strategy-based changes (i.e. in triage or collaboration with other providers), structural and spatial (operative) planning of the ED (S) will face serious problems. Trends, which are regarded as neither good nor bad, should be strategically evaluated, communicated and suitable corrective action taken, if necessary.

It is estimated that more than 75% of reengineering efforts do not produce target performance improvements; and hospitals often supply vivid testimony to the fact that growth strategies often fail to yield real growth. Stories abound of costly organizational change efforts that have either regressed—or worse—exacerbated the situations they aimed to improve. The ED(S) simulation model represents the actual

situation. Thus it is important consider how our performance initiatives come into being. The simple answer is that very often they are just 'thought up'. We work with our mental model of reality, which is actually a **subjective** abstraction of reality. If dynamic methods are used, even process owners are often surprised about the non-linear behaviour of complex systems where a small impact can sometimes have very large consequences.

Scenario ED Treatment Berth System vs. ED Bed System

As visualized in figure 1, the ED(S) distribution of patients in the TBS and the BS is also a result of daily business development and adapts to available facilities. The ED(S) representatives were convinced that more bed capacity in the BS would be the best strategy. This idea was also fed through the newly discussed strategy to stop transferring patients to the ward between 17:00 and 08:00 (i.e. keeping patients in the BS over night). Testing of different scenarios convinced the process owners that they would gain more flexibility and incur lower costs by increasing treatment berths. Analysis of the pattern of patient arrivals showed that bed capacity was not crucial during the night, as they had thought. They therefore requested more treatment berth capacity and not an increase in the number of beds.

To enable new ideas of this sort, the variables must be able to be adjusted in any combination, as shown in the flight simulator interface in figure 9. One of the major strengths of DS is that different scenarios and results are analysed from different points of view by all stakeholders.

Reaction to the trend of increasing numbers of “self-declared non-urgent EM patients”

Waiting times in EDs are a significant problem and are made more complex by “self-declared non-urgent patients”. The patient’s length of stay in a ED varies considerably and this makes effective management of an ED difficult. The authorities’ response to growing patient waiting times was to implementing a “fast track”. The main objective was to exclude the non-urgent patients from the expensive and overloaded ED(S), and to shorten waiting times. A specifically trained nurse performed the triage, and the non-urgent patients were sent directly to the “fast track”. The new situation was easy to map in the model, but the results did not correspond to reality. Simulation showed that with the available infrastructure, it would not be possible to maintain medium waiting time below one hour. The process owners, however, had the impression that the waiting time was much less in reality. The simulation model allowed only one date to be adjusted, which explained this contradiction, but the results were nevertheless paradoxical: after the triage of non-urgent emergency patients, the more severely injured patients stayed shorter in berths and beds. New data from the IT system was evaluated and confirmed this: the length of stay was reduced by 30 to 60 minutes.

The process owners commented that they have better IT solutions, better management and more employees. Previously, patients passed through a sequence of independent steps, such as signing in, filling out a history, waiting for a triage nurse, noting vital signs. Establishing the “fast track” brought about a general shift in organization. The triage process was simplified by starting assessment at the time of the patient’s arrival. Now, at entry, the triage nurse made the first contact with the patient and immediately contacted the physicians. This was a first step from

sequential to parallel processing at ED(S), and higher patient satisfaction and shorter stays in ED(S) will be the result of the complete shift to parallel processing. This example shows that retrospective analysis of simulations can also lead to improvement. The next step might be scenarios of different parallel processing models to obtain even better results.

Better management ultimately led to lower infrastructural demands, as had been requested at the beginning of the planning process.

Lessons learned for the planning process.

Forward-looking decision-making processes have far-reaching consequences for the healthcare sector. Decision-makers must know what they are doing, why they taking certain measures, and what action has to taken to achieve a satisfactory outcome. The advantage of using simulation is that it attracts increased attention from within the healthcare sector. Overall, there is a growing awareness of the need to ensure viability and effectiveness of healthcare services, particularly emergency services. To achieve this, it is necessary to create three complementary processes (10):

- The process owners define the problems (system knowledge)
- The modellers bring in synergies for simulation scenarios (transformation knowledge)
- The strategic planners define roles and new fields (objective knowledge)

Ensuring a continuous dialogue within this triangle is instrumental in problem solving and acceptance of decisions. Cultural transformation is possible by achieving win-win situations. The process owner is able to communicate through the model and to

simulate problems and bottlenecks. The strategic management is able to discuss new ideas and roles and to reflect this dynamically. Solutions are the result of teamwork and enabled innovations.

The overall objective is to generate information which will enable appropriate decisions to be taken for the ED(S) **high level**. The simulation model of the current ED(S) also provides the leaders with a means of evaluating future proposed changes in a timelier and less resource-intensive manner. However, simulation cannot provide the answer to high-level development, such as an increasing number of patients with lower acuity, or how the hospital and ED can arrive at best practice future strategies. These questions can be *discussed* using the results of the simulated scenarios within a cooperative culture. DS simulation is therefore indispensable as a successful strategic design feature for EDs. The decision-making process requires full, balanced and continuous *integration* of process owners (system knowledge), dynamic modelling (transformation knowledge) and strategic management (objective knowledge). It is also essential that stakeholders exchange relevant information and that up-to-date static input figures are always available to maintain the structural actuality of the model. Some hospitals, especially university hospitals, may claim that they would have problems in establishing a multidisciplinary cooperative culture. However, this is also facilitated by DS simulation, because it offers an objective and transparent platform for interdisciplinary discussion.

Conclusion:

The simulation model was useful for investigating specific scenarios in terms of patient flow and bottlenecks, and, perhaps more importantly, as a device for provoking and facilitating discussion and comment amongst all those concerned. The team involved readily accepted that the model gave only an indication of the relative effects of different interventions, rather than mathematically precise forecasts or point predictions, and were very keen on suggesting alternative scenarios for testing based on earlier simulations.

References:

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Figures and legends 1- 9

Fig 1

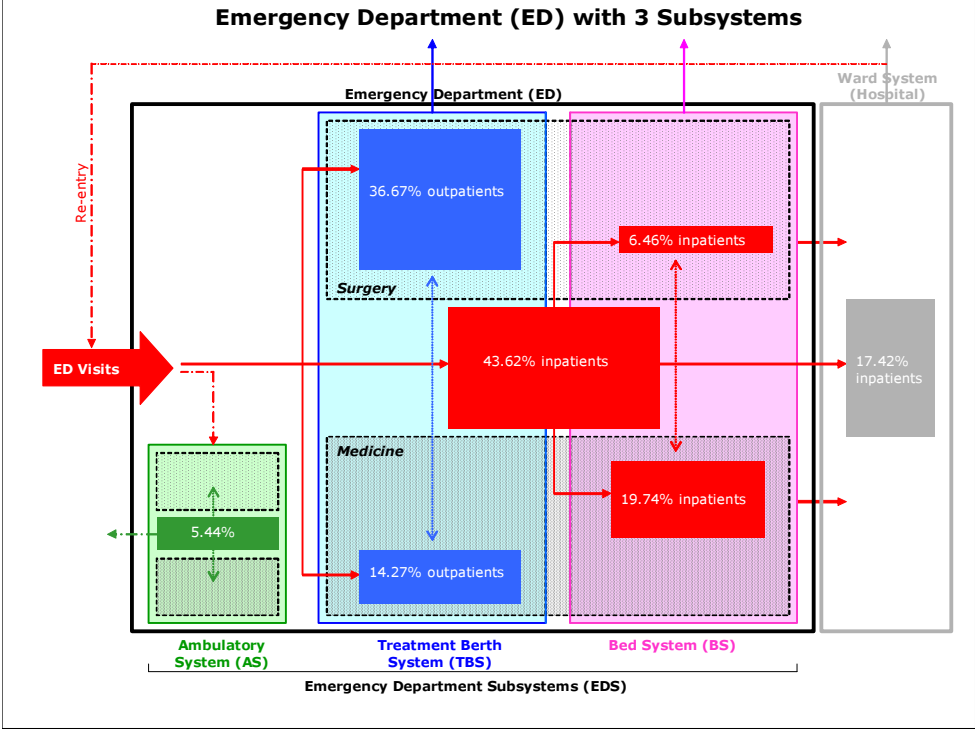


Figure 1: The emergency department (ED) has three subsystems: the Ambulatory System (AS), Treatment Berth System (TBS) and Bed System (BS). Patient are treated either in the surgical or medical track or unit, depending on their profile. The surgical track has more outpatients than inpatients, and the medical track the opposite. The data are retrospective clinical data, and may allow the assumption that more medical emergencies have higher acuity (see fig 2) than surgical emergencies, due to the higher number of inpatients in the medical track.

Fig 2

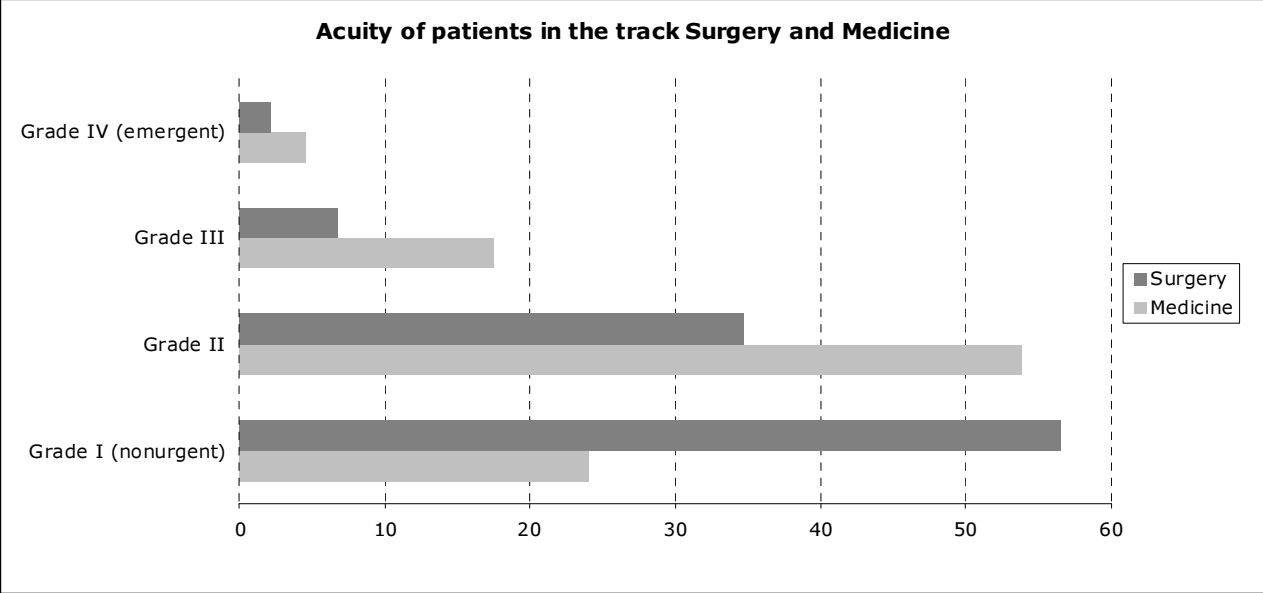


Figure 2: Distribution of acuity from grade I (non-urgent) to grade IV (emergent) in the surgical and medical tracks. The diagram is important when discussing operational and strategic questions.

Fig 3

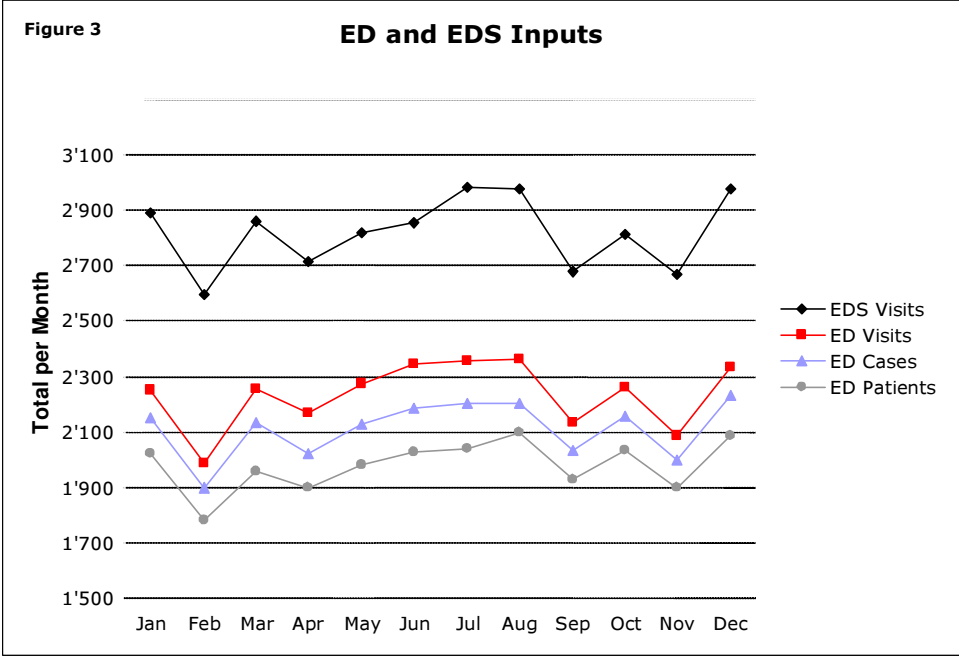


Figure 3: The *ED visits* is the number of patient visits to the emergency department in a certain period. The *EDS visits* are the sum of the visits to the subsystems (ambulatory system, treatment berth system, bed system) within the ED in a certain period. The EDS visits figure is higher than the ED visits figure due to the cumulative effect (the same patient may pass through different subsystems within one patient process). The difference between the two figures may provide additional information on workload. Similarly to ED visits, we distinguish between ED cases (number of cases of illness) and ED patients (personal identity).

Fig 4

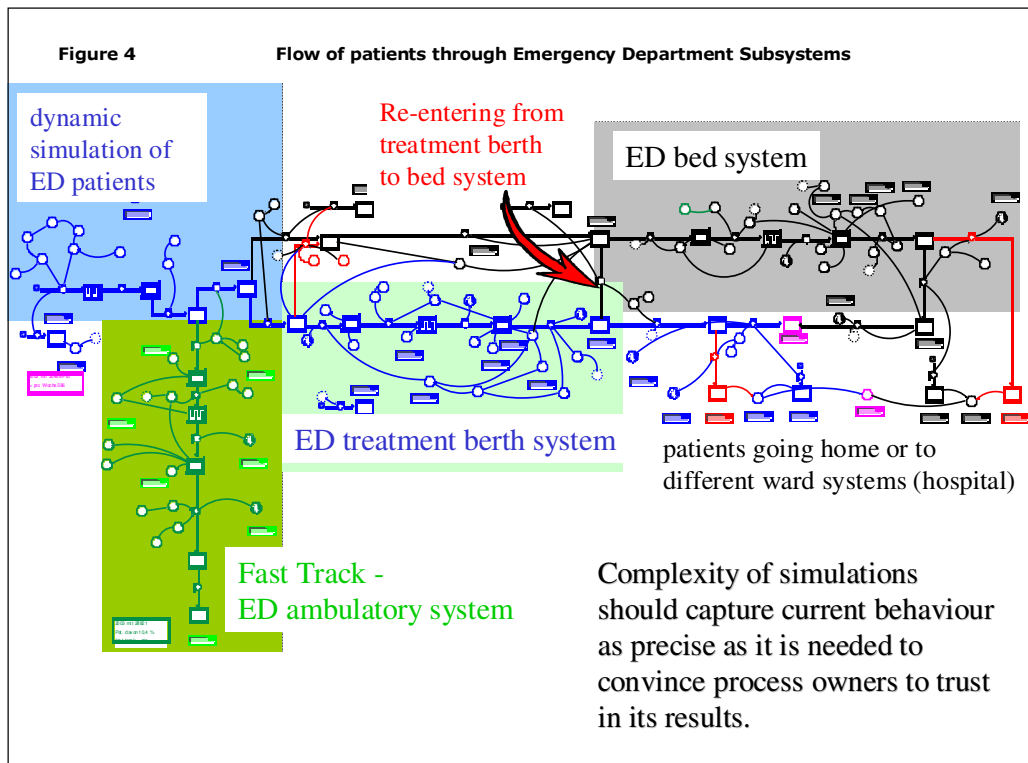


Figure 4: The simulation model shows the patient process through different emergency department systems. The design (development) level of the model allows all requested scenarios for planning tasks to be simulated.

Fig 5

Figure 5

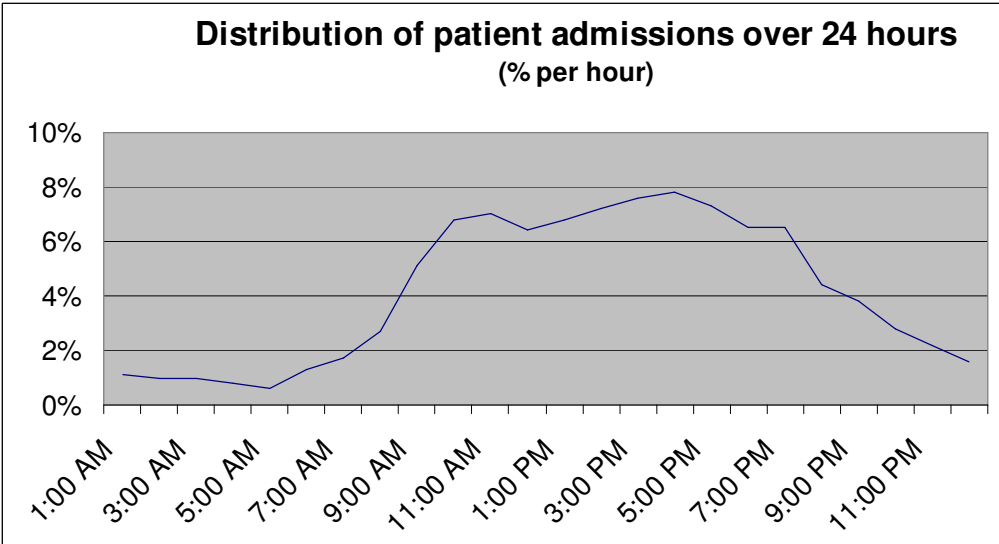


Figure 5: Data required for the simulation: Distribution of patient admissions over 24 hours. Data was collected for three months: number of surgical, medical and fast track patients.

Fig 6

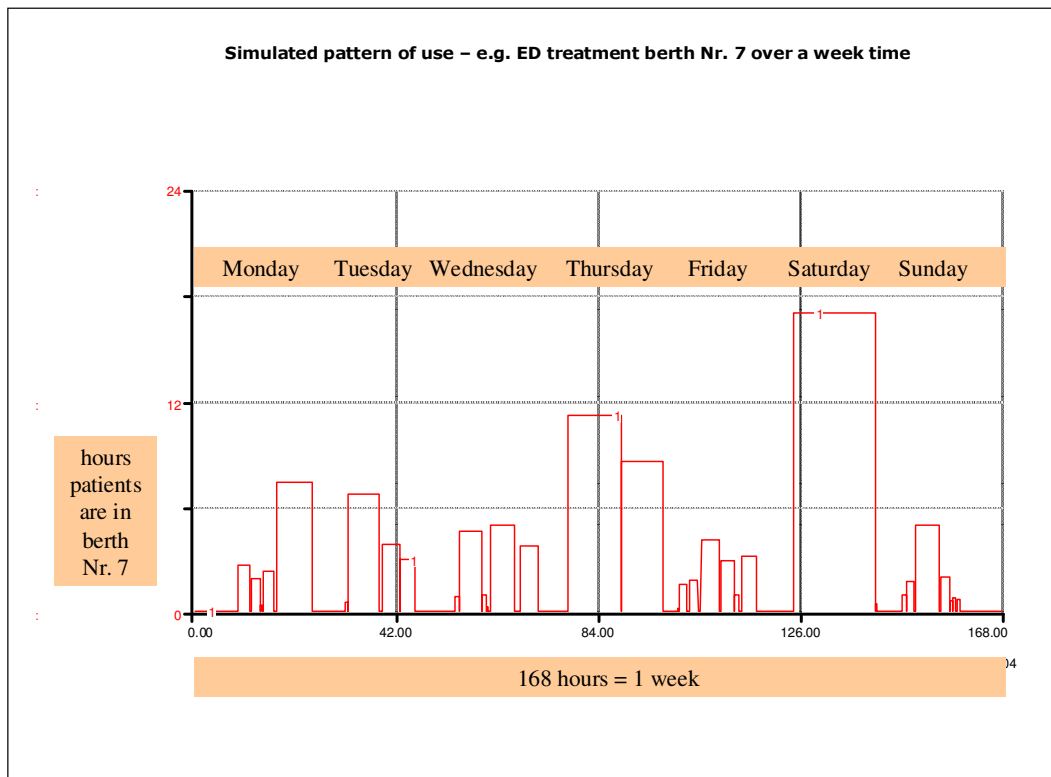


Figure 6: Example of the occupation pattern of the ED treatment in a berth (No. 7) during one week: The x-axis shows one week (hours) and the y-axis indicates the hours of occupation. All berths are simulated independently and in real-time. The pattern of occupation of all berths must be as realistic as possible to gain maximum benefit in the scenarios developed by the process owners.

Fig 7

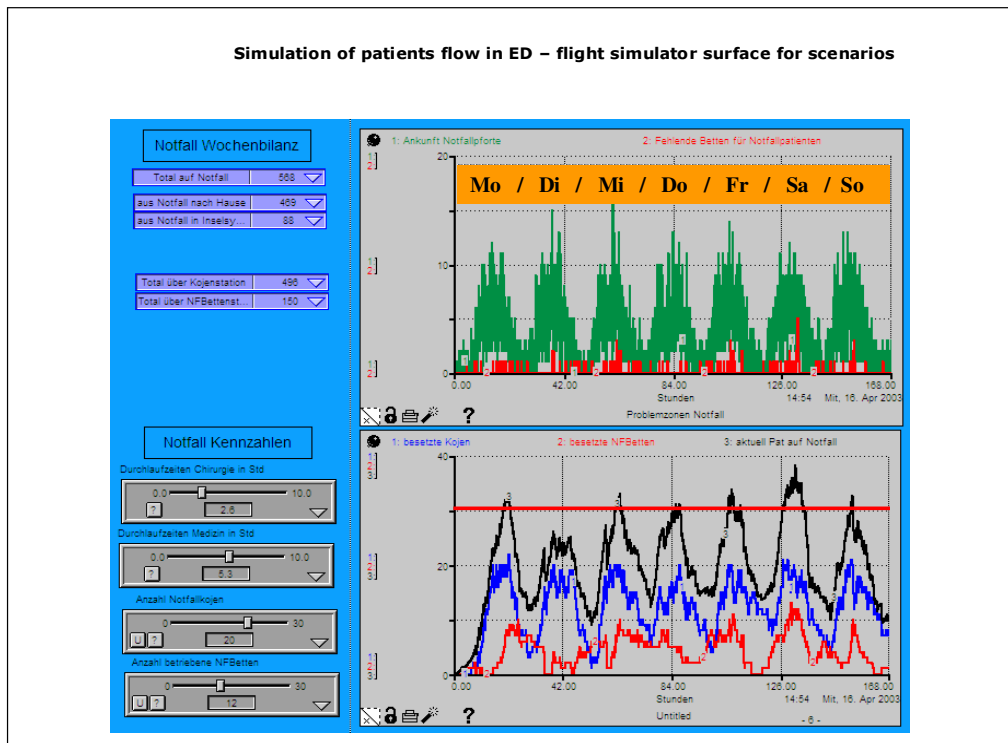


Figure 7: Simulation graphics allow comparison of different scenarios. The upper and lower diagrams cover one week. The upper diagram shows the **loops of** ED visits (green graph) and the number of ED patient places (beds)lacking (red graph). The lower diagram shows the total of ED patients in the ED (black graph), the number of treatment berths occupied (blue graph), and the number of beds occupied (red graph). The horizontal red line indicates the capacity limit of available ED patient places. The system is overloaded almost every day, especially on Saturday for several hours, which is dangerous for an emergency department. By manipulating the sliders on the left side, many different scenarios can easily be created.

Fig 8

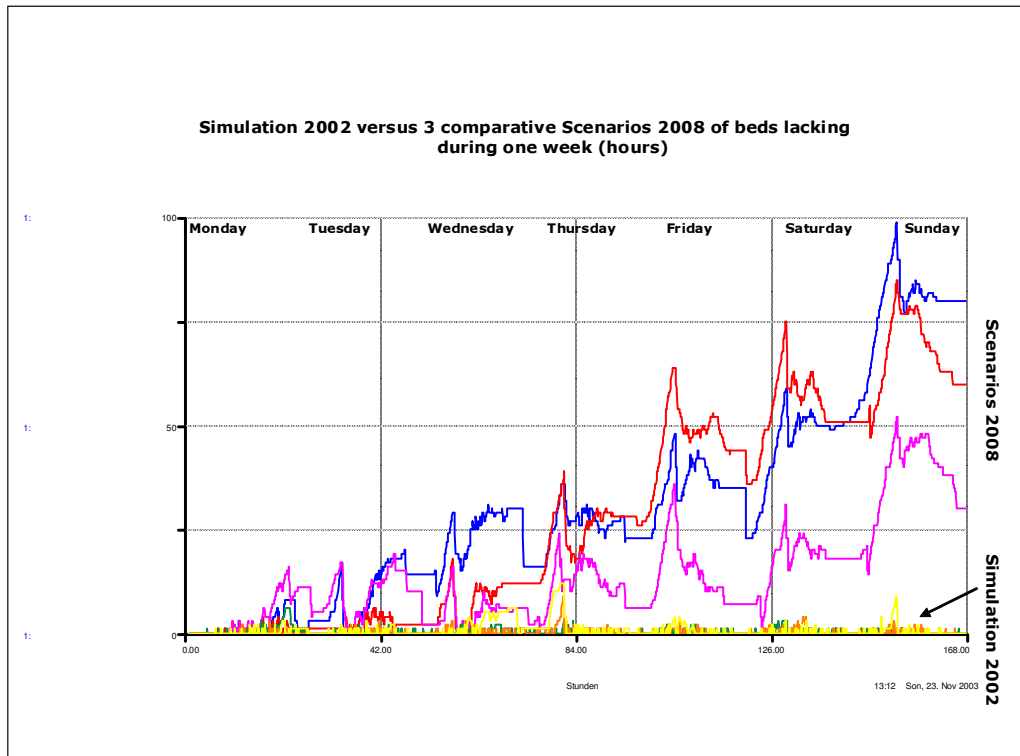


Figure 8: The graph represents the number of *beds lacking* at a given capacity (BS) during one week for different scenarios; it shows a 2002 simulation (yellow, orange, green) and 3 comparative scenarios in 2008 (blue, red, pink). The scenarios were varied according to adjustable variables such as patient volume, patient mix (i.e. acuity, surgery vs. medicine), arrival time distribution, and average length of stay (LOS).

Fig 9

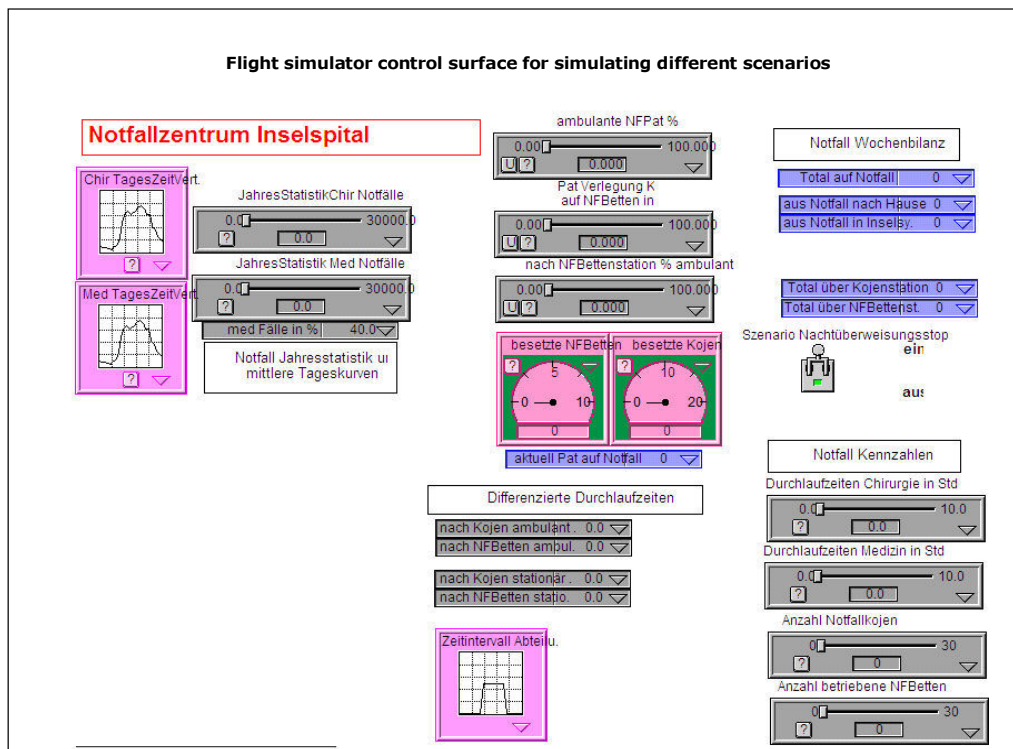


Figure 9: The control interface of the model allows adjustment of the variables (e.g. patient volume, patient mix, distribution functions) considered useful. Different combinations result in different simulation scenarios which can then be compared. Sensitivity testing is possible using “Monte Carlo simulation” (running of scenarios several hundred times to show the range of variation in results).