Improving the Efficiency of a Hospital ED According to Lean Management Principles Through System Dynamics and Discrete Event Simulation Combined with Quantitative Methods

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Abstract. The Emergency Department of a Hospital has both exogenous and endogenous management problems. The first ones are about the relationship with the other Departments, for which the Emergency Department is a noise element on the planned activities, as it generates an unplanned beds occupation. The second ones strictly depend on the Department organizational model.

After an intensive study on the Emergency Department of a medium size Italian Hospital, the Authors illustrate how, through the use of Lean Management philosophy combined with quantitative methods, the current situation can be analyzed and they propose a set of corrective actions. These allow to increase the system efficiency and to reduce both the number of the waiting patients and their stay. At the same time, the activities are reallocated to the staff, improving their utilization coefficient. So the Management can assess the validity of the proposed strategies before their eventual implementation in the field.

Keywords: Emergency Department · Lean Management · System Dynamic · Discrete Event Simulation · Design of Experiment

1 Introduction

The Emergency Departments (EDs) in Hospital structures may have two critical elements from a managerial viewpoint. The first element is given by the fact that the ED may cause a negative impact on the planning of the other Hospital Departments. Indeed the ED represents a significant disturbance, often generating unexpected occupation of beds allocated to specialist activities with a reduction or even blockage of other already planned activities (e.g. surgery). This event occurs more frequently as a consequence of peaks of requests of Hospital admission like those generated above all in winter as a result of flu viruses, worsening of chronic pathologies connected to the climate and so on. The second critical element, on the other hand, is the crowding problem inside the ED [1]. The users are often forced to spend hours waiting in the Department waiting rooms. Both problems can be analysed first and tackled later by using quantitative

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methods combined with the modern philosophy of Lean Management. Using these instruments, the consequences of the possible solutions determined can be assessed *a priori,* that is before practical implementation. The Authors of this paper have attempted to tackle both critical elements, by firstly studying the impact of an ED on the Hospital connected to it, a study already illustrated in a previous paper [2], and, now, by analysing the problem of the Department optimised management with a view to Lean Management.

The aim of this paper is to provide an overview of the problems tackled, of the adopted analysis methods and of the solutions found. The approach adopted allowed us to provide the decision makers with a complete framework of the solutions to help ED efficiency and also to assess the benefits to be obtained from the different solutions adopted thanks to quantitative methods application.

2 Theoretical Framework

The main problem considered in this paper can be defined “the crowding problem”. Hoot and Aronsky [3] approve the American College of Emergency Physician’s definition: “Crowding occurs when the identified need for emergency services exceeds available resources for patient care in the ED, Hospital, or both” [4]. The problem first became apparent in the 1980s, and was thought to be of crisis proportions by the end of that decade. The American College of Emergency Physicians issued several policy recommendations, but the problem just went on growing [5–8]. The topic was also taken into consideration by the Academic Emergency Medicine review in different papers [9–16] but, despite this attention, crowding got worse in the subsequent years [17, 18] culminating in a total breakdown [19]. Crowding has multiple and complex causes and many ‘obvious’ causes have been discredited [5]. A lot of papers tend to naturally fall into two separate areas, one concerned with long term trends and conditions, and the other with more specific triggering factors. While not denying the influence of the general causal factors, the work on specific factors has introduced issues such as the ones related to internal ED operating efficiency. It could be thought that ED crowding is due to increased number of patients with relatively trivial, non-emergent problems while [1], although not dismissing the concern about non-urgent ED use as a policy issue, it shows that diverting low urgency patients away from the ED will not have a significant impact on crowding.

One of the main observations about the crowding problem is its persistence despite general agreement that it hurts both patients and health care organizations [20, 21]. This seems to be a case of “policy resistance”, arising from an incomplete understanding of the problem. Researchers have been “looking in the wrong place” for insights into the crowding problem [22].

A lot of different approaches have been studied to face the crowding problem like the, so called, “4 h mandate”. This is a National Health Service (NHS) regulation that patients in the ED must be either admitted, transferred or discharged within 4 h from the time they first signed in to the Department [23]. An analysis of the effect of this mandate shows a sharp peak in Hospital admissions and ED discharges just at 4 h [24]. In literature some System Dynamic (SD) studies over EDs can be found: Lattimer et al.

Table 1. Number of Hospital admissions

Admission sources	Hospital admissions
From E.D.	9361
Ordinary admissions	7944
TOTAL	17305

[25] built an SD model to investigate the patients flow through EDs and how system capacity could be improved; Morrison and Wears [1] evaluated the crowding phenomenon affecting emergency rooms.

3 Methodology

3.1 The Case Study

The ED concerned in this study represents the main source of patients admitted to this Hospital (over 55 %) as shown in Table 1.

There follows a negative impact on the activity of the medical/nursing staff, a serious disservice for the patients on the waiting list, but also, last but not least, the significant economic damage for the Hospital caused by the lack of use of the structures (e.g. operating rooms) generated by the ED.

3.2 Phase 1: Impact of the ED on the Hospital Departments

As mentioned in Sect. 1, the subject of the impact of the ED on the surgical activity and on ordinary Hospital admissions of the other Departments in an Italian Hospital has already been considered by the Authors in a previous paper. The objective of this paper was to specifically assess the influence of those patients who were attributed Yellow code in the phase of triage, on Hospital admissions [2]. The method used by the Authors for this part of the study was System Dynamics, a particularly suitable simulation technique for studying management policies. According to the methodological precepts of SD, the three fundamental elements of the system were considered (ED, Short Stay Observation and Hospital) and the flows of patients into and out of them. With 397 Hospital beds available along with 13 “crisis” beds addressed to face possible emergency situations, two initial management hypotheses to cope with the possible higher loads on the Hospital, generated by the ED, were first determined and then studied. The strategies determined by the Authors in the first analysis were those regarding a reduction of the patients mean stay inside the Hospital Departments and the increase of the beds number. The second hypothesis, while still being a valid one, was rejected from the outset due to the current Italian policies of reducing healthcare costs and, as a consequence, it was not tested on the simulation model.

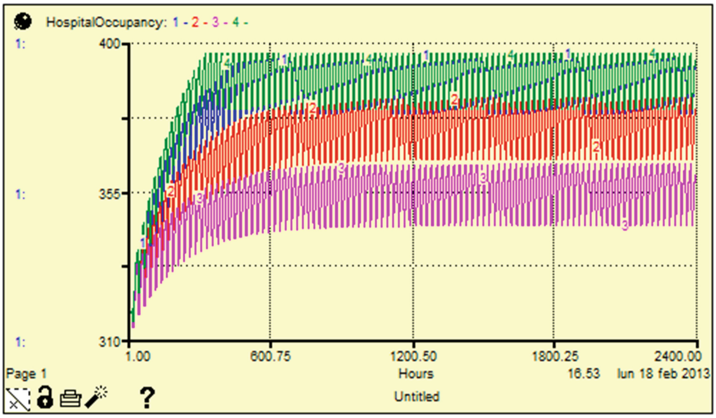

Fig. 1. Hospital occupancy (Color figure online)

The first solution, on the other hand, was implemented on the SD model, producing the following results (Fig. 1):

- if the Hospital mean stay remains at the current levels (9.6 days) the system is critical. It can be seen that there is an oscillation zone (blue zone) which constantly borders on the maximum number of available beds, which is normally reached with a 10 days stay (green zone);
- if the Hospital mean stay drops to even just 0.6 days, the system is more reactive to the critical events as it has not only crisis beds, but also around twenty ordinary beds available (red zone);
- if, finally, the Hospital mean stay is reduced by a whole day, bringing it to 8.5 days, the system, with a reserve of about 40 beds as well as the 13 crisis beds already mentioned, would be capable of coping with the great majority of critical situations (purple zone).

In assessing the feasibility of this possible strategy, the Authors still clashed with the opinions of the clinicians. According to them the shorter Hospital stays lead to an increase of requests to the ED with subsequent new admissions. As a consequence, the Authors have studied another possible solution to the problem. In particular, with further consideration of the data about ED admissions, the Authors identified chronic illness patients (diabetes, heart disease, lung disease) who enter the acute phase as an important component of occupancy of Hospital beds by the ED. It has, therefore, been proposed to establish special monitoring rooms inside the ED dedicated to this kind of pathology typical of elderly patients in order to drastically reduce admissions (chronic patients actually count for approximately 5,000 days/year with an overall cost in the range of 4,000,000€). Further investigations carried out recently on this have enabled the Authors to make a fourth suggestion for chronic patients: online, real time monitoring obtained by using body sensors, which are easy to find on the market nowadays at a limited cost, with data transmission to special supervision centres and specific interventions in order to limit their entry to the acute phase.

3.3 Phase 2: Reengineering of the ED by Means of Discrete Event Simulation

Having come to these conclusions, the Authors set the aim of assessing the need to make the ED more efficient, with a view to Lean Management, by re-engineering the internal processes of the ED itself. This study phase had the aim of reducing the waiting time of the patients and of allowing the emergency medicine specialists to concentrate on the true emergencies (life threatening red and Yellow codes), leaving patients who do not have life threatening problems (Green and White codes) to clinicians without specific emergency skills. All this while respecting the need to safeguard the economic budget of the Department without introducing additional costs to the planned budget, but on the contrary by trying to reduce it.

Mapping, Data Collection and Statistical Analysis of Admission to the ED. In order to better understand the operation of the ED studied, an initial analysis was carried out in order to map the main activities which characterise the inflow of Patients passing through the ED, as shown in Fig. 2.

Subsequently a meticulous campaign of data collection was carried out. It aimed at finding all the information necessary to be able to start up the research. The data collection phase was particularly complex as it was necessary to integrate the information coming from the Hospital information systems with the data collected directly on the field 24/7 (24 h per day and 7 days per week). In this phase the Patient's colour code and the admissions distribution were both taken into account. The admissions distribution varied according both to the time of the day and to the day of the year, with significant differences compared to the mean values. In particular, admissions to the ED were first determined for the year, amounting to 54,141, of which 77.4 % with non-life threatening codes (White or Green), 20.1 % with yellow life threatening codes and the remaining 2.5 % with red life threatening code. Then, the Patients daily admissions were studied, also by colour code, to understand whether affluence trends and/or

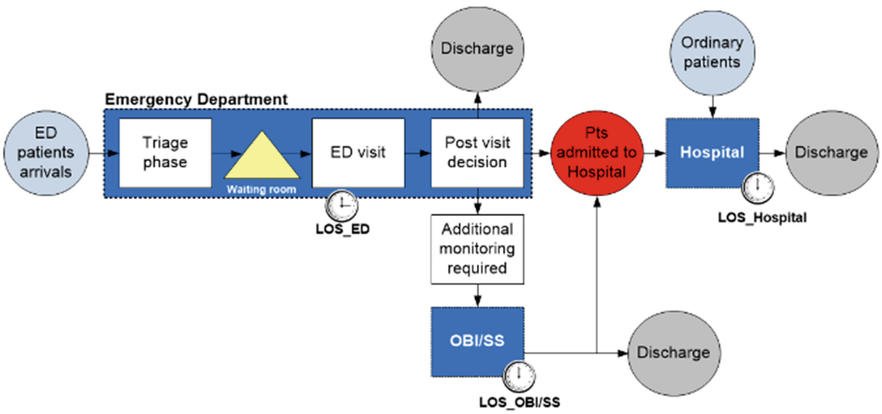

Fig. 2. Flow of the Patients in the ED

regular distribution flows could be found. In Fig. 3 the analysis for the Yellow codes is shown (the other codes analysis are not shown for reasons of space).

By analysing Figs. 3 it can be seen how there are no seasonal trends for any of the three colour codes: the trend is totally random and there are no repeated trends in time.

Analysing the data in more detail, the Authors then studied the admissions distribution during the different hours of the day. To this aim, 30 sample days were chosen and the mean number of Patient admissions was calculated for each time range, as reported in Fig. 4.

Observing the bar chart concerning Patient admissions with Green/White and Yellow codes the presence of a peak demand during the central hours of the day (from 8 am to 3 pm) can be seen, with a mean number of patients found, for about 330 days a year, of 115 for the Green/White codes and of 30 for the Yellow codes. The phenomenon of the White and Green codes high affluence in Italy is accentuated by the lack of day Hospital assistance in the country, which is why people are obliged to go to the ED even for problems not requiring emergency treatment.

Considering the Red code trend, on the other hand, it can be seen how the admission of this type of Patient is totally random. A further analysis was then carried out to identify the days of maximum inflow and the admissions distribution within

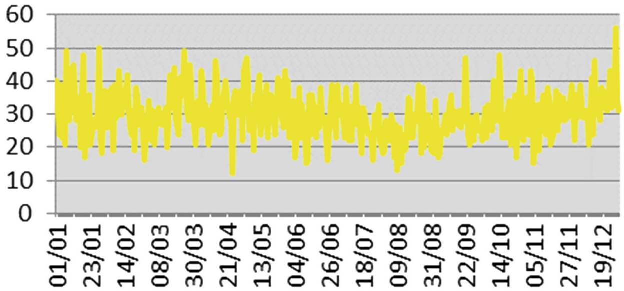

Fig. 3. Yellow code admission trends (Color figure online)

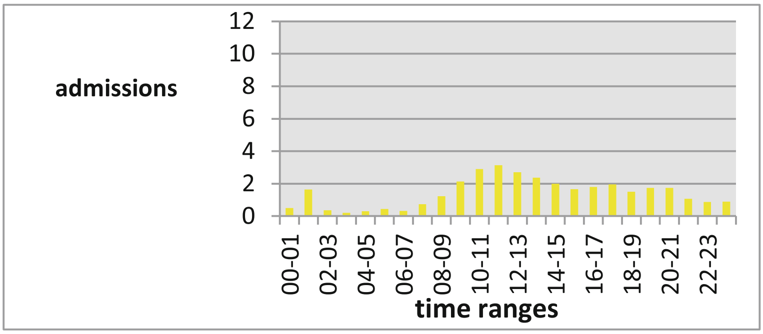

Fig. 4. Distribution of Patient admissions with Yellow code (Color figure online)

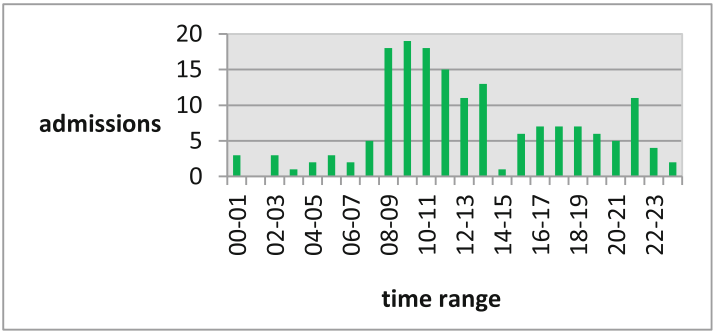

Fig. 5. Green/White code admissions in a maximum load day (Color figure online)

them. This was necessary because, with a view to carrying out simulation tests on the operation of the processes within the ED, the Authors considered it worthwhile assessing the response of the system in conditions of usual staffing, not only with "normal" workloads but also in conditions of maximum service request. Figures 5 and 6 show the admissions bar charts in two sample days of maximum inflow for Green/White codes and for Yellow codes respectively.

It can be seen that, as far as the Green/White codes are concerned, an inflow of more than 140 units occurred on 29 days with peaks of up to 169 patients. For Yellow codes, on the other hand, there were 28 days with a number of patients exceeding 40 and with peaks of up to 56. The maximum load of Red codes has not been illustrated as it was insignificant due to the intrinsic admissions randomness. In the day of maximum inflow, 14 admissions of Red codes was recorded. Indeed, in a typical year, only on 38 days did the number of Red code admissions exceed 6 units. From this it can be seen that the critical period in which the ED response to the work load must be assessed is from 8 am to 3 pm.

Data Collection and Statistical Analysis of the Medical Examination Time. In order to carry out the tests on the simulation model, along with the data previously collected, it was also necessary to document the data about the staff (doctors, nurses

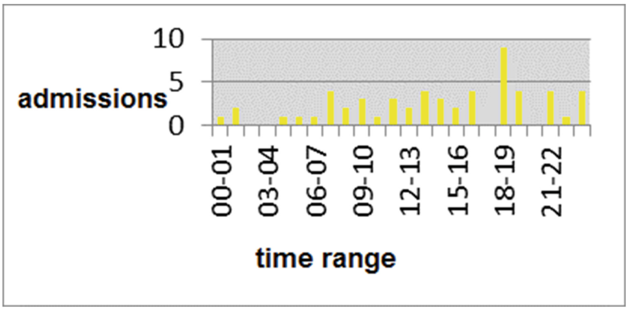

Fig. 6. Yellow code admissions in a maximum load day (Color figure online)

and porters) present in that time period, with the time of examination of the patients (first examination, examinations of various kinds, admission and/or discharge) and with the data concerning the other activities that are carried out inside the ED.

There are basically three categories of personnel involved in this analysis:

- Doctors: in the ED examined 2–3 doctors are operative during the day and just one at night;
- Nurses: this category is in turn divided into nurses devoted to triage and to the area of observing the Patients, and examining nurses. The examining nurses are strictly dependent on the number of operative doctors, because generally each doctor has a nurse assisting them during each examination;
- Porters: there are generally 2 of these members of staff per shift.

As far as the first examination time is concerned, Fig. 7 shows the examination duration distribution for Green codes. By observing the graph in Fig. 7 it can be seen that the duration of the examination is equal to or less than 5 min for 65 % of the Patients. In the event of Yellow codes very similar first examination times were also found.

As regards the post examination flows, whose determination is fundamental to ensure that the simulation model complies to the reality of the ED, it was found that, after the first examination, 61 % of the Patients were directed towards the diagnostic areas (e.g. radiology Department), while the other 39 % remained under observation inside the structure (with periodical re-assessment of the health condition). Once the observation period is over, a doctor may order admission or discharge.

Construction of the Model. It has been shown, from the data collection phase, how the prevalent inflow of White or Green codes involve the Emergency Medicine specialists in uncharacteristic activity, force the Patients to wait a long time and the Hospital authorities to overestimate the needed number of doctors and nurses.

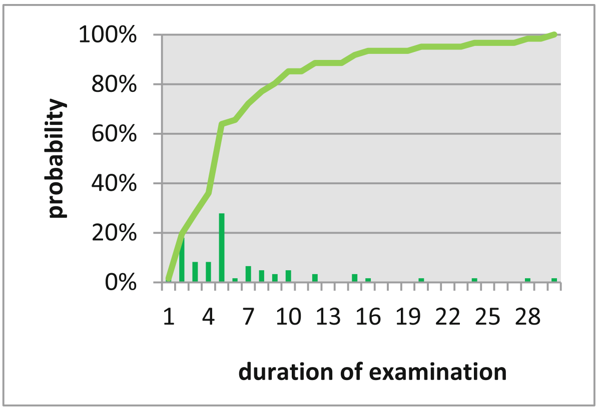

Fig. 7. Distribution of the first examination times of Green codes (Color figure online)

In order to be able to cope with the indicated problems in terms of numbers, the Authors have deemed it necessary to use suitable models. This was done to assess both the efficiency level of the management strategies currently actuated and to determine possible actions of improvement for the overall ED performance. Considering the random nature of the data characterising the various activities and the presence of appointment problems amongst the various actors present in the ED (for example the patient is examined if a doctor is free, the patient is transferred if there is a stretcher free, etc.), the model choice could only be that of Discrete Event Simulation (DES) [26]. In particular, considering the high descriptive capability, also in terms of three-dimensional graphics (which allows the so-called "visual management" to be activated), and for the possibility of presenting the results in an effective and easily understandable manner, the Authors have chosen the DES "FLEXSIM HEALTH-CARE" shell of FLEXSIM SOFTWARE PRODUCTS for the modelling. The result of the modelling is the construction of a true "virtual copy" of the investigated ED: library elements of the programme indeed permit a detailed construction of both the individual activities performed and the possibility of inserting the internal elements of the ED like the instruments and all the process actors (doctors, nurses, porters, nursing assistants and Patients). The software also allows the layout of the investigated system to be easily represented, so as to take the real distances and measurements into precise account. Figure 8 shows Green code examination room.

Using the data collected on the field and from the Hospital databases, the Authors thus constructed, using FLEXSIM HEALTHCARE, a DES model capable of providing a faithful reproduction of the activity, which the assistance service inside the ED is broken down into, from the Patient admission to his discharge from the structure. The aim of the modelling is that of permitting a first phase analysis of the performance of the individual resources involved and then, on the basis of the obtained results, to assess the need to make managerial modifications in order to improve the Department efficiency (e.g. more doctors, more nurses, more porters, lower mean patient waiting time). The first phase was to define the AS IS and then to determine and implement special variants on the basis of the results highlighted by the experimentation.

Fig. 8. View of the model: Green code examination room (Color figure online)

4 Results

4.1 Study of the AS IS Situation

It should be considered that the evolution of the ED in time must be studied on distinct daily time slots according to the different statistical distributions of the patient admissions. As a consequence, each time block in the different load conditions (standard day, day of maximum request), must be replicated several times in order to correctly reproduce the reality of the ED. The number of repeated simulation runs must be such that the investigated sample becomes representative of the population. The first step of the experimentation was, therefore, that of determining a suitable number of replications (size of the sample) to permit the correct inference on the parameters of the population (mean and variance). This was performed by analysing the trend on a standard day of the statistical measurements of Mean Square Pure Error of the mean ($MSPE_{MED}$) and Mean Square Pure Error of the standard deviation ($MSPE_{STDEV}$) (see Appendix A and B) according to the number of repeated simulation runs (Fig. 9).

Both the curves reach settlement after about 200 launches. On reaching the value, the simulation provides stable responses under a known error.

The confidence interval on the mean value of the result obtained by FLEX-SIM HEALTHCARE model, using a level of trust of 95 %, is contained within the interval indicated below:

$$\bar{y} - t_{\frac{\alpha}{2},n-1}\left(\sqrt{\frac{MSPE_{MED}}{n}}\right) \leq \bar{y} \leq \bar{y} + t_{\frac{\alpha}{2},n-1}\left(\sqrt{\frac{MSPE_{MED}}{n}}\right) \quad (1)$$

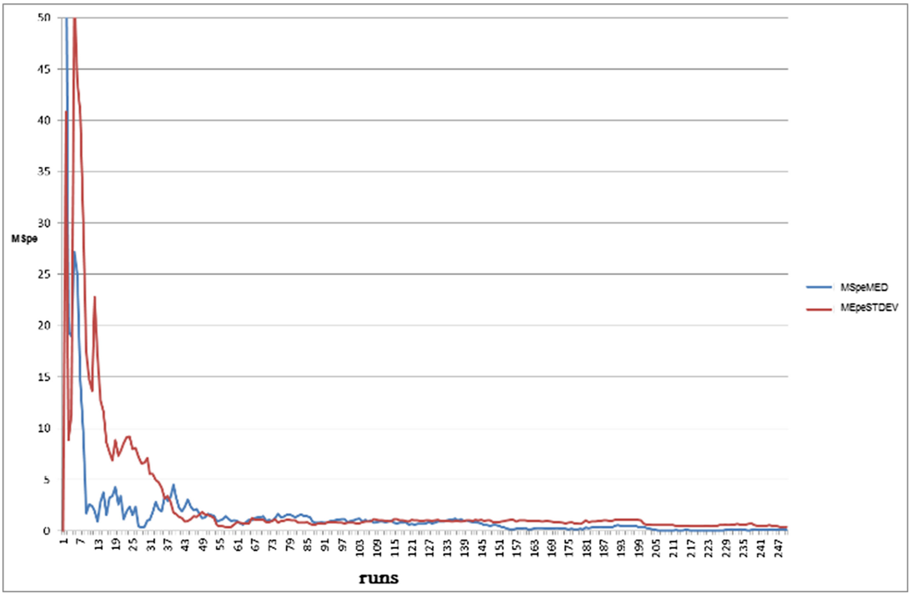

Fig. 9. $MSPE_{MED}$ and $MSPE_{STDEV}$ curves in the standard work day load

where:
n = number of experimental replications (4 in the case studied);
$\bar{y}$ = mean waiting time;
$t_{\frac{\alpha}{2},n-1}$ = value obtained from a t-student distribution with n – 1 degrees of freedom;
α = significance level.

Therefore the mean waiting time will be contained, with a 95 % probability, within the following interval:

$$94' \leq \bar{y} \leq 98' \tag{2}$$

The error interval on the mean value of the result corresponds, on the other hand, to the interval:

$$\bar{y} - 3\sqrt{MSPE_{MED}} - 3\sqrt{VAR + MSPE_{STDEV}} \leq y^* \leq \bar{y} + 3\sqrt{MSPE_{MED}} + \\ + 3\sqrt{VAR + MSPE_{STDEV}} \tag{3}$$

where:
VAR = is the square of standard deviation.
Therefore, the real mean waiting time will be contained, with a 99.98 % probability, within the following interval:

$$78' \leq y^* \leq 114' \tag{4}$$

The same analysis of the curves of the MSPE was carried out for the work day at the maximum load.

This was necessary because the probability distributions which regulate the inter-arrival of the patients are different from the previous ones. The two curves, which are omitted for reasons of space, highlighted the need to increase the number of simulation runs replicated from 200 to 250 in order to stabilise the error to acceptable levels.

In this second scenario the bounds of the confidence interval at 95 % and of the error interval are respectively:

$$101' \leq \bar{y} \leq 105' \tag{5}$$

and:

$$83' \leq y^* \leq 123' \tag{6}$$

Whereas the coefficients of use of the doctors are:

- 80 % for the day at standard load
- 85 % for the day at maximum load.

4.2 Sensitivity Analysis

Once the AS IS configuration has been analysed, the stability of the system must be controlled to assess its reaction ability in the event of changes to the set parameters (TO BE scenario). The analysis basically includes two aspects:

1. sustainability of the system in case of absence of a key resource (doctor)
2. reaction ability of the system against the increase of a key resource (doctor).

In the first configuration, in which a single doctor is considered to be present, the bounds of the confidence interval at 95 % and of the error interval are respectively:

$$131' \leq \bar{y} \leq 132' \tag{7}$$

and:

$$106' \leq y^* \leq 157' \tag{8}$$

whereas the doctors utilization coefficient is 83 %.

In the event of the maximum load days, the presence of a single doctor, after some simulation launches, was revealed to be unsustainable, so it was not taken into consideration in view of a possible implementation on the field in the 8 am to 3 pm time slot.

With reference to the second configuration, with 3 doctors present, the bounds of the confidence interval at 95 % and of the error interval were respectively:

$$55' \leq \bar{y} \leq 57' \tag{9}$$

and:

$$43' \leq y^* \leq 69' \tag{10}$$

with a consistent reduction of the mean waiting time.

A similar improvement can be found in the day of maximum load in which the bounds of the confidence interval at 95 % and of the error interval are respectively:

$$87' \leq \bar{y} \leq 90' \tag{11}$$

and:

$$64' \leq y^* \leq 113' \tag{12}$$

whereas the doctors utilization coefficients are:

- 75 % for the standard load day
- 82 % for the maximum load day.

In spite of the substantial improvements that the Authors have determined in the increase from 2 to 3 doctors, the addition of a highly qualified resource is economically and organisationally extremely complex, as also confirmed by the Managers of the ED themselves.

As a consequence the Authors have found an alternative solution which considers a separation of the path of the Yellow/Red codes and Green/White ones. Separation of the paths means a diversification of the two process lines that become almost independent. Indeed, each line will have a pre-assigned number of dedicated doctors. The new configuration would give rise to a "virtual" splitting of the ED by increasing the speed of response of the real emergencies and by creating a structure, suitable for promptly providing care to less critical patients. This was done without affecting the performances of the main function of the ED. In this scenario, in the days of medium load work, the bounds of the confidence interval at 95 % and of the error interval are respectively:

$$31' \leq \bar{y} \leq 34' \tag{13}$$

and:

$$18' \leq y^* \leq 48' \tag{14}$$

In the event of maximum workload the bounds of the confidence interval at 95 % and of the error interval are respectively:

$$86' \leq \bar{y} \leq 91' \tag{15}$$

and:

$$64' \leq y^* \leq 114' \tag{16}$$

whereas the doctors utilization coefficients are:

- 70 % for Yellow and Red codes for the day at standard load
- 76 % for Green and White codes for the day at standard load
- 70 % for Yellow and Red codes for the day at maximum load.
- 79 % for Green and White codes for the day at maximum load

Following the indications of possible organisational configurations of the ED system in terms of assigned personnel, the Authors wanted to investigate further the ED reaction ability with changes in the number of doctors (and thus of nurses) employed in the day at standard loads. For this reason it was analysed whether there are statistically significant differences on the mean waiting time of patients, with changes in the number of ED doctors, by using a statistical analysis technique called One-Way ANOVA and belonging to the Design of Experiments [27]. The experimental campaign is shown in Table 2 whereas the ANOVA table is shown in Table 3.

From the ANOVA table (Table 3) it can be seen how, with changes of the number of doctors present, there are effectively significant differences between the mean waiting times.

Table 2. Experimental campaign

Number of doctors	n_1	n_2	n_3	n_4
1	132.1	128.24	132.89	132.33
2	96.33	96.73	97.37	93.97
3	56.4	55.44	55.9	55.76

Table 3. Variance analysis

Source	DOF	Sum of the quadrates	Mean of the quadrates	Pr > F
Model	1	7.974	7.974	<0.0001
Error	10	0.026	0.003	
Corrected total	11	8.000		

Application of the Tuckey test also confirms that the mean waiting times resulting from the comparisons between the three levels of doctors involved all differ statistically significantly from one another.

By applying a linear regression model to the Table 2 data, we find the analytical relation existing between the independent variable X_1 (doctors) and the dependent variable Y_1 (mean patient waiting time):

$$Y_1 = 4,49 - 2,64E - 02 * X_1 \tag{17}$$

the trend of this is shown in Fig. 10, along with the relevant confidence and prediction intervals.

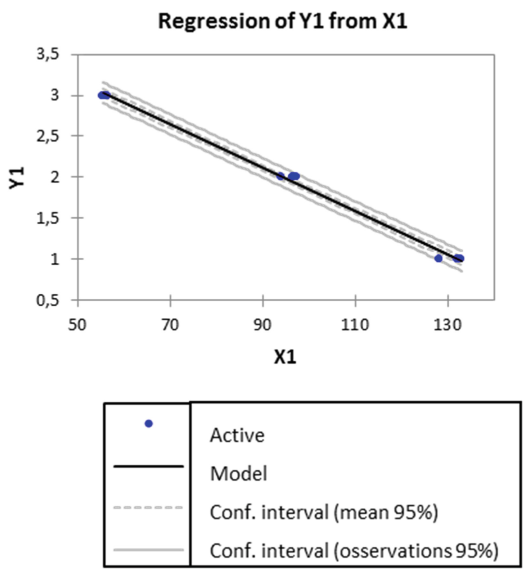

Fig. 10. Regression model

Having established the maximum waiting time required, the regression model obtained thus enables the decision makers to determine the number of doctors necessary and vice versa.

5 Discussion

The Authors' aim, on request of the Management of an average-sized Italian Hospital, was that of analysing the behaviour of the ED in its dual function, on the one hand of connecting element of the Hospital with the outside world (55 % of admissions actually come from the ED) and on the other, of Hospital Department with its relevant internal organisational and management problems. The first aspect mentioned above, already analysed partially in a previous paper, is a source of continuous dispute between the ED and the other Hospital Departments. Indeed the ED is considered by them as a serious disturbing element for their planning, due to the random admissions, a negative element capable of partially paralysing some characteristic activities with the consequent inevitable waste of resources. In order to cope with this situation, the Authors, having dismissed the idea of increasing the number of beds for economic reasons, had highlighted the advantages deriving from reducing the mean Hospital stay from the current 9.6 to 9 and 8.5 days. This was done through the use of an ED model in System Dynamics that allowed to point out to the Clinicians the existence of this possibility, but leaving the final decision to them. As a further solution, the Authors had also determined a second possibility based on the creation, inside the ED, of specific day Hospitals where chronic patients can be monitored (heart disease, lung disease, diabetes) in order to prevent them from entering in the acute phase. This because, if they enter in the acute phase they need for an unspecified Hospital stay, since they are frequently elderly, alone and not self-sufficient (incidence of 5000 days/year and 4000 k€ of relevant cost).

A further possible alternative, which nowadays becomes increasingly possible, thanks to technological improvement and a reduction in the cost of the equipment, is currently undergoing investigation by the Authors. It consists of remotely monitoring chronic patients, on line in real time 24/7, through body sensors which send measurements to specially equipped control centres, which can act in a timely manner with suitable care to prevent a worsening of the condition.

As regards the second aspect of the study, that is, the analysis of the existing organisational model in the ED, considering the discrete and random nature of the activity carried out in it, the Authors have used a DES simulation model.

After a careful phase of observing the ED examined, the flow diagram was firstly drawn up in order to better assess the relations between the different actors and the efficiency of the flow. At the same time a careful and accurate data collection campaign was carried out, divided by colour code, by time period and by day of the year, in order to distinguish the data regarding the days of normal load from those of maximum load. Then a DES model was built combined with a powerful three-dimensional graphic layout. After a careful validation phase, simulation campaigns were set up by using the model to test the Key Performance Indicators chosen as a measure of the ED efficiency (doctors utilization coefficient, patients waiting time, number of patients waiting, etc.)

in the existing AS IS managerial conditions. In the subsequent phase, three hypotheses (TO BE scenarios) were tested through the appropriately modified simulator. One to verify the system reactivity in case of a single doctor and in case of two potential improvements regarding the aim of reducing the patients' stay inside the ED. One was based on the increase of the doctors by one unit, the other on splitting the admitted patients flow. Inspired by the fundamental principles of Lean management, the idea of splitting, in the critical part of the day (8am-3 pm), has the dual purpose of:

1. assigning only the characteristic cases (Yellow and Red codes) to the emergency medicine specialists, thus preventing the waste of professional skills and energies on the most trivial cases (White and Green codes)
2. assigning the Green and White codes to the doctors from the internal Departments who are made available by effect of other Lean Management reorganisations carried out by the Authors in the Hospital itself (e.g. parallel operating rooms and redesigning the route of the surgical patient).

A direct consequence of the flows splitting is a reduction of the patients' waiting time, the recover of hours from doctors and nurses in the Hospital Departments, who would otherwise be underused, less pressure on the emergency medicine specialists, as well as less need for their simultaneous presence.

Concluding, the Authors point out that:

1. the use of quantitative methods and models combined with the Lean Management philosophy allows the Health Managers to test possible solutions of improving the system. The use of these quantitative instruments means that the impact of the different solutions on the Hospital system is already known before they are implemented and this makes it possible to concentrate only on the solutions with a truly significant impact. All this contributes to improving the process of Decision Making, otherwise based exclusively on experience, on common sense, on the intuition of the decision makers and, as a consequence, with obvious limits in seeking possible solutions;
2. by effect of the results obtained on the ED studied in this paper, the Manager of the ED of another large Hospital has begun an active collaboration with the Authors to carry out a similar streamlining study in his Department. The study performed was considered extremely positive, also in relation to the possibility of pooling the reciprocal skills of doctors and process engineers in a constructive and respectful relationship.

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