Preliminary comparison of different EDs performance, using Simulation.

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Abstract. A reference model is a model of something that contains a fundamental objective or idea of something and can be established as a reference for multiple purposes. We performed an analysis based on a reference model following the Spanish Ministry of Health's document of standards and recommendations to achieve better care, efficiency, and uniformity in emergency services. This standard describes the guidelines and resources needed in hospital emergency services for better patient care. We also analyzed the standards of emergency services in the following countries: the United States, the United Kingdom, Germany, Canada, Paraguay, Argentina, the United Arab Emirates, and Turkey. The objective of the research is to analyze the efficiency of the Spanish model following its reference standard compared to the standards of other countries, to explore how the Spanish emergency service would work using the parameters of the emergency service standards compared to the standards of different countries, specifically the KPI we analyzed is the Door to the Doctor (DtD), through simulation. It was concluded that in some countries, DtD times improve compared to the Spanish reference standard, and in some cases, they worsen.

Keywords: simulation · agent-based model · KPI · standard.

1 Introduction

The standards outline the guidelines and resources required for hospital Emergency Departments (EDs) to care for patients. As the ED is a central clinical unit

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of a hospital, it aims to achieve greater efficiency, more transparent communication, and uniformity of services across the health system. Spain has standards and recommendations for EDs. The objective of this document of standards and recommendations is to make criteria available to the administrators of hospital EDs for the organization and management of these units, for improving safety, efficiency, and quality in service provision, as well as for their design and equipment [1].

Some studies carried out on the analysis of standards in EDs are the following: The study conducted by Bermejo et al. [4], the objective is to determine which triage systems are used in Spain, specifically in the hospital emergency services of the national public health network, define their characteristics, and evaluate the degree of compliance with the recommendations regarding the study. The study conducted by Arco et al. [3] compares the physical structure, human resources, and quality indicators of emergency services in public hospitals in the Spanish regions of Madrid and Catalonia. The study conducted by Jones et al. [7] compares emergency nursing practice standards across five countries(United States, Canada, United Kingdom, New Zealand, and Australia). The study conducted by Moon et al. [12] studied triage accuracy using the Korean triage, they used Korean Triage and Acuity Scales (KTAS) based on the Canadian Triage and Acuity Scale (CTAS) to classify patients according to their symptoms. The nurses determine the triage level based on the symptoms. The study conducted by Pines et al. [13] provides an international perspective on ED crowding, including data and trends from 15 countries outside the United States.

In this paper, we present a simulation study using an Agent-Based Model (ABM) grounded in the standards and recommendations for hospital EDs in Spain [1]. The model incorporates key parameters outlined in the Spanish guidelines, including triage procedures, staffing, treatment, boxes, and patient volume. Using these specifications, we configured our ED simulator and conducted a comparative analysis with healthcare systems in Germany, the United Kingdom, the United States, Turkey, the United Arab Emirates, Canada, Argentina, and Paraguay. The objective was to evaluate the performance of the Spanish ED system when simulated under the parameters defined by these other countries. A key Performance Indicator (KPI) in this study is the Door-to-Doctor (DtD) time. DtD is a metric that measures the length of time from when the patient enters the Emergency Department until the medical screening exam begins by the physician. The simulator employed in this research was developed in earlier work by the High-Performance Computing for Efficient Applications and Simulation (HPC4EAS) research group at the UAB [8]. Section 2 describes The emergency department model. Section 3 presents the Results and discussion, and Section 4 presents the Conclusions and Future Work.

2 The emergency department model

In our research, we present a simulation of an ABM taking as a reference the document of standards and recommendations for hospital emergencies of Spain [1],

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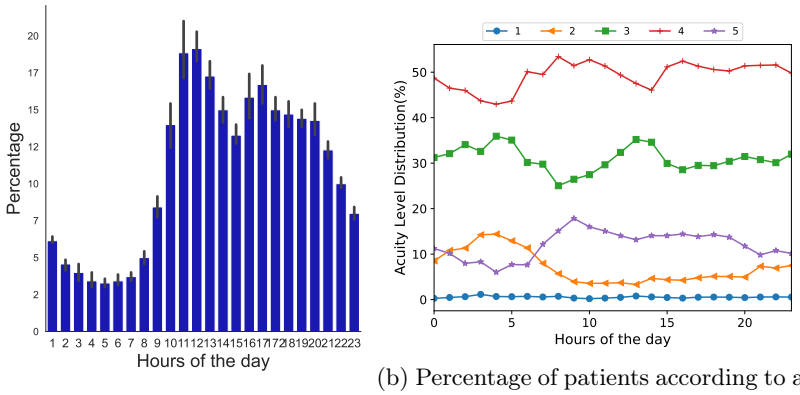
using the parameters specified in that standard: staffing of doctors and nurses, staffing of triage, number of boxes, number of patients. The other unmodified parameters, such as patient flow distribution, doctor and nurse patient attention time, triage time, imaging and labs services, are those validated by the Parc Tauli Hospital in Sabadell. The patient entrance used is from the Parc Tauli Hospital, as can be seen in Fig. 1 (a); on the x-axis, the hours of the day in which the patients arrive are observed, and on the y-axis, the percentage of patient arrivals per hour can be observed. As can be seen in the graph, the hours with the lowest number of patients arriving are between 1 a.m. and 8 a.m., after which patients come in a more significant proportion. The time when the peak of patients increases considerably is between 11 a.m. and 12 a.m.



(a) Patient and distribution.

(b) Percentage of patients according to acuity level by hour of day.

Fig. 1: Percentage of arrivals and distribution of patients by time of day and percentage of patients according to acuity level by hour of day.

In the Fig. 1 (b) shows the percentage of acuity level of patients arriving per hour. There are five acuity levels used in triage, where patients with acuity levels I, II, and III are the most serious, and IV and V are the mildest. It can be observed in the graph that the lowest percentage of patients who arrive at the ED are patients with severity level I, which is represented by the blue lines. Acuity level I represents 1 percent of patients who arrive at the hospital, acuity level II represents 10 percent of patients, acuity level III represents 30 percent, acuity level IV represents 49 percent, and acuity level V approximately 15 percent. On the x-axis, you can see the hours of the day, and on the y-axis, the percentage.

In Table 1 compares triage times in each country according to the triage standard used by that country, grouped by patient severity level. United Kingdom (UK) uses the MTS[10], United States (US) uses Emergency Severity Index (ESI)[6], Germany uses the MTS[5], Canada uses the CTAS[1], United Arab Emirates (UAE) uses the ESI[2], Turkye uses the ESI[14], Argentina uses the MTS[9],

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Spain uses the CTAS and Spanish Triage System (SET)[1], and Paraguay uses the SET[11].

Table 1: Comparison of triage time used in each country according to the acuity level. At level I, for all countries, attention must be immediate. Level II-V: Standard time of medical care from arrival at the hospital to the visit (DtD), expressed in minutes. Triage type, input, and parameters.

Country	**Type**	**Triage time (minutes)**				**Input**	**Parameters**		
		Level II	**Level III**	**Level IV**	**Level V**	**Patient**	**Nurse**	**Doc**	**Box**
Spain	CTAS/SET	15	30	60	120	300	9	8	22
US	ESI	10	60	120	240	100	20	10	30
UK	MTS	10	60	120	240	200	20	10	30
Germany	MTS	10	60	120	240	150	10	6	15
Canada	CTAS	15	45	120	240	70	10	8	20
UAE	ESI	10	60	120	240	200	15	10	30
Turkye	ESI	10	60	120	240	250	15	8	25
Argentina	MTS	10	60	120	240	50	10	6	20
Paraguay	SET	15	30	60	120	20	5	4	10

3 Results and discussion

Using our emergency simulator, we ran several simulations, each lasting nine months. We modified the patient, doctor, nurse, and box parameters established in the standards and recommendations document for Spain [1] and the standards of the other countries analyzed. This data can be found in Table 1. We substituted this data into our simulator as input parameters for each country. The severity acuity level distribution and other data, such as patient flow distribution, doctor and nurse patient attention time, triage time, imaging and labs services are the real data from the Parc Tauli Hospital in Sabadell. In all the figures analyzed, the x-axis shows the hours of the day, and the y-axis shows the average time of medical care from arrival at the hospital to the visit (DtD), expressed in minutes. The value in each Level column is the "maximum" DtD time for each acuity level (I to V) in each country. At level I for all countries, attention must be immediate. The value in the patient column is the total number of patients arriving at the ED per day in each country. The patient, nurse, doctor, and box columns are parameters for simulation according to each country's standards. Severity acuity level I patients, neither pass admission nor triage, they go directly to doctor. Patients with severity level I are very few and do not have significant differences, which is why we selected patients with severity levels II and III.

The first set of simulation results can be seen in Fig. 2; we group 4 countries, which are (a) Spain, (b) the United States, (c) Canada, and (d) the UK. The objective is to analyze how hospitals in Spain would behave using the parameters

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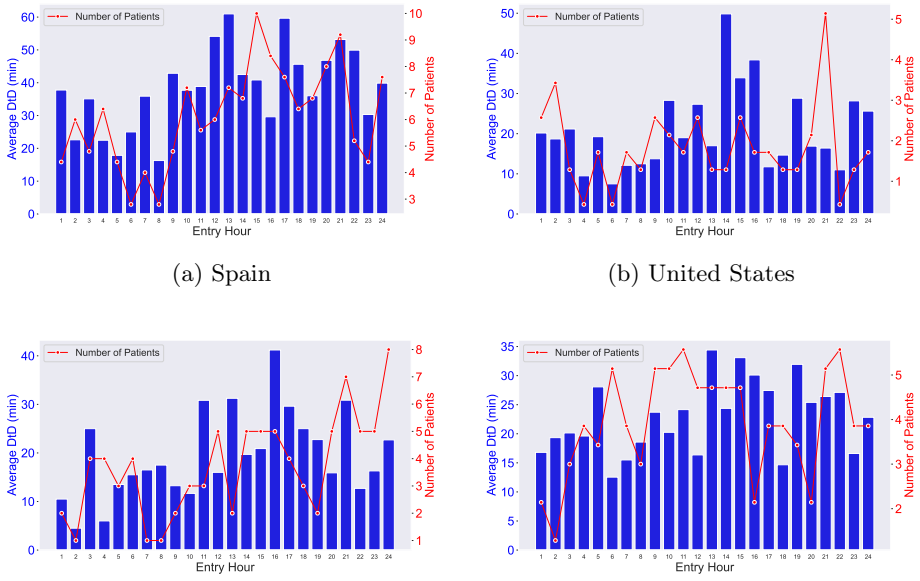
of standards in other countries. We analyze the acuity level II for Spain, the United States, Canada, and the UK. For this level, the standard triage time for these countries is 15 minutes for Spain, 10 minutes for the United States, 15 minutes for Canada, and 10 minutes for the UK, as shown in Table 1.



(a) Spain (b) United States

(c) Canada (d) UK

Fig. 2: Comparison of the average DtD for patients with acuity level II from Spain, United States, Canada and UK.

We can see in Fig. 2 (b) that in the United States, the DtD times improve much more than those of Spain; on average, they reach more than the time required by the triage standard for that acuity level. We can see in Fig. 2 (c) that in Canada it shows that the times for DtD improve much more than those of Spain, and on average, they manage to reach more than the time required by the triage standard for acuity level II. We can see in Fig. 2 (d) For the UK, using the data from the UK standard, the times are better than those of Spain, and the average maximum DtD time is shorter than that of Spain.

In Fig. 3, we group 6 countries, which are (a) Spain, (b) Argentina, (c) Paraguay, (d) Germany, (e) United Arab Emirates and, (d) Turkey. We analyzed the acuity level III for Spain, Argentina, Paraguay, Germany, United Arab Emirates and, Turkey. For this acuity level, the standard triage time for these countries is 30 minutes for Spain, 60 minutes for Argentina, 30 minutes for Paraguay, 60 minutes for Germany, 60 minutes for United Arab Emirates and, 60 minutes for Turkey as shown in Table 1.

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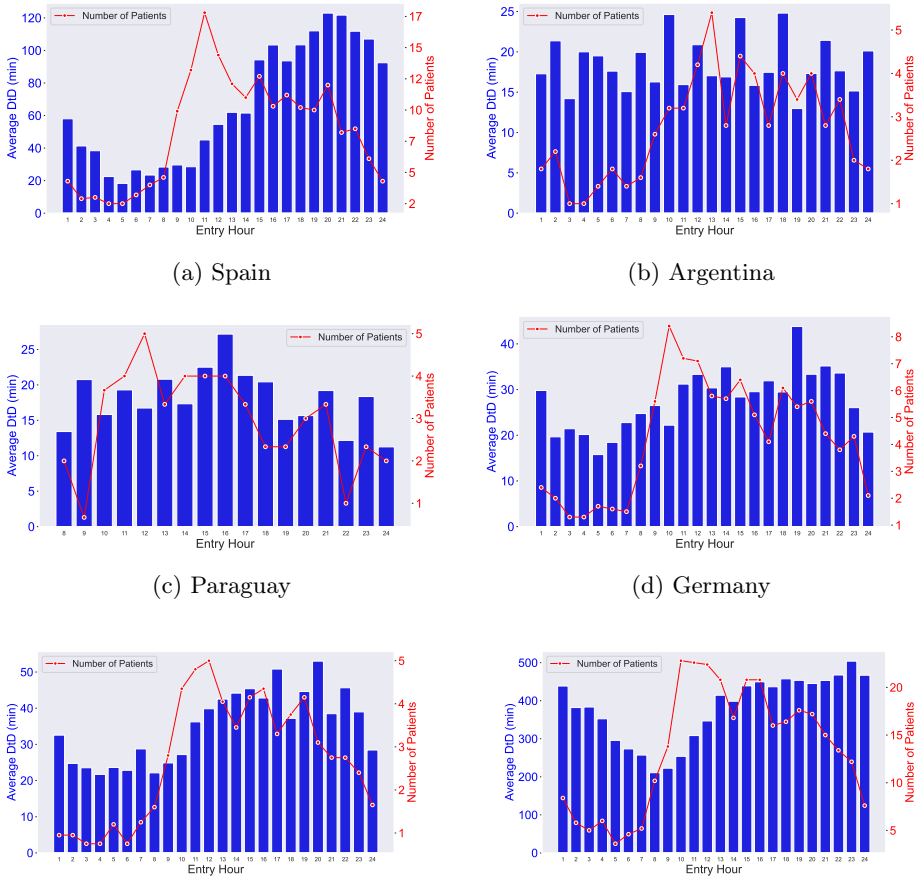

(a) Spain (b) Argentina

(c) Paraguay (d) Germany

(e) United Arab Emirates (f) Turkey

Fig. 3: Comparison of the average DtD for patients with acuity level III from Spain, Argentina, Paraguay, Germany, United Arab Emirates and, Turkey.

We can see in Fig. 3 (b) that in Argentina, the DtD times improve much more than those of Spain, and on average, they manage to reach more than the time required by the triage standard for that acuity level. We can see in Fig. 3 (c) that in Paraguay, the DtD times improve much more than those of Spain, and on average, they manage to reach more than the time required by the triage standard for acuity level III. In the case of Argentina and Paraguay, they always meet the time required by the standard of those countries for acuity level III, as can be seen in Fig. 3. It can be observed that between 4 and 10 a.m. Spain reached the 30-minute time required by the standard. It can be seen that (d)

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Germany achieves the DtD time required by its standard, which is 60 minutes, and its times are better than those of Spain.

In Fig. 3 (e), it is observed that in the United Arab Emirates, the DtD times behave better than those of Spain for severity level III. It reaches the DtD time required by its standard for all hours. In Fig. 3 (f), with the data from the Turkish standard, it shows that the DtD times are worse than those of Spain in all cases. The triage system used by the United Arab Emirates is the ESI, and the one used by Turkey is also the ESI, as shown in Table 1 as well as the parameters used for the simulation, such as the number of resources of patients, nurses, doctors, and boxes according to each country.

4 Conclusion and Future work

In this research, we present a simulation of an ABM, taking the reference standard and recommendations for ED in Spain as a reference, using the parameters specified in said standard, such as triage, staffing, boxes, and number of patients. Based on the parameters of said standard, we substitute these data from our ED simulator. We compare it with the parameters of the standards of other countries such as Germany, UK, the US, Turkey, the United Arab Emirates, Canada, Argentina, and Paraguay through simulations. We analyze how the Spanish system works using the parameters of the standards of the other countries. Specifically, the KPI we analyze is the DtD. We concluded that with some countries, the DtD time in Spain can be reduced, and it worsens by replacing it with other countries' standards. This research could help to re-evaluate the standard that is being used in that country so that it helps to reduce patient waiting time. Hospital administrators or government health managers could benefit from our simulator to evaluate if there are standards that could be applied to the country to help reduce patient waiting time and use them in hospitals. In future work, we intend to expand this research further and include the parameters of the population pyramid and more KPIs in the study, such as the Length of Patient Stay (LoS).

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Disclosure of Interests. The authors have declared that no competing interests exist.

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