

# A Systematic Literature Review Identifying the Dimensions and Components of Simulation of the Hospital Emergency Department During Emergencies and Disasters

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## Abstract

**Background:** The use of simulation in medical education is evolving widely around the world. Hospital emergency services in the event of accidents and disasters affect the quality of health care. It is critical to determine the fundamental features for developing a hospital emergency department simulation to improve emergency services. In this regard, the current study conducted a comprehensive assessment of studies with the determinations and components of hospital emergency department simulation during accidents and disasters.

**Methods:** In this systematic literature review, all studies between January 2010 and July 2021 were searched in MEDLINE/PubMed, EMBASE, ProQuest, Scopus, Web of Science, Iran medex Google Scholar, and Scientific Information Database (SID), MagIran databases and were analyzed with the thematic analysis approach and results were expressed based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 guidelines. The quality of the included studies was assessed using related checklists.

**Results:** The findings of this study were divided into 3 main categories and 10 subcategories, including factors related to manpower (manpower arrangement, performance-awareness-skills, safety, and communication), factors related to medical services (triage, time, and transfer of the injured), and factors related to resource management and support (physical environment, equipment, and the information system).

**Conclusion:** Through systematic planning, simulation allows for the identification of emergency department difficulties during accidents and disasters. Identifying dimensions and components, such as resource management and support, manpower, and medical services, is effective in designing the simulation of the hospital emergency department during accidents and disasters. Therefore, it is recommended to conduct future studies with a qualitative approach and focus on the factors affecting the simulation of the hospital emergency department during disasters, which has been done by the same researchers.

**Keywords:** Emergency Departments, Simulation, Disasters, Emergencies, Hospitals

**Conflicts of Interest:** None declared

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## Introduction

In recent years, the use of simulation in the field of education has found a growing position, and in countries

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### ↑What is “already known” in this topic:

Emergency preparedness of hospitals in the event of disasters depends on having highly skilled, confident, experienced, and trained staff. Despite the existence of different approaches and training tools for emergency department staff around the world, a comprehensive and systematic review to identify different dimensions There are no educational and influential factors.

### →What this article adds:

This study analyzes the present documentation to help policymakers and managers in the field of health to make employees more familiar with various aspects of education, including simulations and virtual reality, so that hospitals are fully prepared for disasters in the Emergencies and Disasters.

with newer and more complete computer and noncomputer technologies, it has become very popular among health education activists so that health care providers and hospital managers consider simulation as a new and effective strategy to provide more appropriate and effective training. This increases the level of knowledge in target groups and ultimately improves the quality of services provided to patients and provides a higher level of safety for them (1). The use of simulation allows emergency personnel to come to the bedside of a real critically injured person without stress and worry (2).

The emergency department is a subunit of a hospital, active 24 hours a day and 7 days a week the year. The emergency department is the entrance door for patients to the hospital. The official statistics of Iran show that the emergency departments of different hospitals in the country accept about 30,000,000 patients every year and subject them to emergency procedures (3). It is obvious that the development and readiness of hospital emergency departments against disasters are of great importance and it is necessary for the government health care system to pay special attention to strengthening the various dimensions and pillars of this department in the field of proper response to accidents and disasters (4).

The use of simulation in the field of health is expanding as a very important component. Because emergency department staff are more likely than other hospital staff to be in unforeseen situations, and they are constantly faced with the challenge of caring for critically ill patients in a complex hospital setting without having enough time to access information or practical skills before arriving at the patient's bedside, the use of this technology has received more attention to better train this ward's staff than other wards' staff. Because learning is done with all of the senses, as well as providing excellent teamwork tactics to assist lessen the obstacles that the hospital emergency department faces at various times, including at the time of the event, a training simulation is very good and engaging for learners (5, 6). In this regard, to identify the dimensions of the hospital emergency department in terms of preparedness and appropriate response to disasters, various simulated programs have been used by various involved organizations and institutions (7).

The simulation program helps hospital emergency personnel gain an understanding of the scientific and practical capabilities needed to care for the injured in the event of an accident. With the help of this method, they learn what skills they need to learn at what level to immediately treat the injured without imposing further complications on the patient (8, 9). Identifying the dimensions and components of simulation in the hospital during accidents and disasters to provide solutions and designing a simulation model of the hospital emergency department to teach people and solve problems in a virtual and persuasive environment gives more value to people's skills. This simulation is an innovative technology for changing or improving real systems. As a result, given the importance of the emergency department hospital in the face of emergencies and disasters, the goal of this study was to identify the dimensions and components of hospital emergency department

simulation during emergencies and disasters.

## Methods

### Protocol and Registration

This systematic review protocol was registered in PROSPERO, CRD42021242995, dated April 15, 2021.

### Eligibility Criteria

All studies conducted between January 2010 and July 2021 in which the hospital emergency department was considered as one of the important dependent or independent variables in the purpose of the study were included in this systematic literature review, which addressed the identification of the components of simulation of the hospital emergency department during accidents and disasters.

### Literature Search and Data Extraction

The search strategy was based on hand searching and electronic search. The main keywords in this systematic review were emergency departments, hospitals, disasters, and simulation. Electronic databases of MEDLINE (PubMed), EMBASE, Web of Science, Scopus, ProQuest, Iran medex, MagIran Google Scholar, and Scientific Information Database (SID) were searched. The International Journal of Environmental Research and Public Health, as well as Healthy Simulation and Virtual Emergency Department, were all investigated. Appendix 1 includes a syntax search of Scopus. Following that, a publication search was undertaken, and articles of interest were chosen based on titles and abstracts. The full text of all selected publications was reviewed after the screening. According to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020; relevant information was extracted from specified publications (Fig. 1) (10).

### Inclusion Criteria

All of these studies included qualitative and quantitative approaches in this systematic review, including simulation, virtual reality, and primary investigations. Quantitative methods such as descriptive and analytical design, as well as qualitative methods such as semi-structured interviews. The researcher also addressed descriptive (processing simulation, agent-based simulation) and continuous (decision-making process) simulation studies, as well as the components and dimensions of simulation of the hospital emergency department during accidents and disasters.

### Exclusion Criteria

As a result, all studies relating to a prehospital emergency, air emergency, and emergency relief to the simulation of other hospital nonemergency departments, engineering, and nonmedical sections, and emergency evacuation chemical biologic radiation nuclear emergencies were excluded.

All studies that involved simulating the entire hospital during a specific occurrence, such as earthquakes, floods, chemical radiation mishaps, and so on, were ruled out.

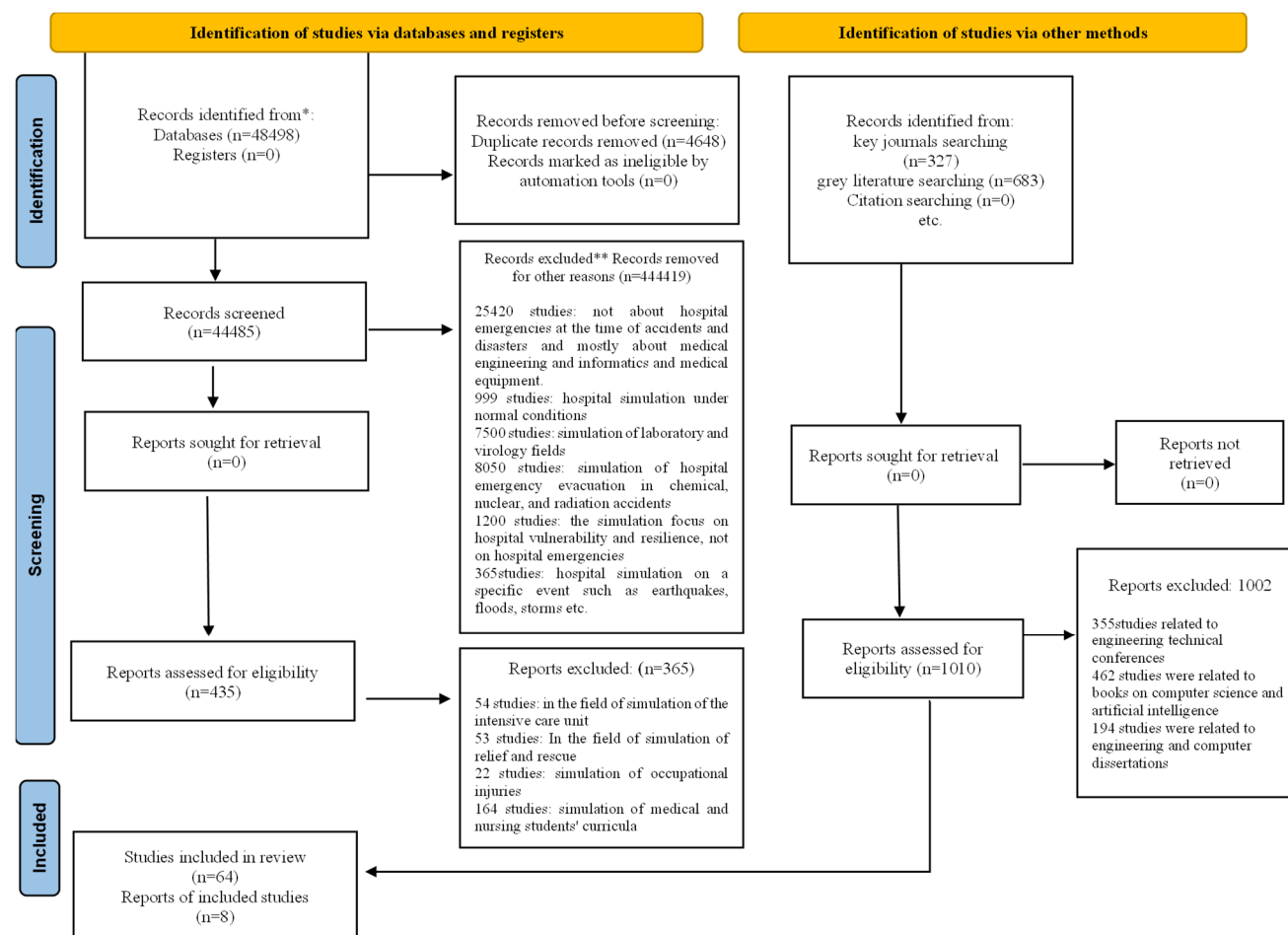


Fig. 1. PRISMA 2020 flow diagram for new systematic reviews of Identifying the dimensions and components of simulation of the hospital emergency department during emergencies and disasters \*Consider, if feasible to do so, reporting the number of identified records from each register or database searched (rather than the total number across all registers / databases).

To avoid linguistic bias, non-English language publications were included, and data were extracted from these papers.

### Data Extraction

In this study, searched articles all were transferred in EndNote software (EndNote X9; Thomson Reuters) and duplicates were removed. Then, the 2 authors independently screened the original articles. First, the title and the articles were reviewed and the selected articles were divided into the 3 groups of relevant, irrelevant, and unsure.

Articles deemed irrelevant by both reviewers were removed from the study, and each researcher reviewed the full text of the remaining studies and prepared a list of their included articles.

The 2 lists were then compared, and any differences were discussed. In cases where no agreement could be achieved, a third team member made the final decision on whether or not to include the article. Author names, year of publication, format (journal article or conference paper), study design, outcome, and corresponding studies were collected from each study included in this systematic literature review (Table 1). Then, the factors affecting the simulation of the hospital emergency department at the time of accidents and disasters normally by the researchers' data extraction form—were extracted.

### Risk of Bias in Individual Studies

Two reviewers (first and second authors) performed the risk of bias assessment independently.

The lack of consensus among the authors was settled through consultation with the third author and reaching a consensus. Due to the high heterogeneity of studies, articles were reviewed using the checklist of the Critical Appraisal Skills Program (CASP) (11).

The CASP is a method for reviewing articles and evaluating their quality, which includes 8 different checklists. In the present study, these checklists were used according to the type of selected articles. Following the evaluation of the quality of articles using these checklists, articles that did not have the minimum quality were not included in the study. By studying the full text, the articles were separately included by the 2 authors. The questions in this checklist consisted of 4 main sections such as type of study, study design, screening question, strength, and findings of recommendation.

All studies included in this systematic review were independently reviewed based on the questions in this checklist.

### Results

Out of 49,498 studies searched with the search syntax in databases, based on the compliance of the abstract and title of articles with the exclusion and inclusion criteria, 435 articles were reviewed, and finally, 72 were included in this study.

The dimensions and components of the simulation of the hospital emergency department at the time of accidents and disasters were extracted from their findings and results. The

articles were assessed by the thematic analysis approach.

From the total number of researched studies after removing duplicates ( $n = 4648$ ), a total of 44,419 studies were excluded due to the lack of inclusion criteria. These studies were divided into three 3 groups, with 25,420 being excluded from the current study due to their concentration on themes such as medical informatics, medical equipment, air relief, technical engineering simulations, and the lack of attention to hospital emergencies.

Also, 999 studies were excluded due to the focus on hospital simulation under normal circumstances, and 7500 studies were excluded due to the focus on laboratory and virology simulation, pediatric-related operations, and emergency department outpatient surgery procedures.

A total of 8050 studies were also excluded from the current study due to a focus on simulation of hospital emergency evacuation in chemical, nuclear, and radiation accidents, 1200 studies due to a focus on simulation of hospital vulnerability and resilience and not addressing hospital emergencies, and 365 studies due to a focus on simulation of the hospital in a specific event such as earthquakes, floods, storms, and so on. 7500 studies due to the focus on simulation of laboratory and virology fields, pediatric-related procedures, and outpatient surgical procedures of the emergency department, 8050 studies due to the focus on simulation of hospital emergency evacuation in chemical, nuclear, and radiation accidents, 1200 studies due to the focus on simulation of hospital vulnerability and resilience, and due to not addressing hospital emergencies, and 365 studies due to the focus on simulation of the hospital in a specific event such as earthquakes, floods, storms, et cetera were also excluded from the present study.

A total of 435 studies entered the risk of bias assessment stage and their full texts were studied based on the CASP checklist (Appendix 2a) (12) and appraisal strengthening of the reporting of empirical simulation studies (Appendix 2b) (2) and 365 studies were excluded due to the lack of factors related to the purpose of the present systematic literature review, which was to identify the dimensions and components of simulation of the hospital emergency department at the time of accidents and disasters.

Also, out of 435 studies reviewed in the full text, only 3 studies were qualitatively identified, which were excluded at the screening stage due to noncompliance with the inclusion criteria. Hence, all 72 included studies had been qualitatively performed and no quantitative studies were included in this systematic review.

A total of 64 journal articles, 5 conference papers, 2 book parts, and 1 thesis were among the first studies covered. Most of the studies were conducted by simulation through the discrete-continuous approach, and the agent-based approach, or by study through the qualitative method, and descriptive-analytical method (Table 1).

**Table 1.** Summary of characteristics of studies dimensions and components of simulation of the hospital emergency department

Authors	Years	Country	Type	Design	Finding focus of article	Study quality
Alsabr, et al (18)	2022	USA	Journal article	descriptive	Teamwork and communication training improve Emergency Department providing continuing education and competence management for emergency nurses simulated emergency care situations	High
Calder et al (19)	2022	Zealand	Journal article	qualitatively		Moderate
Abelsson, et al (20)	2021	Sweden	Journal article	descriptive		Moderate
Monette, et al (21)	2021	USA	Journal article	Simulation	In situ simulation is a valuable educational Emergency Department Modeling, Assessment and Design of an Emergency Department model for detection of emergency department	Moderate
Castanheira, et al (5)	2021	Guimarães	Journal article	Simulation		High
d'Etienne, et al (8)	2021	USA	Journal article	Simulation		Moderate
Shrestha, et al (22)	2021	Indian	Journal article	Simulation	Simulation of training and skills simulation model of an emergency department	High
Santis, et al (16)	2021	Italy	Journal article	Simulation		High
Matthew L, et al (23)	2020	USA	Journal article	Simulation	Strategies for providers in the emergency department	High
Vanbrabant, et al (24)	2020	Belgium	Journal article	Simulation	Simulation and optimization of an emergency department	High
Kiely, et al (25)	2020	Shawinigan	Journal article	Simulation	Simulation-Based Education Simulated patients in disaster medicine Simulation of the design of a new healthcare emergency department Design in the emergency department	High
Ingrassia, et al (26)	2020	Italy	Journal article	Simulation		Moderate
Colman, et al (27)	2020	USA	Journal article	Simulation		High
Agarwal, et al (28)	2020	Philadelphia	Journal article	Simulation		Moderate
Akkan, et al (29)	2020	Turkey	Journal article	Simulation	Models developed for emergency departments of hospitals Simulation for COVID-19 in the emergency departments Method to develop a response policy using in situ simulation Experimental simulation design for the emergency departments Healthcare simulation for the emergency departments Development in a standardized simulation	Moderate
Aldeky, et al (30)	2020	Saudi Arabia	Journal article	Simulation		High
Argintaru, et al (31)	2020	Canada	Journal article	Simulation		High
Atalan, et al (32)	2020	Turkey.	Journal article	Simulation		Moderate
Barker, et al (33)	2020	USA	Journal article	Simulation		High
Baylis, et al (34)	2020	Canada	Journal article	Simulation		High
Abraham, et al (35)	2020	USA	Journal article	Simulation		Moderate
Delisle, et al (36)	2020	UAS	Journal article	Simulation		Moderate
Hou, et al (37)	2020	China	Journal article	Simulation	Emergency department over-crowding The effect of nurse hospital staffing models on staff and patient -related outcomes. Simulation-based clinical systems virtual reality (VR) technology is suitable very for fields many of disaster medicine Simulation approach for analysis of patient flow in the emergency department Drills and simulation into medical training Virtual reality- pain management in the ED A comprehensive review on studies of emergency department simulation is provided.	Moderate
Butler, et al (38)	2019	Ireland	Journal article	Simulation		Moderate
Colman, et al (39)	2019	USA	Journal article	Simulation		High
Duan, et al (40)	2019	China	Journal article	Simulation		Moderate
Ghafari, et al (41)	2019	Iran	Journal article	Simulation		High
Sheen, et al (42)	2019	USA	Journal article	Simulation		Moderate
Sikka, et al (43)	2019	USA	Journal article	Simulation		Moderate
Vanbrabant, et al (44)	2019	Belgium	Journal article	Simulation		Moderate



## Identifying the Dimensions and Components of Simulation of the Hospital

Table 1. Continued

Authors	Years	Country	Type	Design	Finding focus of article	Study quality
Alshyyab, et al (45)	2019	Australia	Journal article	Emergency Department	Conceptual framework of patient safety culture in hospital emergency department.	Moderate
Traoré, et al (46)	2019	France	Journal article	Simulation	Simulation and modeling framework to support a analysis holistic of healthcare system	Moderate
Adel, et al (47)	2018	Cairo	Book	Emergency Department	study is to develop a novel approach which improves patient flow within ED.	Moderate
Adler, et al (48)	2018	Chicago	Conference article	Simulation	Use of simulation as a method to test hospital system.	Moderate
Akdag, et al (49)	2018	Istanbul	Conference paper	Simulation	Simulation program helps the emergency department process	High
Aminuddin, et al (50)	2018	Malaysia	Journal article	Simulation	Simulation technique is used to build a simulation model of the ED.	High
Aroua, et al (51)	2018	canada	Conference paper	Simulation	Optimization of the emergency department in hospitals using simulation	High
Kuo, et al (52)	2018	Hong Kong	Journal article	Simulation	System simulation to model the operations and patient flows at a hospital ED	High
Nofal, et al (53)	2018	Saudi Arabia	Journal article	Simulation	Knowledge, attitudes, and practices regarding emergencies disasters and preparedness among staff Emergency Department	Moderate
Aghera, et al (54)	2018	Brooklyn	Journal article	Education	SMART framework, the impact on the development of learning of educational actions in the ED	High
Carvalho-Silva, et al (55)	2018	Portugal	Journal article	Emergency Department	Management of the human resources and the required number of beds in the ED	High
Oueida, et al (56)	2018	Kuwait	Journal article	Simulation	Emergency department services using simulation	Moderate
Dehghani, et al (57)	2017	IRAN	Journal article	Simulation	Framework for simulation in the emergency department.	Moderate
Dubovsky et al (58)	2017	USA	Journal article	Simulation	Model simulation of essential functions in a busy E.	Moderate
Gardner, et al (59)	2017	USA	Journal article	Simulation	-Based utility broad of simulation-based in health care technologic	High
Jonson, et al (60)	2017	Sweden	Journal article	Simulation	The study was computer-based. Simulation exercises could improve head emergency nurses' skills.	Moderate
Cimellaro, et al (61)	2017	California	Journal article	Simulation	Developing a model which could describe the ability of the hospital ED to provide services to all patients after a natural disaster or any other emergencies.	High
Dunn, et al (62)	2017	Boston	Journal article	Simulation	Using simulation techniques as a tool to provide consistently safe care	Moderate
Nahhas, et al (63)	2017	Germany	Journal article	Simulation	A simulation study is conducted to identify aspects critical and propose possible to configure an urgent care center. scenarios	High
Aminuddin, et al (64)	2016	Malaysia	Journal article	Simulation	To determine the best resource allocation and to increase the efficient services of an ED in the simulation	Moderate
Bucci, et al (65)	2016	Italy	Journal article	Emergency Department	Emergency Department worldwide faces the challenges of crowding, waiting times, and cost containment	High
Fard, et al (66)	2016	USA	Journal article	Simulation	Emergency Department crowding, a hospital capacity sensitive indicator, is associated with unsafe reduced and operations quality of care.	High
Lantz, et al (67)	2016	Sweden	Journal article	Emergency Department	Effective capacity in an emergency department	Moderate
Ardalan, et al (68)	2015	IRAN	Journal article	Simulation	education innovative by using a virtual simulation method.	Moderate
Bearman, et al (69)	2015	Australia	Journal article	Simulation	Simulation may be a useful educational methodology for developing learning.	Moderate
Ghanes, et al (70)	2015	France	Journal article	Simulation	Efficiency of the ED performance through simulation	Moderate

Table 1. Continued

Authors	Years	Country	Type	Design	Finding focus of article	Study quality
Luigi Ingrassia, et al (71)	2015	Italy	Journal article	virtual reality	Virtual reality simulation is for abilities to mass casualty perform triage using (START) algorithm.	High
Hu, et al (72)	2015	China	Journal article	Simulation	Application tool for the simulation, assessment and analysis of disaster	High
Bloch et al (73)	2015	USA	Journal article	Simulation	Simulation is becoming standard during emergency medicine (EM) training.	High
Uriarte, et al (74)	2015	Sweden	Journal article	Simulation	Use of simulation for improving healthcare providers	High
Pucher, et al (75)	2014	London	Journal article	virtual reality	Feasibility of a novel virtual-worlds-based system for training and assessment in major emergencies response	High
Elmqvist, et al (76)	2014	Sweden	Journal article	virtual reality	' Strategies Patients for dealing with their situation at an Emergency Department	High
ElGammal, et al (77)	2014	Saudi Arabia	Journal article	Emergency Department	Emergency Department triage	High
Bruballa, et al (78)	2014	Spain	Journal article	Simulation	Knowledge discovery by the simulation	High
Al Owad, et al (79)	2014	Australia	Book	Emergency Department	Integrated approach for patient flow improvement in the hospital ED	High
Aboueljinane, et al (80)	2014	France	Thesis	Simulation	A simulation to improve the performance of an emergency	High
Abo-Hamad, et al (81)	2014	Ireland	Journal article	Simulation	An simulation-based decision support framework support is presented in this paper for process improvement. healthcare	High
Keshtkar, et al (82)	2014	IRAN	Journal article	Simulation	An emergency department performance uses simulation.	High
Cabrera, et al (83)	2012	Spain	Conference paper	Simulation	Simulation to design a system for healthcare emergency departments	High
Zheng, et al (84)	2011	China	Conference paper	Simulation	Simulations are for improving the efficiency.	High
Christ, et al (85)	2010	USA	Journal article	Simulation	To identify modern triage instruments	High

The findings of this study show that identifying the dimensions and components of simulation of the hospital emergency department at the time of accidents and disasters were divided into 3 main categories and 10 subcategories, including factors related to manpower (manpower

arrangement, performance-awareness-skills, safety, and communication), factors related to medical services (triage, time, and transfer of the injured), and factors related to resource management and support (physical environment, equipment, and the information system) (Table 2).

**Table 2.** The dimensions and components of simulation of the hospital emergency department at the time of emergency and disasters based on the systematic review

Group	Dimensions	Identifying the components of simulation of the hospital emergency department
Manpower	Manpower arrangement	Work shift pattern
		Number of manpower
		Distribution of manpower in each unit of the emergency department
		Planning the presence of service providers in the emergency department
		Work plan of service providers in emergencies
	Performance, awareness, skills	Manpower for triage
		Manpower for resuscitation
		Providing manpower in an emergency
		Clinical knowledge and skills of health care providers
		Effectiveness of services (quality of services and efficient services) provided by service providers
		Knowledge and preparedness of service providers in an emergency
		Clinical capability of health care providers
		Care team ready to provide health care services
		Awareness of the caring role of each service provider
		Awareness of guidelines and standards of the hospital emergency department
	Safety	Threats to health care providers
	Communication	Dangers threatening the injured
		Physical hazards of the environment
		Interaction between the patient and the physician
		Teamwork between health care providers
		Behavioral skills
Medical services	Triage	Dynamic interactions of service providers
		How to communicate with the injured
		Prioritizing the injured
		Leveling triage for the injured
		Triage process
	Time	Duration of triage (start and end times of triage)
		Waiting time for a visit to the treatment room
		Waiting time for admission
		Duration of stay in the emergency room
		Time of entry of the injured to the emergency department
	Transfer of the injured	Emergency management
		The process of transferring the injured
		Patient entry flow to the emergency department (by ambulance or personal car)
		Accumulation of the injured in the emergency department
		Increase in the number of the injured referring to the emergency department
Resource management and support	Physical environment	Waiting space for treatment
		Resuscitation space
		Triage space
		Outpatient surgery space
		Treatment space
		Pharmaceutical space
		Isolated space
		Space for an ambulance in an emergency
		Location of the emergency department
		Specific entry and exit paths
	Information system	Integrating the healthcare space
		Technology infrastructure of the emergency department (HIS system)
		Registration of the injured information in the emergency department (file formation)
		How to admit and discharge the injured
		Electronic service records of the injured
	Equipment	Informing and communication with other departments
		Manpower recruitment
		Availability of equipment
		Standby equipment
		How to allocate emergency beds
		Optimal use of equipment
		Proper distribution and sharing of equipment
		Equipment supply chain (logistics, and storage)
		Increase in capacity to respond



## Discussion

### 1. Factors Related to Manpower

The most important factors related to manpower identified in the simulation components of the emergency department during emergencies and disasters included manpower arrangement, performance-awareness-skills, safety, and communication.

#### 1-1-Knowledge, Skills, and Performance

Based on the findings of the systematic review of related articles, manpower arrangement, performance-awareness-skills, safety, and communication were identified as the most effective factors related to manpower. In total, 22 studies examined the effects of knowledge, skills, training, and performance of health care providers. According to the results of these studies, physicians and nurses in the emergency department were the primary manpower staff in abnormal conditions. However, their responsibilities increased several times in the event of a hospital emergency. High efficiency and appropriate skills along with real capabilities were essential to save human lives and improve their health in emergencies (11, 12). The findings of studies also revealed that having the right information, skills, and experience is critical for providing good and safe care and that doing simulation exercises can help them enhance their skills (13). In terms of training and competency evaluation, practice is critical to becoming an experienced and highly talented individual. Because simulation allows theoretical and practical knowledge to be transformed into an experience, it is becoming more popular in education (13-15, 11). Other studies found that health care personnel's abilities and disaster preparedness were critical in responding to the World Health Organization's and Pan American Health Organization's requests for fundamental health care measures to ensure safe facilities in an emergency. Because health care providers are the first critical caregivers of the injured, such a response should involve safety assessments, protection, and training of health personnel in emergencies, as well as disaster strategy planning to manage the situation. To minimize the effect of disasters, health care providers should be prepared and take care of the injured with various abilities and care (16-19, 2). Studying the impact of health care team training and simulation-based training is essential for preparing health care services to respond to disasters. There are two key areas where educational priorities have been established. The first is service quality and a capable team in the care process (eg, proper use of equipment and standardization of services) (20, 21, 17).

#### 1-2 -Safety

Another relevant element highlighted in this systematic review is safety and error reduction. Studies in this field have found that protecting the safety of health care workers by enhancing technical skills, boosting team performance, and lowering medical errors has led to an increased focus on practices and simulation in medical education, continuing education, and team training. They provide a safe environment for learning, maintaining technical skills, and improving knowledge, confidence, communication, and group behaviors (22, 12). Simulation-based learning related to error reduction is a tool to improve the quality of services

to injured people in the event of accidents and disasters. Simulation training in a real clinical environment is a new approach to identify health care system deficiencies (23, 24, 18).

Effective interpersonal communication and skills have long been recognized as essential to providing quality health care. Interactions between the patient and the physician in stressful work areas, such as hospital emergency departments, can challenge the provision of quality care (25, 26).

#### 1-3- Manpower Arrangement

One of the associated elements revealed in this systematic review was the workforce. Nurses make up the greatest group have been introduced, components and specifications including the skill, degree, or competency, staffing, staff levels, nursing shifts, or nurses' work patterns (26). Related studies showed that one of the main strategies for selecting staff has been how to plan work shifts, which is very important in times of accidents and disasters so that today appropriate person layout is used to determine the allocation of the optimal staff resources (medical number of staff and a combination of medical staff) to meet the needs of patient care (27-29). Because the emergency department is one of the most important departments in health care centers, organizing the flow of patients in this department is an important issue. Factors such as a shortage of nurses and physicians, long hospitalization periods in the triage area, long waiting times, and slow laboratory and radiology stages can cause problems for patients; thus, in the event of accidents or disasters, it is necessary to use efficient human capacity for clinical management of patients' flow (30, 31). Some existing studies showed the use of a more realistic and accurate simulation model was necessary to estimate system performance based on human resources, deployment, and relocation, work shift planning, human resource dimensions, manpower recruitment, and replacement or control of variables (manpower or service providers), including determination of skills and the total number of human resources because the amount of human resource utilization, as the total workload divided by the total operating time of these 2 criteria, was very important (32-35, 29).

### 2. Factors Related to Medical Services

The most important factors related to medical services identified in the simulation components of the emergency department at the time of accidents and disasters included triage, time, and transfer of the injured.

#### 2-1-Triage of the Injured

One of the main components related to medical services in the triage of the injured. The purpose of triage is to quickly and safely assess patients, their health care needs, and the level of care, and base the priority on their medical needs (36, 37). The results of the study showed that triage was essential for most busy emergency departments. The tools of Simple Triage and Rapid Transport have been commonly included in many hospital programs. This method is thought to be prevalent into facilitate 2-way communication between first responders, hospital staff, and medical transport teams (38, 30, 26, 13). The global development of scales triage over the past 2 decades has led to considerable

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research into the reliability and validity of this scale (39-41, 27). Congestion is prevalent in emergency rooms, and it can result in catastrophic errors. Throughout triage, care priorities and acute levels are assessed, and omissions during the triage process might have negative consequences for patients (42). The results of studies showed that with the increase in referrals to emergency departments at the time of emergencies and disasters to more than 130 million people in the year, triage nurses were under pressure to quickly and accurately assess each patient. The crucial start of treatment for patients in emergency rooms is assessment triage, which determines the severity of patients to prioritize care. Initial evaluation of triage can affect the length and quality of visits to emergency departments. Because of the nature of the emergency department, nurses are subjected to frequent errors that can lead to inaccuracies in the assessment, lowering the quality of care. However, by placing nurses in a simulation environment during accidents and disasters, as well as having experience with mass injured people, these errors can be reduced to some extent (43-48, 25). All research dealing with the expanding and well-known congestion problem needed modeling of injured triage at the emergency department, according to studies. Because simulation models are often used to evaluate solutions to reduce the impact of this phenomenon worldwide (49, 40), in the field of triage and triage training, simulated exercises and courses are less considered and this is when the results of studies have shown the positive impact of such activities on the strength and awareness of health care personnel in the field of triage. By practicing, people can imagine themselves in critical and special situations, and as a result, when they face these situations, they can control the existing pressures and stresses and can act in a structured way (13-15). Bulduc et al (2018) evaluated human and computer triage in catastrophes and found little difference in the accuracy of system and the human triage. Therefore, due to the high potential of computer systems and artificial intelligence, the necessary upgrades should be done to be able to help humans in the field of triage (53). The findings of this study were somewhat different from those of the present study. The results of the present study showed that decision-making systems and artificial intelligence lacked the requisite power and efficiency, and performed poorly when compared to humans, but the Bulduc study found that computer systems' triage accuracy was comparable to humans.

## 2-2- Time

One of the factors influencing medical services is time, which is very important to treat the injured and reduce the waiting time. Studies showed that due to the important role of hospital emergency departments in providing emergency care, the emergency department was in constant demand, which often led to long waiting times. The use of emergency department simulation modeling and its contribution to reducing patient wait times has been significant (54-57). Some studies showed that despite the development of information and the growth of medical technology, patient waiting times still existed. The problem with today's healthcare systems is that patients frequently have terrible experiences in waiting rooms, even though their presence is required for receiving medical treatment. The health care

system affects the patient's waiting time under unpredictable circumstances and complexity. To deal with these conditions and reduce patient dissatisfaction with waiting time, the queue theory implementation is necessary (58-61).

## 2-3- Transfer of the Injured

Another factor related to the medical services is the transfer of the injured. Studies showed that the transportation of the injured has highlighted the lack of intensive care beds and appropriate systems for the transfer of this group of patients (62, 63). Appropriate measures before transferring the injured, clinical conditions, physiological parameters, and appropriate equipment are necessary (16, 17). According to studies, trauma is the most common reason for moving people from the emergency ward to other wards. A significant number of injured people are transported with acute conditions and require surgery. Emergency physicians should be actively involved in the development of intensive care systems (65, 29, 23, 19, 2).

## 3. Factors Related to Resource Management and Support

Findings extracted from the studies indicated that some resource-related factors were effective in the simulation components of the hospital emergency department. In the present study, these factors were classified and discussed in 3 categories, including physical environment, equipment, and the information system.

### 3-1- Physical Environment

The physical environment is one of the effective factors in identifying the components of the hospital emergency department in the simulation. Simulation provides a better understanding of the physical environment of the emergency department and the decision to create optimal strategies (66-68). According to studies, the emergency department's physical environment should be a fully isolated place from the rest of the hospital. Due to the crowds and the volume of patient admissions, triage rooms (41), the cardiac resuscitation room of the injured (69, 70), the treatment room (71), a space for the ambulance entry into the hospital (72, 21), and specific entry and exit paths (73) should be integrated and coordinated. This coordination between different parts in times of accidents and disasters can be achieved by a simulation model to avoid congestion (74). Other studies in the field of simulation also stated that the design of a hospital emergency simulation when referring the massively injured to the emergency room of the cardiopulmonary resuscitation room and the intensive care unit, the operating room is needed (75).

### 3-2- Equipment

One of the elements affecting resources in a hospital emergency is equipment, which has an impact on the dimensions and components of the simulation. According to studies, hospitals provide their employees with resources and equipment to fulfill the demands of patients sent to the emergency department to provide quality services and proper allocation and sharing (76-78, 28). Researchers showed that simulation could be effective in improving the capacity of equipment (79, 54) and also simulation methods could be used to optimize the evolution of equipment in the event of accidents and disasters (76, 35). Other research has

found that properly planning the capacity and facilities of a hospital's emergency department can considerably improve the capability and efficacy of treating emergency patients who have been injured in a disaster. Such information can be used for patient/ ambulance routing, equipment planning, and management of emergency operations (80, 83, 73, 2).

### 3-3- Information System

The information system is also one of the components in the simulation design of the emergency department. In this regard, many studies were conducted and researchers found that recording the information, and electronic service records of the injured referred to the emergency department could be effective in providing health services to the injured (59, 39, 25). Studies showed that computerized registration of the injured referring to the hospital emergency department helped reduce the risk of errors in clinical decision-making (84, 85, 15).

### Conclusion

The systematic review of studies on the dimensions and components of simulation of the hospital emergency department showed that most studies were conducted to identify the components of the hospital emergency department to design a simulation model and the impact of factors related to manpower, factors related to health services, and factors related to sources were investigated. However, the study of the simulation of other hospital wards, including the intensive care unit and general wards, has received less attention from researchers. Also, among the conducted studies, the number of ones related to occupational injury simulation was very limited.

Since in most of the studies reviewed in the present systematic review, the focus has been on providing services to the injured to identify the dimensions and components of simulation of the hospital emergency department during accidents and disasters, the main theme of the study was related to environmental factors, skills, awareness, and knowledge of service providers. On the other hand, the results of studies on the effect of health care factors in the simulation of the emergency department showed that the referral of the injured to the hospital emergency department in the face of emergencies was unpredictable. Therefore, the assessment of readiness to provide services has drawn more attention. Thus, according to the results of this systematic review, identifying the dimensions and components of simulation of the hospital emergency department at the time of accidents and disasters is with the approach of identifying all risks. Thus, identification of the dimensions and components of a hospital at the time of accidents and disasters, including radiation, chemical, and nuclear accidents with a focus on human health and with minimal damage to human health, is recommended in future studies.

Finally, because the present systematic review focuses on identifying the simulation components of the hospital emergency department, such as the equipment supply chain and the provision of health services to injured patients referred to the hospital emergency department, the findings suggest that the hospital emergency department's equipment,

manpower, and physical environment are effective in designing the simulation. As a result, future studies should use a qualitative approach and concentrate on simulating the hospital emergency department during disasters, as done by the same researchers.

### Acknowledgment

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### Ethical Approval

The study was approved by Iran University of Medical Sciences with the code of ethics of IR.IUMS.REC.1400.633.

### Abbreviation List

Simple Triage and Rapid Transport = START

Cardiopulmonary Resuscitation = CPR

Operating Room = OR

Intensive Care Unit = ICU

Critical Appraisal = CASP

Strengthening the Reporting of Empirical Simulation Studies = STRESS

Emergency Departments = ED

Pan American Health Organization = PAHO

World Health Organization = WHO

Cardiopulmonary resuscitation= CPR

### Conflict of Interests

The authors declare that they have no competing interests.

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## Appendix 1. Search strategy SCOPUS

Our initial search syntax for SCOPUS was (ALL("Emergency department") OR ALL("Emergency Unit") OR ALL(Unit AND Emergency) OR ALL("Emergency Department") OR ALL(Department AND Emergency) OR ALL("Emergency Ward") OR ALL(Ward AND Emergency) OR ALL(Accident AND "Emergency Department"))AND(ALL(Disaster) OR ALL(Emergency) OR ALL(Emergencies) OR ALL("Natural Disaster") OR ALL (catastrophe) OR ALL (phenomena) ALL(Disaster AND Natural))OR(ALL("Emergency department") OR ALL("Emergency Unit")OR ALL(Unit AND Emergency) OR ALL("Emergency Department") OR ALL(Department AND Emergency)OR ALL("Emergency Ward") OR ALL(Ward AND Emergency) OR ALL(Accident AND "Emergency Department"))AND(ALL(Simulation) OR ALL(modeling) OR ALL("virtual reality") OR ALL(virtual) OR ALL("Computer Simulations") OR ALL("Computerized Model") OR ALL(Model AND Computerized))AND(TITLE-ABS("Emergency department") OR TITLE-ABS ("Emergency Unit") OR ALL(Unit AND Emergency) OR TITLE-ABS("Emergency Department") OR TITLE-ABS (catastrophe) OR ALL (phenomena) OR ALL(Department AND Emergency)OR TITLE-ABS("Emergency Ward") OR ALL(Ward AND Emergency) OR TITLE-ABS (Accident AND "Emergency Department"))AND(TITLE-ABS (Disaster) OR ALL(Emergency) OR TITLE-ABS (Emergencies) OR TITLE-ABS("Natural Disaster") OR ALL(Disaster AND Natural))OR(TITLE-ABS("Emergency department") OR TITLE-ABS ("Emergency Unit")OR ALL(Unit AND Emergency) OR TITLE-ABS("Emergency Department") OR ALL(Department AND Emergency)OR ALL("Emergency Ward") OR ALL(Ward AND Emergency) OR ALL(Accident AND "Emergency Department"))AND(TITLE-ABS(Simulation) OR ALL(modeling) OR TITLE-ABS ("virtual reality") OR TITLE-ABS (virtual) OR ALL("Computer Simulations") OR ALL("Computerized Model") OR ALL(Model AND Computerized))AND(TITLE ("Emergency department") OR TITLE-ABS ("Emergency Unit") OR ALL(Unit AND Emergency) OR TITLE-ABS("Emergency Department") OR TITLE (catastrophe) OR TITLE-ABS (phenomena) OR ALL(Department AND Emergency)OR TITLE-ABS("Emergency Ward") OR ALL(Ward AND Emergency) OR TITLE-ABS (Accident AND "Emergency Department"))AND(TITLE (Disaster) OR ALL(Emergency) OR TITLE (Emergencies) OR TITLE-ABS("Natural Disaster") OR ALL(Disaster AND Natural))OR(TITLE-ABS("Emergency department") OR TITLE-ABS ("Emergency Unit")OR ALL(Unit AND Emergency) OR TITLE-ABS("Emergency Department") OR ALL(Department AND Emergency)OR ALL("Emergency Ward") OR ALL(Ward AND Emergency) OR ALL(Accident AND "Emergency Department"))AND(TITLE (Simulation) OR ALL(modeling) OR TITLE ("virtual reality") OR TITLE-ABS (virtual) OR ALL("Computer Simulations") OR ALL("Computerized Model") OR ALL(Model AND Computerized))AND(PUBYEAR < 2021 AND PUBYEAR > 2010).

## Appendix 2a. The Critical Appraisal Skills Programme (CASP) checklist

Major Components	Response options		
Section A: Are the results of the study valid?			
1. Did the study address a clearly focused issue?	Yes	No	Can't Tell
2. Did the authors use an appropriate method?	Yes	No	Can't Tell
Is it worth continuing?			
3. Was the research design appropriate to address the aims of the research?	Yes	No	Can't Tell
4. Was the recruitment strategy appropriate to the aims of the research?	Yes	No	Can't Tell
5. Have the authors identified all important confounding factors and bias?	Yes	No	Can't Tell
6. Is it possible to reflect, expand results and achievements?	Yes	No	Can't Tell
Section B: What are the results?			
7. Have ethical issues been taken into consideration?			
8. Was the data analysis sufficiently rigorous?			
9. Is there a clear statement of findings?	Yes	No	Can't Tell
Section C: Will the results help locally?			
10. How valuable is the research?	Yes	No	Can't Tell



**Appendix 2b. The Critical Appraisal Strengthening the Reporting of Empirical Simulation Studies (STRESS)**

Section/Subsection	Item	Recommendation
<b>1. Objectives</b>		
Purpose of the model	1.1	Explain the background and rationale for the model.
Model Outputs	1.2	State the qualitative or quantitative system level outputs that emerge from agent interactions within the ABS or DCS.  Define all quantitative performance measures that are reported, using equations where necessary. Specify how and when they are calculated during the model run along with how any measures of error such as confidence intervals are calculated
Experimentation Aims	1.3	If the model has been used for experimentation, state the research questions that it was used to answer.  a.) Theory driven analysis. – Provide details and reference the theories that are tested within the model.  b.) Scenario based analysis – Provide a name and description for each scenario, including a rationale for the choice of scenarios and ensure that item 2.3 (below) is completed.  c.) Design of experiments – Provide details of the overall design of the experiments with reference to performance measures and their parameters (provide further details in data below).  d.) Simulation Optimisation – (if appropriate) Provide full details of what is to be optimised, the parameters that were included and the algorithm(s) that was used. Where possible provide a citation of the algorithm(s).
<b>2. Logic</b>		
Base model overview diagram	2.1	Provide one or more of: state chart, process flow or equivalent diagrams to describe the basic logic of the base model to readers. Avoid complicated diagrams in the main text.
Base model logic	2.2	Give details of the base model logic. This could be text to explain the overview diagram along with extra details including ABS product and process patterns. Include details of all intermediate calculations.
Scenario logic	2.3	Give details of any difference in the model logic between the base case model and scenarios. This could be incorporated as text or, where differences are substantial, could be incorporated in the same manner as 2.1.
Algorithms	2.4	Provide further detail on any algorithms in the model that (for example) mimic complex or manual processes in the real world (i.e. scheduling of arrivals/appointments/operations/maintenance, operation of a conveyor system, machine breakdowns, etc.). Sufficient detail should be included (or referred to in other published work) for the algorithms to be reproducible. Pseudo-code may be used to describe an algorithm.
Components	2.5	2.5.1. Environment  Describe the environment agents interact within, indicating its structure, and how it is generated. For example, are agents bound within a homogeneous grid, or do they have continuous movement through a detailed landscape incorporating geographic or environmental information?
		2.5.2. Agents  List all agents and agent groups within the simulation. Include a description of their role in the model, their possible states, state transitions, and all their attributes.  Describe all decision-making rules that agents follow in either algorithmic or equation form. Where relevant authors should report: <ul style="list-style-type: none"> <li>• The data that agents access (I.e. internal attributes or external information from the environment) and how it is used.</li> <li>• The objectives agents seek to achieve.</li> <li>• The algorithms, optimisations, heuristics and rules that agents use to achieve objectives.</li> <li>• How agents work together within a group along with any rules for changes in group membership.</li> <li>• Predictions of future events and adaptive action.</li> </ul>
		2.5.3. Interaction Topology  Describe how agents and agent groupings are connected with each other in the model define: <ul style="list-style-type: none"> <li>• with whom agents can interact,</li> <li>• how recipients of interactions are selected</li> <li>• what frequency interaction occurs.</li> <li>• How agents handle and assign priorities to concurrent events</li> </ul> It is recommended that interactions are described using a combination of equations pseudo-code and logic diagrams.  Report how interactions are affected by agent states and the environment state
		2.5.4 Entry / Exit  Where relevant, define how agents are created and destroyed in the model.

## Appendix 2b. Continued

Section/Subsection	Item	Recommendation
3. Data		
Data sources	3.1	<p>List and detail all data sources. Sources may include:</p> <ul style="list-style-type: none"> <li>• Interviews with stakeholders</li> <li>• samples of routinely collected data,</li> <li>• prospectively collected samples for the purpose of the simulation study,</li> <li>• public domain data published in either academic or organisational literature. Provide, where possible, the link and DOI to the data or reference to published literature.</li> </ul> <p>All data source descriptions should include details of the sample size, date ranges and use within the study.</p>
Pre-processing	3.2	Provide details of any data manipulation or filtering that has taken place before its use in the simulation, e.g., interpolation to account for missing data, removal of outliers or filtering of large scale data.
Input parameters	3.3	<p>List all input parameters in the model, providing a description of each parameter and the values used. For stochastic inputs provide details of any continuous, discrete or empirical distributions used along with all associated parameters. Where applicable define the time/spatial dependence of parameters and any correlation structure.</p> <p>Clearly state:</p> <ul style="list-style-type: none"> <li>• Base case inputs</li> <li>• Inputs used in experimentation, where different from the base case.</li> <li>• Where optimisation or design of experiments has been used, state the range of values that parameters can take.</li> </ul> <p>Where theoretical distributions are used, state how, these were selected and prioritised above other candidate distributions.</p>
Assumptions	3.4	Where data or knowledge of the real system is unavailable, state and justify the assumptions used to set input parameter values and distributions; agent interactions or behaviour; or model logic.
4. Experimentation		
Initialisation	4.1	<p>State if a warm-up period has been used, its length and the analysis method used to select it.</p> <p>State what if any initial agent and environmental conditions have been included. For example, the initial agent population size, agent states and attributes, initial agent network structure(s), and resources within the environment. Report whether initialisation of these variables is deterministic or stochastic.</p>
Run length	4.2	Detail the run length of the simulation model and time units.
Estimation approach	4.3	State if the model is deterministic or stochastic. If the model is stochastic, state the number of replications that have been used. If an alternative estimation method has been used (e.g., batch means), provide full details.
5. Implementation		
Software or programming language	5.1	<p>State the operating system and version and build number.</p> <p>State the name, version and build number of commercial or open-source ABS software that the model is implemented in.</p> <p>State the name and version of general-purpose programming languages used (e.g., Python 3.5.2). Where packages, frameworks and libraries have been used provide all detailed including version numbers.</p>
Random sampling	5.2	State the algorithm or package used to generate random samples within the software/programming language used e.g. Mersenne Twister or Java. Random version x.y
Model execution	5.3	<p>If the ABS model has a time component, describe how time is modelled (e.g., fixed time steps or discrete-event). State the order of variable updating within the model. In time-stepped execution state how concurrent events are resolved.</p> <p>If the model is parallel, distributed and/or use grid or cloud computing, etc., state and preferably reference the technology used. For parallel and distributed simulations, the time management algorithms used. If the HLA is used then state the version of the standard, which run-time infrastructure (and version), and any supporting documents (FOMs, etc.)</p>
System Specification	5.4	State the model run time and specification of hardware used. This is particularly important for large scale models that require substantial computing power. For parallel, distributed and/or use grid or cloud computing, etc. state the details of all systems used in the implementation (processors, network, etc.)
6. Code Access		
Computer Model Sharing Statement	6.1	Describe how someone could obtain the model described in the paper, the simulation software and any other associated software (or hardware) needed to reproduce the results. Provide, where possible, the link and DOIs to these.