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A GIS Tool That Provides Intelligent Solutions in Emergency Departments during COVID-19

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Abstract

The response to the COVID-19 pandemic has led to a revolution in open geographic information system (GIS) sources and Web GIS, which have grown considerably. Patient handover and crowding are critical issues to address during the COVID-19 pandemic. Saudi Arabia's Vision 2030 aims to optimise quality and resource utilisation in emergency departments (EDs). GIS technology has been used to clarify the state of COVID-19 at the country level, however, the potential of GIS technology requires ongoing investigation to support Saudi Arabia's Vision 2030. During a pandemic, great pressure is placed on EDs, with patients waiting long periods for treatment, which can lead to great health risks. This paper aims to illustrate the rule of GIS in providing intelligent solutions in emergency services during the COVID-19 pandemic. A satisfaction questionnaire was distributed to over 180 patients who were selected randomly from the nine emergency rooms of Jeddah governorate hospitals from different priority levels. Fifteen factors are determined and grouped into five domains to reflect patients' satisfaction: emergency department environment, emergency department staff, physician care satisfaction, and wait time satisfaction. The critical values reveal in wait time were 84% of patients from the second to the fourth level of priority had waited a long or extremely. Most of the respondents (87%) wanted to know ER wait times before arrival hospital. The website was the most preferred choice for publishing wait times outside the ER for 56.7% of them. An online ArcGIS dashboard was developed to monitor hospital wait times in Jeddah City. This dashboard can be useful to the public to guide them in determining which hospital is the most suitable regarding a minimum waiting time and can also help in considering the travel distance.

Keywords

Emergency Department, Waiting time, Dashboard, GIS, COVID-19

1. Introduction

A medical treatment that considers being effective for life-saving care without prior appointment [1]. The time that the patient needs from the entry gate to the exit gate after he got the emergency services is the key to evaluating EDs and improving patients' experiences [2]. Crowding is one of the most pervasive problems that obstruct the proper functioning of an ED [3] [4] [5]. Lengthy wait time to hand over patients is an issue to address to optimise the health services in an ED [6]. Time is considered a critical and significant factor in an ED that can affect patient satisfaction and health outcomes [7] [8]. Hence, reducing wait times for access to healthcare services can increase the quality of resource utilisation in an ED [9] [10]. In Saudi Arabia, the number of patients in EDs has increased dramatically [11]. Non-urgent patients—who have reported various reasons for visiting EDs, *i.e.*, quick access and better care—represent the most important factor that has led to ED overcrowding [12] [13] [14] [15]. Triage is another important factor that as-signs priority to those who require prioritised care [16]. Therefore, waiting time should be reduced based on the priority level [17]. During the COVID-19 pandemic, a noticeable reduction was found in the number of patients attending EDs in Saudi Arabia and the reason may include fear of infection during their visits [18]. These patients with non-COVID-19-related medical issues—fear long waiting times for treatment. This may lead to the possibility of poor satisfaction that leads to a further negative impact on the patient's health and public health in general [19].

Patient wait times in the same area can vary significantly for different providers [20] and solutions involve the adoption of information technologies in the healthcare system. Appropriately, Geographic Information System (GIS) serves as a powerful tool in emergency management and planning in-hospital healthcare [21]. Previous studies in Saudi Arabia indicate that overcrowding is one of the most challenging problems facing EDs [22], while others investigating the waiting times in the 3 emergency departments public concluded that the efficiency of the EDs is below the recommended standards [23]. The response to COVID-19 has caused a revolution in open GIS sources and web GIS which have grown considerably [24]. In the fight against the COVID-19 pandemic, GIS and open data rapid analysis and elaboration of data from different sources [25] have shifted the visualisation and communication of pandemic information towards different levels of detail [26] and provided transmission prediction with a degree of risk at the local and regional scale [27]. The Ministry of Health in Saudi Arabia implemented multiple GIS web-based and smartphone applications to provide public health information for the community and individuals [28], however, more effort is required in ED services. Publishing wait time information for different EDs could be a powerful tool to reduce waiting time and increase satisfaction [29]. In previous studies, it was found that those ED patients who were surveyed strongly supported having website access to wait-time information before hospital arrival [30]. GIS has been used by the public to find the closest hos-

pital using straight-line or road distance and establishing service areas for future optimal services' location [31] [32]. Most of the previous studies agree that patient satisfaction will increase by providing ED wait-time information and provide quality indicators for future management. However, few studies have explored how to develop a tool to support wait-time publications in real-time. No studies were found during the literature review that developed a web-based GIS dashboard to publish and monitor near-real-time hospital wait in Saudi Arabia. This tool collected data from each ED; the study can be useful in improving patient knowledge of estimated waiting time and the procedures during ED visits.

2. Materials and Methods

2.1. Study Area and Data Source

Jeddah City is both the commercial capital and second-largest city of Saudi Arabia, located on the Red Sea. The city has a population that represents 14% of the total population in Saudi Arabia—estimated at 25.37 million [33]. Its health facilities are divided into public and private health facilities. The study will be restricted to public hospitals with services, including an ED. The main factor considered in selecting these hospitals is the availability to all people, especially low-income individuals.

The nine emergency departments of Jeddah Governorate hospitals (**Figure 1**) provide services to 563,276 patients. **Table 1** reviews all emergency departments for 2020 in Jeddah City, Saudi Arabia [34]. Currently, in Jeddah City, there is a substantial overuse of ED services in hospitals linked to the Ministry of Health. Furthermore, critical issues have been reported concerning Jeddah's emergency departments including insufficient organisation, long ED waiting times (≥3 hours), and a lack of medical staff [13].

Table 1. Review of emergency departments for the year 2020 in Jeddah.

No.	Hospital Name	Emergency Reviews
1	East Jeddah General Hospital	136,670
2	King Abdullah Medical Complex	92,759
3	King Abdulaziz Hospital	83,846
4	Ophthalmology Hospital	59,207
5	Al Thaghr Hospital	52,662
6	Al Azizyah Children Hospital	37,358
7	Mental Health Hospital	11,988
8	King Abdulaziz University Hospital	4553
9	King Fahed General Hospital	84,233
Total		563,276

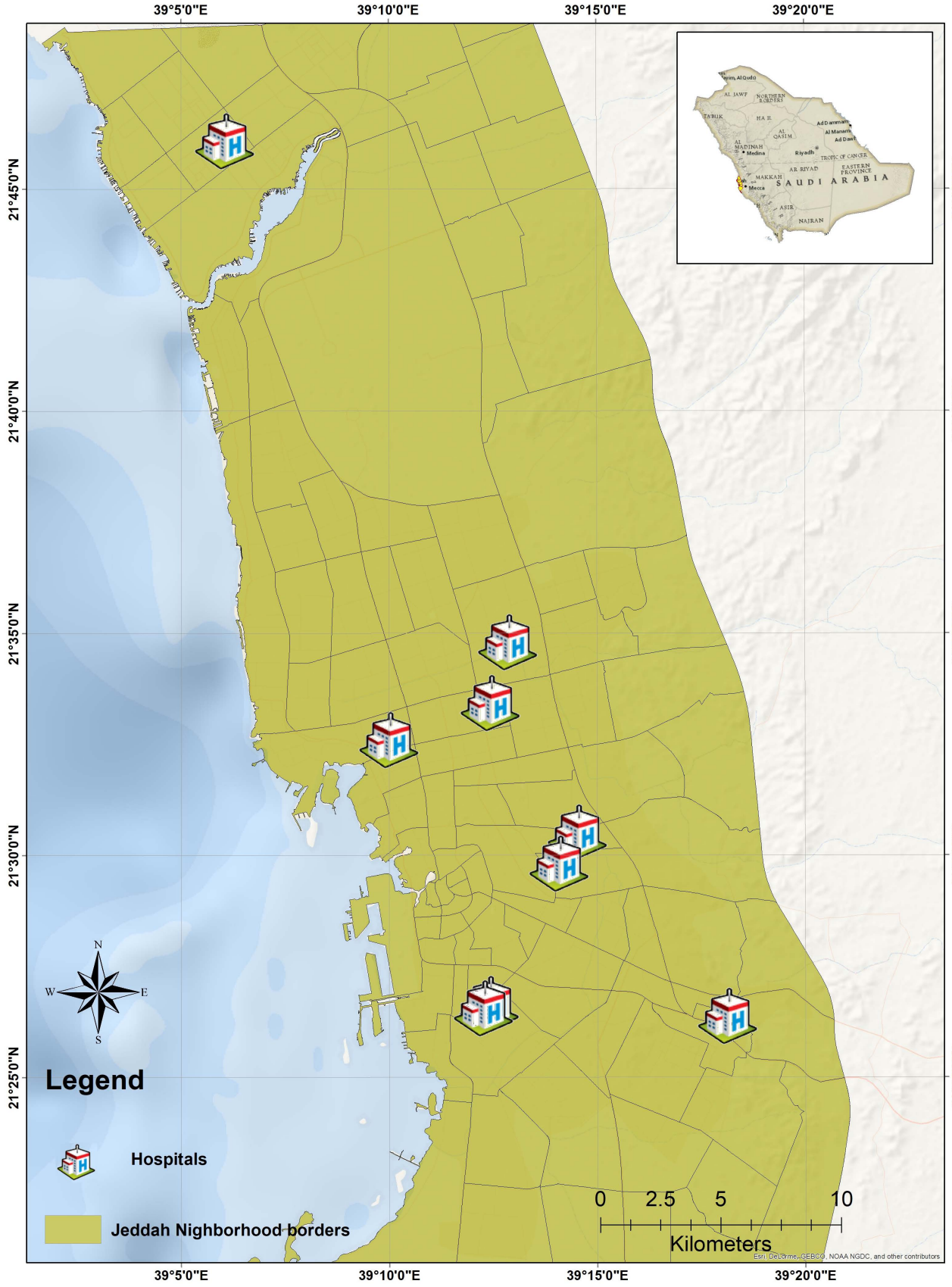

Figure 1. Public hospital locations in Jeddah.

2.2. Sample and Procedure

Patient rights should be observed through several factors to develop and improve patient satisfaction [35] [36]. These factors should be coordinated to make an appropriate condition for improvement and development of patient satisfaction with observing their rights in all aspects [37]. The study is limited to none-COVID19 patients. A random sample of 180 patients who visited the ED within one month is calculated based on an 80% confidence interval and with a margin error that does not exceed ± 5%. Data were collected from June till July 2020. Patients were selected to participate in the study, aged 20 years or older during their visit to Eds from the nine emergency departments of Jeddah governorate hospitals from different priority levels. The EDs is divided into three areas which consist of the first level of priority (Life-threatening emergencies), with an average of 365 patients per month, the second level of priority (potentially life-threatening emergencies) with an average of 1467 patients per month and the third level of priority (non-life-threatening) with an average of 2738 patients per month. Each patient was given 10 to 15 minutes to answer the questionnaire. In some cases, the questions were answered by the patient's family. Two hundred and fifty questionnaires were distributed and face-to-face interviews were conducted but only 180 returned which brings to a response rate of 72%. Fifteen factors are determined and grouped into five categories: emergency department environment, emergency department staff, physician care satisfaction, and waiting time. A spreadsheet is scale involves15 factors that range from strongly agree to score 1 to disagree score of 4.

2.3. An Online ED Dashboard

The ED dashboard has been developed to help the user obtain online waiting time information in ED sites in near-real-time. The dashboard contains two screens: The first screen allows users to determine their location as well as to locate the nearest hospital within a specified distance which is useful for enabling patients to select the hospital that is nearest to their location. The second screen assists users in exploring the waiting time for each ED. The data were created and organised in ArcGIS Pro and then shared as a web map layer through ArcGIS online; the dashboard was built based on the web layer. The main item is "emergency room points" which is represented as a layer and categorised based on wait time. Moreover, a gauge, indicators, and charts provide information regarding the available resources such as beds and room capacity (**Figure 2**).

2.3.1. Feature Classes

One of the points features classes represents the geographic locations of the ycnegreme centers. The attributes include basic information such as name, ID and location.

2.3.2. Tables

Two tables are used in this model. The first table is for general information

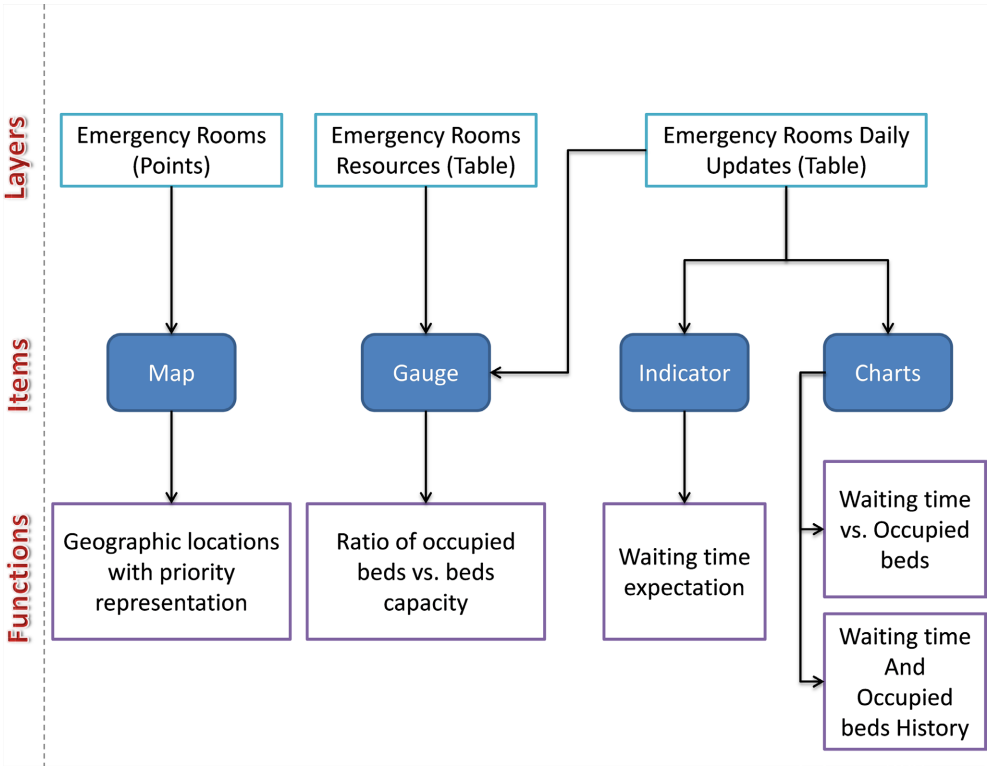

Figure 2. Elements of ED dashboard and its functions.

regarding the center's capabilities such as the emergency service levels. There are three emergency levels: Life-threatening emergency, potentially life-threatening emergency, and non-life-threatening emergency (sorted in levels from 1 to 3, respectively). The second table is designed to store the daily number of nonurgent emergency cases and the waiting patients and the expected waiting time for new cases to be admitted on a date/time basis.

2.3.3. Relationship Feature Classes

The design includes three geodatabase relationship classes to ensure the integrity between the emergency centers' point feature class and the related tables. The emergency center ID was selected as the unique field that controls the relationships.

2.3.4. Field Domains

Three domains were designed to unify and facilitate the data entry of the fields related to the emergency center name, service level, and the emergency center type as indicated in (**Figures 3(a)-(e)**) where:

a) Table stores the daily updates about the occupied patients, the awaiting persons and the expected waiting time respectively.

b) Table contains the basic information about the emergency department such as the capacity and the department service level.

c) Domain contains the three emergency department service levels; the study adopted three levels based on the services capabilities. Level 1 is the highest rank

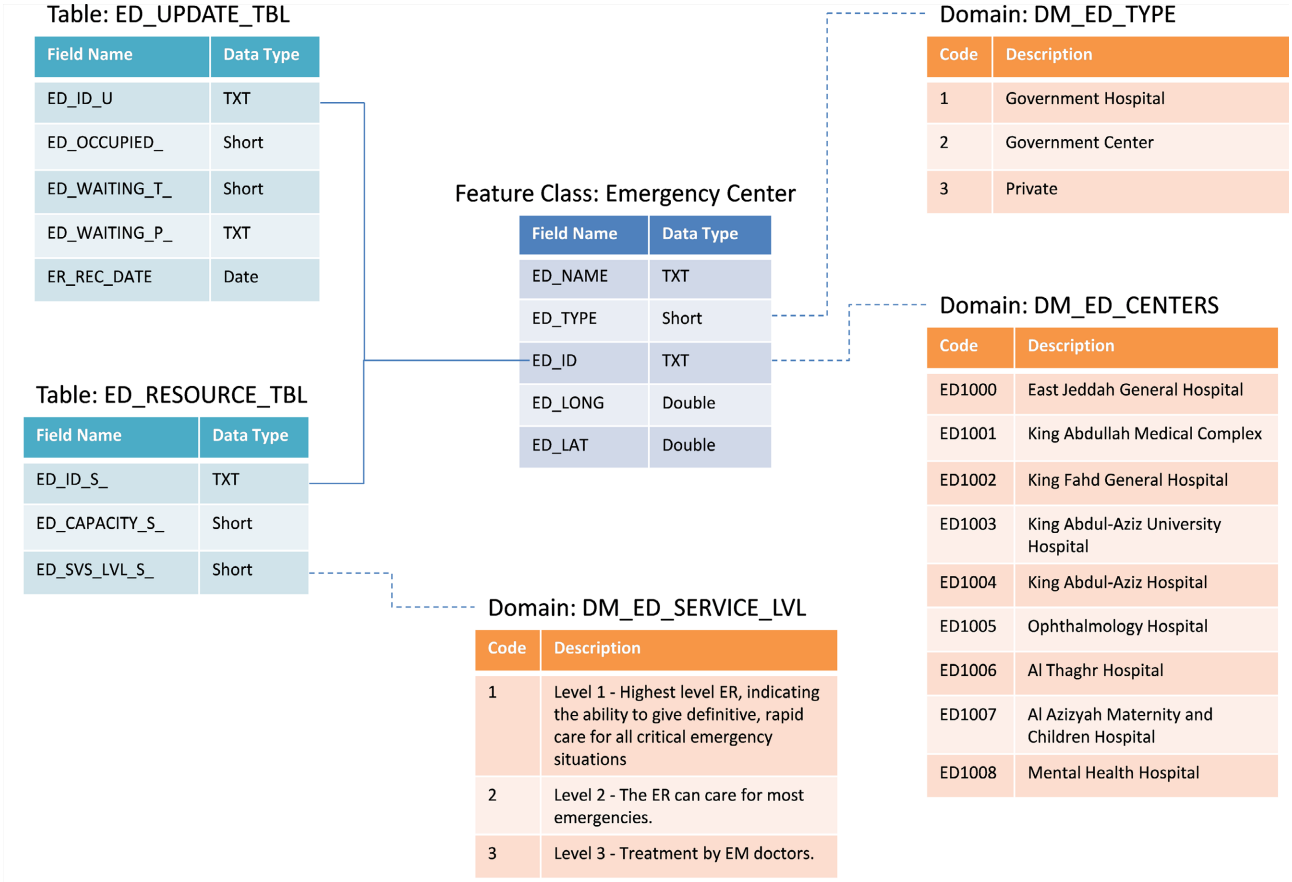

Figure 3. Emergency Departments Geo-Database Model.

indicating the ability to give definitive, rapid care for all critical emergency situations.

d) Domain contains the emergency departments list.

e) Domain contains the emergency department types such as government hospitals.

2.3.5. Calculate Emergency Waiting Time

The total wait time was considered: starting from the triage stage to the physical assessment and treatment and ending with discharge [38]. The length of stay (LOS) was determined by several factors, including the Patient's condition, medical intervention needed, availability of emergency rooms beds, and the level of activity in the ED [39] (**Figure 4**). The ED wait time is updated every 30 minutes and it is calculated using a 4-hour rolling average. Each time used to calculate the average is defined as the time of patient registration at the ED until the time a patient is greeted by a qualified medical professional.

3. Results and Discussion

The methodology of this study was conducted at two different stages. Firstly, the questionnaire distributed over 180 patients from 9 ED providers with three

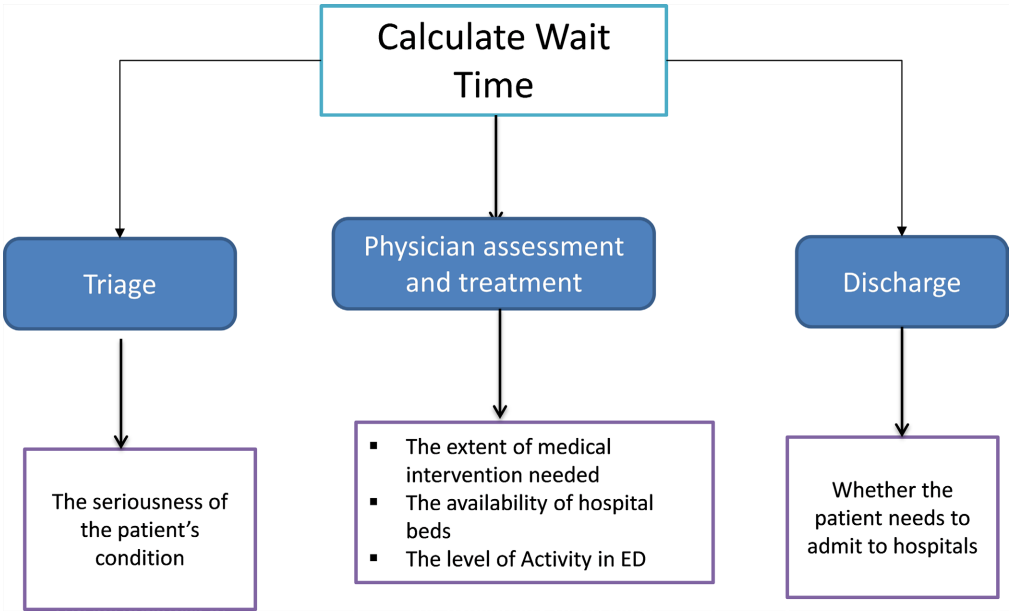

Figure 4. Patient wait time based on triage, physician assessment/treatment and discharge.

different levels of priority (discussed in section 2.2). It reflects that more than 85% of patients were satisfied with four categories, emergency department environment, emergency department staff and physician care satisfaction. The most critical indicator directly influences patient satisfaction from moderate to non-urgent categories in wait time. 84% of patients from the second to the third level of priority had waited a long or extremely. Most of respondents (87%) wanted to know ER wait times before arrival hospital and the website was the most preferred choice for publishing wait times outside the ED for 56.7% of respondents. **Figure 5** presents statistics descriptive analysis of the study variables. Therefore, the results of this study support that ED wait time has a statistically significant association with waiting time spent in the ED. Most of the previous studies agree that patient satisfaction will increase by providing ED wait-time information and provide quality indicators for future management [5] [6] [38]. However, few studies have explored how to develop a tool to support wait-time publications in real-time. Hence, in the second stage, an emergency room dashboard was developed to monitor hospital wait times for non-COVID-19-related medical needs. The dashboards were de-signed based on ArcGIS Pro to visualise data and provide key insights for decision making. Our ED dashboard is composed of eight items (**Figure 6**) including a map displaying a list of hospital emergency rooms, the status of ED centers, an indicator of waiting time and a gauge to display occupied beds against the total numbers of beds in real-time. Furthermore, there are three dynamic charts that provide the history of ER occupied beds, beds waiting for patients, and the final chart indicates both waiting times and occupied beds in near-real-time for each hospital. The map (shown in **Figure 2**) represents the geographic locations of EDs as points in different hospitals. The points are categorised into two colours that represent the waiting

time status in each: The green colour suggests the waiting time is less than an hour while the red colour indicates a longer waiting time. The gauge indicates the status of the waiting time and ratio of occupied beds. The information is

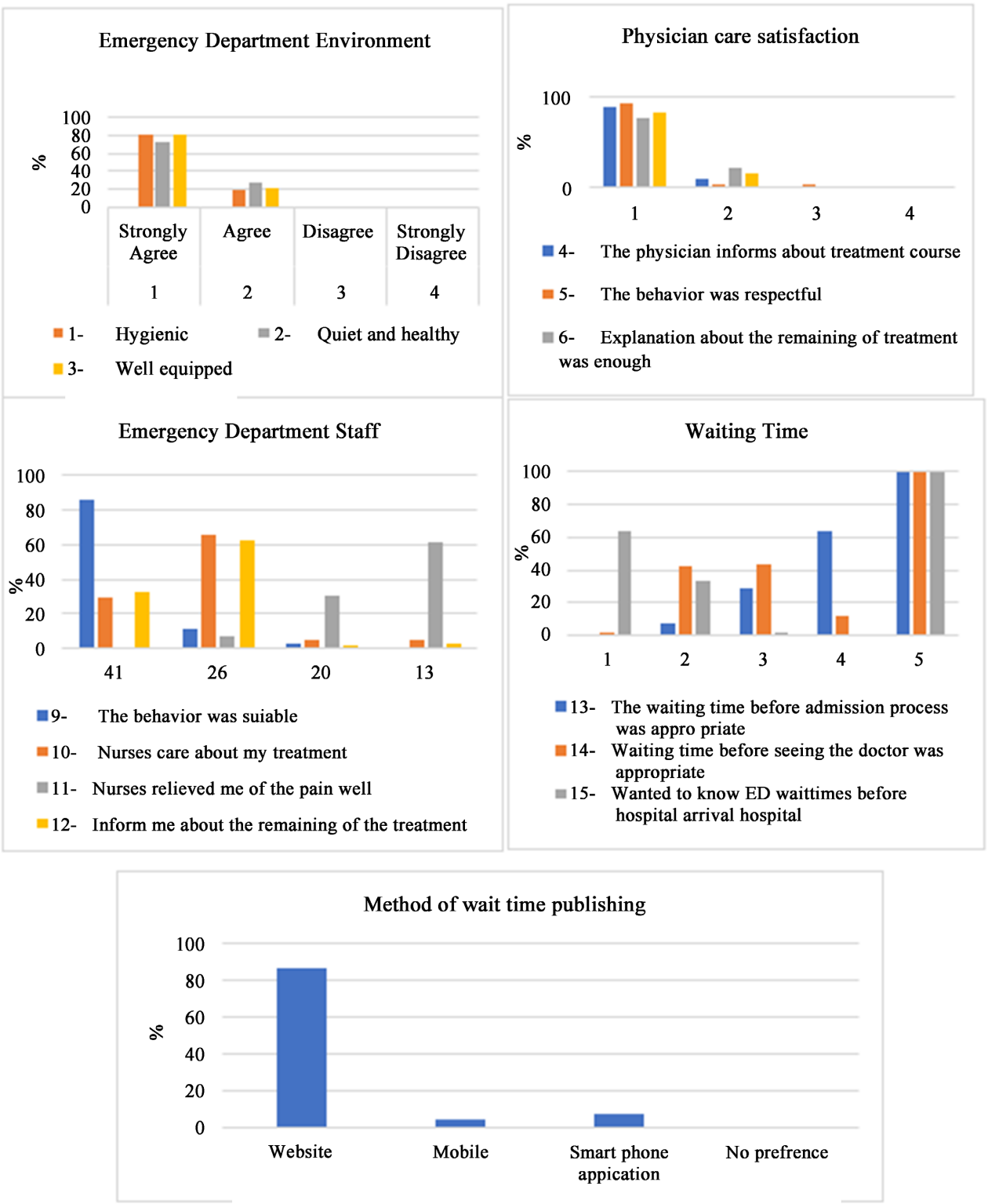

Figure 5. Result of the questionnaire survey.

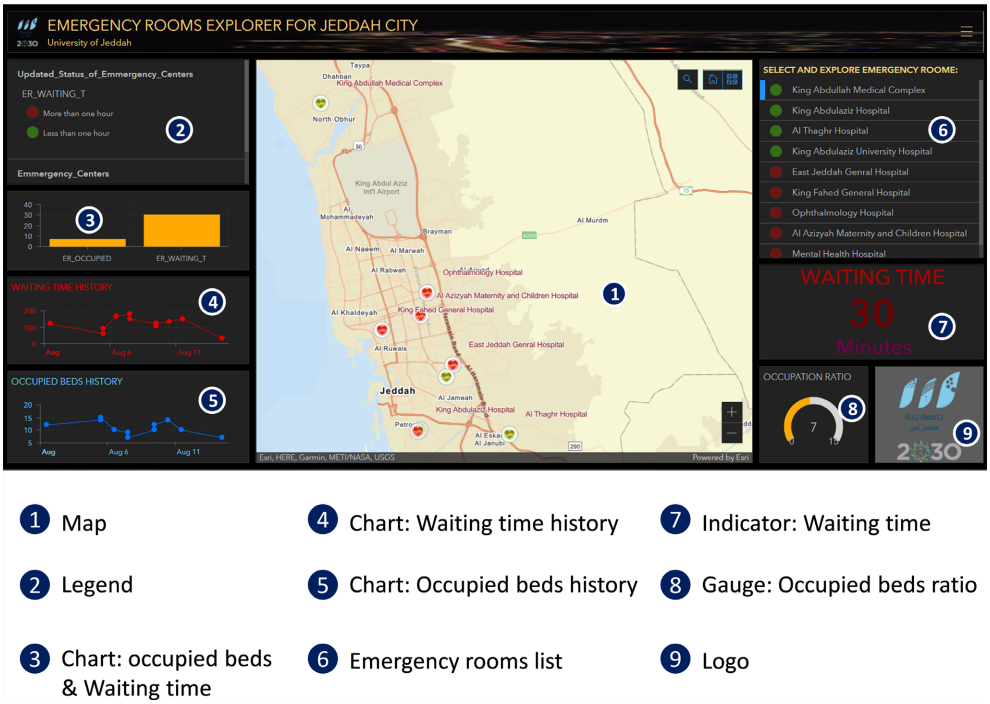

Figure 6. ER waiting time dashboard.

presented as indicators and charts based on an updated database. Triage categories are assigned to each patient based on presenting conditions of assessment, graduating from 1 (the most urgent) to triage 3 (the least urgent). The average waiting time presented on the dashboard page is for patients who have been assessed as triage 3 since that is the most frequently allocated category. The EDs overcrowding leads to long lengths of stay and increases waiting time. However, despite the technological revolution, the accuracy of the wait time's predictable value remains a topic of debate due to the variations in patient arrival rate and the dynamic nature of activities involved in the ED [36] [40].

4. Conclusion

Since the emergence of COVID-19 across the world, including in Saudi Arabia, GIS technology has provided intelligent solutions and best practices for responding to COVID-19. Many factors affect wait times, including population, staff GIS technology has played an important role in providing intelligent solutions in emergency departments during the COVID-19 pandemic. An emergency waiting room dashboard was developed to publish wait times for EDs in Jeddah City in near-real-time. This tool will help users to identify a suitable provider with a minimum waiting time. Hence it will be effective by guiding patients away from already crowded EDs in nearby geographical locations, to less crowded EDs that will improve the quality of care and satisfaction of ED patients. The limitations of a study are that sample-sized should be larger to increase the confidence level and the dashboard should include the private hospitals. Future studies should look for dashboard functionalities, and performance indicators qual-

ity, and analyze the challenges associated with dashboard implementation in the ED.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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