FindED.io - A Patient Decision Tool for Determining the Optimal Emergency Room for Non-Ambulance Emergencies

Prashant D. Tailor[1,2,3], Tony Shu[4,5,6], Farhan I. Khan[4], Dale R. Rivera[4]
Faculty Advisor: Eva K. Lee, Ph.D.[1,2,3,4]
Clinical Advisors: Harold K Simon, M.D.[7,8], Prabhu Shankar, M.D.[7,8]
[1]Center for Operations Research in Medicine and HealthCare;
[2]Industrial & Systems Engineering;
[3]NSF I/UCRC Center for Health Organization Transformation, Georgia Institute of Technology;
[4]Computer Science;
[5]Materials Science and Engineering;
[6]Georgia Institute of Technology AMBER Lab;
[7]Department of Emergency Medicine, Children's Healthcare of Atlanta;
[8]Department of Pediatrics, Emory University School of Medicine, Atlanta, GA 30322, USA
Georgia Institute of Technology, Atlanta, GA, 30332, USA

1. Abstract

Currently there exist few tools for patients to search for and rank hospitals based on reported statistics. This study aims to analyze a mobile patient tool developed by the authors, www.FindED.io, capable of displaying nearby emergency departments (EDs) and ranking results based on average wait time, travel time, and quality of care. Utilizing reported data from 4,931 hospitals to the Centers for Medicare & Medicaid Services (CMS) Hospital Quality Initiative during the period between October 1, 2012 and September 31, 2013, we create regression models and design a singular heuristic Quality Index for hospital quality based on knowledge extracted from CMS reported timely care and hospital infection rates.

Using FindED, nearby hospitals can be found via a real time filter based on the user's current location or inputted address. The calculated Quality Index score is utilized along with Google Maps Direction Service Travel Time and CMS Average Time to See a Practitioner in a weighted average that prioritizes average wait time as a default choice, though users are able to select alternative ranking heuristics once they receive their results. In the state of Georgia, the insurance companies accepted at each hospital are displayed so that users can focus on hospitals that accept their insurance, and detailed hospital metrics are displayed for nationwide results in interactive charts as additional decision factors. The application is built using Google App Engine in Python with additional Google Directions & Geocoder Application Programming Interfaces (APIs).

From a web traffic analysis of 53,500 unique users within a 48-hour period starting December 10^th^, 2015, FindED is found to be ubiquitously accessible from a variety of platforms and responsive in terms of user experience, hosting an average browsing session duration of 1 minute 3 seconds. User statistics concerning gender and age correlated strongly to the user base of a news aggregate website upon which FindED was shared (88% male users vs. 85% reported male population on the news website; 84% ages between 18 and 35 vs. 85% between 18 and 35 on the news website), demonstrating broad appeal. Users also displayed the most interest in knowing the Quality Index ranking of their hospital results, as occurrences of sorting by Quality Index outnumber the next most frequent sort heuristic by 30.48%.

In the event of a non-ambulance emergency, the resulting tool affords patients the ability to know in advance certain differences between local emergency departments, allowing for a more informed decision to be made on which to visit, ideally improving patient satisfaction.

2. Introduction

Throughout the past two decades, hospital EDs have experienced increasing demands at a rate not met by expanding facilities. From 2003 to 2009, the average wait time in US emergency departments between arrival and being seen by a medical professional increased 25%, from 46.5 minutes to 58.1 minutes [1, 2]. This average wait time increase is strongly correlated with the annual ED visit volume increase [2]. The number of visits to EDs increased 32% while encompassing the same time period, from 102.8 million visits in 1999 to 136.1 million visits in 2009 [2]. Hing et al. indicate that EDs continue to experience pressure to treat more patients with fewer beds and facilities. In 2008, at least 33% of hospitals studied admitted to resorting to ambulance diversion while 78% of hospitals studied in 2009 boarded ED patients in hallways while inpatient beds were full. It was found that either of these practices increased wait time from arrival before being seen by an ED practitioner by at least 15.6 minutes on average. In addition, patients with issues deemed urgent, which made up a plurality of ED visits in the study, have the longest ED wait times [2]. Prolonged wait times are reported to be a central concern in EDs and are a major reason why patients, especially young males (with a 0.978 odds ratio for leaving per year of age), leave the ED without being seen [3].

This response to perceived slow service is not uncommon and should be carefully considered in light of its implications. Of patients who do not wait for treatment in the ED, over 50% stated that they sought treatment elsewhere after leaving [4]. Some factors behind long wait times are claimed to be the following: low ratios of doctors and triage nurses to patients in EDs, socio-economic characteristics of those using EDs, increased admissions to EDs, and inappropriate use of the service [4]. Fry et al. found that of 222 patients who left without being seen, 49% left because of the time delay, and 52% of all patients would have stayed if the wait time were shorter [5]. In a separate study, Arendt et al surveyed patients who left EDs without being seen on the reasons they left and found that 67% of responding patients said they believed that the wait would be too long or had already been too long [6]. Additional studies have listed even higher percentages of patients being concerned about wait times [3, 7]. Specifically, 75% of patients in a Hong Kong based study and 86% in an American study cited wait time as the overwhelming reason for patients to leave without being seen [3]. In fact, the results of Bindman et al.'s paper found that patients were more likely to leave as waiting times increased across all demographics [8]. Sun et al. concluded that high ED crowding is associated with higher mortality, length of stay, and cost per admission [9]. A particular group highlighted in Baker et al.'s paper had 53% of patients leaving without being seen as they reported feeling too sick to wait longer [10]. Other studies have reported lower rates of patients leaving because of feeling too ill, but regardless, these patients represent a group of people at high risk for adverse health conditions [3].

Though recognized as a problem, the solution to long ED wait times is not as apparent. A literature review concerning the issue of patients balking at wait times investigated what could be done to prevent patients from leaving. The review reported that 85% of responders who left without being seen by a physician identified "more frequent updates on wait time" as an area lacking development [6]. Members of the American College of Emergency Physicians Medicine Practice Committee also recognized the importance of wait time in the ER and listed pros and cons about hospitals publishing wait times for ED Care [11]. They found that the length of time until a provider is seen is inversely proportional to patient satisfaction and patients prefer to be provided with information and updates regarding their progress during the ED visit [11, 12]. In addition, the report highlighted a lack of information in literature exploring the practice of publishing ED wait times, designating it an area of future research [11]. Many benefits of publishing wait times are mentioned in the report, such as: additional patient visits from competing institutions, generation of additional revenue, and the potential for self-triage on the patient's end by visiting the ED with the shortest wait [11]. The Committee proposed that self-triage will help evenly distribute the patient load among system's hospitals by temporarily decreasing arrivals for overburdened facilities [11].

On the other hand, barriers to implementation exist as there is no standardized definition of wait time, which may lead to misinterpretation of displayed wait times and compromised care [11].

The vast majority of existing systems are websites owned by specific hospital systems, which only display hospitals under their ownership and therefore lack a multi-system perspective. More thorough tools which are currently available, such as ProPublica, relay to the user a limited subset of the CMS dataset focusing on Timely & Effective Care metrics and directions to the most prominent hospitals [13, 14]. Despite this improvement in information availability, hospitalization encompasses more than just the time taken until a patient is seen by a practitioner- a fact few, if any systems have accounted for. For example, an area most lacking is information on accepted insurance providers at each hospital. In this study, we define a new application paradigm that addresses many areas of improvement: standardization of wait time data, utilization of quality of care metrics and insurance providers, and visualization of such metrics in an effective manner.

3. Existing Applications: Features, Limitations, and Challenges

Most existing applications are built for specific hospitals or hospital systems and only provide the current wait time estimate for the ED. An example of this practice is found on Children's Healthcare of Atlanta's website which provides users with an approximate timing for each of its ED locations [15]. Such systems rarely provide directions and travel time to the ED or information about hospitals outside of its ownership. Outside of basic functionality of wait time, the majority of systems fail to provide any additional data without an exhaustive search through their website. Potential patients in an unfamiliar area must navigate through a separate mapping application in addition to individual hospital websites to obtain total wait time information. The only system identified that differs is ProPublica's ER Wait Watcher, which aggregates wait times and displays the most significant hospitals closest to the user-entered address [14].

Many existing applications that aggregate data from multiple hospitals utilize the Google Places API to reference nearby hospitals. While this approach is easy to utilize, smaller hospitals are often omitted from search results in favor of larger hospitals which the API deems more prominent [16]. In addition, the performance of these sites is slower because of the volume of necessary API calls, requesting and retrieving data from another server every time a search is initiated. Because of the API's internal ranking algorithm, results show stochastic tendencies as slightly different geographical coordinates return different hospital lists. The challenge in implementing an improved proximate hospital feature is developing an algorithm that correctly identifies relevant existing hospitals while improving runtime.

Beyond wait time, few systems utilize CMS Timely and Effective Care metrics, despite their relevance to the patient [13]. Some of the metrics in question include average time it takes until a patient sees a practitioner and the average time it takes to receive pain medication while suffering from broken bones [13]. CMS metrics can be utilized in conjunction with directions services to provide the user with an estimate of the time until treatment. This timeline completely addresses travel from the patient's current location up until the moment he or she is seen by an ED doctor. The challenges with implementing this improved functionality include obtaining data for several thousands of hospitals while conveying to the user a variety of technical metrics in a succinct, user-friendly interface. Still, the usefulness of time-based CMS metrics fail to account for other factors such as quality of care and infection rates, which become relevant while the patient is being treated.

All existing applications studied lack functionality for users to check if nearby hospitals accept their existing insurance. This is especially concerning since patients may delay treatment if they do not believe it is affordable, taking time to search for their accepted insurance plans before going to the hospital. Easily accessible knowledge of accepted insurances is key in the patient care process, relieving stress from fiscal concerns and reducing time spent searching before treatment [17]. Implementing this feature provides many challenges due to high variability of both accepted insurances and availability of this information between hospitals.

Finally, many applications deliver a cumbersome user experience because of extraneous information and features. Lack of research on how users value hospital metrics further complicate the design of an application. Even with an effective interface, acquiring and maintaining up-to-date data on thousands of hospitals is difficult with current available resources. Challenges in providing patients with hospital information exist on many levels, and this difficulty may contribute to the low prevalence of available tools in this area.

4. FindED

FindED is a web application whose design is derived from the perceived needs of emergency room patients which attempts to remedy the shortcomings of existing hospital wait time applications. This web application addresses the limitations and challenges previously described by proposing a responsive design paradigm to the potential ED patient. Briefly, FindED currently supports:

(a) Either automatic location detection or manual address input through an input field
(b) Visualization of the user's location and nearby hospitals on an interactive map
(c) Holistic quality of care metric through a computed Quality Index
(d) Accepted insurance information for hospitals in Georgia
(e) Composite wait time displayed for 4,913 US hospitals
(f) Visualization of hospital metrics compared to other state and local hospitals
(g) Visualization of relevant hospital data in a succinct panel
(h) Real time ranking of nearby hospitals according to estimated wait time and quality of care

FindED is designed for use by non-ambulance ED patients whose time is limited, but not critical. These users would benefit from a mobile or desktop web-application that can display and rank the results of nearby EDs in an easy-to-read aggregated format as it would save them time until being seen. Even if not experiencing an emergency, individuals who are curious about nearby hospitals and their statistics can utilize FindED to make more informed decisions about what hospital to visit should an emergency arise in the future. When a user initiates a search through their current location or entered address, FindED begins the real time search process, i.e. the Google App Engine NDB datastore is queried for hospitals within the default 15 mile radius of the user's specified location. The related data is pulled, filtered, and ranked based off of distance and calculated metric rank values for each hospital returned. Polynomial regression, weighted averages, and cumulative distribution functions are calculated on all hospital metrics to generate composite scores for Quality Index and overall score. The results are sent to the front end of the application where the user's location and hospital locations are populated on an interactive map. In addition, panels are created which display hospitals ranked according to our internal metric, composite time (travel time plus wait time to see a practitioner), Quality Index, and accepted insurance providers (if in Georgia). Upon clicking each panel, the user can see a detailed visualization on the specific hospital compared to its peers and a detailed list of insurance providers, if available. The key challenges in the development of FindED were minimizing the computational time in calculating travel time, filtering of nearby hospitals in real time, aggregating and representing insurance data, developing the holistic quality metric, and calculating hospital rankings.

The FindED home screen includes 1) input field, 2) geo-locator button, and 3) a simple tagline of the application. The input fields accept the user's address, city, state, and zip code. The geo-locator button asks the user's permission for access to their device's location based off their internet connection. Both the input field and geo-locator convert the user's input into longitude and latitude coordinates for datastore querying. These features are displayed Figure 1. If the user scrolls down the page, a sample hospital panel appears with interactive mouseover portions that explain data displays in detail.

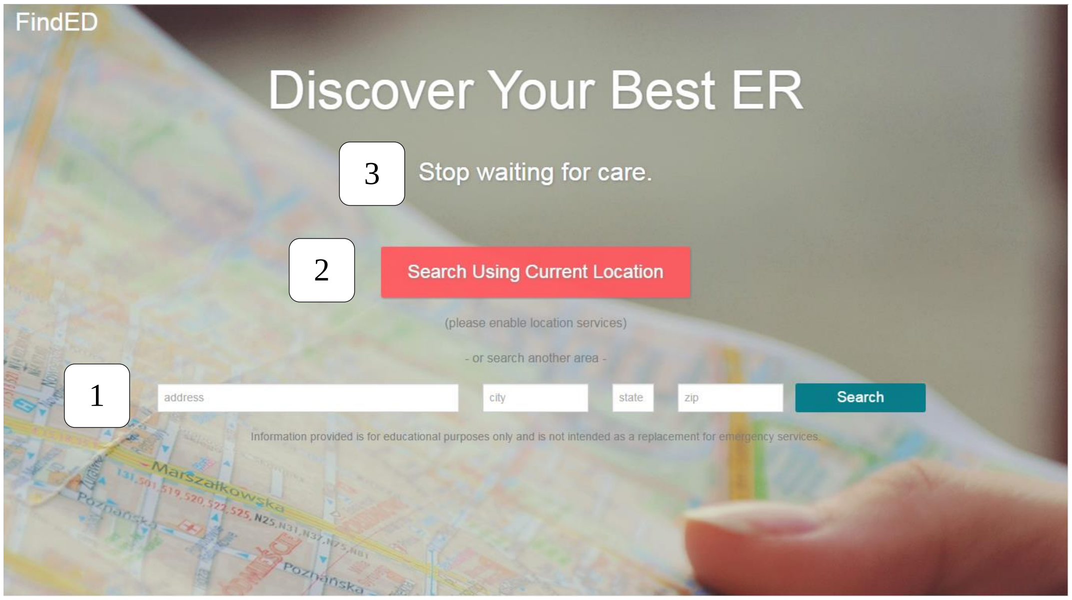

Figure 1. FindED Home Screen: 1) Input Field, 2) Geo-locator Button, and a 3) Simple Tagline of the Application

After the user has submitted a location, they are redirected to the results screen as shown in Figure 2. The results screen includes 1) an interactive map, 2) ranking, 3) Quality Index for each hospital, 4) approximate travel time, wait time and composite time, and 5) insurance logos for the top five insurance providers (by market share) if searching in Georgia. Specifically, the interactive map displays the user's location relative to nearby hospitals as a result of real time filtering. Hospital panels are on the right side of the screen and contain the most important information for every result. The ranking of each hospital is shown by a number from 1 to *n* where *n* is the number of returned results based on the hospital's composite time and Quality Index. The approximate travel time, mean wait, and composite time are taken from Google maps, CMS data, and the sum of the previous two respectively. The insurance information area displays the logo of each of the largest five private insurers, if accepted.

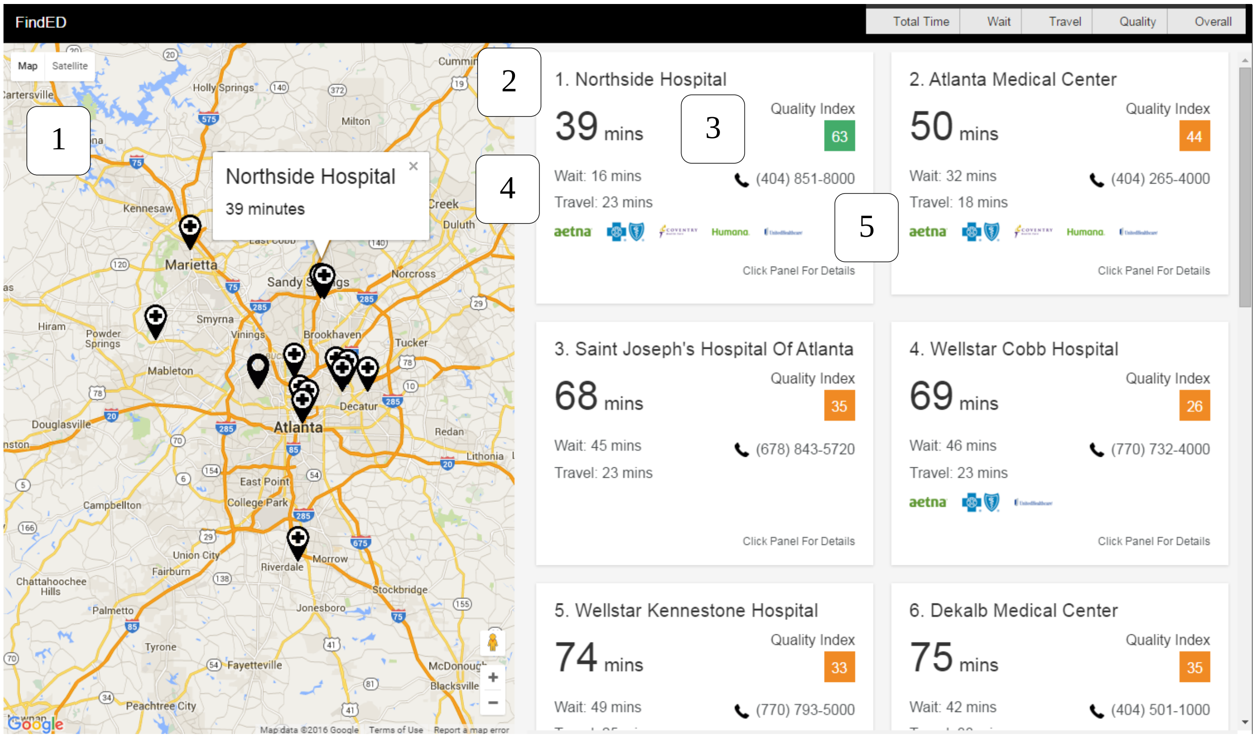

Figure 2. FindED Result Panel: 1) Interactive Map, 2) Ranking, 3) Quality Index, 4) Approximate Travel Time, Wait Time and Composite Time, 5) Insurance for Georgia Hospitals

1. Input Field/Auto Geo-locator Button

The input field for the user's location is a necessary part of the application given that certain users prefer to withhold automatic web browser retrieval of location data. The field has inputs for the user's address, city, state, and zip code, which can be filled in any combination to search for their location. If the user utilizes the geo-locator button, the user's web browser asks for permission to obtain their geographical coordinates. Given a valid location submission to the website's back end, a real time query is sent to the NDB datastore to return valid hospitals within range. The datastore is formatted in a tree data structure where the root node is the US and each additional level allows another level of specificity, by state first and then city. Within each city the hospitals are listed as entities. Each hospital entity has specially selected CMS data, location data, and geographical coordinates. Filtering is done dynamically, first utilizing the 15 mile default search radius to create an area of valid hospitals centered on the user's location. The search radius is converted into geographic coordinates and used as a bound for the search. If no results are returned, the radius is expanded exponentially until at least one result is returned. The results are ranked and aggregated within FindED and sent to the user's front end.

2. Interactive Map

After results are aggregated in FindED's back end, the front end obtains the ranked data in a JSON file. Google Maps Javascript API is utilized to display each of the nearby hospitals with a marker and the user's location is also indicated with a different unique marker. Figure 2 shows these markers after making a query for Atlanta, GA. The user can zoom in/out and pan left/right of the fully scalable map. If the user selects a hospital by either clicking on a panel or on a map marker, the hospital's name and composite time are displayed in a pop-out bubble from the hospital's map marker. The interactive map also adds a jumping animation to a hospital's pin when its panel is moused over, allowing the user to visually distinguish where each hospital is. This feature is especially useful in cities where the hospital density is high. Finally, clicking on a hospital's result panel will re-center the map on that hospital's location.

3. Approximate Travel, Wait and Composite Time

The travel times for the user to each nearby hospital are obtained through Google Directions API service, which takes into account traffic [18]. Times are based on travel by automobile. The wait time is from the CMS Timely & Effective Care Dataset from OP_20 or the average time until a patient sees a practitioner[13]. The composite time is the sum of the two previously mentioned metrics. These time values are used throughout FindED as detailed in other sections of this report.

4. Ranking/Quality Index

After the filtered hospitals are aggregated in FindED's back end, the ranking process is utilized to display hospitals in order of combined best quality and timeliness of care. The first step of ranking generates the Quality Index for each hospital. This includes using data from a selection of relevant CMS metrics that relate to quality and timeliness of care. Specifically, the Timely & Effective Care CMS and Hospital Acquired Conditions (HAC) Datasets were utilized for this purpose as we wanted to prioritize ER care in our ranking algorithm [13, 19]. The specific metrics selected from both datasets are displayed in Table 1.

Table 1. Metrics selected from CMS Timely & Effect Care and Hospital Acquired Conditions Datasets

Metric	Description
OP-18b	Average time patients spent in the ED before being sent home
OP-20	Average time patients spent in the ED before they were seen by a healthcare professional
OP-21	Average time patients who came to the ED with broken bones had to wait before receiving pain medication
OP-22	Percentage of patient who left the ED before being seen
OP-23	Percentage of patients who came to the ED with stroke symptoms who received brain scan results within 45 minutes of arrival
HAI-1	Central Line-Associated Bloodstream Infection (CLABSI)
HAI-2	Catheter-Associated Urinary Tract Infections (CAUTI)
HAI-3	Surgical Site Infection from colon surgery (SSI: Colon)
HAI-4	Surgical Site Infection from abdominal hysterectomy (SSI: Hysterectomy)
HAI-5	Methicillin-resistant Staphylococcus Aureus (or MRSA) blood Laboratory-identified Events (bloodstream infections)
HAI-6	Clostridium difficile (C.diff.) Laboratory identified Events (Intestinal infections)

For each metric selected from within the dataset, a cumulative distribution function considering all hospitals' scores was generated to enable comparison of hospitals based on national percentiles. To improve the computational speed of each hospital result query, a minimum five degree polynomial was fitted for each metric's cumulative distribution function via polynomial regression. The regression models were created solely for their function mapping abilities rather than their predictive applications and as a result the dataset was overfit with all available data. Each standardized metric from both datasets was then combined into a weighted average to create an aggregate Timely Care score and an aggregate HAC score.

$$timelyCareScore = \frac{1*OP18b + 4*OP20 + 3*OP21 + 2*OP22 + 1*OP23}{11} \quad (1)$$

$$hacScore = \frac{2*HAI1 + 2*HAI2 + 1*HAI3 + 1*HAI4 + 1*HAI5 + 1*HAI6}{8} \quad (2)$$

By creating an aggregate score for each dataset, the ranking process could accommodate the lack of a specific metric if a hospital did not report it. The missing term would be removed from the numerator calculation and the denominator would scale accordingly. Another weighted average was calculated between both aggregate scores and travel time to generate the Quality Index, a holistic quality of care score.

$$qualityIndex = 0.25 * timelyCareScore + 0.75 * hacScore \quad (3)$$

From an informal survey, most potential users valued Timely & Effective Care metrics over HAC metrics. Because the HACs are a direct outcome of quality of care, the HAC score was weighted three times as much as the Timely & Effective Care score when computing the Quality Index. The Quality Index was developed because potential users requested a single quality of care metric. However, when choosing a hospital in emergency situations, the same users valued the Timely & Effective Care metrics over the HAC metrics. Therefore when calculating the overall rank of a hospital, another ranking methodology is needed to resolve this conflict.

The methodology for calculating the overall ranking of hospitals involves weighting the time-to-care metric greater than their HAC metrics. This is achieved by computing an additional weighted average, Total Score, combining the average time-to-practitioner (OP-20) added with travel time at 75% and the Quality Index at 25% weight. The hospitals are then ranked in descending order by their Total Score and a JSON file with this information is sent to the application's front end. Total Score is used as the default heuristic for ranking, however, to cater to a variety of user preferences, the option to rank hospitals by the following additional heuristics are included in Table 2.

Table 2. FindED Ranking Heuristics

Heuristic	Description
Default	Prioritizes the sum of the average time-to-practitioner (OP-20) and Google Directions API travel time over Quality Index (75%-25% split)
Wait Time	Average time-to-practitioner (OP-20) only
Travel Time	Google Directions API travel time estimate only
Quality	Quality Index scores only
Total Time	The sum of the Google Directions API travel time estimate and average time-to-practitioner

5. Insurance

For Georgia hospitals within the CMS dataset, the application has information on accepted insurances. On the results page, the hospital panels will display the logos of the top six health insurance companies by market size listed in Table 3, if accepted [20-25]. Upon clicking the panel, a more detailed list of accepted providers are listed, if available. Insurance data was obtained by manually searching each Georgia hospital's website for insurance information. Many hospitals' insurance coverage was unclear on which insurances were accepted. To prevent falsely reporting insurance coverage, these hospitals' lists of accepted insurance plans were left unpopulated.

Table 3. Top Six Health Insurance Companies in Georgia by Market Size [20-25]

Logo	Name
	Aetna
	Blue Cross Blue Shield
	Coventry Healthcare
	Humana
	United Healthcare
	Cigna

6. Interactive Charts

For each nearby hospital visible to the user, a visual summary of the CMS and insurance data is shown. An example panel is shown in Figure 3. To efficiently convey to the users comparisons between nearby hospitals, interactive bar graphs are displayed in each hospital panel. The user has the ability to compare their selected hospital against nearby hospitals and the state average across both CMS datasets for the metrics in Table 1. In addition, for queries in Georgia, the complete list of accepted insurance providers is shown.

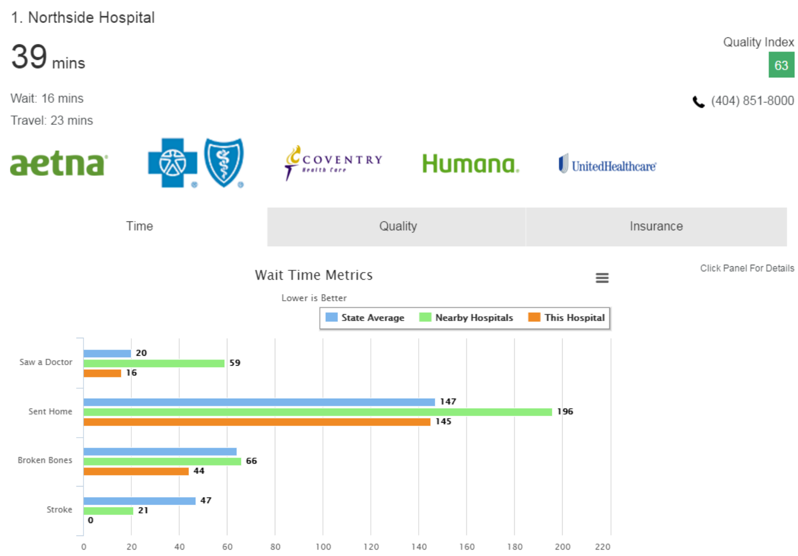

Figure 3. Example Panel with Interactive Chart

7. FindED System Architecture

FindED is developed via Google App Engine, Python, R, Javascript, HTML 5, CSS, Foundation, jQuery, Ajax, and Google Maps API. HTML, CSS, Foundation, jQuery, Ajax were utilized to provide a user-friendly graphical interface and to communicate user inputs with the back end. Google App Engine was used to host the web application in its entirety. Python was implemented for all back end logic, to extract data from CSVs, and to populate the NDB datastore. Within Google App Engine, the NDB datastore provides the web application's database. NDB datastore was cost effective for our usage when compared to a traditional MySQL database. To generate the polynomial regression fits on hospital metric cumulative distribution functions, R was utilized for its statistical applications. HTML 5 is utilized to automatically geocode a user's location. Google Maps API provides an interactive map for the users to interact with and directions to all hospital results returned. Foundation, Javascript, HTML, and CSS were utilized to build mobile and desktop applications versions of the site simultaneously. Figure 4 shows the relationship between various components of the application.

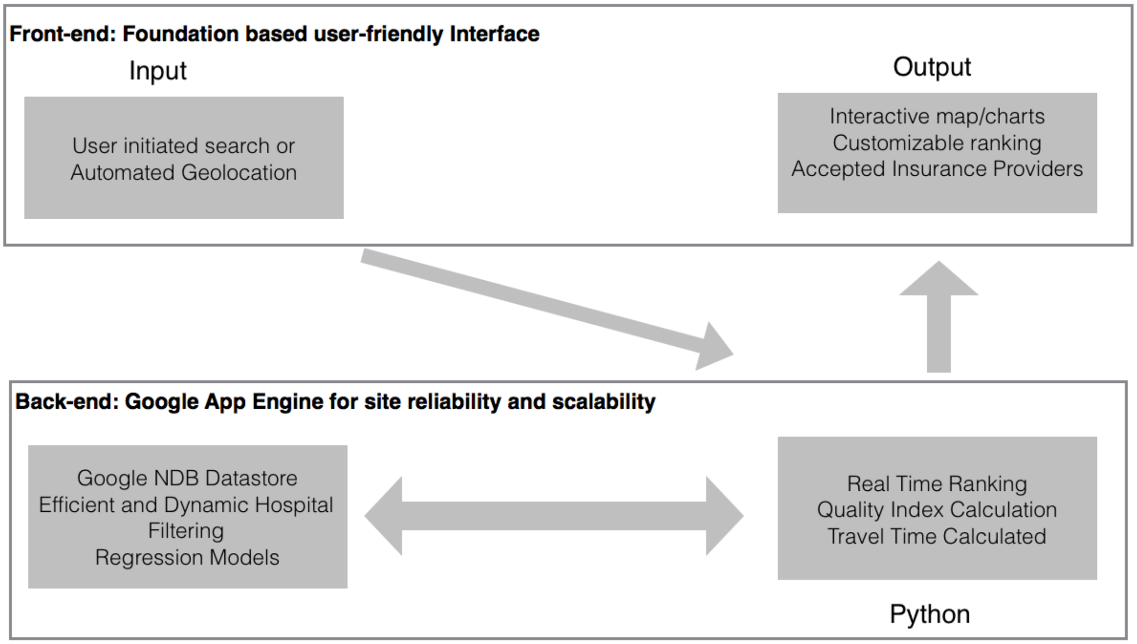

Figure 4. System Architecture for FindED

5. Results and Evaluation

The design of FindED addresses the following limitations and challenges: 1) lack of outside of system information, 2) scope of nearby hospital results, 3) Timely and Effective Care metric utilization, 4) hospital infection rates, 5) accepted insurance providers, and 6) information overload. The list of all nearby hospitals, the use of CMS datasets to rank and generate Quality Index, the detailed list of Georgia insurance providers, and the succinct hospital panels in FindED address issues 1 through 5. Here, to shed light on the results of the features, FindED is compared to other ED wait time tools in Table 4.

The features comparison is conducted between FindED, ProPublica, and the Children's Healthcare of Atlanta's wait time website [14, 15]. The features selected for comparison were picked because of their significance from the literature review and from feedback from potential users. FindED is the only tool with quality of care, multiple heuristics for ranking, holistic nearby hospital filtering, insurance coverage, and interactive multi-platform charts on one address. The other two focused solely on estimated wait time [14, 15]. Therefore, in order to search for the best hospital, the user is constrained to the singular heuristic of wait times or wait and travel times. If querying in Georgia, the user also has the ability to see accepted insurance providers for each hospital. With the other two systems, the user has to search through the each hospital's website [14, 15]. The comprehensive feature list among the three systems are summarized in Table 4.

Table 4. Feature comparison of FindED, ProPublica, and Children's Healthcare of Atlanta

Feature List	FindED	ProPublica	Children's Healthcare of Atlanta
Mobile device compatibility	✓	✓	✓
Directions to each hospital	✓	✓	✓
Contact information	✓	✓	✓
Breakdown of metrics	✓	✓	X
Data visualization of metrics	✓	✓	X
Visualization of nearby hospitals/Map	✓	✓	X
Location-based search	✓	✓	X
Geolocation search	✓	✓	X
Explanation of medical terms	✓	✓	X
Average wait times	✓	✓	X
Hospital infection rates	✓	X	X
Filtering for all nearby hospitals	✓	X	X
Multiple ranking algorithms	✓	X	X
Quality of Care metric	✓	X	X
Accepted insurance providers	✓	X	X
Real time wait times	X	X	✓

From Table 4, it is evident that FindED addresses the largest number of features referenced in literature and requested by prospective users. FindED allows users to rank nearby hospitals with five heuristics. ProPublica and Children's Healthcare of Atlanta only have one: travel plus wait time and wait time respectively [14, 15]. Filtering of all nearby hospitals is unique to FindED as it provides the users with all hospitals around the user's location. ProPublica only displays a limited number of results and Children's Healthcare of Atlanta only displays their three EDs in Georgia [14, 15]. For a sample search of New York City, San Francisco, and Atlanta, FindED obtains 93 results, ProPublica obtains 30, and Children's Healthcare of Atlanta obtains 3 as shown in Table 5 [14, 15]. FindED obtained over 300% the number of results ProPublica obtained with only an additional second of load time [14, 15]. Furthermore, FindED displays accepted insurance providers logos on results page, while ProPublica and Children's Healthcare of Atlanta display no insurance information at all [14, 15].

Table 5. Sample Search of New York City, San Francisco, Atlanta

Application	Total Results	Total Results with Wait Time Data	Time to Load (s)
FindED	93	82	2.66
ProPublica	30	23	1.67
Children's Healthcare of Atlanta	3	3	3.15

On December 10, 2015, an article detailing FindED was posted and shared on reddit.com, a news aggregate website [26]. According to Google Analytics web traffic monitoring, the web application served 53,500 unique users within a 48 hour time period. Of these users, 32,117 reported their gender, and this distribution is displayed in Figure 5.

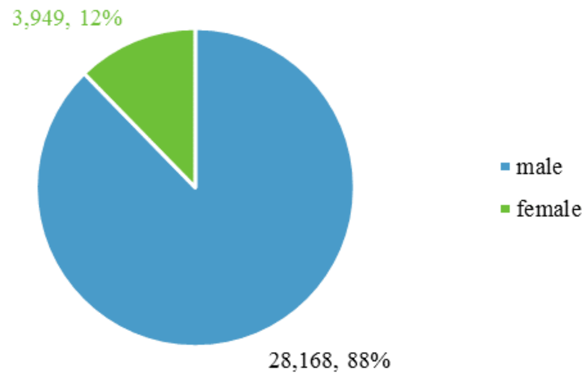

Figure 5. User Gender Distribution

Additionally, 31,040 (54.56% of total sessions) users reported their age brackets, displayed in Figure 6.

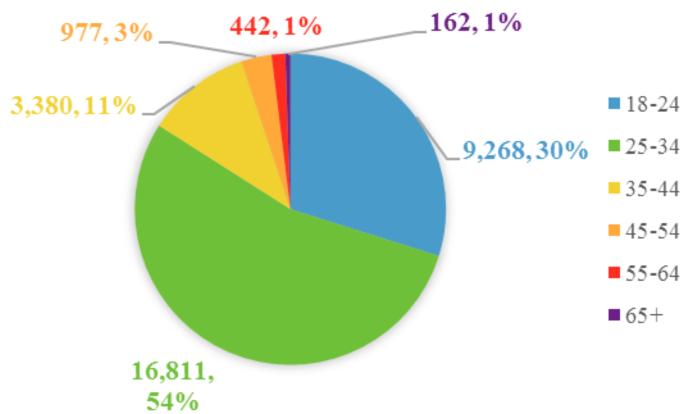

Figure 6. User Age Distribution

The application was accessed 55,582 times and the distribution of devices used to access the site is shown in Figure 7. This session value is larger than then number of unique users because of site revisits.

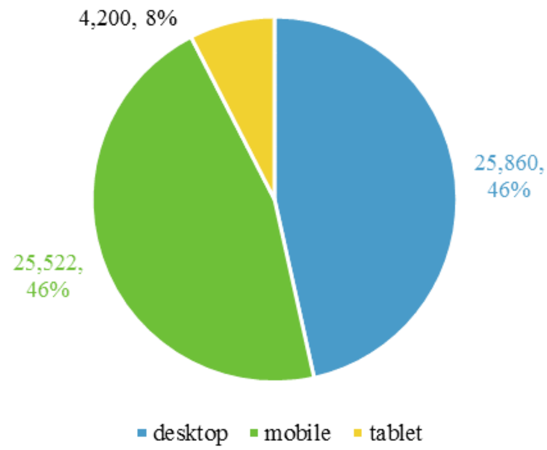

Figure 7. Access Device Distribution

The average session duration before leaving the application is shown in Figure 8.

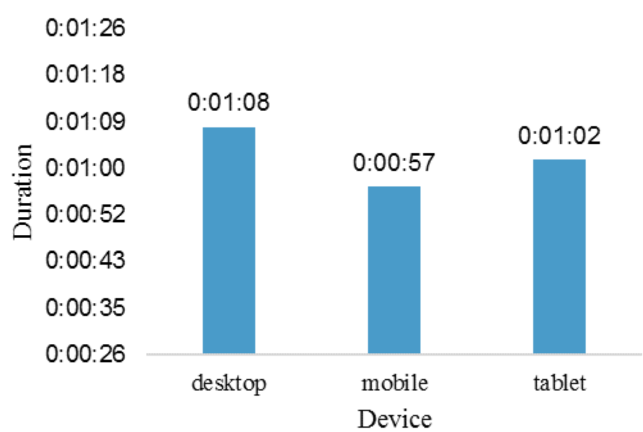

Figure 8. Average Session Duration vs. Device Type

Once at the results page, mouse clicks were tracked to determine which parts of the application users were interacting with. Figure 9 shows which result panels were clicked for more details.

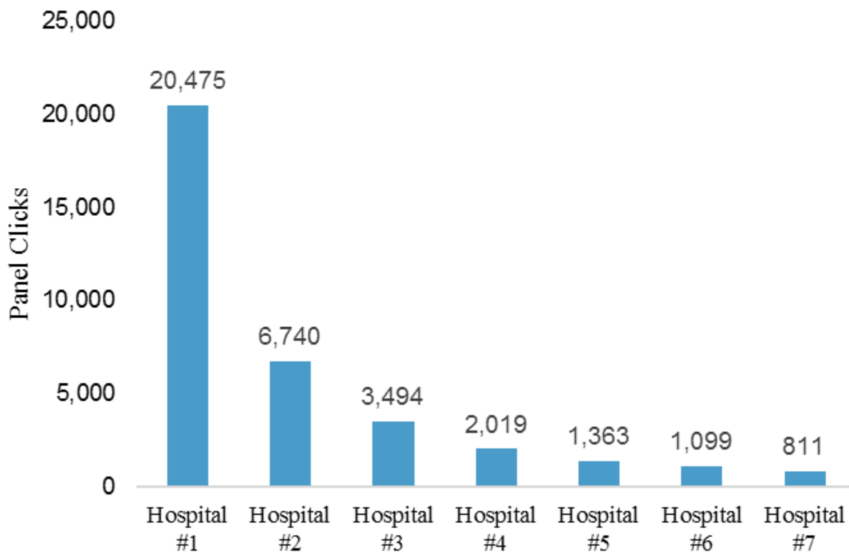

Figure 9. Panel Clicks vs. Hospital Result Ranking

Results filtering events were tracked, corresponding to a user selecting to rank hospital results by a heuristic other than the default. These occurrences are shown in Figure 10.

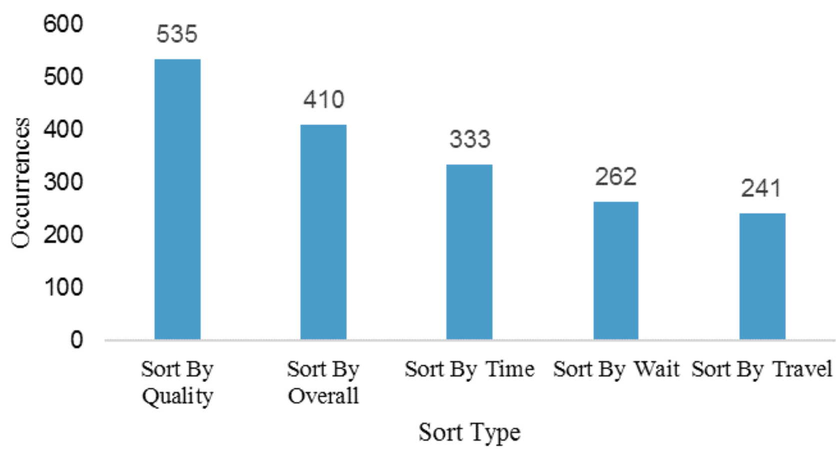

Figure 10. Histogram of Results Sorting Events

Finally, user locations were tracked and the top 28 search areas are shown in Figure 11, accounting for 62.5% of all traffic to the application within the 48 hour period.

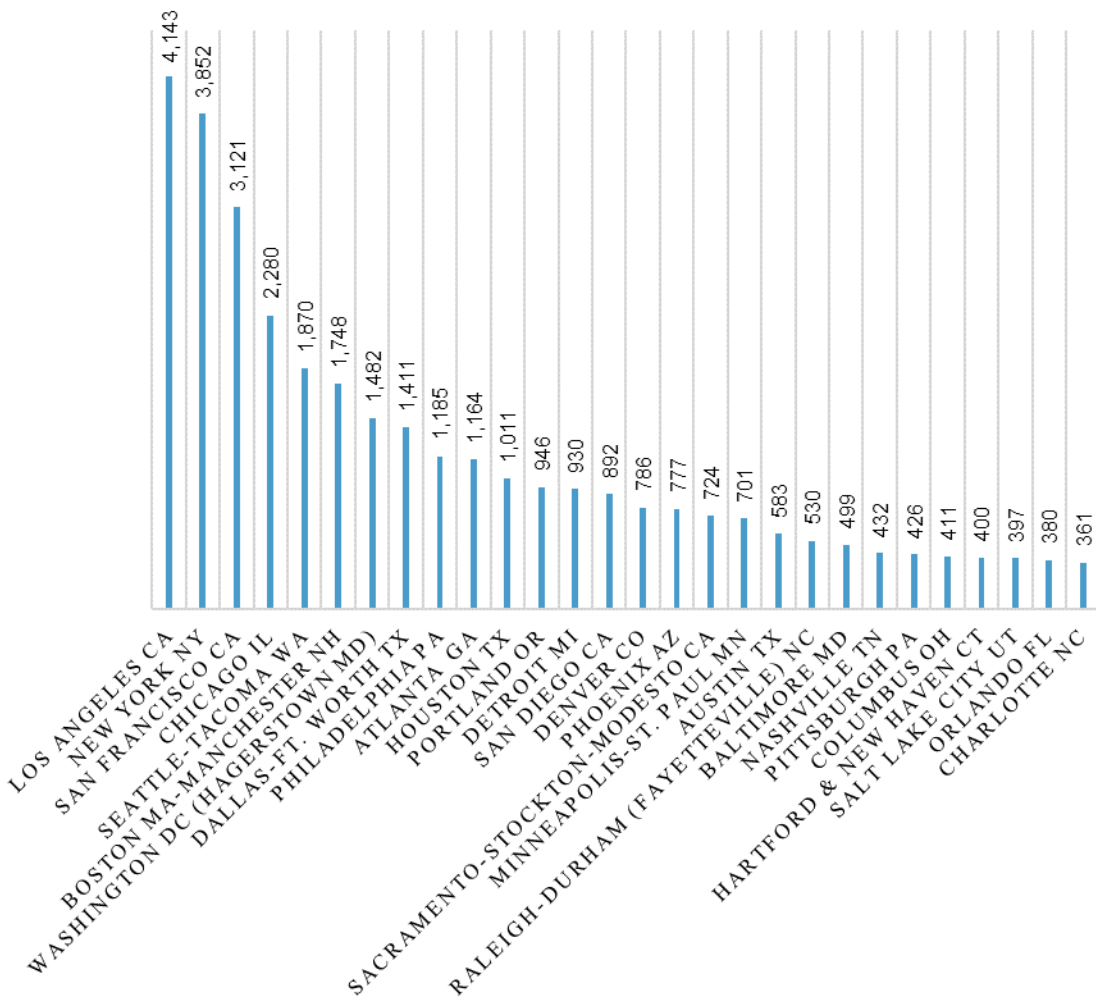

Figure 11. Application Users per City

From Figures 5 and 6, it is clear that the overwhelming majority of users during the 48 hour period are male (88%) and between the ages of 18 and 34 (84%). These demographics match closely to an informal study done in 2012 on reddit.com's demographics where 84% self-reported as male and 85% self-reported to be between the ages of 18 and 35 with n = 26,886 [27]. One interpretation of the high correlation between these two sets of demographic data would be that FindED has universal appeal to internet users. It is not obvious that any one group of people demonstrated less interest in the application than another. The ability of the application to gain usership from the young, male demographic demonstrates effective outreach considering how that group is most sensitive to long wait times in the ED, having the highest probability of leaving without being seen [3].

With regards to accessibility, the application was used equally from stationary desktops and mobile platforms, according to Figure 7. Moreover, the average session duration was 0:01:03 with a maximum average deviation of 0:00:06 across all platforms, as shown in Figure 8. Combined with the measured user actions documented in Figures 9 and 10, the data indicates that any sort of internet access point is suitable to use the application, and users are not simply accessing the site and leaving without exploring the content. Given the availability of both desktops and mobile devices in the US, time spent gaining accessing either is expected to be negligible for the target population. Should a target user require emergency department services, an additional minute spent using FindED to compare local EDs would not unnecessarily delay treatment. FindED has no application in any situation where a minute's difference would significantly decrease the condition of the patient; professional emergency transportation would be used instead.

Monitored web traffic suggests FindED's results are presented in a responsive and relevant format. According to Figure 9, a plurality of users inspected the highest ranked hospital in the results section, and the second ranked choice only received 32.9% as many views while the remaining hospitals had even fewer. This pattern of user interactions may indicate that the user's attention is appropriately drawn to the most highly ranked hospital. The lack of inspections on following hospitals may indicate user trust in the results ranking or that sufficient information is displayed in the initial results panel for the user to reach a conclusion. One important caveat is that the amount of hospital results displayed differ based on search areas, which may affect result inspection counts. However, as at least 62.5% of users performed searches on established cities within the US, as seen in Figure 11, the general observation on user attention is still expected.

When manually sorting results, sorting by Quality Index is the most selected criterion, with occurrences greater than the next most frequent heuristic by 30.48%. A full breakdown can be seen in Figure 10. Assuming most of the users tracked during the 48 hour period do not have emergency medical needs, sorting by Quality Index indicates a general user interest in understanding relative rankings of hospitals according to performance. This behavior provides evidence for the earlier suggestion that the general population desires hospital-related medical information though it is not readily available. It cannot be reliably stated at this time how effective FindED is in influencing users' when choosing an ED; conclusive inductions require further user studies with follow-ups.

6. Limitations and Improvements

There are observed limitations in FindED. Specifically, all CMS is outdated the moment it is released and self-reported from the hospital. Improvements such as gathering real-time wait data from partnered hospitals could rectify this limitation. As a potential useful feature for hospitals, crowd-sourced data on number of patients leaving without being seen and general public sentiment about specific hospitals could provide significant benefits.

Variations between trauma center specifics are currently unaccounted for, as CMS does not fully distinguish EDs in this manner when reporting statistics. Additionally, insurance information is currently only available by manually searching each hospital's resources and is subject to change over time. To alleviate this limitation, partnerships with major insurance companies and other hospitals can be attempted for updated insurance coverage and detailed services. These are only a few of the reasons reporting an accurate singular quantity for Quality Index remains challenging.

The equations used to determine Timely Care score, HAC score, and Quality Index are also open to refinement. Originally formulated based on intimate knowledge of Atlanta area hospitals and careful consideration of CMS metrics, there is no unified equation to accurately characterize all US hospitals according to their quality of care. Further studies should be performed to determine relevant performance metrics, including those not reported by the CMS. With so many fields to characterize hospitals by, such an endeavor appears conducive to machine learning regression techniques. One promising model for hospital quality score is proposed by Hospital Safety Score, detailed in their Fall 2015 Scoring Methodology report [28].

7. Summary

Considerable research has been conducted to discover the rationale behind why patients leave the ED and the effects wait times have on patient satisfaction. In this work we present FindED, a web-based application that attempts to alleviate the shortcomings of existing ED wait technology. FindED is designed for use by non-ambulance patients whose time is limited and who can benefit from a desktop/mobile website to present and rank nearby hospital EDs in an easy-to-understand and content-driven summarized format. The system performs real-time searches, filtering and ranking of nearby hospitals, visualization of nearby hospitals, and develops user-driven metrics that focus on user needs, enabling them to visualize geographically nearby hospitals ranked on timely care metrics and quality of care metrics. It also compares nearby hospitals with state, national and peer averages and avoids information overload by focusing on only essential functions with interactive visualization that allow users to control the amount of detail desired.

FindED does not require specialized knowledge or experience for the user to discover nearby hospitals, hospital wait and travel times, and determine hospital quality metrics. Users can utilize the system as a standard website and only need one mouse click to obtain results. The system is designed for fast analysis, easy scalability, and strong reliability, ensuring that there is no compromise in system performance. The Foundation front end CSS template facilitates a user-interface that is responsive to everyday consumers. In a similar manner, the panel view for hospitals provides a quick overview of the hospitals information and allows users to quickly digest the most significant information without compromising design and functionality. Linking the panel to the interactive graph by using pin animations helps users visualize where the hospital is compared to where they are. The system empowers users with the ability to have additional knowledge and information, allowing for a more informed decision on where to proceed with their services. Further, users are given the choice to view more detailed information by clicking on a hospital of interest, displaying various timely and quality of care metrics relative to the hospital's peers', state, and national averages. The filtering function allows for greater visibility of smaller known hospitals compared to Google Maps API searches, allowing users to have a holistic view on any location selected within the US.

FindED provides the users with a single page visual-data summarization, comparable to Propublica ED Wait Watcher which also filters and ranks hospitals based on the users location [14]. However, FindED filters and ranks on a wider set of feature better encapsulating the ER hospitalization process taking into account additional metrics such as quality of care and wider search birth. This is very different than existing hospitals where users are conformed to the present hospital sites where users are conformed to a limited subset of hospitals and an information overload of metrics and technical language.

Future work will involve adding support for real time wait times, expanding accepted insurance provider coverage, and implementing the ability to send directions to a mobile device. In addition, the accuracy of the wait times must be improved so that relevant information is conveyed rather than an average. More generally, user accessibility and system design feedback will be incorporated. The system is currently being tested in order to understand how patient-hospital interactions respond to the availability of care metrics, and we expect continued advances on this front.

8. References

1. Horwitz, L.I., J. Green, and E.H. Bradley, US Emergency Department Performance on Wait Time and Length of Visit. Annals of Emergency Medicine, 2010. 55(2): p. 133-141.

2. Hing, E. and F. Bhuiya, Wait time for treatment in hospital emergency departments: 2009. NCHS Data Brief, 2012(102): p. 1-8.

3. Kennedy, M., et al., Review article: Leaving the emergency department without being seen. Emergency Medicine Australasia, 2008. 20(4): p. 306-313.

4. Geraldine Lee, R.E., Karen Flett, Rosie Bushnell, Characteristics of patients who did not wait for treatment in the emergency department: A follow up survey. Accident and Emergency Nursing, 2005. 14(1): p. 56-62.

5. Fry, M., J. Thompson, and A. Chan, Patients regularly leave emergency departments before medical assessment: A study of did not wait patients, medical profile and outcome characteristics. Australian Emergency Nursing Journal, 2004. 6(2): p. 21-26.

6. Arendt, K.W., et al., The left-without-being-seen patients: what would keep them from leaving? Ann Emerg Med, 2003. 42(3): p. 317-23.

7. Boudreaux, E.D. and E.L. O'Hea, Patient satisfaction in the Emergency Department: a review of the literature and implications for practice. The Journal of Emergency Medicine, 2004. 26(1): p. 13-26.

8. Bindman, A.B., et al., Consequences of queuing for care at a public hospital emergency department. JAMA, 1991. 266(8): p. 1091-6.

9. Sun, B.C., et al., Effect of emergency department crowding on outcomes of admitted patients. Ann Emerg Med, 2013. 61(6): p. 605-611 e6.

10. Baker, D.W., C.D. Stevens, and R.H. Brook, Patients who leave a public hospital emergency department without being seen by a physician. Causes and consequences. JAMA, 1991. 266(8): p. 1085-90.

11. Publishing Wait Times for Emergency Department Care. American College of Emergency Physicians, 2012. Available from: http://www.acep.org/workarea/DownloadAsset.aspx?id=86983

12. Goodacre, S., Who waits longest in the emergency department and who leaves without being seen? Emergency Medicine Journal, 2005. 22(2): p. 93-96.

13. Network, N.H.S., Timely and Effective Care - Hospital, C.f.M.M. Services, Editor. 2014: Medicare.gov.

14. Lena Groeger, M.T.a.S.W. ER Wait Watcher: Which Emergency Room Will See You Fastest. 14 January 2015 [cited 2015 3 March 2015]; Available from: http://projects.propublica.org/emergency/.

15. Atlanta, C.s.H.o. Urgent Care and Emergency Wait Times. 0215 3 March 2015 [cited 2015 3 March 2015]; Available from: http://www.choa.org/waittimes.

16. Google. Place Search. 2015 23 February, 2015 [cited 2015 4 March 2015]; Available from: https://developers.google.com/places/documentation/search.

17. Anderson, M., C. Dobkin, and T. Gross, The Effect of Health Insurance Coverage on the Use of Medical Services. American Economic Journal: Economic Policy, 2012. 3(4): p. 1-27.

18. Google. The Google Directions API. 2015 23 February 2015 [cited 4 March 2015]; Available from: https://developers.google.com/maps/documentation/directions/.

19. Network, N.H.S., Healthcare Associated Infections - Hospital, C.f.M.M. Services, Editor. 2014, Center for Medicare & Medicaid Services: data.medicare.gov.

20. Aetna, Aetna Logo. Aetna: Aetna Website. p. Aetna Logo.

21. Association, B.C.B.S., Blue Cross Blue Shield Association Logo. Blue Cross Blue Shield.

22. Care, C.H., Coventry Health Care Logo. Coventry Healthcare: coventryhealthcare.com.

23. Humana, Humana Logo. Humana.

24. Cigna, Cigna Logo. 2015, Cigna: Cigna Website.

25. Healthcare, U., United Healthcare Logo. 2015, United Healthcare: United Healthcare Website.

26. Reddit. A website that ranks nearby Emergency Rooms by their wait time, quality, and travel time in the US. 2005 June 23 [cited 24 January 2016]; Available from: https://redd.it/3w5hc9.

27. Reddit. I made a basic Reddit Demographic Survey. Let's find out who we are... 2005 June 23 [cited 24 January 2016]; Available from: https://redd.it/gzb2w

28. Hospital Safety Score. Scoring Methodology Fall 2015. The Leapfrog Group, 2015. Available from: http://www.hospitalsafetyscore.org/media/file/HospitalSafetyScore_ScoringMethodology_Fall2015_Final_v2.pdf