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Going to the Nearest Hospital vs. Designated Trauma Centre for Road Traffic Crashes: Estimating the time difference in Delhi, India

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Abstract

Background: Time to hospital after a road traffic crash (RTC) plays a vital role in determining the outcome for crash victims. In Delhi there are 7 designated trauma centres where crash victims are typically taken, may not be nearest hospital. We compare the difference in transport time (crash to hospital) depending on whether the victim is transported to a designated trauma centre or the nearest hospital.

Methods: For each RTC, the nearest hospital and the designated trauma centre was identified using Google Maps Places Nearby Search API and government guidelines. Travel time between RTCs and identified hospitals were determined by using Google Maps Distance Matrix API. An index was developed for inter-district differences.

Results and Conclusions: The network of designated trauma centres in New Delhi are located such that they can be accessed within 45 minutes of most crashes while nearest hospital within 30 minutes. As a result the vast majority of crash victims are likely to receive timely care if they are rapidly transferred to these locations. However, for the most severely injured and time-sensitive cases, stabilization at a closer hospital prior to transfer to definitive care, could substantially improve survival outcomes.

Peer-review under responsibility of WORLD CONFERENCE ON TRANSPORT RESEARCH SOCIETY.

Keywords: Trauma Care; Road Traffic Crashes; Google Maps API; Pre-hospital Transport, Access

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1. Introduction

Trauma systems for providing care to road traffic crash (RTC) victims are under-developed in India. The process of forming a robust care system for injury prevention, pre-hospital & acute hospital care and rehabilitation units to diminish the risk of permanent disability within demographic profile is still underway (Pal et al., 2014). The Planning Commission of India estimates that the cost of injury to Indian society is 3% of GDP (Kumar Gupta et al., 2011). The prime concern after a RTC is to reduce the impact of injury by reaching appropriate health care facility as early as possible. An appropriate health care facility could be a hospital, defined as geographically fixed facility with acceptably trained personnel to deliver emergency medical care or it could be a specialized trauma care unit equipped with appropriate and specialized care facilities to deal with severe trauma injury which would require timely diagnosis and treatment by a multidisciplinary team of health care professionals (Kobusingye et al., 2006; Kumar Gupta et al., 2011).

Many studies have shown that the duration of time between a crash and definitive care are important for survival of victims. Observations from a Swedish study on survivability in road traffic crashes shows that, from the group that sustained survivable injuries, about 12% of crash victims could have survived if they had reached the hospital earlier but reaching a “trauma care unit” would have been even better and that would save an additional 20% which means, 32% of survivable injuries could be saved if they were taken to a trauma care unit quickly (European Commision, 2009).The most efficient emergency services take about 30-45 minutes to take the victim from crash location to the hospital in non-urban areas (Coats and Davies, 2002; Bigdeli, Khorasani-Zavareh and Mohammadi, 2010). Timely arrival of emergency services, followed by quick transport is crucial for an efficient emergency system(Lerner, 2001; Roy *et al.*, 2010; Radjou, Mahajan and Baliga, 2013). The first 60 minutes after the crash is generally termed as the golden hour. While the golden hour is not the perfect framework but an internationally accepted framework to highlight the importance of time. A significant amount of the literature claims that time is an important determinant of the outcomes of the road crash victims. Starting from “Critical 4 min”, during which if airway is blocked and not immediately cleared may lead to death. Next is “Platinum 10 min”, which is recommended maximum on-scene stabilization time for seriously injured persons (Rogers, Rittenhouse, & Gross, 2015). For total time to receive definitive care, it is believed that if proper first aid is given to RTC victims in first one hour, their chance of survival increases. Some studies endorse first 60 minutes, claimed as “Golden Hour” as the acceptable time window to access adequate treatment for accident victim while some claim its origins to be hoax (Gopala krishnan 2012; Lerner & Moscati 2001). There is still an ongoing debate on the adequate time for appropriate treatment, while international standards tend to highlight importance of time to access hospital care in terms of golden hour. Even though, the literature has substantial use of golden hour terminology, we are too far from generalizing pre-hospital time window to outcomes/survival (Rogers et al., 2015). Thus, while it is controversial whether the first hour after a traumatic event has a special status as a time threshold, it is widely understood that rapid transfer to a medical facility improves outcomes.

Measures to reduce travel time to hospital care after a road traffic crash include better pre hospital transportation services, and the provision of a higher number of healthcare units that are geographically distributed for effective spatial coverage (Coats and Davies, 2002; Bigdeli, Khorasani-Zavareh and Mohammadi, 2010). The total time to medical care is a combination of several time intervals: notification time, activation time, response time, on scene time and transport time. Transport time is only one component (Coats & Davies, 2002). In formal emergency response systems, components other than transport time might have a huge impact on the total time to reach hospital care (Bigdeli et al., 2010; Corrado et al., 2017; Nobhojit Roy, 2017). A research study based in Iran points out that scene-hospital transport time are significantly longer for interurban incidents. The authors stress the need for more research on local needs and accessibility for city based interurban roads and allied locations (Bigdeli, Khorasani-Zavareh and Mohammadi, 2010). In India, the national government’s trauma care capacity building guidelines recommend a level I designated trauma care unit within 750 to 800 km from locations of high crash frequency (Government of India. Ministry of Health and Family Welfare, 2015).

Globally, pre-hospital care systems either emphasize a “scoop-and-run” approach, where the goal is to rapidly transport the victim to the hospital, or “stay-and-stabilize”, which emphasizes the need to perform stabilizing

interventions such as intubation and placement of intravenous access lines for fluid replacement prior to transportation of the victim. A growing literature suggests that scoop-and-run has better outcomes because performing invasive interventions in the field is difficult and results in delays(Haas & Nathens 2008; Varghese,M. 2016 ; Jayaraman et al. 2009). Regardless, in LMIC settings that do not have an established infrastructure to support advanced life support (ALS) in the pre-hospital setting, scoop-and-run is the only option, and minimizing time to hospital is a key strategy for improving outcomes. Currently, in India people tend to scoop and run the crash victims to nearest hospital using whatever vehicle is available instantly. In fact, scoop and run is one of the most recommended approaches in emergency transportation. In typical urban settings of urban environment, with relatively short transport times, there isn't much evidence available to support field ALS while some suggestion of harm exists. In very rare cases ALS acts as lifesaving, but the rarity of such events and the effort required to maintain the competence is quite disproportionate. The support towards complex EMS systems emerged with a hope for its effectiveness without much evidence (Sasser et al. 2006; Varghese,M. 2016; Nagata et al. 2011; Morrison 2015; Sanghavi et al. 2015; Haas & Nathens 2008).

Besides minimizing transport time, other key issues that affect outcome include training of first responders, and the choice of medical facility to which the victim should be transported. Providing basic training to citizens and police personnel in India still remains a disconnected link in the current structure of post-crash management which is generally taken care by fragmented bodies such as non-government organizations and other alike (Pal et al., 2014; Posaw, Aggarwal, & Bernstein, 1998). A parallel discussion prevails in pre-hospital care and road safety science, which tends to differentiate between decision to take the road crash victim to appropriate/definitive care or to the nearest hospital. Effect of pre-hospital interventions or by other hospitals on life-threatening events, prior to trauma care was studied in Portugal. It revealed decreased mortality of trauma patients even after extended time to trauma care (Gomes et al., 2010). Selection of best hospital after road traffic crash has been highly debatable. Should it be level I trauma centre or the nearest community hospital or level III/IV trauma care unit is still under discussion. Spatial factors like distances from crash location to the nearest local hospital or tertiary care trauma centre have different individual challenges in each region. Triaging recommendations for Emergency Medical Services (EMS) is to identify the best hospital as per the condition of the victim and not merely take them to the nearest hospital. With proper triaging and ambulatory services, about 1/3rd lives could be saved in a year (Kobusingye et al., 2006). In India, injury victims generally end up in Government Hospitals for Emergency Care while reasonably good acute care facilities are provided by tertiary care teaching hospitals. Other institutions giving medical care include private hospitals, private medical practitioners and institutions (Pal et al., 2014).

Studies recommend that when transport times are higher than 60 minutes, patients would benefit from visiting nearest hospital, however when its less than 30 minutes, its beneficial to bypass smaller hospital and visit definitive care facility (Harrington et al., 2005). A study based in Rhode Island with one designated trauma centre mentions transfer protocol to trauma centre if transportation time is less than 20 minutes and to the nearest medical facility if patients injured are beyond 20 minutes travel time from the trauma centre. Their results show that 91% of the patients who were transported directly from the scene to the trauma centre reached within 20 minutes and 96.1% within 25 minutes (Harrington et al., 2005).

While the final verdict/best practice is still undecided among academic community and policy makers, certain guidelines reflect this distributed view on above issue. Perhaps, few emergency care services are purposefully directed to take the victims to the appropriate designated healthcare facility/trauma centre (Harrington et al., 2005). Another advisory is to take the road crash victim to the nearby hospitals to be able to stabilize the patient earlier and before being transferred to higher level facilities for appropriate care (Harrington et al., 2005; World Health Organization, 2015). As per Supreme Court guidelines, India, no hospital and medical facility can deny treatment to a road crash victim. Many victims end up going to the nearest hospital, however nearest hospital may not have the requisite facilities and they tend to get transferred to nearest designated trauma centre (Radjou et al., 2013; Nobhojit Roy, 2017). These guidelines recommend taking road crash victims to the nearest hospital. Under these directives, no hospital whatsoever can deny admission in emergency cases of road accident and women in labour. They are bound to provide primary treatment to emergency cases under current legal framework. All legal formalities and expenditure would be claimed after stabilizing the patient. If the hospital lacks the infrastructure required for full treatment of the patient, it should first stabilize the patient and then

transfer the victims in stabilized condition, in proper transportation vehicle with a paramedic and doctor trained to handle the condition of the patient during the transfer (Rao, M, 2006). We understand that if the patients were to go directly to the designated trauma centre which is equipped with facilities to deal with accident related serious injury, it might save some time of their overall recovery. As previously mentioned, poly-trauma cases need specialized care and the crash locations considered here are representative of such crashes with each having at least one fatality during crash. These cases need appropriate care as early as possible. We compare how access to trauma centre fare as compared to nearest hospital. So therefore in this paper, our core objective is only to estimate how much time it would save if patients were taken to the nearest hospital compared with directly to trauma centres.

1.1. Objectives

In this paper we compare access time (i.e. time from crash scene to hospital) of crash victims to designated trauma centre with access time to the nearest hospital in New Delhi. This study focuses solely on time from the crash site to the hospital. Other components of time (i.e. calling for help, arrival of help and on scene time) are independent of hospital choice and, therefore, are not considered in this study.

The study objectives include:

- To estimate the travel time to the designated trauma centre and geographically nearest hospital from each RTC in New Delhi.
- To evaluate district-level variation in travel time to designated trauma centre and geographically nearest hospital from each RTC.
- To estimate the time lapse for the destination as designated trauma centre instead of geographically nearest hospital after a road traffic crash.

1.2. Assumptions

We are assuming that the trauma centre has the facilities for appropriate care and that the nearest hospitals has the ability to stabilize the victim but may or may not have the facilities needed for definitive care. Also, trauma care facilities would be capable of better triaging the victims, owing to their expertise and experience in dealing with trauma victims. Other major assumption, is that Google maps API is able to identify the nearest hospitals correctly, while this might have certain degree of error (Table 1). Although, we propose to measure these as differences in travel times as predicted by Google Maps API Platform. We understand that the accuracy of Google Maps API for predicting travel times and distances has been appreciated substantially in literature but is not completely infallible and the travel time predicted would thus only be representative of the situational travel time when the API is called and not the actual travel time always (Shaw et al., 2017).

Table 1: Descriptive analysis of the Nearest Hospital results obtained from Google Maps API

Type Of Facility	Count	%
Maternity Care	7	1.13
Clinic	14	2.27
Other	29	4.69
Paediatric Hospital	3	0.49
Eye Hospital	8	1.29
Hospital	557	90.13
Total	618	100

1.3. Google Maps API

Google Maps provide a range of Application Programming Interface (API) which enable the users to fetch data from Google's extensive database, within terms and conditions. The functionality enables users to determine the nearby places, calculate distance and approximate time to reach a specified destination point from a specified location. The command to get results requires a key, which needs billing details as per Google's revised policies, June 2018. One key can be obtained per project, Google supports up to 10 projects per user. Each key has restricted usage of up to 2500 calls for free users. The limit varies as per the API called for. The results returned are in JSON/XML format. For instance, a sample call of the Google API to fetch restaurant within 1500m radius of a certain address- Latitude and Longitude is: https://maps.googleapis.com/maps/api/place/nearbysearch/json?location=-33.8670522,151.1957362&radius=1500&type=restaurant&keyword=cruise&key=***YOUR_API_KEY*** (Munir & Omair, 2015).

2. Methodology

Delhi is the capital city of India with about 1800 fatal crashes per year (Police, 2018). Due to its vast extent, it has been subdivided into nine districts, namely North, South, East, West, Central, New Delhi, South West, North West and North East (Registrar General of India. New Delhi, 2011). To manage the burden of road traffic crashes, the government of Delhi specifies a definitive care or trauma care facility for each district within Delhi (Table 2). The guidelines suggest government services and citizens to visit these centres of care in case of medical emergencies (Government, 2018). The trauma centre and district boundaries are plotted showing their location and spatial boundaries respectively (Figure 2). The identified definitive care units are taken as the trauma centre destinations for each district. Police records have been identified as the best source of information on road traffic crashes in India. While these crashes underrepresent non-fatal injury data, they quite adequately capture fatalities in cities (Mohan, Tiwari, & Bhalla, 2015; Pal et al., 2014).

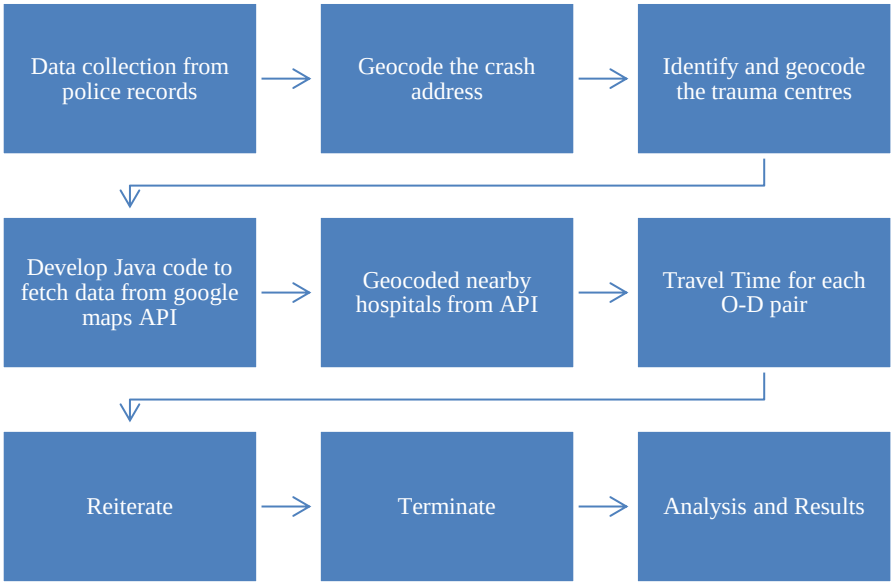

Figure 1: Flowchart of Study Implementation

Fatal Road Traffic Crash records from January, 2013 to December, 2016 were obtained from Delhi Police Records for Delhi, India. The record consisted of 6738 fatal crash location addresses. The addresses were geocoded manually by searching for address in Google Maps. Out of these 1167 locations could not be found exactly as per given address, these locations were plotted by approximately locating crash on nearest location on road. Due to their discrepancies in recording format of addresses, it was difficult to use the automated methods of finding geo-locations, which was initially experimented with and later given up owing to inefficient results. The identified geo-locations were plotted on ArcGIS and overlapping locations were collated. Certain locations appeared to lie outside Delhi boundary, they were discarded. This led to discarding of 200 crash records. Further 200 records were discarded after identifying nearest hospital, as results returned were missing values of either travel time or distance or both, even after three iterations of fetching results for these location pairs.

Table 2: District wise area and their respective designated trauma centre

District	**Area (km^2)**	**Designated Trauma Centre**
North	69.3	Sushruta Trauma Centre
South	255	Jai Prakash Narayan Apex Trauma Centre (JPNATC)
East	65.5	Guru Teg Bahadur Hospital (GTB)
North-East	62.8	Guru Teg Bahadur Hospital (GTB)
West	123	Deen Dayal Upadhyay Hospital (DDU)
Central	15.2	Ram Manohar Lohia Hospital (RML)
South-West	436	Safdarjung Hospital
North-West	445	Baba Saheb Ambedkar Hospital
New Delhi	38.6	Jai Prakash Narayan Apex Trauma Centre (JPNATC)

There are two types of health facilities included in the study: designated trauma centres and nearest hospitals. Nearest hospital in this study has been identified as the geographically nearest hospital to the crash location. Google maps API identifies these facilities with 90% accuracy in this study (Table 4). Rest 10% cases are either health facilities other than hospitals or hospitals like specialized maternity care units, Ayurveda centres, veterinary hospitals, dental and eye centres or paediatric care units. In cases, where the trauma centre might be the nearest hospital to the crash location, they would overlap in the travel time result estimates. The nearest hospital to all identified crash locations were identified using Google Maps Places API (Google, Mountain View, California, USA). The data was fetched with keyword = hospital and type = hospital. To automate and expedite the process of getting the travel time estimates, a project in Java was developed, which was further run in Eclipse Jee Oxygen. The standard version of API gives basic results in the form of name of the hospital, place id and geometry (Latitude and Longitude). These fields were recorded and matrix representing nearest hospital was generated for all the crash locations. API returns nearest hospital ranked by distance, of which the nearest hospital name, its place id and geometry (latitude-Longitude) were extracted from the results into a Microsoft Excel spreadsheet. Further, taking crash location as the origin and nearest hospital as the destination, travel time and distance was found for each pair using Google Maps Distance Matrix API (Google, Mountain View, California, USA). Both the API were embedded in the Java project.

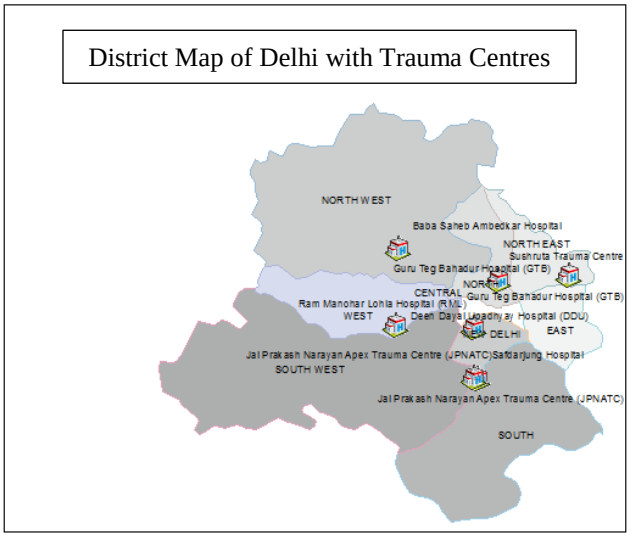

Figure 2: District Map of Delhi

As discussed, the literature identifies the difference in opinion on nearest versus appropriate healthcare facility selection in case of health emergency. To estimate the actual travel time and distance differences between trauma centre and nearest facility, the Google Maps Distance Matrix API (Google, Mountain View, California, USA) was used to find the travel time and distance for each crash - designated trauma centre pair and each crash - nearest hospital pair and results were compared individually. The results were obtained in MS Excel 2013 in which analysis was performed. An index was developed to assess the differences between districts with respect to golden hour, called Dissimilarity Index.

2.1. Dissimilarity Index

In terms of proportions, most districts seem comparable. However to understand if there is any difference among the districts in terms of travel time to trauma centre or nearest hospital, we formulated a Dissimilarity Index. International standards identify 60 minutes as the time within which if victims reach a hospital, their chances of survival and recovery are high. To assess the difference among the districts, an index was formulated with respect to 60 minutes.

$$\textit{Dissimilarity Index with respect to first 60 minutes after crash} = \left(\sum(xij/60)/N\right) \quad (1)$$

Where,
xij = travel time from crash locations to the assigned destination (definitive trauma centre or nearest hospital)
N = total number of crash locations

3. Results

3.1. RTC's distribution per district in Delhi

Overall there are 6738 Fatal RTC's reported in Delhi from Jan 2013 to Dec 2016. Out of these only 6338 could be accurately geo-located. In each of nine districts in Delhi: North, South, East, West, Central, New Delhi, South West, North West and North East , road crash burden aggregated for four years is 707, 930, 647, 1057,

269, 361, 1002, 999, 366. While South, West, South West, North West have highest fatalities; North East, New Delhi and Central Delhi are the least affected by fatalities in road crashes (Figure 3).

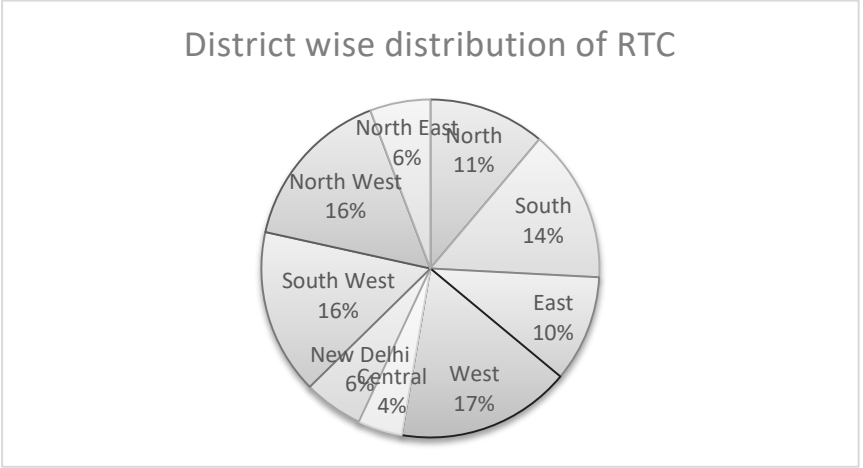

Figure 3: District wise distribution of Road Traffic Crashes

3.2. Travel time estimates to Trauma Centre

In the nine districts, there are seven trauma centres as identified by Delhi government, the plot for trauma centre and district boundaries are shown in (Figure 2). Considering each crash location in each district as origin and designated trauma centre as the destination, travel time was estimated using Google Distance Matrix API. The estimated results (Table 3, Figure 4) show that 2.7 % of RTC victims are within 0 to 5 minutes from the designated trauma centre, 20% are within 5 to 15 minutes, 45.3 % are within 15 to 30 minutes, 22.3% are within 30 to 45 minutes, 10.3% are within 45 to 60 minutes, while only 2% are beyond 60 minutes. It is observed that while in North West, East, North and Central districts, about 70 to 80% of road crash locations are within 30 minutes distance, for West, Southwest, Northeast and New Delhi, these proportions fall down to 35 to 55 %.

3.3. Travel time estimates to Nearest Hospital

Considering each crash location in each district as origin and the identified nearest hospital as the destination, travel time was further estimated using Google Distance Matrix API. The identified nearest hospitals were checked for their appropriateness by manually searching each unit and finding out if it actually is a hospital or other type of facility. About 90% of these are general medicine hospitals and other 10% are other types of hospitals and facilities (Table 4). The spatial distribution of these identified hospitals is plotted (Figure 5). The overlapping hospitals were collated and shown as single unit in spatial representation (Figure 5). The estimated results (Table 3, Figure 4) show that 40.9 % of RTC victims are within 0 to 5 minutes from the nearest hospital, 53.2% are within 5 to 15 minutes, 5.9 % are within 15 to 30 minutes, 0.1% are within 30 to 45 minutes. Interestingly, within Delhi, none of the fatal crash locations in the past four years was more than 45 minutes from a hospital. A hospital presence was observed within a 30 minute drive from the crash location for about 70 to 90% of the cases. This reveals that given the road crash victims have access to some form of mode of transportation after crash, the possibility to reach a nearby hospital within 30 minutes is quite high.

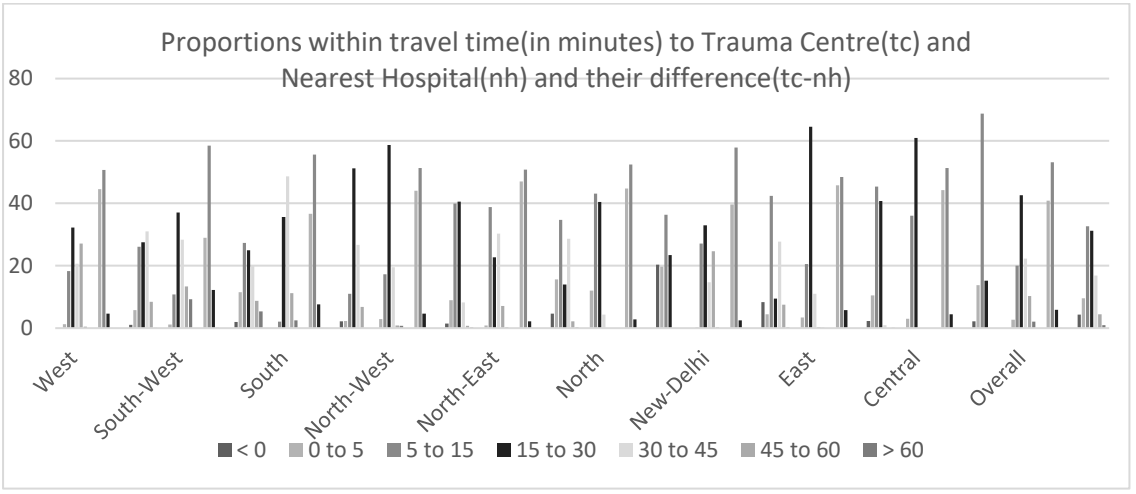

Figure 4: Proportion of RTC's within travel time (in minutes) to Trauma Centre (Tc) and Nearest Hospital (Nh) and Difference (Tc-Nh)

Table 3: % Travel time distribution of RTCs to Trauma Centre (Tc) and Nearest Hospital (Nh) and difference (Tc-Nh)

Time In Minutes		**< 0**	**0 to 5**	**5 to 15**	**15 to 30**	**30 to 45**	**45 to 60**	**>60**
	*Tc	0.0	1.2	18.3	32.3	20.6	27.2	0.5
West	**Nh	0.0	44.6	50.7	4.6	0.1	0.0	0.0
	***Diff	1.0	5.8	26.1	27.5	31.0	8.4	0.1
South West	Tc	0.0	1.2	10.8	37.0	28.3	13.4	9.3
	Nh	0.0	28.9	58.5	12.3	0.3	0.0	0.0
	Diff	2.0	11.5	27.4	25.0	20.1	8.8	5.4
South	Tc	0.0	0.0	2.0	35.6	48.7	11.2	2.5
	Nh	0.0	36.7	55.6	7.6	0.1	0.0	0.0
	Diff	2.2	2.3	11.0	51.2	26.7	6.8	0.0
North West	Tc	0.0	2.9	17.2	58.8	19.5	0.9	0.7
	Nh	0.0	44.0	51.4	4.6	0.0	0.0	0.0
	Diff	1.5	8.9	39.9	40.5	8.2	0.7	0.2
North East	Tc	0.0	0.8	38.8	22.7	30.3	7.1	0.3
	Nh	0.0	47.0	50.8	2.2	0.0	0.0	0.0
	Diff	4.6	15.6	34.7	13.9	28.7	2.2	0.3
North	Tc	0.0	12.0	43.2	40.5	4.4	0.0	0.0
	Nh	0.0	44.7	52.5	2.8	0.0	0.0	0.0
	Diff	20.3	19.8	36.4	23.4	0.1	0.0	0.0
New Delhi	Tc	0.0	0.3	27.2	33.0	14.7	24.7	0.3
	Nh	0.0	39.6	57.9	2.5	0.0	0.0	0.0

	Diff	8.3	4.4	42.4	9.4	27.7	7.5	0.3
East	Tc	0.0	3.4	20.6	64.6	11.0	0.3	0.2
	Nh	0.0	45.8	48.5	5.7	0.0	0.0	0.0
	Diff	2.3	10.5	45.4	40.7	0.9	0.0	0.2
Central	Tc	0.0	3.0	36.1	61.0	0.0	0.0	0.0
	Nh	0.0	44.2	51.3	4.5	0.0	0.0	0.0
	Diff	2.2	13.8	68.8	15.2	0.0	0.0	0.0
Overall	Tc	0.0	2.7	20.0	42.6	22.3	10.3	2.1
	Nh	0.0	40.8	53.2	5.9	0.1	0.0	0.0
	Diff	4.4	9.5	32.6	31.2	16.9	4.5	1.0

*Tc: Trauma Centre **Nh: Nearest Hospital, *** Difference

3.4. Travel time estimate comparison between Trauma Centre and Nearest Hospital

One of the objectives of this study was to assess how much is the difference if the trauma care is visited instead of nearest hospital for each crash. To find this, the travel time for trauma centre as the destination and nearest hospital as the destination was subtracted for each crash and the proportions of cases that vary within the time difference slabs were identified for each district separately and combined for an overall estimate. It was observed that (Table 1) 9.5% cases are within 5 minutes difference from a trauma centre versus nearest hospital. For 32.6% cases this difference ranged between 5 to 15 minutes, for 31.2% between 15 to 30 minutes, for 16.9% between 30 to 45 minutes. For about 5% of the cases this difference was beyond 45 minutes, where accessing the nearest hospital could be a better choice.

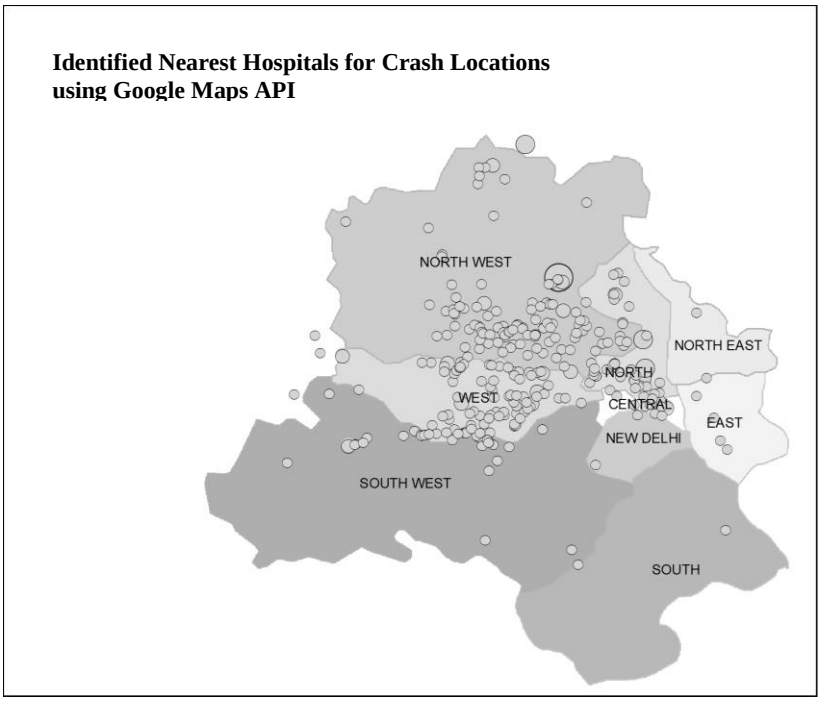

Figure 5: Spatial Distribution of Identified Nearest Hospitals for Crash Locations

3.5. Travel time estimation and its dependence on Mode of transport

In the above results it appears that most crash locations are accessible to a hospital within first 60 minutes. However, this is applicable only if the mode of transport is available right at the time of crash and at the site of crash. In most countries, it is observed that road crash victims are brought by non-ambulatory transportation modes such as taxis, three wheelers (autos), private vehicles etc (Demetriades et al., 2005; Prakashy, Tiwari, Sherin Raj, & Nair, 2013). In Delhi, India, recent estimates from an urban university hospital observe that of the 34.4% patients had come directly to the hospital after a road traffic crash, came by regular taxis/auto rickshaws-13.5%, private cars-12.4% and police vans-9.3% are the predominant modes of transport used after a road traffic crash (Nobhojit Roy, 2017). Considering that vehicles like three wheelers (autos), taxis are available on site or some public person takes the initiative to help in his private vehicle, these estimates might then fare well amid international standard of 60 minutes. If otherwise, help needs to be called for in the form of ambulance/police or relatives, then we need to account time taken for someone to initiate the call for help and then the response time taken by the help to reach the site. These estimates then might considerably change depending on the availability and response of the called modes of transport for transportation of road crash victims.

3.6. Dissimilarity Index

Lesser the value of this index shows better overall access to hospitals with respect to 60 minutes for that district (Table 4). The values of index are relatively higher for trauma centre as the destination. Two districts: Central (0.28) and North (0.24) fare better and are comparable. They are closely followed by East (0.35) and North West (0.38). The other districts such as West, South West and North West have higher values showing comparably higher travel time to reach trauma care. As far as nearest hospitals are concerned, index shows that almost all the districts are consistently comparable. Although, mere presence of hospitals may not prove their competence to treat or handle road traffic crash victims (Government of India. Ministry of Health and Family Welfare, 2015).

Table 4: Dissimilarity Index between districts in Delhi

Dissimilarity Index										
Time	Overall index=sum/N	West	South West	South	North West	North East	North	New Delhi	East	Central
#tcgh	0.45	0.52	0.57	0.57	0.39	0.42	0.25	0.47	0.36	0.28
##nhgh	0.12	0.11	0.15	0.13	0.11	0.10	0.11	0.12	0.12	0.12
###diff_gh	0.33	0.41	0.42	0.44	0.28	0.32	0.14	0.36	0.24	0.17

#tcgh: Trauma centre with respect to Golden hour
##nhgh: Nearest hospital with respect to Golden hour
###diff_gh: (Trauma centre minus Nearest hospital) with respect to Golden hour

4. Discussion

4.1. Travel time estimates to Trauma Centre

The study in Rhode Island shows that 91% of the patients who were transported directly from the scene to the trauma centre reached within 20 minutes and 96% within 25 minutes (Harrington et al., 2005). The results from our study reveal 68% are within 30 minutes reach of trauma centre. The variation could be attributed to differences between the crash patterns and spatial distribution of trauma centre in both the regions- Rhode Island and Delhi. Also, Delhi is a metropolitan city, with heavily congested roads and large variation in travel times (Tiwari, 2002) while in Rhode Island 80% of population lives within 20 minutes driving distance from a trauma

centre. Another reason for this variation could be the presence of multiple trauma centres in Delhi, each responsible for its specific coverage area. While the results highlighted from other studies are only for a single trauma unit (Harrington et al., 2005).

Accounting one trauma centre at a time, it was observed that in North West, East, North and Central Districts, about 70 to 80% of road crash locations are within 30 minutes distance, for West, Southwest, Northeast and New Delhi, these values fall down to 35 to 55%. Although, these trauma centres have been designated to cater to a certain region of Delhi, there is no hard evidence which establishes this direction. There is a possibility of distribution of patient load among these trauma centres as well, which is fairly indicated by these numbers which are on lower side as compared to regions with only one trauma centre catering to the population. Also these variations in locations and their reach can explain geographical variations in traffic mortality rates in areas with different emergency services accessibility, for which further investigation would be required (Bentham, 1986; Durkin, McElroy, Guan, Bigelow, & Brazelton, 2005; Li, Doong, Chang, Lu, & Jeng, 2008; Sánchez-Mangas, García-Ferrrer, De Juan, & Arroyo, 2010; Zwerling et al., 2005).

4.2. Travel time estimates to Nearest Hospital

When the study is compared to the standards followed in Harrington et al.'s work based in Rhode Island, only about 10% victims would need to be taken to the nearest hospital (Harrington et al., 2005). Few other results estimate benefits for patients in visiting nearest hospital if the travel time to trauma care exceeds 30 minutes (Bentham, 1986; Durkin et al., 2005; Harrington et al., 2005; Li et al., 2008; Sánchez-Mangas et al., 2010; Zwerling et al., 2005). Having a standardized system of centre designation for injury care as per injury burden of a region can aid in reducing its effects. In our estimated results about 99% lie within 30 minutes' drive from a nearby hospital. This might instinctively drive us to recommend the trauma centre as the ideal destination for all the crashes but we need to carefully account for other factors like the resources, capacity and existing load on individual trauma centre before making this as policy decision. Current trauma care guidelines do not give clear protocols for transportation of injured in Delhi. Better triaging systems and clear protocols for redirecting to proper care facilities allows for effective use of limited resources (Cameron et al., 2008; Government of India. Ministry of Health and Family Welfare, 2015; S. Sasser et al., 2005). Setting up this type of system in low and middle income countries like India could help in management of trauma care systems. For countries lacking formal pre-hospital care systems, simple steps like issuing advice lines and providing layperson education programmes could help in establishing better community wide triaging systems(World Health Organization & Publications, 2016).

4.3. Travel time estimate comparison between Trauma Centre and Nearest Hospital

For about 5% of the cases, this difference in travel time between trauma centre and nearest hospital was beyond 45 minutes, where accessing the nearest hospital could be a sensible choice. Observations show survival of 32% of survivable injuries if the primary destination is the trauma centre (European Commision, 2009). Nearest hospital versus trauma centre though in theory seems insightful, in practice it might be difficult to identify the nearest hospital and nearest trauma centre for a layperson transport to the hospital if digital aid or locations are not known to the people who end up transporting the victims to the hospitals. In a similar study of patient transportation by Chicago Fire Department (CFD) the travel time from the scene to the hospital (transport time) also was three minutes longer in the group with chose to bypass nearest hospital (7 ± 3 vs. 4 ± 2 minutes, $P < .005$), they infer that the urban use of hospital bypass would not reduce trauma patient survival in those who arrive at the trauma centre with serious injury (Sloan et al., 1989).

4.4. Dissimilarity Index

Absence of an appropriate triaging and first responder system in most low and middle income countries like India, lead to regional differences of patient distribution across health care facilities. Studies indicate that gaps within systems and inefficiencies of different stakeholders and care givers leads to death of about a third patients and only about a fifth are able to receive medical care within first 60 minutes after road crash (Bigdeli et al.,

2010; Clark, Winchell, & Betensky, 2013; Dinh et al., 2013; Newgard et al., 2010; Vanderschuren & McKune, 2015). To find the regional difference between trauma care districts, this study estimates an index with respect to first 60 minutes after road crash. In our estimates, index values are relatively higher for trauma centre as the destination. As far as nearest hospitals are concerned, index shows that almost all the districts are consistently comparable. The estimation does show some mild differences between these districts. Comparable districts being Central (0.28) and North (0.24), closely followed by East(0.35) and North West(0.38). Then there are other districts such as West, South West and North West which have higher values showing comparably higher travel time to reach trauma care. The distinction could be attributable to differences within districts. Delhi, being a million plus city with extensive burden of road traffic injuries, it is difficult to account the credibility of this index as compared to actual numbers(Joshipura, Shah, Patel, Divatia, & Desai, 2003; Nobhojit Roy et al., 2016).The current data recording system is incapable of recording this distribution of patients across different healthcare facilities(Fitzgerald et al., 2006; Kumar, Lalwani, Agrawal, Rautji, & Dogra, 2008).In light of absence of any data to check the accountability of this result, this index gives us a wise estimate and a starting point for system improvement.

5. Conclusion

On the surface, there appears to be adequacy of hospitals and trauma centres in Delhi based on travel time access. Spatial disparity of travel time access (Dissimilarity Index) to care is observed between individual districts, suggesting starting point for systemic improvements. Within the state, 90% of the crash locations could access trauma care within 45 minutes. Further investigation needs to be done for individual trauma centre's capacity to handle the overall daily inflow of patients, which might induce the need to strengthen other hospitals to manage trauma cases. 99.97% have a nearby hospital within 30 minutes of travel time. The study could not account for available pre-hospital facilities for transportation, which would further affect the overall travel time. Also, mere presence of hospitals might not signify their capabilities to be able to treat these patients. There is a need of auditing the available facilities for their operational characteristics and rating the trauma centres for their true capabilities to deal with poly trauma cases.

6. Limitations

- The study is only a descriptive of how the system appears to be in the current scenario. While the crash locations chosen are only indicative of the proportion of crashes happening within the Delhi city. The crash dataset used for this study doesn't cover injury crashes due to their inefficient recording. There is a possibility of influence of injury locations on these proportions, as it's not necessary to have all crashes on the similar locations.
- The basis of travel time estimation employed in this study is Google Maps API. Although Google has a defined framework which is followed to estimate the travel time, the accuracy of the estimated results depends on the tracking based on their real time users which might be a cause of inconsistency in the estimates and the actual travel time. Moreover, Google sets a query limit of 2500 calls on non-licenced users, which limits the scope of data extraction in one go. The might be slight differences in the travel time estimated in a particular duration owing to changing congestion patterns, which is difficult to control. Studies assessed the accuracy of three estimation methods (linear arc distance, Google Maps, and ArcGIS Network Analyst) against observed transport times in a large cohort of pre-hospital patient transports, they found that of these three methods Google maps API results were closest to the actual results for 86.6% of the cases while other methods were 79%(linear arc estimates) and 81.3%(ArcGIS estimates) accurate(Wallace et al., 2014). We have tried our best to control for consistency in the time of calling the API as required but this may not be indicative of everyday patterns so explicitly. It only shows a trend towards the travel time access to the health care facilities. (Shaw et al., 2017)
- The delay might be in the response time for the transportation service to arrive or for some help for transportation to be available on the crash location after a road traffic crash(Fitch, 2005).To be able to assess the true nature of total time to a hospital (including response time and travel time) need is to examined further, which is beyond the scope of current study.

- Availability of mode of transport at the instant of crash is discretionary. It varies with many factors like socio-demographic profile, region, time of the day and general travel patterns, bystander behaviour etc. Full time availability of a vehicle to transport at the crash site was assumed in the study.

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