



## Master Thesis

submitted within the UNIGIS MSc. programme  
at the Department of Geoinformatics - Z\_GIS  
University of Salzburg, Austria  
under the provisions of UNIGIS joint study programme with  
Kathmandu Forestry College (KAFCOL), Kathmandu, Nepal

# **Assessing the Appropriateness of Earthquake Emergency Health Care Services in Kathmandu and Lalitpur Municipalities, Nepal**

by

**Shailendra Bajracharya**

GIS\_103424

A thesis submitted in partial fulfillment of the requirements of  
the degree of  
Master of Science (Geographical Information Science & Systems) – MSc (GISc)

Advisor (s):

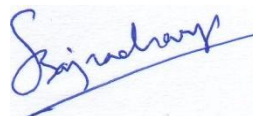
Dr. Shahnawaz

Kathmandu, November 2015

## Science Pledge

By my signature below, I certify that my thesis is entirely the result of my own work. I have cited all sources of information and data I have used in my thesis and indicated their origin.

Kathmandu: 23<sup>rd</sup> Nov, 2015

A handwritten signature in blue ink, appearing to read 'S. J. Choudhary', is written over a horizontal line.

---

Place and Date

Signature

## **Acknowledgements**

I would like to thank all the people who are involved in this study directly or indirectly. First and foremost, I would like to thank our advisor Dr. Shahnawaz for providing me the much-needed guidance to carry out this work. I am really thankful to our principal Dr. Ambika P. Gautam and coordinator Mr. Ram Asheshwor Mandal for their valuable suggestions and instructions.

I am grateful to my wife for supporting me throughout this program, my brother for providing necessary advice and my friends Shailen, Laxman and Achuyt for assisting me in data collection.

I would also like to thank ICIMOD, as well as all the individuals, doctors, matrons, hospital administrators for providing the necessary data and information related to the project.

## **Abstract**

During earthquake disaster scenario, the society falls back on the hospitals for immediate assistance in the form of emergency medical care. Considering the past history of large earthquakes in Nepal, the need to assess the existing hospital based emergency service is largely felt. The disaster situation can be accurately mapped and analyzed using GIS. The study was performed with the perspective of implementing GIS to model the drive time based catchment areas of hospitals that is most likely to provide emergency service, and thereby recognize its accessibility to the percentage of population within Kathmandu and Lalitpur municipalities of Nepal.

The study mainly focused on the hospitals' human resource, equipment and facilities, level and capacity of treatment along with emergency preparedness. The actual emergency service scenario in hospitals on 25th April, 2015 earthquake was also assessed. The study employed ArcGIS network analyst to create network data model for normal, congested and pedestrian traffic scenarios based upon travel speed. The population assigned to service area of various drive time and hospitals were calculated by performing overlay analysis with population density data.

The study revealed that there are overwhelming numbers of 62 hospitals within the study area to cater for the population of 1229941. But for tertiary level of care, these numbers drop down to 4 and up to 15 with some limitations. The overall spatial accessibility of hospitals can be considered good. Even during congested traffic scenario, the nearest hospitals can be reached within drive time of less than one hour for tertiary level of care and 30 minutes for primary treatment. Only about 10% of the population situated at the periphery of the cities will have some difficulty. Even though hospitals are physically accessible, the other three factors a) medical staffs, b) emergency preparedness and

c) the impact of earthquake are largely limiting the accessibility to the first aid measures or trauma life support. Only 25% of the hospitals have full time surgeons and anesthesiologists despite having necessary equipment and supplies. The Hospital Treatment Capacity (HTC) for tertiary level of treatment is found to be less than 0.1% of total population. The average HTC per hour of major hospitals can cater for only 3% of the average number of emergency patients reported on the day of 25<sup>th</sup> April 2015 earthquake. The inadequacy of tertiary level service and capacity of treatment are thus a matter of serious concern that needs to be addressed immediately. Further, the impact of earthquake was observed on 40% of hospital buildings affecting their functioning and stability. In such scenario, the management of inpatients and setting up alternate care site demanded more attention compared to the intake of emergency patients.

These results suggest that the need of better emergency preparedness therefore demands not much; but the availability of full time surgeons and related medical staffs at the hospitals, well-constructed hospital buildings, and an emergency plan to swiftly evacuate inpatients and setting up alternate care site.

# Table of Contents

<b>Science Pledge</b> .....	<b>i</b>
<b>Acknowledgements</b> .....	<b>ii</b>
<b>Abstract</b> .....	<b>iii</b>
<b>Table of Contents</b> .....	<b>v</b>
<b>List of Tables</b> .....	<b>vii</b>
<b>List of Figures</b> .....	<b>viii</b>
<b>List of Maps</b> .....	<b>ix</b>
<b>List of Abbreviations</b> .....	<b>x</b>

<b>Chapter- 1. Introduction</b> .....	<b>1</b>
1.1. Background .....	1
1.2. Objectives of Study .....	5
1.3. Study Area .....	6
1.4. Literature Review .....	7
1.4.1. Accessibility of Hospitals .....	7
1.4.2. Hospital Treatment Capacity and Emergency Preparedness .....	9
1.4.3. Network Analysis .....	15
1.5. Assumptions .....	17

<b>Chapter- 2. Methodology</b> .....	<b>18</b>
2.1. Assessment of Emergency Service Capacity of Hospitals and Their Emergency Preparedness .....	19
2.1.1. Criteria for Identification of Level of Emergency Service .....	19
2.1.2. Method and Parameters for Calculating Hospital Treatment Capacity .....	21
2.1.3. Criteria to Assess Emergency Preparedness of Hospitals .....	23
2.1.4. Method to Assess Emergency Service Situation of Hospitals on the Day of Earthquake 25 <sup>th</sup> April 2015 .....	24
2.1.5. Field Data Collection .....	24
2.2. Software Used .....	25
2.3. GIS Data Collection and Preparation .....	25
2.3.1. Hospital Location Data .....	27
2.3.2. Road Data .....	27

2.3.3. Network Dataset.....	28
2.4. Network Analysis Process .....	35
2.5. Demographic Data.....	38
2.6. Preparation of Ward wise Population Density Map .....	39
2.7. Overlay Analysis Process .....	43
<b>Chapter- 3. Results .....</b>	<b>45</b>
3.1. Categorization of Hospitals based upon Level of Emergency Service.....	45
3.2. Categorization of Hospitals within each Level based upon Hospital Treatment Capacity (HTC).....	47
3.2.1. HTC per hour of Level 1 Hospitals.....	47
3.2.2. HTC per hour of Level 2 Hospitals.....	47
3.3. Assessment of Emergency Preparedness of Hospitals.....	48
3.4. Identification of Type of Access Roads to the Hospitals.....	49
3.5. Results of Network and Overlay Analysis .....	50
3.5.1. Case1: Normal Traffic Scenario .....	50
3.5.2. Case2: Congested Traffic Scenario.....	56
3.5.3. Case 3: Service Area based upon Pedestrian Time .....	58
3.6. Assessment of Emergency Scenario of Hospitals on 25 <sup>th</sup> April, 2015 Earthquake .....	68
3.6.1. Building Condition .....	68
3.6.2. Service Status.....	68
3.6.3. Number of Emergency Patient Reported.....	69
<b>Chapter- 4. Discussion.....</b>	<b>71</b>
<b>Chapter- 5. Conclusion .....</b>	<b>73</b>
<b>Chapter- 6. Limitations of the Study .....</b>	<b>76</b>
<b>Chapter- 7. Recommendations.....</b>	<b>78</b>
<b>References .....</b>	<b>82</b>
<b>Annex .....</b>	<b>86</b>
A. Survey Form used for Hospital Survey .....	87
B. List of Hospitals Surveyed and the Level of Emergency Service Provided .....	88
C. List of Hospitals Not Included in Survey .....	89

# List of Tables

Table 1.4.a: Method for Calculation of HTC for Trauma Injuries ..... 13

Table 2.1.a: Essential Full Time Medical Staffs for Level 1 Hospital ..... 20

Table 2.1.b: Essential Ancillary Services for Level 1 Hospital ..... 20

Table 2.1.c: Modified Method for Calculation of HTC..... 22

Table 2.1.d: Criteria for Assessment of Emergency Preparedness of Hospitals ..... 23

Table 2.1.e: Categorization of Hospitals' Emergency Preparedness Level ..... 23

Table 2.3.a: GIS Data Layers Used ..... 26

Table 2.3.b : Classification of Roads ..... 31

Table 2.3.c: Defined Speed of Roads for Normal Traffic Scenario ..... 33

Table 2.4.a: ArcGIS Settings for Network Analysis ..... 36

Table 2.6.a : Ward wise Population Density of KMC in Ascending Order ..... 40

Table 2.6.b: Ward wise Population Density of LSMC in Ascending Order ..... 41

Table 3.1.a: Categorization of Hospitals based on Level of Emergency Services ..... 45

Table 3.2.a: HTC per Hour of Level 1 Hospitals ..... 47

Table 3.2.b: HTC per hour of Level 2 Hospitals ..... 47

Table 3.2.c: Categorization of Level 2 Hospitals based on HTC per hour ..... 48

Table 3.3.a: Emergency Preparedness Level of Hospitals..... 48

Table 3.4.a: Hospital Count based upon the Type of Access Road ..... 49

Table 3.5.a: Normal Drive Time based Service Area of Multiple Level 1 Hospitals ..... 50

Table 3.5.b: Normal Drive Time based Service Area of Each Level 1 Hospital ..... 50

Table 3.5.c: Ratio of HTC of Each Level 1 Hospital to the Population within its Service Area for Normal Drive Time ..... 51

Table 3.5.d: Normal Drive Time based Service Area of Multiple Level 1 & 2 Hospitals .... 52

Table 3.5.e: Normal Drive Time based Service Area of Each Level 1 & 2 Hospital..... 53

Table 3.5.f: Ratio of HTC of Each Level 1 & 2 Hospital to the Population within its Service Area for Normal Drive Time .....	54
Table 3.5.g: Normal Drive Time based Service Area of All Hospitals for Primary Treatment .....	55
Table 3.5.h: Congested Drive Time based Service Area of Multiple Level 1 Hospitals ....	56
Table 3.5.i: Congested Drive Time based Service Area of Multiple Level 1 & 2 Hospitals	57
Table 3.5.j: Congested Drive Time based Service Area of All Hospitals for Primary Treatment.....	57
Table 3.5.k: Pedestrian Time based Service Area of All Hospitals for Primary Treatment	58
Table 3.6.a: Building Condition of Hospitals after 25 <sup>th</sup> April 2015 Earthquake.....	68
Table 3.6.b: Emergency Patients in Hospitals on 25 <sup>th</sup> April 2015 Earthquake .....	69

## List of Figures

Figure 1: Methodology of the Study .....	18
Figure 2: Verification and Updating of Road with Reference to Google Earth Image .....	27
Figure 3: Network Analysis Process in ArcGIS 10.2 .....	37
Figure 4: Overlay Analysis Process .....	44

# List of Maps

- Map 1: District wise Earthquake Fatalities for April 25, 2015 Earthquake in Nepal ..... 1
- Map 2: Earthquake History Map of Nepal ..... 2
- Map 3: Location Map ..... 6
- Map 4: Road Network of KMC and LSMC ..... 32
- Map 5: Population Density Map of KMC and LSMC ..... 42
- Map 6: Hospitals in KMC and LSMC incorporated in the Study ..... 46
- Map 7: Drive Time Based (Normal Traffic) Service Area of Multiple Level 1 Hospitals in KMC and LSMC ..... 59
- Map 8: Drive Time Based Service Area of Each Level 1 Hospital, Its Population & Treatment Capacity ..... 60
- Map 9: Drive Time Based (Normal Traffic) Service Area of Multiple Level 1 & 2 Hospitals in KMC and LSMC..... 61
- Map 10: Drive Time Based Service Area of Each Level 1 & 2 Hospital, Its Population & Treatment Capacity ..... 62
- Map 11: Drive Time Based (Normal Traffic) Service Area of All Hospitals in KMC and LSMC ..... 63
- Map 12: Drive Time Based (Congested Traffic) Service Area of Multiple Level 1 Hospitals in KMC and LSMC..... 64
- Map 13: Drive Time Based (Congested Traffic) Service Area of Multiple Level 1 & 2 Hospitals in KMC and LSMC ..... 65
- Map 14: Drive Time Based (Congested Traffic) Service Area of All Hospitals in KMC and LSMC ..... 66
- Map 15: Pedestrian Time Based Service Area of All Hospitals in KMC and LSMC ..... 67
- Map 16: Number of Emergency Patients on the Day of Earthquake (April 25, 2015) ..... 70
- Map 17: Recommended Location for Additional Level 1 Hospital ..... 79

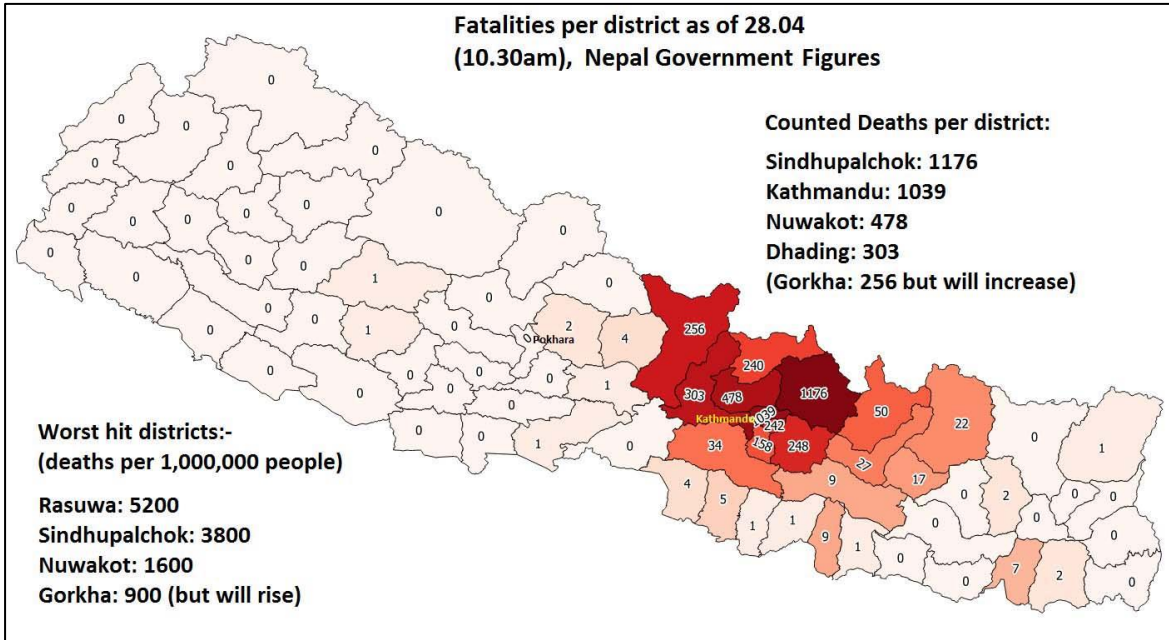
## List of Abbreviations

ACS	American College of Surgeons
CBS	Central Bureau of Statistics
DOS	Department of Survey
EMS	Emergency Medical Service
EMT	Emergency Medical Technicians
ES	Emergency Service
ESRI	Environmental System Research Institute
GCS	Geographic Coordinate System
GIS	Geographic Information System
GPS	Global Positioning System
ha	Hectare
HTC	Hospital Treatment Capacity
HSC	Hospital Surgical Capacity
KMC	Kathmandu Metropolitan City
KMPH	Kilometer per hour
LSMC	Lalitpur Sub-Metropolitan City
MBBS	Bachelor of Medicine, Bachelor of Surgery
MO	Medical Officer
MRC	Medical Rescue Capacity
MTC	Medical Transport Capacity
NA	Not Applicable \ Not Available
NAS	Nepal Ambulance Service
PCS	Projected Coordinate System
TIN	Triangulated Irregular Network
UNDP	United Nations Development Programme
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WGS	World Geodetic System
WHO	World Health Organization

# Chapter- 1. Introduction

## 1.1. Background

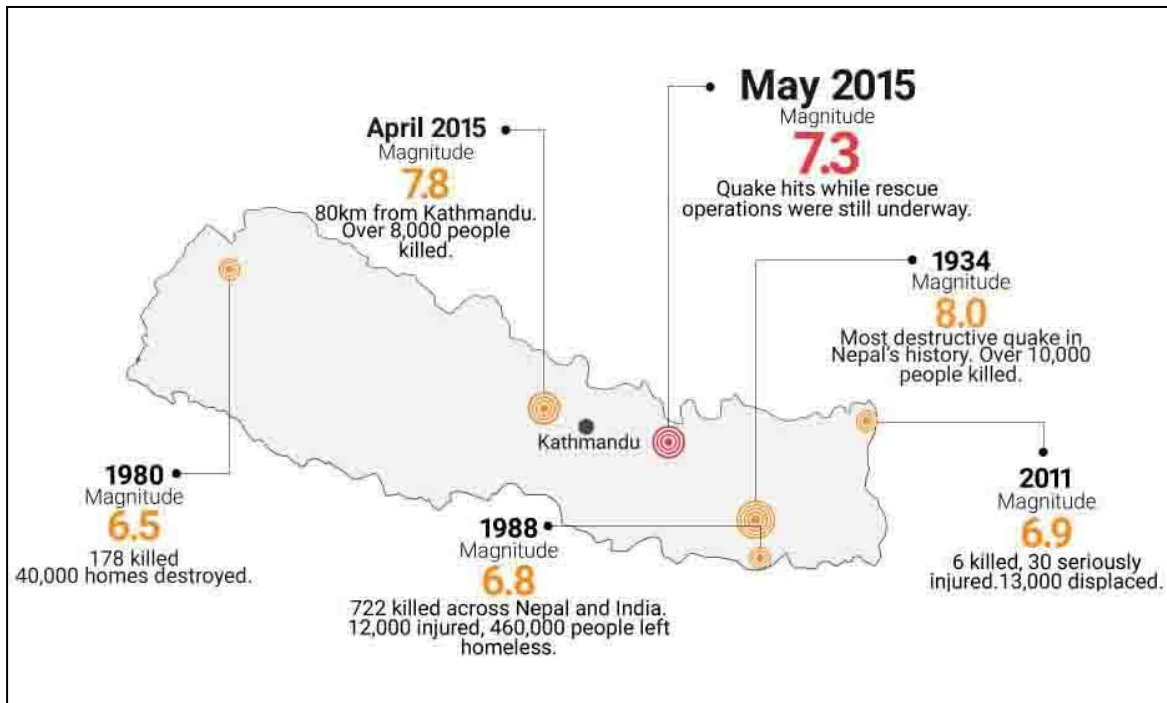
A massive earthquake of magnitude of 7.9 in Richter scale (as reported by USGS) struck Nepal on 25<sup>th</sup> April 2015, followed by hundreds of aftershocks. It not only damaged infrastructure worth millions, unfortunately it took away lives of thousands of people as well as leaving double the numbers of people injured. The press release of 11<sup>th</sup> May, 2015 of Ministry of Home Affairs, Nepal puts the number of death tolls at 8020, injured at 16033 and missing at 375.



**Map 1: District wise Earthquake Fatalities for April 25, 2015 Earthquake in Nepal**  
 (Map Source: www.earthquake-report.com, 2015)

The cause of the earthquake can be attributed to the continental collision of the Indian and the Eurasian plates, which are converging at a relative rate of 40-500 mm/yr. Northward under thrusting of Indian plate beneath Eurasian plate causes frequent earthquakes in this region making it highly prone to seismic vulnerability (USGS, 2015). This earthquake was

one of the most powerful earthquakes to strike Nepal since the 1934 Nepal-Bihar earthquake of magnitude 8.1 (Ayadan and Ulusay, 2015). The first earthquake to be recorded in history of Nepal was in June 7, 1255; it was then followed by multiple earthquakes in years 1260, 1408, 1681, 1767, 1810, 1823, 1833, 1834, 1934, 1974, 1980, 1988, 1993, 1994, 1995, 1997, 2001, 2002, 2003 1803, 1810, 1833, 1842, 1866 1947, 1950, 1980, 1988 and 2011.



**Map 2: Earthquake History Map of Nepal;** the map shows the location of biggest earthquakes in Nepal since 1934. (Map Source: [www. Aljazeera.com](http://www.aljazeera.com), 2015)

These past records have shown that Nepal can expect two earthquakes of magnitude 7.5 to 8 on the Richter scale every forty years and one earthquake of magnitude of 8+ in Richter scale every eighty years (Poudel, 2011). Therefore, with due consideration to the fact that the probability of earthquake in Nepal cannot be overlooked, and the amount of threat it poses, we in Nepal, should take earthquake preparedness in coming days more seriously.

On the other hand, whenever such earthquake strikes, the society falls back on the hospitals for immediate assistance in the form of emergency medical care (Government of India - UNDP DRM Programme, 2008). Normally, it is the primary responsibility of hospitals of saving lives by providing 24x7 Emergency Service (ES); and during such disaster, it becomes even more important to deliver such service without fail. But it cannot be overlooked that hospital itself might become a victim of earthquake. Therefore, the hospitals can be accessible to the people, only if they can withstand the shocks of earthquake and remain open for service. Hospitals with well designed structure are more likely to withstand earthquake shocks. Next, not all the hospitals will have trained staffs and necessary resources to deal with the scale of injury that might occur (Government of India - UNDP DRM Programme, 2008). Therefore, it becomes equally important to identify the hospitals that can provide emergency services in such scenario as well as the number of casualties it can handle. Further, in emergency medicine, the "Golden hour" term suggests that patient's chances of survival are greatest if they receive care within one hour from traumatic injury (In Wikipedia, 2015). Thus, the accessibility of hospitals within one hour or lesser time span plays vital role in saving peoples' live.

The disparity in the accessibility of hospitals generally arises due to manner in which people and the facilities are arranged spatially. Usually the hospitals are located at a finite number of fixed locations, but they serve populations that are continuously and unevenly distributed throughout the region. Consequently, the factors that cause the inequalities in the accessibility of hospitals are mainly the spatial arrangement of hospitals, the location and distribution of the population within a region, and the characteristics of the transportation infrastructure (Delamater et al., 2012). During the emergency scenario, the population in a location that requires longer travel duration to reach the hospitals will experience greater difficulty as well as risk of not getting treatment on time. Therefore, for the better emergency preparedness, the capacity of the hospitals and the population

count dependent upon it, based upon the travel time will give us a better estimate of geographic access to hospital based emergency services.

Several researchers have developed and used Geographic Information System (GIS) and its associated tools and techniques to model the physical/geographical accessibility of human beings to different facilities (Nadeem, 2012). The term GIS can be broadly defined as a powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world (Burrough and McDonnell, 1998). It is a technology to support science and problem solving, using both specific and general knowledge about geographic reality (Longley et al., 2011). In GIS, two spatial models are generally used to represent the real world; either vector based i.e. point, line and polygons, or raster based, i.e. cells of a continuous grid (Hudsal, 2011). A GIS based network analysis, which uses vector based road network data, can be employed to model service areas that represent accessibility to hospitals (Schuurman et al., 2006). Walsh et al. (1996) describe network analysis as

"...an approach of routing and allocating resource flows through a system connected by a set of linear features (e.g., roads and trails), where distance optimization decisions within the network are made dependent on (a) the nature of the travel conduits; (b) links between conduits; (c) location and characteristics of barriers to movement; (d) directionality of resource flows, position, and conditions of centers having specific resource capacities; and (e) node locations, where resources are deposited or collected along paths throughout the network."

This study aims to identify the accessibility of hospitals providing emergency services during earthquake in Kathmandu Metropolitan City (KMC) and Lalitpur Sub-Metropolitan City (LSMC) by employing GIS. Accessibility is determined by first identifying the hospitals that have adequate resources, capacity and preparedness to provide the emergency

service, and then calculating the proportion of population that is within a reasonable travel time from these hospitals. Also the population which is more likely to undergo greater difficulty in accessing the hospitals due to longer travel time will be identified. The impact of recent earthquake on 25<sup>th</sup> April 2015 on the delivery of hospital based emergency services will also be incorporated.

## **1.2. Objectives of Study**

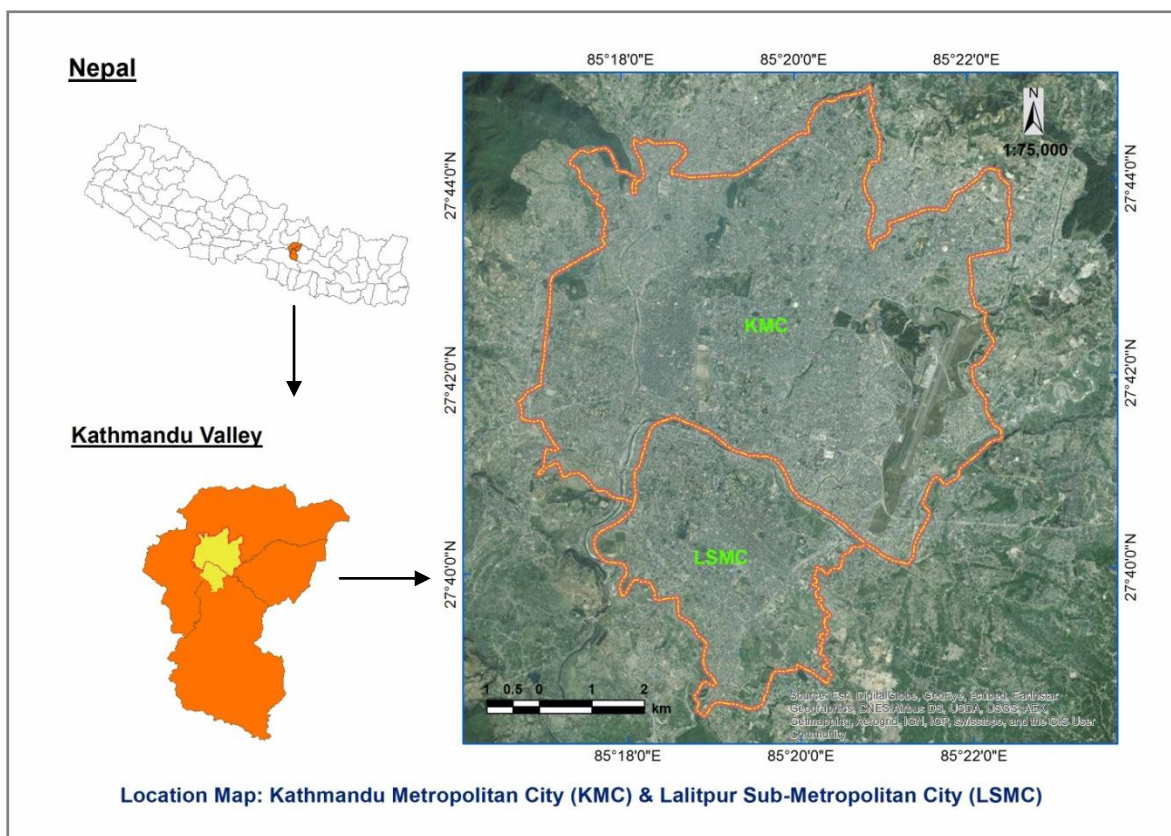
The main objectives of the study are

- i. To identify the spatial distribution of hospitals, with emergency services for trauma related to earthquake, within KMC and LSMC.
- ii. To identify the level of emergency service provided by each hospital and its capacity
- iii. To find out travel time required to access the desired level of emergency service within the study area based on
  - Drive time at various speed to resemble normal, and congested traffic scenario during earthquake
  - Pedestrian time, simulating impossibility of using vehicles due to road blockage
- iv. To create travel-time based service area of each hospital, thereby identify
  - The population that is most likely to utilize its service
  - The section of population that is most likely to experience difficulty in accessing the emergency service
- v. To identify the ratio of hospitals (available emergency service capacity) to population as well as compare the results with the emergency service scenario on 25<sup>th</sup> April earthquake

- vi. To understand the overall accessibility of hospital based emergency services in earthquake scenario

### 1.3. Study Area

The study area was identified as Kathmandu Metropolitan City (KMC) along with adjoining Lalitpur Sub-Metropolitan City (LSMC). It is located at 27° 38' 32" to 27° 45' 00" North and 85° 16' 37" to 85° 22' 20" East. Out of 191 municipalities in Nepal, Kathmandu is the only metropolitan city, and Lalitpur is one of the 11 sub-metropolitan cities. In May 2014, the Ministry of Federal Affairs and Local Development declared the extension in the area of LSMC. However, since it is in the process of implementation, the established area of LSMC prior to 2014 was considered for the study.



Map 3: Location Map (Data Source: DOS, KMC & LSMC 1998)

KMC has 35 wards and area of 5067 ha, whereas LSMC has 22 wards covering 1514 ha. As of 2011 census report, the total population of KMC is 975453 and has 254292 households. LSMC has a population of 220802 and 54581 households.

Both KMC and LSMC have high cultural and economic significance. Further, these are interconnected cities not only in terms of boundaries but also in the form of sharing of resources. The schools, hospital, offices and other resources existing in the area are uniformly shared by the residents of both sides. On the contrary, these cities also have high population density, and poor adherence to engineering standards and regulations for construction of buildings, thereby making it more vulnerable to earthquake casualties. Considering all these factors, these cities were found suitable for this study.

## **1.4. Literature Review**

The most relevant materials found were as follows

### **1.4.1. Accessibility of Hospitals**

**Joseph, A.E., & Philips, D.R., 1984**, Authors have studied the health care delivery from geographical perspectives. According to the study, Locational accessibility represents physical proximity and may be crudely expressed in mileage terms. Effective accessibility concerns whether a facility is always available or open, whether it is socially or financially available to people, and whether a person's time-space budget permits him to use the service (Ambrose, 1977; Moseley, 1979; Phillips and Williams, 1984).

**Schuurman, N. et al. 2006**, Authors have defined the rational hospital catchments for non-urban areas based on travel-time. Healthcare accessibility is multifaceted, but

geographic and social barriers can thwart access to health services. Geographic and social barriers to healthcare access, moreover, manifest themselves differently depending on local context and how health services are delivered. As described by the authors, the assessment of acute care service delivery is expected to consider the following four factors: population/ demographics; professional competence; critical mass; distance/geography. Professional competence and critical mass refer to ability to maintain the quality of healthcare services. Population/demographics and distance/ geography pertain to factors affecting access and utilization of healthcare services.

Further, the authors proposed that vector-based GIS network analysis as useful tool for defining true geographical catchments around rural hospitals as well as modeling the percentage of the population served or not served within certain time guidelines for specific health services.

**Delamater, P. L. et al. 2012**, Authors made a comparative study of raster and network based methods for measuring geographic access to health care. According to the study, inequalities in geographic access to health care result from the configuration of facilities, population distribution and the transportation infrastructure. In recent accessibility studies, the traditional distance measure (Euclidean) has been replaced with more plausible measures such as travel distance or time. Both network and raster-based methods are often utilized for estimating travel time in a Geographic Information System. Therefore, exploring the differences in the underlying data models and associated methods and their impact on geographic accessibility estimates is warranted.

**Cinnamon, J. et al. 2008**, Authors proposed a method to determine spatial access to specialized palliative care service using GIS. According to them, though various methods of measuring travel-time have been used in modeling spatial accessibility to health care

services, Haynes et al. validated the use of travel-time to measure spatial accessibility by comparing a GIS-based travel-time model with actual driving time to service locations. In which results were highly correlated for modeled and actual travel-time to health care service locations. The authors suggest the use of spatial query method to determine the population within each catchment using census block level population data.

#### **1.4.2. Hospital Treatment Capacity and Emergency Preparedness**

**WHO News Release, 2015** highlights that the emergency preparedness in Kathmandu hospitals pays off well as they respond to earthquakes. According to the news, in more than 15 years, World Health Organization (WHO) has supported Nepal's Ministry of Health and Population to prepare health facilities in the Himalayan country that sits on a fault zone. In 2009, WHO focused global attention to the need for safe health facilities in emergencies through its World Health Day campaign. The campaign underscored the need to build strong health systems able to provide medical care in times of disaster and emergency. Apart from retrofitted hospitals, capacity building and staff training is equally important to ensure an adequate health-care response in times of disaster.

**Government of India - UNDP DRM Programme, 2008**, has come up with guidelines for Hospital Emergency Preparedness Planning. The certain guidelines relevant to this study can be listed as follows

- a) A hospital emergency plan is unique to each hospital as it depends upon its bed strength, staff and other resources. Assessment of the capacity of a hospital to respond to a given emergency situation can be assessed by the following two ways.

- **Hospital Treatment Capacity (HTC)**, is defined as the number of casualties that can be treated in the hospital in an hour and is usually calculated as 3% of total number of beds
- **Hospital Surgical Capacity (HSC)** is the number of seriously injured patients that can be operated upon within a 12-hour period  
i.e.,  $HSC = \text{Number of operation rooms} \times 7 \times 0.25 \text{ operations/12 hrs.}$

b) The pre-disaster planning should comprise of formation of

i. Hospital disaster management committee:

The committee should include members from administrative, medical, finance, stores and supplies, engineering, public relation, security, sanitation and kitchen service departments.

The members of medical staffs should be the chiefs/heads of various clinical departments supporting the emergency services; e.g., casualty and emergency services, orthopedics, general surgery, medicine, neurosurgery (if present), cardiothoracic surgery (if present), anesthesia, chief of ancillary departments e.g., radio-diagnosis, transfusion medicine/ blood bank, laboratory services/pathology

- ii. Central command structure (Incident command system)
- iii. Plan activation of different areas of hospital
- iv. Disaster beds/ how to increase bed capacity in emergencies?
- v. Planning of public information and liaison
- vi. Logistics planning ( Communication, Transportation, Stores, Personnel, Financial)
- vii. Operations Planning
  - a. Essential Medical/Non-Medical Staff Activation (In different Areas)
  - b. Essential Nursing Staff Activation

c. Essential Ancillary Services : These can be listed as

- Laboratory Services
- Radiology Services: x-ray exams/ CT scans/ Ultrasounds etc.
- Blood Bank:
- Mortuary Services
- Pharmacy
- Water / Light and power

viii. Phase of Staff Education and Training(Disaster Drills)

**In Wikipedia, Trauma center, 2015**, describes the types of capabilities and categories of trauma centers in United States. A hospital can receive trauma center verification by meeting specific criteria established by the American College of Surgeons (ACS). Trauma centers vary in their specific capabilities and are identified by "Level" designation: Level-I (Level-1) being the highest, to Level-III (Level-3) being the lowest. Higher levels of trauma centers will have trauma surgeons available, including those trained in such specialties as neurosurgery and orthopedic surgery, a nurse specialist in trauma care, as well as highly sophisticated medical diagnostic equipment. Lower levels of trauma centers may only be able to provide initial care and stabilization of a traumatic injury and arrange for transfer of the victim to a higher level of trauma care.

**DeBoer, J., 1995**, in his book "**Order in Chaos: Modeling medical disaster management** ", deals in detail with disaster medicine and medical disaster preparedness. Author describes a disaster as a destructive event which claims so many victims that a discrepancy arises between their number and the treatment capacity. A similar event with victims which do not cause this discrepancy should be called an accident.

In a mass casualty situation, the victims showing disturbances of vital functions are classified as T1, whereas the moderately injured victims who could develop disturbances of vital functions or develop infections are classified as T2. The least mortality, morbidity and disability as low as 5%-10% can be obtained by providing the T1 victims basic and advanced (trauma) life support within 1 hour ( the "Golden hour", a well known concept in traumatology) and , and first-aid measures to T2 victims within 4-6 hours(Friedrich's time).

According to DeBoer, organizationally, the chain of medical care in disaster situation can be divided into three links

- a. Medical organization at the scene of disaster; determined as Medical Rescue Capacity (MRC)
- b. Transport and distribution of casualties to the various hospitals; determined as Medical Transport Capacity (MTC)
- c. Organizational procedures in hospitals; determined as Hospital Treatment Capacity (HTC).

Hospital treatment capacity (HTC), the last phase in the chain of medical care, refers to the number of victims that can be treated in a hospital within a given period of time, e.g. one hour. If the casualties have mechanical and burn injuries, HTC is determined by

- the number of essential medical specialists e.g. surgeons, anesthesiologist and nurses and their training in disaster procedures
- Utilities and supplies

These variables as a rule related to the number of beds in the hospital. Research of both theoretical and empirical approach has shown HTC to be about 2-3% i.e., 2-3 casualties per 100 beds per hour. Thus a medium sized district hospital containing a minimum of 300

beds could treat about 6-9 casualties an hour. Taking account of fatigue of staffs and the diminishing supplies, its total capacity for 8-10 hours would be about 50-70 victims.

The basic parameters suggested by DeBoer for calculation of HTC are

- i. Total number of beds
- ii. Number of surgical beds
- iii. Number of intensive care beds
- iv. Number of operating theaters
- v. Number of operations per year
- vi. Number of surgeons
- vii. Number of anesthesiologists
- viii. Number of surgical residents
- ix. Number of other surgical specialists

The method suggested for calculation of HTC is as follows

**Table 1.4.a: Method for Calculation of HTC for Trauma Injuries**

Description	Number (N)	Weight (W)	N x W
Total number of beds		1/3000	
Number of surgical beds		1/250	
Number of intensive care beds		1/20	
Number of operating theatres		1/10	
Number of operations per year		1/20000	
Number of surgeons		1/5	
Number of anesthesiologists		1/4	
Number of surgical residents		1/10	
Number of other surgical specialists		1/10	
Number of Accident & Emergency patients per year		1/1000	
<b>HTC per Hour (Total)</b>			

(Source: DeBoer, J., 1995)

DeBoer also suggested that each hospital should have a disaster committee to draft a disaster procedure, to organize exercises, to function as troubleshooter when real, to coordinate with external parties concerned and to inventory risks.

**WHO: Tool for Situational Analysis to Assess Emergency and Essential Surgical Care, 2008**, According to this tool, human resources and other ancillary services required for surgical care can be listed as follows

- a) Human resources
  - i. Surgeons (qualified)
  - ii. Anesthesiologist Physician (qualified)
  - iii. Obstetrician/gynecologist(qualified)
  - iv. General doctors providing surgery
  - v. General doctors providing anesthesia
  - vi. Nurse/ Clinical/ Assistant medical officers
  
- b) The other ancillary services required are
  - i. Oxygen supply
  - ii. Running water
  - iii. Electricity source\ operational power generator
  - iv. Blood bank available at the facility
  - v. Facility to test hemoglobin & urine
  - vi. X-ray machine

**Gongal, R., & Vaidya, P., 2012**, Authors highlighted the existing condition of ambulance service in Nepal in their article "Responding to the need of the Society: Nepal Ambulance Service". According to the authors, the situation of Emergency Medical Service (EMS) is

virtually non-existent in Nepal. Authors cite a study done in Patan Hospital in 2007, which showed that only 10% of patients arriving to Emergencies came by ambulances, more than 50% came by taxis which included triage category I patients (who have life threatening conditions and need immediate help). Further the authors reveal that only 17% of ambulances have oxygen and none had personnel who have had even basic first aid training. So the ambulance is a little more than a taxi with siren.

It was also mentioned in their article that for the first time in Nepal, Nepal Ambulance Service (NAS), a non-profit non-governmental organization took initiative to setup a system of professional ambulance service with trained Emergency Medical Technicians (EMTs). It has currently five ambulances.

#### **1.4.3. Network Analysis**

**ArcGIS Help 10.2: Service Area Analysis, 2015**, explains the term "Service Area" as employed in Network Analysis. A network service area can be defined as a region around a facility that encompasses all accessible streets (that is, streets that are within a specified impedance). For instance, the 5-minute service area for a point on a network includes all the streets that can be reached within five minutes from that point. The service area is thus a polygon representing the distance that can be reached from a facility or to the facility in all directions within a given amount of time or any other specified impedance value.

Service areas created by Network Analyst also help evaluate accessibility. Concentric service areas show how accessibility varies with impedance. Once service areas are created, it can be used to identify how much land, how many people, or how much of anything else is within the neighborhood or region.

**ArcGIS Help 10.2: Algorithms used by the ArcGIS Network Analyst extension, 2015,** explains the algorithm behind the ArcGIS Network analyst employed for calculation of Service Area. Its brief description is as follows.

The routing solvers within the ArcGIS Network Analyst extension are based on well-known Dijkstra's algorithm for finding shortest paths. The classic Dijkstra's algorithm solves the single-source, shortest-path problem on a weighted graph. To find a shortest path from a starting location **s** to a destination location **d**, Dijkstra's algorithm maintains a set of junctions, **S**, whose final shortest path from **s** has already been computed. The algorithm repeatedly finds a junction in the set of junctions that has the minimum shortest-path estimate, adds it to the set of junctions **S**, and updates the shortest-path estimates of all neighbors of this junction that are not in **S**. The algorithm continues until the destination junction is added to **S**.

The Service Area solver is also based on Dijkstra's algorithm to traverse the network. Its goal is to return a subset of connected edge features such that they are within the specified network distance or cost cutoff; in addition, it can return the lines categorized by a set of break values that an edge may fall within. The service area solver can generate lines, polygons surrounding these lines, or both.

The polygons are generated by putting the geometry of the lines traversed by the Service Area solver into a triangulated irregular network (TIN) data structure. The travel time estimates along the lines serves as the height of the locations inside the TIN. Locations not traversed by the service area are put in with a much larger height value. A polygon generation routine is used with this TIN to carve out regions encompassing areas in between the specified break values. The polygon generation algorithm has additional logic

to produce the generalized or detailed polygons and to deal with the many special cases that can be encountered.

## **1.5. Assumptions**

The following assumptions were made to carry out the study

- Though the vulnerability towards earthquake is known, predicting its time and impact is beyond human competence. This study assumes that the impact of earthquake will be uniform throughout the study area, and the hospitals will be accessible through roads either by vehicle or on foot irrespective of hospital's structural status. However, the possibility of blockade of roads at some sections of the study area cannot be overlooked, but still the hospitals will still be accessible either on foot or through an alternate route.
- It is noted from the literature review that the availability of ambulances within the study area is limited and they lack EMTs, so they are equivalent to taxis with siren. Therefore, it is assumed that the earthquake victim will be transported to the hospital via available public or private vehicle from the site of casualty.
- The hospital information collected through survey is accurate, as these are collected through representative officer, administrator, matrons and doctors of the hospital.
- Since both Kathmandu and Lalitpur are densely populated cities with very limited open space, narrow roads and rivers; it is assumed that the ward wise population, reported by CBS 2011, is uniformly distributed over its area.

With reference to the objectives of the study, the available processes and possibilities based on the literature review, and assumptions made; a suitable methodology to carry out the study was coined.

# Chapter- 2. Methodology

On the basis of literature review, prospect of data availability and attainability, the given study time frame and resources on hand, the most plausible methodology was formulated as follows

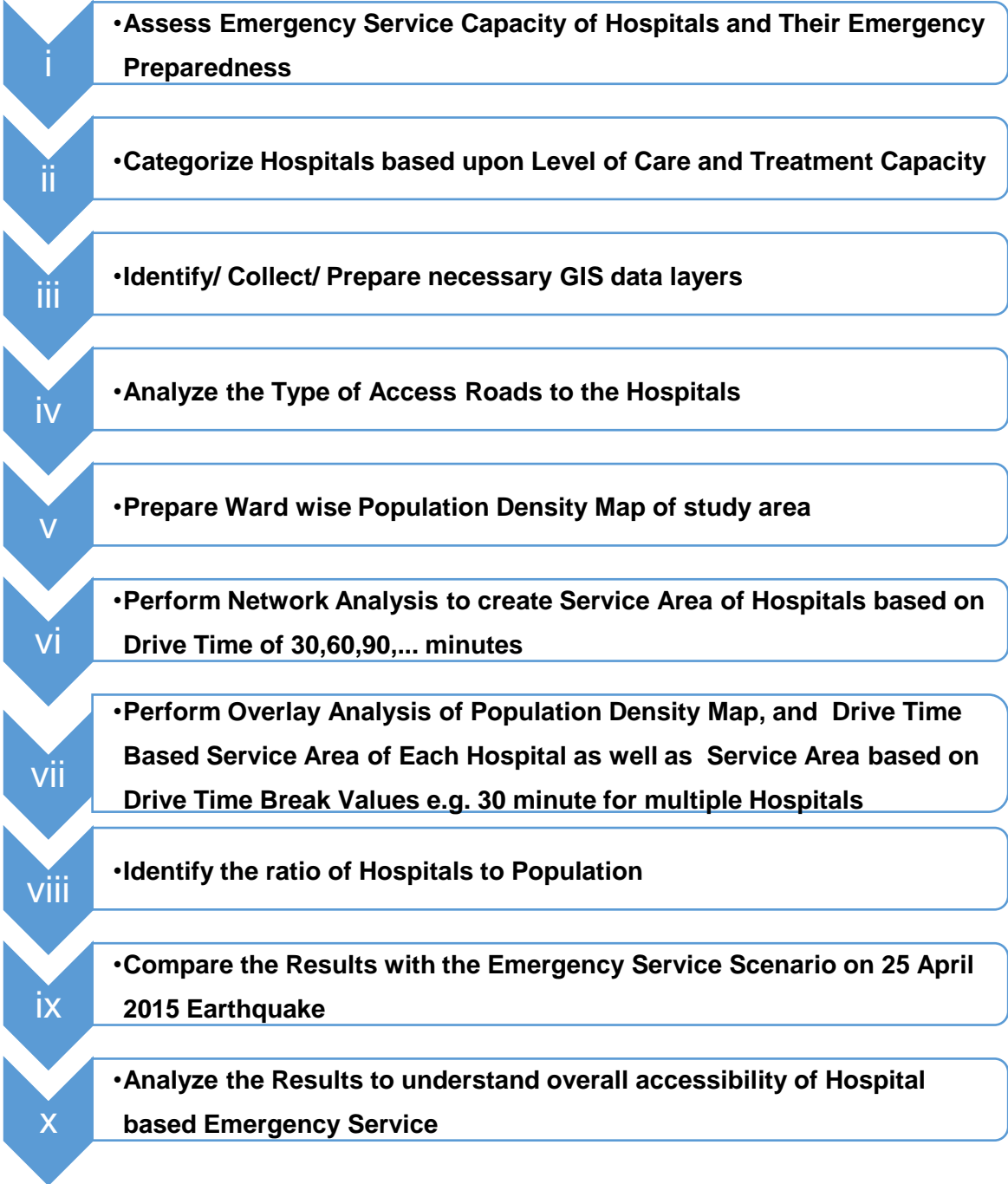


Figure 1: Methodology of the Study

## **2.1. Assessment of Emergency Service Capacity of Hospitals and Their Emergency Preparedness**

### **2.1.1. Criteria for Identification of Level of Emergency Service**

The level of emergency service of hospitals is determined based upon their mission and goals as well as regional needs for their service (Haupt et al., 2003). To some extent, the role of economic and demographic status comes into play. Therefore, it will be impractical to directly follow the international standard for the purpose of classification of level of emergency service for the study. The criteria established by the American College of Surgeons (ACS) for trauma care, World Health Organization's (WHO) Guidelines for Essential Trauma Care as well as other relevant literatures were evaluated for the classification purpose. Most of these criteria are for general trauma and deals with medical process and procedures in detail. However, the focus of this study is on trauma related to earthquake, and it is not within the realm of this study to delve into details of medical services and procedure. Therefore, mainly two factors (1) human resource and (2) ancillary services essential for trauma related to earthquake were considered for criteria formulation. Human resource implies that the staffs (medical and nursing) possess the requisite knowledge and skills to perform during emergency. Equipments and supplies imply that these items are readily available and usable to all who need them during emergency (WHO, 2008).

For this study, based upon the availability of type of emergency service, the hospitals were categorized into three levels. The following criteria were established for the categorization

## I. Level 1

- a) Considering higher rate of fractures, bruises, head trauma, crushed syndrome as well as burns as life threatening injuries during earthquake trauma, it is imperative that the emergency service in **Level 1** hospitals should have following full time medical staffs, but not limited to it.

**Table 2.1.a: Essential Full Time Medical Staffs for Level 1 Hospital**

S.N.	Staffs	Score
1	General surgeon	1
2	Orthopedic surgeon	1
3	Neurosurgeon	1
4	Anesthesiologist	1
5	Nurses	1
	Total	5

\*Score =1 if the staff is available, irrespective of its number

- b) The emergency service in **Level 1** hospitals should have following equipments and supplies readily available, but not limited to it.

**Table 2.1.b: Essential Ancillary Services for Level 1 Hospital**

S.N.	Ancillary Services	Score
1	Laboratory	1
2	X-Ray	1
3	Ultrasound	1
4	CT-Scan	1
5	Medicine Storage	1
6	Blood Bank/ Store	1
7	Burn care	1
8	Ventilators	1
	Total	8

\* Score =1 if the ancillary service is available, irrespective of its number

Therefore, to qualify as **Level 1** hospital, it should score **5** in human resource criteria and **8** in ancillary service criteria.

## II. Level 2

**Level 2** hospitals may be as proficient as or even more capable as **Level 1** hospitals in terms of dealing with general injuries, but it lacks in either neurosurgery or burn care which are of vital importance during earthquake. Therefore to qualify as **Level 2** hospital, it must have all the medical staffs as **Level 1** hospital, except it may not have neurosurgeon. The availability of CT-Scan and burn care can be relaxed.

Therefore, the total score necessary to qualify as **Level 2** hospital will be **4** in human resource criteria and **6** in ancillary services criteria, with omission of neurosurgeon, CT-Scan and burn care.

## III. Level 3

**Level 3** hospitals should have ability to provide initial care and stabilization of a traumatic injury, and arrange for transfer of the critically injured victim to a **Level 1** or **Level 2** hospitals.

Any hospital failing to qualify as **Level 1** or **Level 2** hospitals, but providing emergency service is considered as **Level 3** hospital.

### 2.1.2. Method and Parameters for Calculating Hospital Treatment Capacity

During literature review, the various methods for the estimation of Hospital Treatment Capacity (HTC) were noticed. The simplest method being the estimation of HTC per hour as 3% of number of hospital beds (Government of India - UNDP DRM Programme, 2008). However, this method gives the capacity, irrespective of available number of doctors. The method mentioned by DeBoer (1995), which considers number of available doctors across various faculty as well as other hospital capacities was found suitable for this study. However, the method has to be slightly modified to suit the local condition. Mainly the

parameters a) Number of operations and b) Number of Accident & Emergency patients per year were omitted, citing the unavailability/ difficulty in acquiring the information, and their low weightage of 1/20000 and 1/1000 respectively. The number of Surgical Residents was also omitted, as it was applicable to teaching hospitals only.

**Table 2.1.c:** Modified Method for Calculation of HTC

Description	Number (N)	Weight (W)	N x W
Total number of beds		1/3000	
Number of surgical beds		1/250	
Number of intensive care beds		1/20	
Number of operating theatres		1/10	
Number of surgeons		1/5	
Number of anesthesiologists		1/4	
Number of other surgical specialists (orthopedics, gynecologist, neurosurgeon)		1/10	
<b>HTC per Hour (Total)</b>			

Though some of the parameters have been omitted in this method, it will be suitable for realistic estimation of HTC. Further, it can be used for the categorization of available hospitals within each level for **Level 1** and **Level 2** hospitals.

The **Level 3** hospitals will have hardly any full time surgeons and anesthesiologists; the only full time doctors available will be Medical Officers (MO). The MOs are certified doctors who have recently completed Bachelor of Medicine, Bachelor of Surgery (MBBS), but have not yet done any specialization course. Initial care and stabilization service for traumatic injury are expected from MOs. However, no proper methods and tools could be acknowledged to estimate the initial care or primary treatment capacity of hospitals. Therefore, in this study, only availability of primary treatments in **Level 3** hospitals was considered, and no further categorization was done.

### 2.1.3. Criteria to Assess Emergency Preparedness of Hospitals

Based upon the literature review, the following criteria were enlisted for assessing the emergency preparedness of hospitals

**Table 2.1.d: Criteria for Assessment of Emergency Preparedness of Hospitals**

S.N.	Criteria	Score
1	Emergency Management Plan	3
2	Emergency Management Committee	2
3	Disaster Preparedness Training	1
4	Disaster Preparedness Drill	1
5	Alternate care site	1
6	Tents/Accessories	1
7	Surge Capacity	1
	Total	10

The highest score has been assigned to Emergency Management Plan and Emergency Management Committee, because without them the resources cannot be put to proper use.

**Table 2.1.e: Categorization of Hospitals' Emergency Preparedness Level**

Degree of Emergency Preparedness	Category	Score
Good	A	10
Moderate	B	6 to 9
Poor	C	5 and Below

WHO (2011) defines surge capacity of hospitals as the ability to expand beyond normal capacity to meet increased demand for clinical care, and is an important factor of hospital disaster response and should be addressed early in the planning process

#### **2.1.4. Method to Assess Emergency Service Situation of Hospitals on the Day of Earthquake 25<sup>th</sup> April 2015**

The emergency service scenario was assessed with respect to following factors

- i. Number of emergency patients on the day of earthquake
- ii. Impact of earthquake on hospital buildings as severely damaged, partially damaged or safe
- iii. Service status of hospital whether closed or operational

#### **2.1.5. Field Data Collection**

Based upon the necessary information as outlined in section 2.1.1, 2.1.2, 2.1.3 and 2.1.4, the survey form was developed to assess the emergency capacity and preparedness status of hospitals within KMC and LSMC. The queries related to 25<sup>th</sup> April, 2015 earthquake such as its effect on hospital building and functioning, number of emergency patients on the day were also included in the survey form to assess the actual condition during earthquake.

For conducting the survey, the preliminary list of hospitals in KMC and LSMC were searched in the internet, and the Ministry of Health and Population was approached for the official list. About 100 hospitals within the study area and its periphery were listed, which included government, private, teaching, community and public hospitals. From the list, the specialty hospitals such as Skin, ENT, Heart centre, Mental, Eye etc. that don't provide emergency service related to trauma were excluded. The list of 78 hospitals was finalized for the survey. The survey was conducted within the period of 13<sup>th</sup> July to 4<sup>th</sup> August, 2015. The doctors, matrons, administrative officers and directors of the respective hospitals were approached to fill up the survey form. During the survey, out of 78

hospitals, it was found that 2 hospitals had terminated their service; 8 of the hospitals did not have either surgical emergency or belonged to ayurvedic specialty; 3 hospitals were not operating because of earthquake damage and 1 hospital was completely collapsed; 2 hospitals declined to provide the information. Also the army hospital and one of the government teaching hospitals provided only partial information citing security issues. In total, the information of 62 hospitals was obtained. The details are attached in Annex.

The location information of hospitals was obtained using either mobile GPS or Google Earth.

## **2.2. Software Used**

For the study, all the data preparation, processing and analysis work was done using Environmental System Research Institute's (ESRI) ArcGIS 10.2.2. As a prerequisite, all the data used for the project was first made compatible to ArcGIS 10.2.2 by converting them to "Shapefile" format. ArcGIS 10.2.2 and its Spatial and Network Analyst extensions offer all the facilities and tools necessary for preparing data, performing spatial and network analysis, and presenting it. According to Zamorano et al. (2009), ArcGIS Network Analyst enables users to dynamically model realistic network conditions, speed limits, height restrictions, and traffic conditions at different times of the day (as cited in Nadeem, 2012).

## **2.3. GIS Data Collection and Preparation**

The GIS data layers include vector data in ArcGIS shape file format, which includes administrative boundaries of Kathmandu Metropolitan City and Lalitpur Sub-Metropolitan City, along with road network, and location names, apart from location of hospitals.

**Table 2.3.a: GIS Data Layers Used**

Description	Data Type	Geometry Type	Source
Administrative Boundary <ul style="list-style-type: none"><li>▪ Municipal Boundary</li><li>▪ Ward Boundary</li></ul>	Vector	Polygon	KMC, LSMC 1998
Transportation Network <ul style="list-style-type: none"><li>▪ Road</li></ul>	Vector	Line	Open Street Map, 2015
Location of Hospitals <ul style="list-style-type: none"><li>▪ Hospitals</li></ul>	Vector	Point	Self, 2015

The following Projection was adopted for GIS data layers

**PCS:WGS\_1984\_UTM\_Zone\_45N**

WKID: 32645 Authority: EPSG

Projection: Transverse\_Mercator

False\_Easting: 500000.0

False\_Northing: 0.0

Central\_Meridian: 87.0

Scale\_Factor: 0.9996

Latitude\_Of\_Origin: 0.0

Linear Unit: Meter (1.0)

**Geographic Coordinate System: GCS\_WGS\_1984**

Angular Unit: Degree (0.0174532925199433)

Prime Meridian: Greenwich (0.0)

Datum: D\_WGS\_1984

Spheroid: WGS\_1984

Semimajor Axis: 6378137.0

Semiminor Axis: 6356752.314245179

Inverse Flattening: 298.257223563

### 2.3.1. Hospital Location Data

The hospital information was prepared as vector point data. The location of hospitals were recorded during field survey using mobile GPS and verified over Google Earth. The tabular survey data was then joined with the location data.

### 2.3.2. Road Data

The secondary road data made available by various organizations was not found suitable for the study as most of them dates back to 1999. The road centre line data from "www.OpenStreetMap.org" was found to be of suitable quality and of recent time, and readily available. The road data was clipped according to the administrative boundary of KMC and LSMC. A buffer of 500m from the boundary was used to include any hospitals in the periphery of municipalities.



**Figure 2: Verification and Updating of Road with Reference to Google Earth Image**

The road data was verified with reference to Google Earth image dated 8<sup>th</sup> June, 2015 (Figure 2). The main priority was given to the Highway and major roads, and it was thoroughly checked for any omission and discrepancy, and accordingly updated. However, any missing residential roads and trails were not updated citing time constraint and minimal value addition it provides to the study.

### **2.3.3. Network Dataset**

A network is set of linear features through which resources flow (Trodd, 2005). Road data prepared above follows simple arc-node topology model in which roads are stored as line features and a node is created at every point where two lines meet (Nadeem, 2012). But it does not have connectivity information; without which the flow of resources through it is not possible. ArcGIS 10.2 has the capability to create network dataset, which is the dual representation of linear system i.e., it has geometric network associated with logical network. A geometric network is a collection of features that comprise a connected system of edges and junctions. On the other hand, a logical network stores the connectivity information along with certain attributes (Zeiler, 1999). These features are incorporated in network dataset as network elements which are

- Edges—Connect to other elements (junctions) and are the links over which agents travel
- Junctions—Connect edges and facilitate navigation from one edge to another
- Turns—Store information that can affect movement between two or more edges

These features make it possible to model one-way streets, turn restrictions, and overpass/underpass. The impedances, restrictions and hierarchy for the network are implemented through attribute values. The complex connectivity scenarios such as

multilayer network data having road railway, pedestrian and bus networks can also be modeled as multimodal network datasets (ESRI, 2015).

"New Network Dataset wizard" in ArcGIS 10.2 makes it possible to create network dataset with ease. In this study, the network dataset was prepared using road data as source feature.

The network dataset was prepared with reference to Network dataset preparation tutorial of ArcGIS 10.2 as follows

#### **2.3.3.1. Cleaning up bad digitization**

Before creating network data from road data, it was cleaned up to make it free from inherent geometric errors resulting due to bad digitization such as data duplication, short objects, zero length objects, overlapping nodes, unsnapped clustered node, overshoots/undershoots etc. Treatment of these errors will make network data topologically sound.

#### **2.3.3.2. Break crossing lines**

The default connectivity setting for network datasets establish connectivity only at coincident endpoints of line features. Therefore, any crossing lines were broken down at the intersection, so no lines crossed each other.

#### **2.3.3.3. Adding Elevation Fields**

The real-world overpass/underpass situations must be considered to respect actual road network scenario. In case of KMC and LSMC area, it is mainly observed in river corridor roads which pass under the bridge. This situation was modeled by adding two attribute fields "F\_ELEV" and "T\_ELEV" understood by ArcGIS as values. The "F\_ELEV"

represents the elevation at the starting node from where the street or line segment was digitized, whereas "T\_ELEV" represents the elevation at end node of the segment. The default values for these fields are "0", representing no elevation or ground elevation. In case of overpass, "T\_ELEV" of preceding segment and "F\_ELEV" of following segment were given value of "1", provided that both the segments are digitized in the same direction.

#### **2.3.3.4. Adding Drive-Time field**

The Drive-Time field is the most important attribute for network analysis in this study. It is the parameter that decides how long it takes to drive from origin to destination point or determine the service area. For calculation of drive-time, two necessary components are 'Length' and 'Speed'.

##### **a. Length**

The 'Length' component is automatically created for geodatabase line feature classes as 'Shape\_Length', however it should be first ensured that the data is in Projected Coordinate System to avoid calculation in decimal degree.

##### **b. Speed**

The speed limit data for streets in Kathmandu, Lalitpur or any other part of country is not available. As of Vehicle and Transport Management Regulation 1998, the provisioned speed limit for the vehicles is as follows

- Bus, Truck- 50 Km per hour (KMPH) for hill roads and 70 KMPH for plain road
- Car, jeep Van Pick up- 80 KMPH
- Tempo, Tractor scooter- 40 KMPH
- Motorbike- 50 KMPH

But the Maximum speed is limited to 40 KMPH for all kinds of vehicle in settlement area.

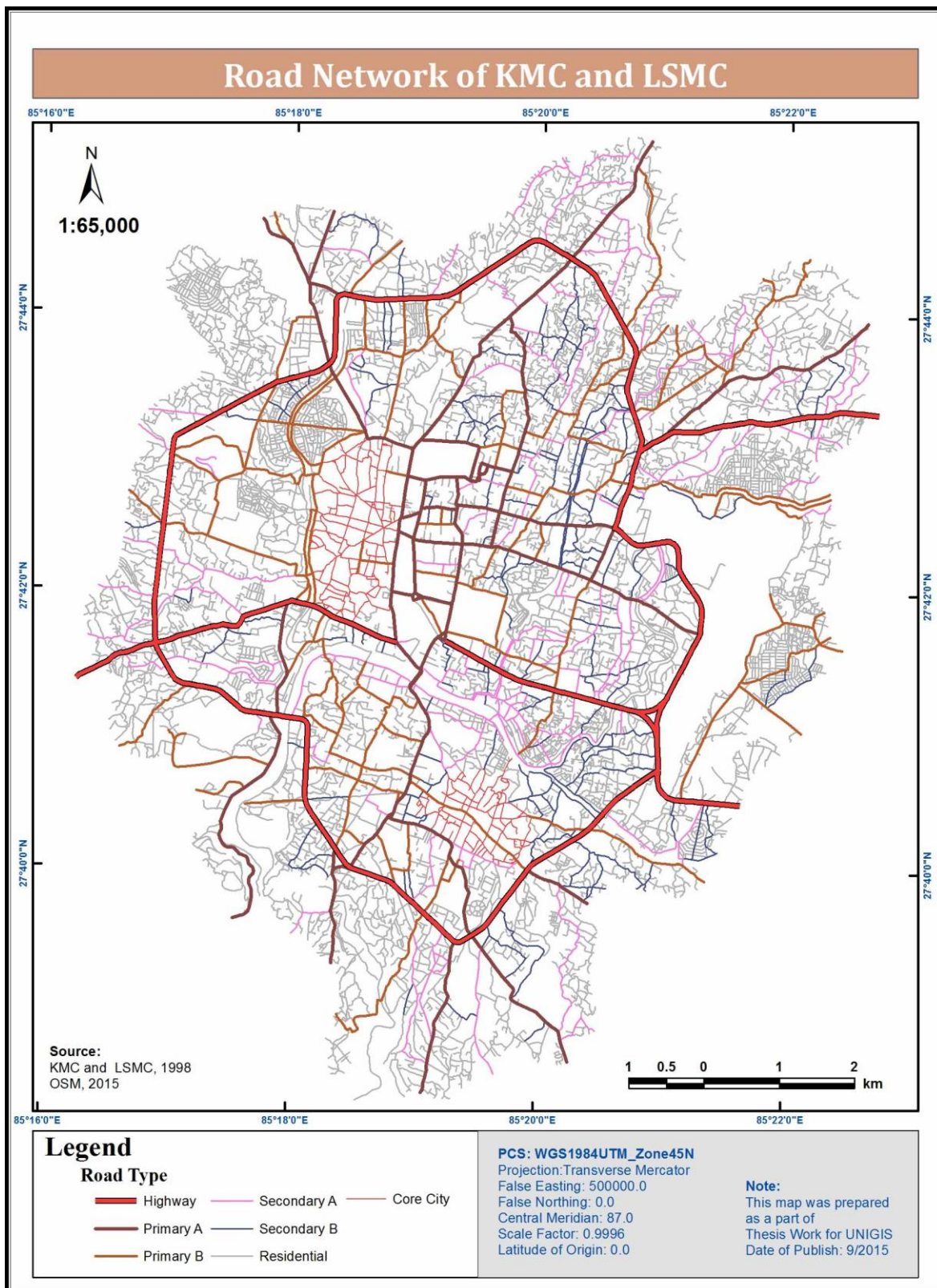
In this study, we will be considering drive time for Car, Jeep or Van, because in absence of ambulance, these are the preferred vehicle for driving the trauma victim to the nearest emergency service. The ambulance in the local context is also a little more than a taxi with siren (Gongal and Vaidya, 2012). Therefore, it is assumed in this study that victim is carried to the hospital in car or van from the point of trauma scene.

Since no speed limit data for the streets was available, estimation of speed based on road classes is a common practice. The Nepal Road Standard, 1988 classifies roads into a) National highways, b) Feeder roads, c) District Roads, and d) City roads; but there is no further classification of City roads. Since KMC and LSMC are cities, this classification is of not much help. Therefore, based on the available road category information in the Openstreetmap data, field observations and consultation with individuals from different parts of the study area, the streets were classified as follows

**Table 2.3.b : Classification of Roads**

<b>Class</b>	<b>Type</b>	<b>Description</b>	<b>Speed Limit</b>
1	Highways	These are National Highways which connects cities across the country and have heavy traffic	< 60
2	Primary A	These are main wide roads that extend across the city and have heavy traffic	<50
3	Primary B	These are roads less wider than Primary A, but are major public transportation routes having heavy traffic	<40
4	Secondary A	These are less popular routes, including new river corridor roads having moderate traffic	<40
5	Secondary B	These are mainly single lane roads having low traffic, and connect residential roads to higher road classes	<20
6	Residential	These are the access roads within residential area, mainly single lane	<15
7	Core City	These are narrow congested roads within historical area of KMC and LSMC	<10
999	Pedestrian	Accessible by pedestrian and two-wheelers only	Walking Speed

The road network map after classification of roads is as follows



**Map 4: Road Network of KMC and LSMC**

After identification of speed limit of each road class, the approximate speed of each street segment was populated for three test conditions necessary for the study.

- i. **Case 1:** For normal traffic scenario i.e., traffic during working hours from 9 A.M. to 6 P.M., the following speed was adopted.

**Table 2.3.c: Defined Speed of Roads for Normal Traffic Scenario**

Class	Speed Range (KMPH)	Average Speed (KMPH)
1	6 to 40	16
2	6 to 40	10
3	6 to 8	8
4	6	6
5	5	5
6	4.5	4.5
7	4	4

The average normal traffic speed during office hours is below 20 KMPH in all classes of roads.

- ii. **Case 2:** Congested traffic scenario during earthquake  
 The traffic congestion is mainly observed along Class 1, 2 and 3 roads. The congestion speed is approximated as a half (1/2) of normal speed, but not less than pedestrian speed. The trauma victim can opt for pedestrian mode, in case of very heavy congestion.

- iii. **Case 3:** Pedestrian Traffic only; simulating impossibility of using vehicles due to road blockage

The pedestrian walking speeds have been reported by various studies to be within range of 4.51 KMPH to 4.75 KMPH for older individuals and from 5.32 KMPH to 5.43 KMPH for younger individuals (In Wikipedia, 2015). The average walking speed of disabled pedestrians and users of various assistive devices ranges from 0.6 to 1.1 meter/sec i.e. 2.16 KMPH to 3.96 KMPH (Dewar, 2002). Since the focus

of the study is on the walking speed of the victim of earthquake trauma, and the people assisting him/her, the pedestrian walking speed will be considered as average of 2.16 to 3.96 KMPH i.e., **3.0 KMPH**. Therefore, for simulating pedestrian traffic mode, all roads were assigned a speed of 3.0 KMPH.

After determining length and speed fields, the drive-time was calculated by dividing length by speed. Since ArcGIS recognizes a field name "MINUTES" as drive-time, a "MINUTES" attribute field was added, and its values were populated using simple following formula

$$\text{"MINUTES"} = [\text{SHAPE\_LENGTH}] * 60 / [\text{SPEED}]$$

The drive time was calculated in minutes as specified by field name.

#### **2.3.3.5. Implementing One-Way and Turn restrictions**

During the earthquake emergency scenario, one-way and turn restrictions can be more or less relaxed. However, the one-way congestion is also one of the possible scenarios, so it was incorporated in the study. But since the emergency vehicles will be given priority at intersections, the global turn or turn restrictions were not enforced.

"ONEWAY" field is automatically understood by ArcGIS as valid network attribute representing one-way parameter. For each one-way street, the field was assigned either 'FT' or 'TF' value. 'FT' means travel is allowed in the digitized direction whereas 'TF' represents the mode of travel in opposite direction. If the field has null value, it will be considered as two-way street. The presence of "ONEWAY" field will be automatically incorporated into network dataset as "Restriction".

#### **2.3.3.6. Creating Multimodal network dataset**

Multimodal network dataset was created to incorporate both streets and pedestrian roads in network analysis. Roads belonging to Class 1 to Class 7 were represented as "Street"

feature class, whereas roads belonging to Class 999 or Pedestrian roads were represented as "Trail" feature class.

For the Case1 and Case 2 analysis, the drive time of "Street" feature class was computed based on "MINUTES" field, and that of "Trail" feature class as value equal to "[SHAPE\_LENGTH]\*60 / 3000" where "3000" is pedestrian walking speed in meters.

For Case 3 analysis, both the feature classes were merged to create single network dataset and the drive time was calculated based on pedestrian walking speed.

## 2.4. Network Analysis Process

On the basis of network dataset prepared above, the service area for all three driving conditions i.e., normal, congested and pedestrian traffic scenario were computed by using ArcGIS Network analyst's "New Service Area" tool. The service area was computed separately for

- i. **Level 1** Hospitals
- ii. **Level 1** and **Level 2** Hospitals jointly
- iii. All Hospitals for Primary care

These hospital layers were loaded as facilities within search tolerance of 500m, separately for each driving condition, and solved for the solution (Figure 3). The default breaks of 15, 30, 60 and 90 minutes were used to generate service area of 15, 30, 60 and 90 minutes drive time respectively. For the type of service area, generalized non-overlapping and concentric ring option were used. However for primary care condition "Merge by break value option" was used.

The process results in two kinds of service area polygons for each driving condition

- a) Service area polygon of each hospital i.e., the area closest to a particular hospital based on drive time. Only a single hospital falls within a polygon and the polygon covers area from where it might take 15, 30, 60, 90 minutes or more drive time to reach this hospital, but still it is the closest hospital.
- b) Service area polygon of multiple hospitals having the same break value e.g. 15 minute break value service area from where one or more hospitals can be reached within 15 minutes drive time. Therefore, we will get separate service area polygons for 15 to 30 minute drive time, 30 to 60 minutes drive time and so on.

The polygons thus generated were converted to individual shape file. These shape files were later used for overlaying with ward wise population density layers to find out the population within each service area.

The other settings used for the process are as follows

**Table 2.4.a: ArcGIS Settings for Network Analysis**

<b>Parameter</b>	<b>Values</b>
Impedance	Drive Time(MINUTES)
Default Breaks	15, 30, 60, 90
Direction	Towards Facility
U-Turns at Junctions	Allowed
Restrictions	Oneway
Polygon Generation	Generalized
Polygon Option	Not Overlapping
Polygon Type	Rings

For the pedestrian traffic scenario, One-way restriction was removed.

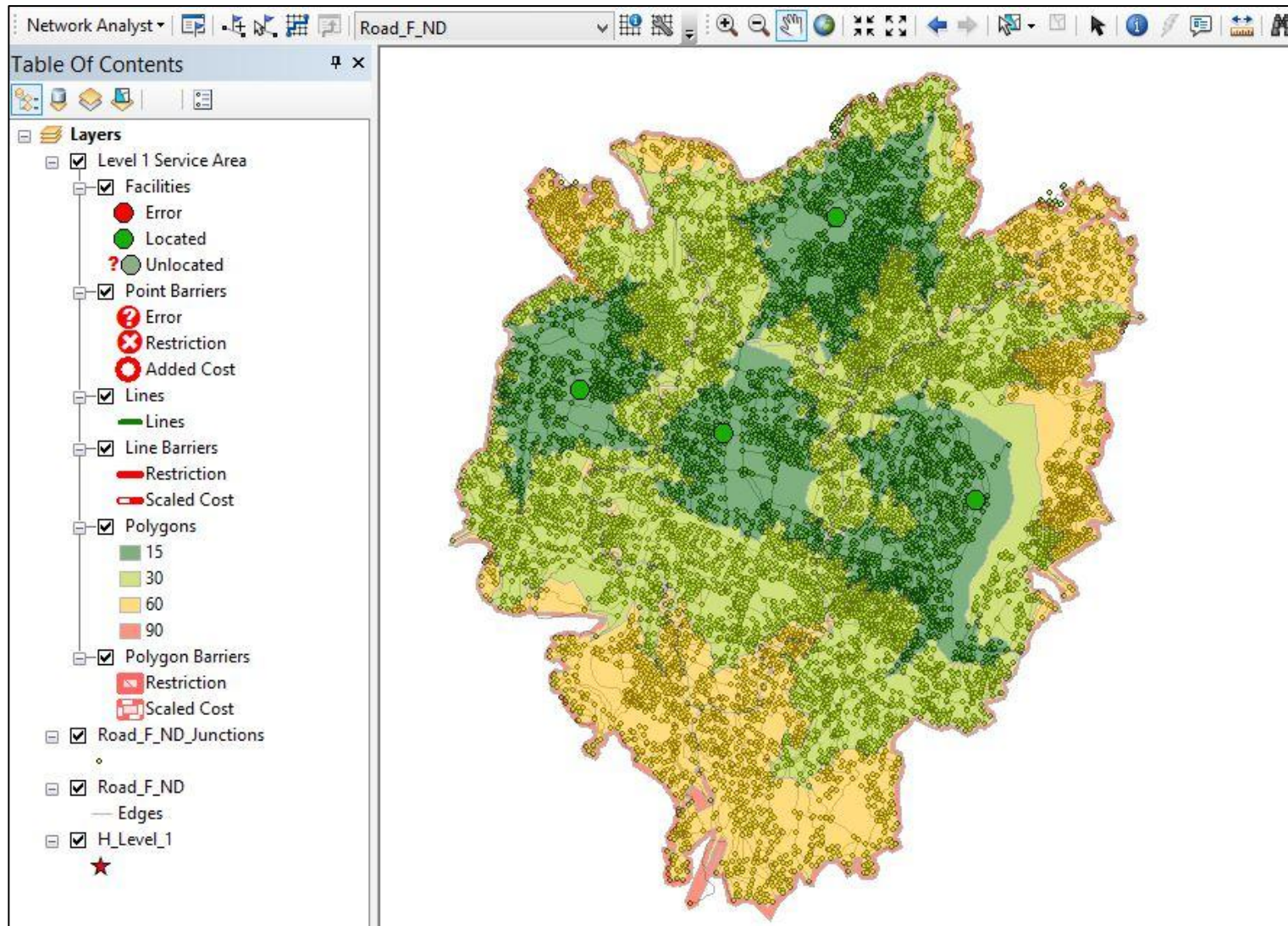


Figure 3: Network Analysis Process in ArcGIS 10.2

## 2.5. Demographic Data

The ward wise population data of KMC and LSMC (Table 2.5.a & 2.5.b), as of National Population and Housing Census 2011 report conducted by Central Bureau of Statistics (CBS), Nepal was used. However, there is slight variation between the ward wise population number and population of municipality as a whole. For this study, ward wise population data was used. KMC has 35 wards and population of 1006656 whereas LSMC has 22 wards and population of 22285. The total population of study area is 1229941.

**Table 2.5.a: Demographic Data of KMC as of CBS 2011;** KMC has 35 wards and a population of 1006656

Ward no.	Total Population	Ward no.	Total Population
1	13728	21	13708
2	13561	22	5846
3	37707	23	8106
4	48215	24	3477
5	18497	25	4794
6	61726	26	3987
7	54998	27	7712
8	13516	28	5675
9	43769	29	44648
10	42972	30	8610
11	17726	31	16603
12	12969	32	35035
13	41223	33	27203
14	59073	34	67494
15	52013	35	76608
16	86993		
17	25758		
18	10720		
19	11391		
20	10595		

(Source: CBS 2011)

**Table 2.5.b: Demographic Data of LSMC as of CBS 2011;** LSMC has 22 wards and population of 23285

Ward no.	Total Population	Ward no.	Total Population
1	8534	12	5988
2	19542	13	14601
3	13179	14	21145
4	16664	15	14723
5	7254	16	4183
6	6871	17	10530
7	7565	18	5681
8	11615	19	7404
9	13271	20	7824
10	7362	21	4659
11	4485	22	10205

(Source: CBS 2011)

## 2.6. Preparation of Ward wise Population Density Map

The population density of each ward was calculated by dividing the ward wise population value by area of respective wards. Out of 57 wards, the area of 35 wards is less than 1 sq.km, and the area of the largest ward is 4.34 sq. km only. Therefore, it was found bit unfeasible to use sq.km as the spatial unit for calculation of population density. So unit hectare (ha), next to sq.km in sequence, was chosen for the study. The population density map was then created by using graduate color symbology. The positions of class breaks were predetermined by using "Jenks Natural Break" classification technique with seven classes. It was then manually adjusted to give them round figure for easy comprehension.

KMC has minimum population density of 75 persons per ha in ward 8, and maximum of 1195 in the smallest ward 28. The mean population density of wards is 370. The largest ward 35 having area of 434 ha has density of 176. The highest population of 86993 exists in ward 16, and it has a population density of 212 persons per ha (Table 2.6.a & Map 5).

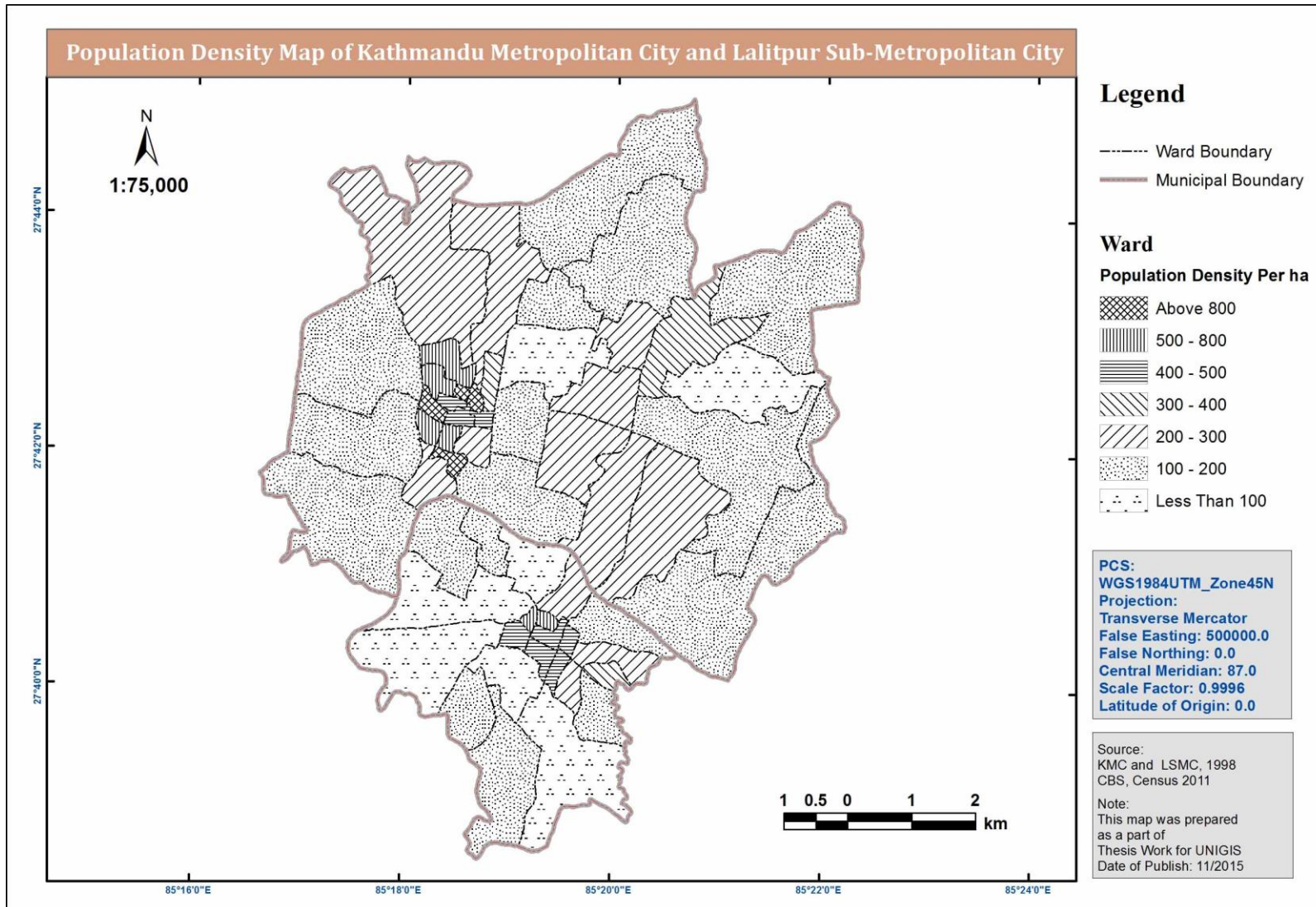
**Table 2.6.a : Ward wise Population Density of KMC in Ascending Order**

<b>Ward No.</b>	<b>Municipality</b>	<b>Area in ha</b>	<b>Total Population</b>	<b>Population Density Per ha</b>
8	KMC	180.71	13,516	75
1	KMC	137.47	13,728	100
11	KMC	173.57	17,726	102
9	KMC	375.60	43,769	117
3	KMC	320.39	37,707	118
2	KMC	84.14	13,561	161
4	KMC	285.84	48,215	169
31	KMC	94.12	16,603	176
35	KMC	434.17	76,608	176
15	KMC	291.52	52,013	178
6	KMC	339.39	61,726	182
14	KMC	319.67	59,073	185
13	KMC	213.52	41,223	193
22	KMC	28.63	5,846	204
16	KMC	410.97	86,993	212
29	KMC	193.58	44,648	231
5	KMC	71.12	18,497	260
12	KMC	49.19	12,969	264
32	KMC	130.12	35,035	269
10	KMC	157.40	42,972	273
34	KMC	233.25	67,494	289
33	KMC	91.86	27,203	296
7	KMC	154.45	54,998	356
30	KMC	22.88	8,610	376
25	KMC	11.68	4,794	410
24	KMC	7.87	3,477	442
26	KMC	8.24	3,987	484
18	KMC	19.92	10,720	538
20	KMC	15.64	10,595	677
23	KMC	11.72	8,106	692
17	KMC	35.72	25,758	721
19	KMC	13.38	11,391	852
27	KMC	8.06	7,712	957
21	KMC	13.15	13,708	1,042
28	KMC	4.75	5,675	1,195

**Table 2.6.b: Ward wise Population Density of LSMC in Ascending Order**

Ward No.	Municipality	Area in ha	Total Population	Population Density Per ha
15	LSMC	227.99	14,723	65
3	LSMC	165.18	13,179	80
4	LSMC	203.80	16,664	82
5	LSMC	76.33	7,254	95
10	LSMC	76.16	7,362	97
14	LSMC	171.99	21,145	123
9	LSMC	76.74	13,271	173
17	LSMC	60.16	10,530	175
2	LSMC	111.12	19,542	176
1	LSMC	48.09	8,534	177
13	LSMC	75.11	14,601	194
22	LSMC	45.11	10,205	226
8	LSMC	47.79	11,615	243
6	LSMC	24.25	6,871	283
7	LSMC	20.97	7,565	361
18	LSMC	14.20	5,681	400
11	LSMC	10.04	4,485	447
19	LSMC	16.22	7,404	456
12	LSMC	12.73	5,988	470
20	LSMC	16.21	7,824	483
16	LSMC	8.05	4,183	520
21	LSMC	6.62	4,659	704

LSMC has minimum population density of 65 persons per ha in ward 15, and maximum of 704 in ward 21. On the contrary, ward 15 is the largest ward with area of 228 ha, and ward 21 is the smallest with area of 6.6 ha. The mean population density of wards is 274. The highest population of 21145 exists in ward 14, and it has a population density of 123 persons per ha (Table 2.6.b & Map 5).



**Map 5: Population Density Map of KMC and LSMC**

## 2.7. Overlay Analysis Process

The purpose of the overlay analysis is to find out the population that lies within each service area of drive time of 15 minutes, 15-30 minutes, 30-60 minutes and above 60 minutes, as well as population within service area of each hospital.

The resulting shape files from network analysis i.e. service area polygons were overlaid with ward wise population density shape file (Figure 4). The spatial extent of both the shape files was limited to external boundary of KMC and LSMC. The overlay analysis was performed using intersect tool in ArcGIS. The process created separate polygons wherever the ward boundary data intersected with service area boundary, resulting in multiple polygon data. Consequently, the service area polygon for a particular drive time or hospital area becomes a constituent of multiple ward polygons. In this study, we have assumed that the population distribution within each ward is uniform citing the dense settlement and lack of open spaces. So the population of any portion of a particular ward can be found out by multiplying the area of that portion of ward and its population density. Therefore, the population of each service area thus becomes the sum of population of portion of wards falling within it. The population was calculated on tabular data.

The overlay analysis was performed for service area polygons of each

- i. **Level 1** Hospitals
- ii. **Level 1** and **Level 2** Hospitals jointly
- iii. All Hospitals for Primary care

After the calculation of population of service area, tabular data was prepared to list the population of each drive time based service area and the service area of each hospital.

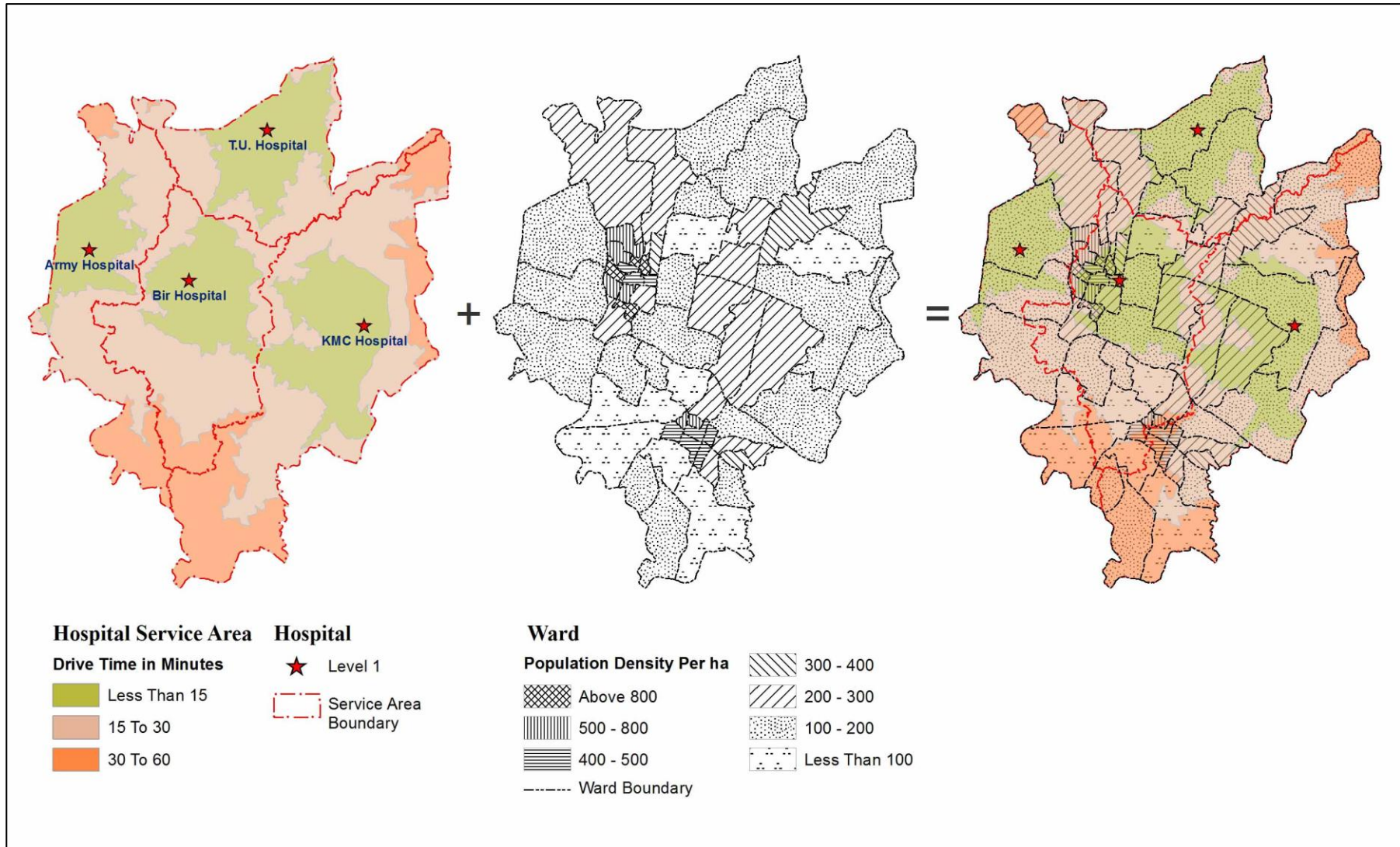


Figure 4: Overlay Analysis Process

# Chapter- 3. Results

The results of the various aforementioned processes are discussed in this section.

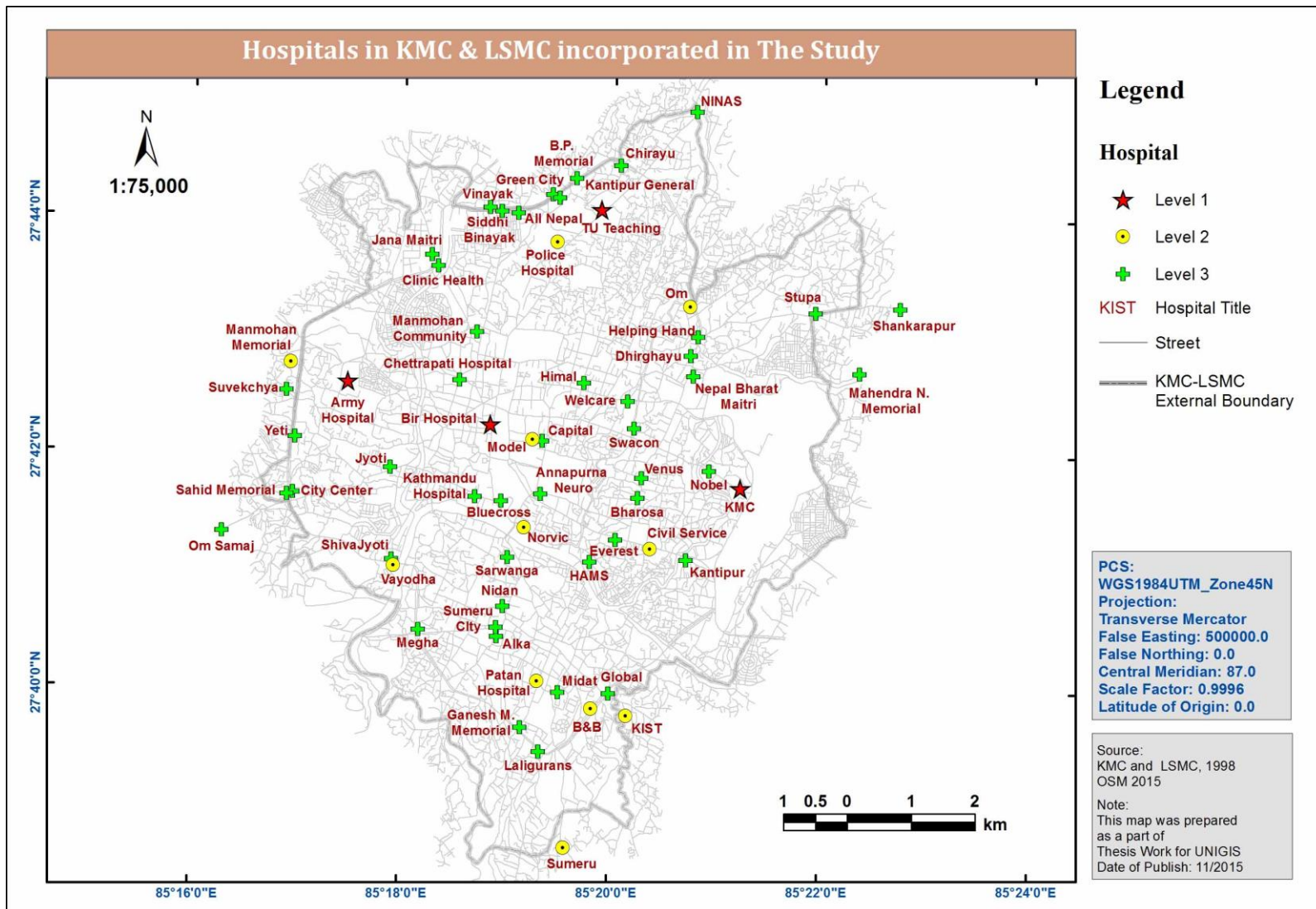
## 3.1. Categorization of Hospitals based upon Level of Emergency Service

Based upon the criteria discussed in section 2.1.1, the hospitals were categorized as **Level 1**, **Level 2** and **Level 3** hospitals (Table3.1.a & Map 6). Out of 62 hospitals, only 4 hospitals could be considered as **Level 1** hospitals, which can provide complete emergency service related to earthquake trauma. 11 hospitals falls in **Level 2** category, which can provide almost all the emergency services related to earthquake trauma, except neurosurgical cases. About 76% of total hospitals in KMC and LSMC i.e., 47 hospitals are of **Level 3**, which though don't have full time surgical staffs, are in a position to provide initial care and stabilization of a traumatic injury.

**Table 3.1.a: Categorization of Hospitals based on Level of Emergency Services; Level 1: Full Trauma care, Level 2: Trauma care without neurosurgery, Level 3: Primary stabilization**

Level	Numbers of Hospitals
1	4
2	11
3	47
Total	62

The details of categorization are provided in **Annex**.



**Map 6: Hospitals in KMC and LSMC incorporated in the Study**

## 3.2. Categorization of Hospitals within each Level based upon Hospital Treatment Capacity (HTC)

Based upon the method explained in section 2.1.2, HTC for hospitals within each level i.e.

**Level 1** and **Level 2** were calculated. The result is as follows

### 3.2.1. HTC per hour of Level 1 Hospitals

**Table 3.2.a: HTC per Hour of Level 1 Hospitals**

S.N.	Hospital	Level	HTC
1	T.U. Teaching Hospital	1	13.6
2	Kathmandu Medical College Teaching Hospital(KMC)	1	11.0
3	Bir Hospital/ Trauma Center	1	10.5
4	Shree Birendra Hospital (Army Hospital)	1	NA

The information of Army hospital is not listed as it is a classified information. The HTC of all three hospitals were in similar range, so no further categorization was required.

### 3.2.2. HTC per hour of Level 2 Hospitals

**Table 3.2.b: HTC per hour of Level 2 Hospitals**

S.N.	Hospital	Level	HTC
1	Patan Academic of Health Sciences (Patan Hospital)	2	8.7
2	B&B Hospital (College of Physicians & Surgeons of Pakistan)	2	7.2
3	KIST Medical College & Teaching Hospital	2	7.1
4	Kathmandu Model Hospital	2	5.3
5	Om Hospital	2	4.5
6	Civil Service Hospital	2	4.2
7	Sumeru Samudaik Hospital	2	3.7
8	Manmohan Memorial Medical College & Teaching Hospital	2	3.5
9	Nepal Police Hospital	2	2.8
10	Norvic International Hospital	2	2.7
11	Vayodha Hospital	2	1.3

The HTC of **Level 2** hospitals ranges from 1.3 to 8.7 patients per hours; Patan hospital has the highest HTC equivalent to **Level 1** hospitals whereas Vayodha has the lowest HTC (Table3.2.b). The average HTC of Level 2 Hospitals stands at 4. Based on it, it can be further categorized into 3 classes.

**Table 3.2.c: Categorization of Level 2 Hospitals based on HTC per hour**

S.N.	HTC Range (Per Hour)	Number of Hospitals
1	6-9	3
2	3-6	5
3	1-3	3

### 3.3. Assessment of Emergency Preparedness of Hospitals

**Table 3.3.a: Emergency Preparedness Level of Hospitals;** "A" indicates good preparedness; "B" shows moderate level of preparedness; "C" stands for poor preparedness

Preparedness Level	Number of Hospitals	Percentage (%)
A	13	21%
B	29	47%
C	20	32%
Total	62	100%

In totality, 70% of the hospitals are found to have good to adequate emergency preparedness (Table 3.3.a). However, one out of each **Level 1** and **Level 2** hospitals have poor emergency preparedness.

### 3.4. Identification of Type of Access Roads to the Hospitals

The near analysis was performed in ArcGIS to find out the type of access roads to the hospitals

**Table 3.4.a: Hospital Count based upon the Type of Access Road**

S.N.	Road Type	Road Class	Number of Hospitals
1	Highway	1	18
2	Primary A	2	12
3	Primary B	3	11
4	Secondary A	4	7
5	Secondary B	5	3
6	Residential	6	10
7	Core City	7	1

41 out of 62 hospitals are accessible through Highway and Primary roads, and only 11 hospitals lie in residential zone (Table 3.4.a). The buffer analysis of Highway showed that 30 hospitals are within a distance of 100 m, and 36 hospitals are within a distance of 200m from Highway roads. Mainly the hospitals are situated in the periphery of Ring road. Since Highway and Primary roads are well paved wide roads having less possibility of obstruction during earthquake, the overall access roads leading to the hospitals can be considered as good. Those hospitals which are accessible through residential road lie within core city area having high population density, so they are accessible to large population residing within small area.

### 3.5. Results of Network and Overlay Analysis

#### 3.5.1. Case1: Normal Traffic Scenario (During working hours from 9 A.M. to 6 P.M)

##### 3.5.1.1. Service Area of Level 1 Hospitals

The two types of service area of **Level 1** hospitals or tertiary level of emergency service were identified for normal traffic scenario, along with the population it covers.

- i. **Service area of multiple Level 1 hospitals** i.e. service area based on drive time break values of 15, 15 to 30, 30 to 60 minutes and so on from multiple **Level 1** hospitals
- ii. **Service area of each Level 1 hospital** i.e., service area closest to particular **Level 1** hospital

**Table 3.5.a: Normal Drive Time based Service Area of Multiple Level 1 Hospitals**

S.N.	Drive Time (Minutes)	Service Area (ha)	Population	Service Area (%)	Population (%)
1	0-15	2173	415,554	34%	34%
2	15-30	3133	650,373	49%	53%
3	30-60	1153	164,009	18%	13%
	Total	6459	1,229,936	100%	100%

**Table 3.5.b: Normal Drive Time based Service Area of Each Level 1 Hospital**

S.N.	Hospital	Drive Time (Minutes)	Service Area (ha)	Population
1	Bir Hospital-Trauma Center	0-15	542	135,487
		15-30	812	173,753
		30-60	138	22,755
2	Army Hospital	0-15	376	70,121
		15-30	682	139,563
		30-60	254	29,616

S.N.	Hospital	Drive Time (Minutes)	Service Area (ha)	Population
3	T.U. Teaching Hospital	0-15	560	81,291
		15-30	526	110,321
		30-60	28	5,131
4	KMC Teaching Hospital	0-15	694	128,656
		15-30	1112	226,735
		30-60	734	106,507

In case of normal traffic scenario (Table 3.5.a & Map 7), all the population in KMC and LSMC are within one hour drive time from the **Level 1** hospital. More than 60 % of the people can access the nearest hospital within 30 minutes drive time. The population distribution within spatial coverage of each drive time is also uniform. The population that is considered at risk i.e. beyond one-hour drive time does not exist.

For each **Level 1** hospital, the population count within 15-30 minutes drive time is on higher side, and that of 30-60 minutes drive time is on lower side. Therefore, the overall accessibility during normal traffic scenario is reasonably good.

**Table 3.5.c: Ratio of HTC of Each Level 1 Hospital to the Population within its Service Area for Normal Drive Time**

S.N.	Hospital	Service Area (ha)	Population	HTC/ Day (10 Hours)	HTC/ Population
1	Bir Hospital-Trauma Center	1492	331,996	105	0.03%
2	Army Hospital	1312	239,299	NA	NA
3	T.U. Teaching Hospital	1114	196,743	136	0.07%
4	KMC Teaching Hospital	2541	461,898	110	0.02%
	Total	6459	1,229,936	351	0.03%

KMC hospital commands the largest area as well as the largest population. However, despite having highest HTC, the population falling within T.U. Teaching hospital is the least in terms of drive time (Table 3.5.b & c, Map 8). Overall, the treatment capacity of hospitals stands too low in relation to the total population it serves. If we consider that the hospital staffs will be able to operate continuously over 10 hours, HTC will come around 100 patients. Based upon it, HTC for tertiary level of treatment can be considered less than 0.05% of total population. Though it is an approximation, in reality it cannot drastically vary. So HTC of **Level 1** hospitals is distinctly low compared to the possible demand.

**3.5.1.2. Service Area Analysis of Level 1 and Level 2 Hospitals Combined**

Similarly, two kinds of service area were determined for normal traffic scenario when **Level 1** and **Level 2** hospitals were considered simultaneously for **Level 2** category emergency service.

**Table 3.5.d: Normal Drive Time based Service Area of Multiple Level 1 & 2 Hospitals**

S.N.	Drive Time (Minutes)	Service Area	Population
1	0 - 15	4773.4	894,543
2	15 - 30	1597.6	319,443
3	30 - 60	86.1	15,761

With the inclusion of **Level 2** hospitals for secondary level of treatment, the population within 15 minutes drive time from the hospitals has increased from 415000 to 895000 i.e., more than double the population within 15 minutes drive time of **Level 1** hospitals. Also, the population that needs more than 30 minutes to reach the hospital has dropped to 15000 i.e., only 1% of the population (Table 3.5.d & Map 9).

**Table 3.5.e: Normal Drive Time based Service Area of Each Level 1 & 2 Hospital**

<b>Drive Time (Minutes)</b>	<b>Hospital</b>	<b>Service Area (ha)</b>	<b>Population</b>
0-15	B&B Hospital	331.1	52,347
	Bir Hospital-Trauma Center	161.6	66,379
	Civil Service Hospital	591.3	133,688
	Kathmandu Model Hospital	400.8	82,379
	KIST Medical College & Teaching Hospital	7.8	1,551
	Manmohan Memorial Medical College & Teaching Hospital	227.7	43,841
	Nepal Police Hospital	131.6	20,689
	Norvic International Hospital	282.3	40,896
	Om Hospital	509.9	112,620
	Patan Hospital	383.1	71,667
	Shree Birendra Hospital (Army Hospital)	241.7	45,328
	Sumeru Samudaik Hospital	56.3	3,964
	T.U. Teaching Hospital	412.8	58,604
	KMC Teaching Hospital	376.4	59,052
	Vayodha Hospital	659.0	101,539
15-30	B&B Hospital	75.2	11,227
	Bir Hospital-Trauma Center	53.0	31,438
	Civil Service Hospital	251.4	41,916
	Kathmandu Model Hospital	76.8	16,862
	KIST Medical College & Teaching Hospital	0.2	16
	Manmohan Memorial Medical College & Teaching Hospital	261.1	54,994
	Nepal Police Hospital	96.0	21,053
	Norvic International Hospital	12.0	2,995
	Om Hospital	359.8	56,399
	Patan Hospital	87.9	15,271
	Shree Birendra Hospital (Army Hospital)	124.4	35,595
	Sumeru Samudaik Hospital	19.8	2,430
	T.U. Teaching Hospital	78.3	14,300
	KMC Teaching Hospital	0.9	70
	Vayodha Hospital	100.8	14,878

Drive Time (Minutes)	Hospital	Service Area (ha)	Population
30-60	Civil Service Hospital	27.9	5,903
	Manmohan Memorial Medical College & Teaching Hospital	29.0	4,791
	Om Hospital	28.2	4,945
	Patan Hospital	1.0	122

For **Level 2** service accessible within drive time of 15 minutes, the average service area of hospitals comes around 320 ha with average population of 60000 (Table 3.5.e & f, Map 10). However, the service area allocation for each hospital is not uniform, as the largest service area is around 660 ha whereas smallest area is fairly small at 7 ha. The population coverage stands at maximum of 133000 and minimum of 1500. Similarly, for 15-30 minutes drive time, the average service is 100 ha and average population is 21000. The largest service area is around 360 ha having highest population coverage of 56000, and the lowest service area is only of 0.2 ha with lowest population coverage of 16 persons. Lastly, only 4 hospitals need more than 30 minutes drive time to be accessible within KMC and LSMC area and it accounts for population around 15000.

**Table 3.5.f: Ratio of HTC of Each Level 1 & 2 Hospital to the Population within its Service Area for Normal Drive Time**

Hospital	Service Area	Population	HTC/ Day (10 Hours)	HTC/ Population
B&B Hospital	406.3	63,574	72	0.11%
Bir Hospital-Trauma Center	214.7	97,817	105	0.11%
Civil Service Hospital	870.8	180,549	42	0.02%
Kathmandu Model Hospital	477.6	99,241	53	0.05%
KIST Medical College & Teaching Hospital	8.1	1,567	71	4.53%
Manmohan Memorial Medical College & Teaching Hospital	516.8	104,738	35	0.03%
Nepal Police Hospital	227.6	41,742	28	0.07%

Hospital	Service Area	Population	HTC/ Day (10 Hours)	HTC/ Population
Norvic International Hospital	294.3	43,891	27	0.06%
Om Hospital	898.7	173,810	45	0.03%
Patan Academic of Health Sciences (Patan Hospital)	471.9	87,059	87	0.10%
Shree Birendra Hospital (Army Hospital)	366.2	80,923	NA	NA
Sumeru Samudaik Hospital	76.1	6,394	37	0.58%
T.U. Teaching Hospital	491.1	72,905	136	0.19%
Kathmandu Medical College Teaching Hospital(KMC)	377.3	59,122	110	0.19%
Vayodha Hospital	759.7	116,417	13	0.01%
Total	6457.2	1,229,749	861	0.07%

Though the nearest hospitals are almost within the 30 minutes drive time, the distribution of population to each hospital is not uniform (Table 3.5.f & Map 10). Mainly, the hospitals that are easily accessible to the largest group of population have the least HTC. For instance Civil Service, Vayodha, Manmohan and Om hospitals have the largest population catchment, but their HTC stands at less than 0.03% to it. KIST and Sumeru Samudaik Hospitals are the least accessible hospitals to people of KMC and LSMC, as these are situated at southern periphery of LSMC. In totality, the HTC for **Level 2** service is less than 0.1% of total population of the study area.

### 3.5.1.3. Service Area of All Hospitals for Primary Treatment

**Table 3.5.g: Normal Drive Time based Service Area of All Hospitals for Primary Treatment**

Drive Time (Minutes)	Service Area (ha)	Population
0 - 15	5922.9	1,145,219
15 - 30	498.4	77,990
30 - 60	37.2	6,732

The calculation of individual service area of each hospital was deemed surplus because 93% of population are within 15 minutes drive from the nearest hospital (Table 3.5.g & Map 11).

Similarly, as the service area of each hospital will not differ much with the change in traffic condition, the service area analysis for individual hospital was omitted for remaining congested and pedestrian traffic scenario.

### 3.5.2. Case2: Congested Traffic Scenario

Similar to normal traffic scenario, the service areas of hospitals for congested traffic scenario were calculated.

**Table 3.5.h: Congested Drive Time based Service Area of Multiple Level 1 Hospitals**

S.N.	Drive Time (Minutes)	Service Area (ha)	Population	Service Area (%)	Population (%)
1	0 - 15	589.4	106,994	9%	9%
2	15 - 30	2001.2	420,432	31%	34%
3	30 - 60	2909.6	576,985	45%	47%
4	60 - 90	940.2	123,292	15%	10%
5	90 - 120	18.2	2,238	0%	0.2%
	Total	6458.6	1,229,941	100%	100%

With the inclusion of congestion parameter, the accessibility of **Level 1** hospitals became more difficult to the largest group of population (Table 3.5.h & Map 12). The drive time limit also sharply increased from maximum 60 minutes to 120 minutes. 10% of total population is at higher risk, as their drive time to the hospitals takes more than 60 minutes i.e. above golden hour time requirement. The large group of this population lies at the southern part of LSMC and few around north-east and north-west part of KMC.

### 3.5.2.1. Service Area of All Level 1 and Level 2 Hospitals

**Table 3.5.i: Congested Drive Time based Service Area of Multiple Level 1 & 2 Hospitals**

S.N.	Drive Time (Minutes)	Service Area (ha)	Population	Service Area (%)	Population (%)
1	0 - 15	1717.8	330,787	27%	27%
2	15 - 30	3576.9	687,810	55%	56%
3	30 - 60	1125.4	204,595	17%	17%
4	60 - 90	38.5	6,749	1%	1%
		6458.6	1,229,941	100%	100%

The accessibility of hospitals is still within the desired time frame of less than 60 minutes (Table 3.5.i & Map 13).

### 3.5.2.2. Service Area of All Hospitals for Primary Treatment

**Table 3.5.j: Congested Drive Time based Service Area of All Hospitals for Primary Treatment**

S.N.	Drive Time (Minutes)	Service Area (ha)	Population
1	0 - 15	4070.2	809,180
2	15 - 30	1991.2	357,398
3	30 - 60	383.1	60,883
4	60 - 90	14.1	2,480

For congested driver time scenario, the primary treatment is still accessible within 60 minutes drive time and only 5% of population will have to drive for more than 30 minutes (Table 3.5.j & Map 14).

### 3.5.3. Case 3: Service Area based upon Pedestrian Time

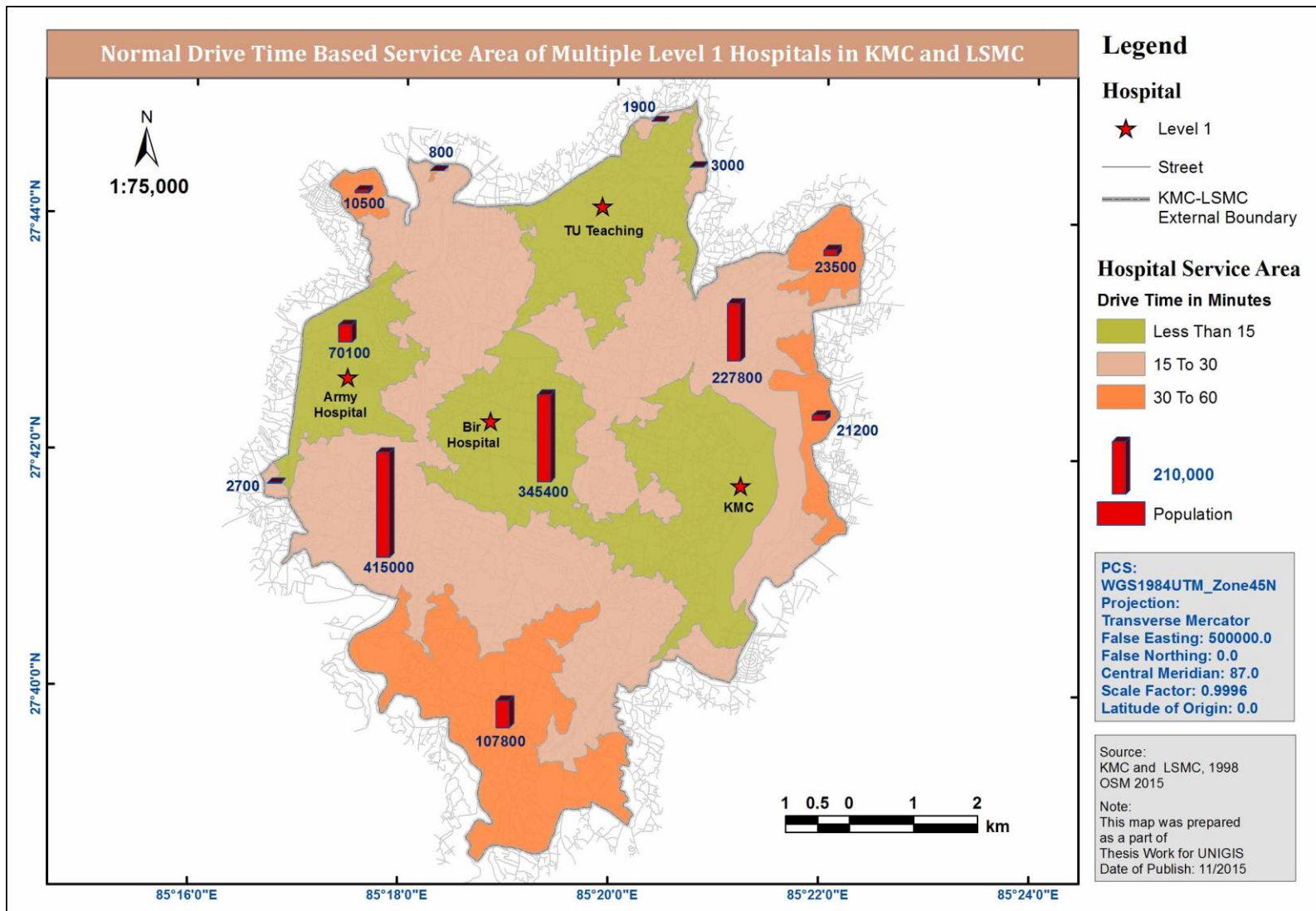
In case of road blockade scenario, the tertiary care can not be immediately accessed and it would be imperative to get initial stabilization first from the nearest hospital by reaching there on foot. Therefore, pedestrian time based service area for initial stabilization requirement was calculated by considering all the hospitals.

**Table 3.5.k: Pedestrian Time based Service Area of All Hospitals for Primary Treatment**

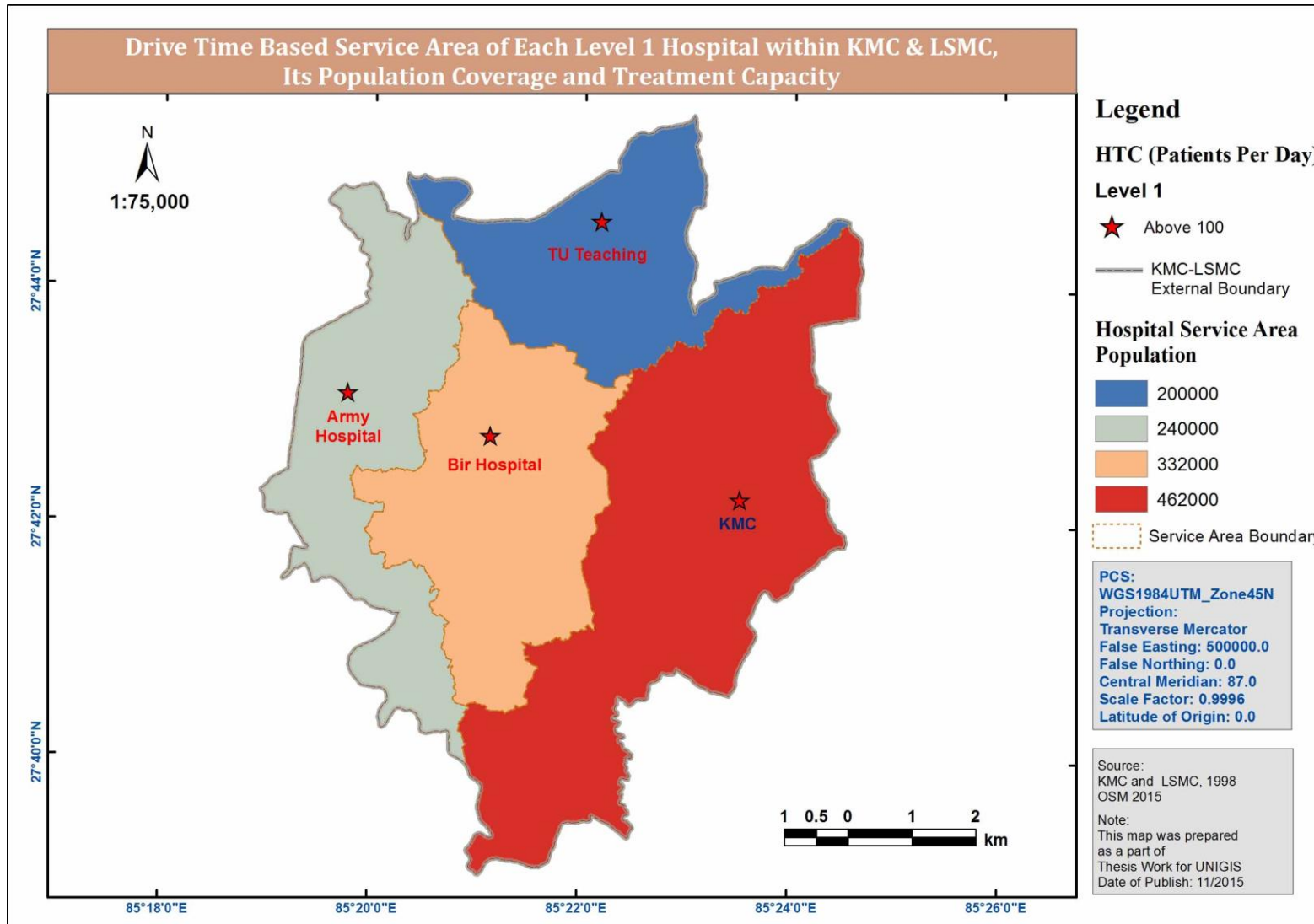
S.N.	Pedestrian Time (Minutes)	Service Area (ha)	Population	Service Area (%)	Population (%)
1	0 - 15	2914.1	598,362	45%	49%
2	15 - 30	2785.3	514,284	43%	42%
3	30 - 60	601.7	90,665	9%	7%
4	60 - 90	154.8	26,162	2%	2%
5	90 - 120	2.7	468	0%	0%
	Total	6458.6	1,229,941	100%	100%

For the 50% of the total population, the primary treatment can be accessible from the nearest hospital within 15 minutes on foot; another 40% will need 15 to 30 minutes; only 10% will have difficulty as they will require more than 30 minutes (Table 3.5.k & Map 15). In terms of service area, 45% of the study area is within 15 minutes drive time and next 40% within 15-30 minutes. Only 10% of service area falls beyond 30 minutes drive time. So it can be considered that people can get initial stabilization treatment within one hour time and thereby transferred to tertiary care unit if they have serious injury.

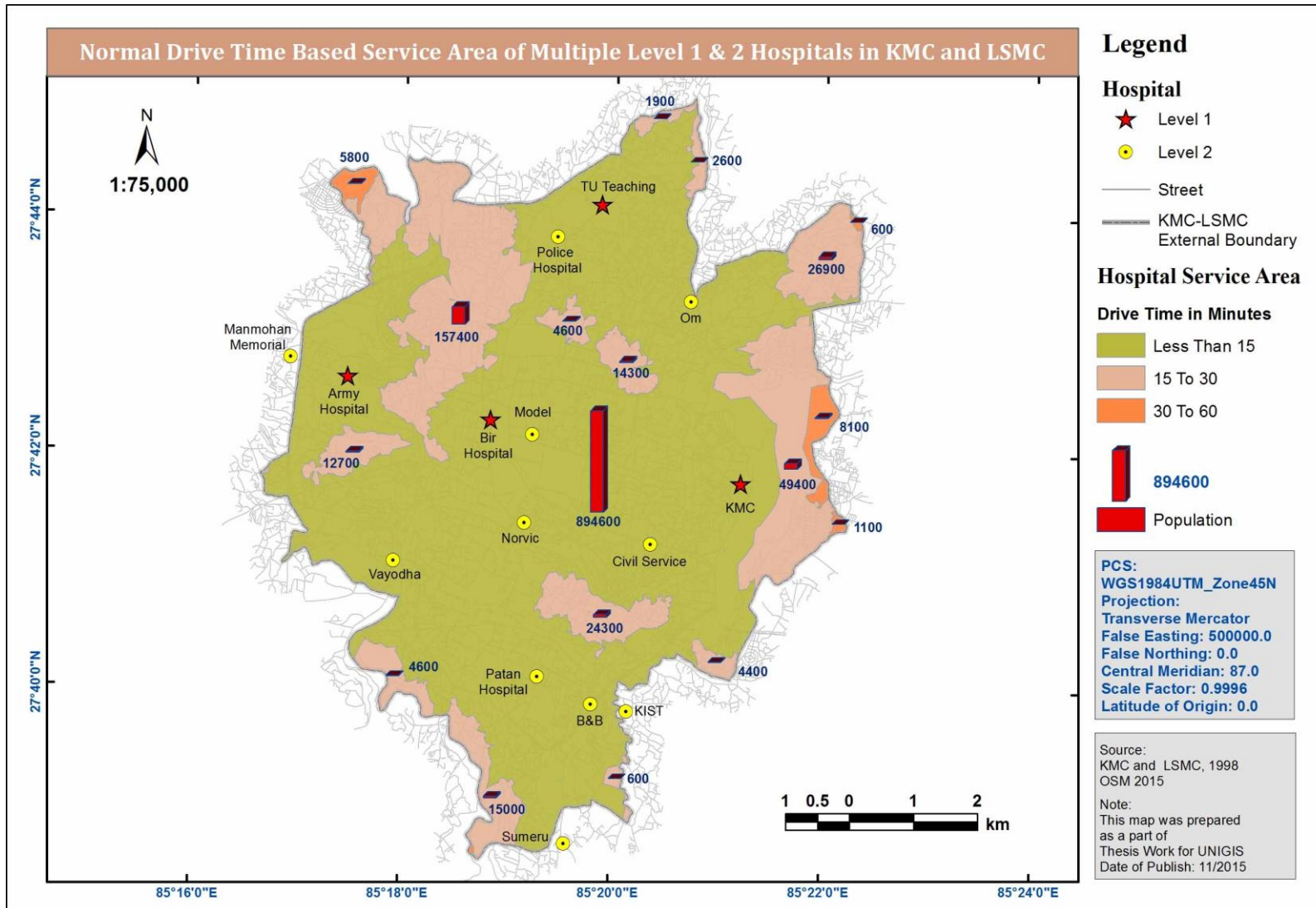
The maps prepared as a part of results of analysis have been listed in sequential order for comparative viewing.



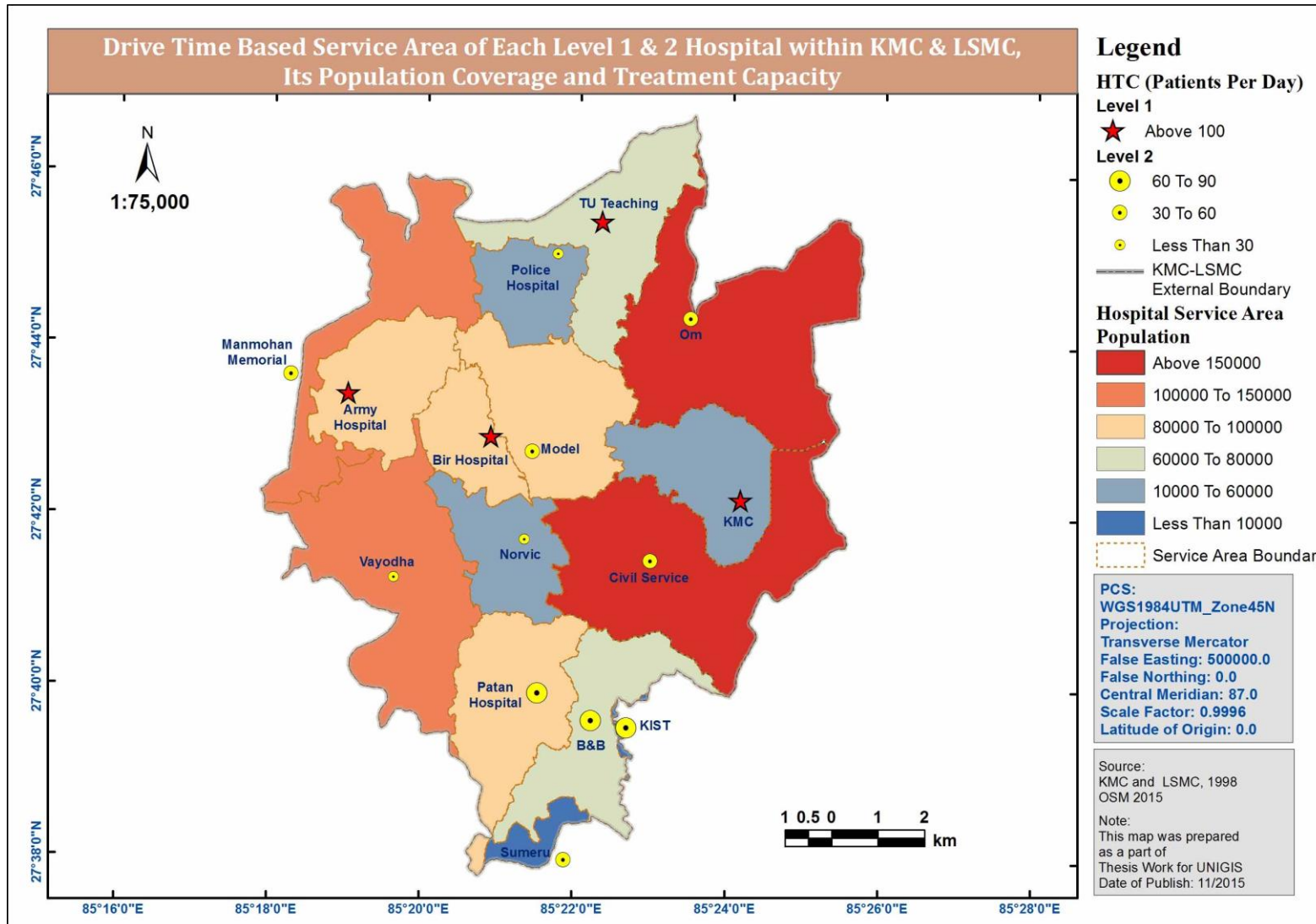
**Map 7: Drive Time Based (Normal Traffic) Service Area of Multiple Level 1 Hospitals in KMC and LSMC**



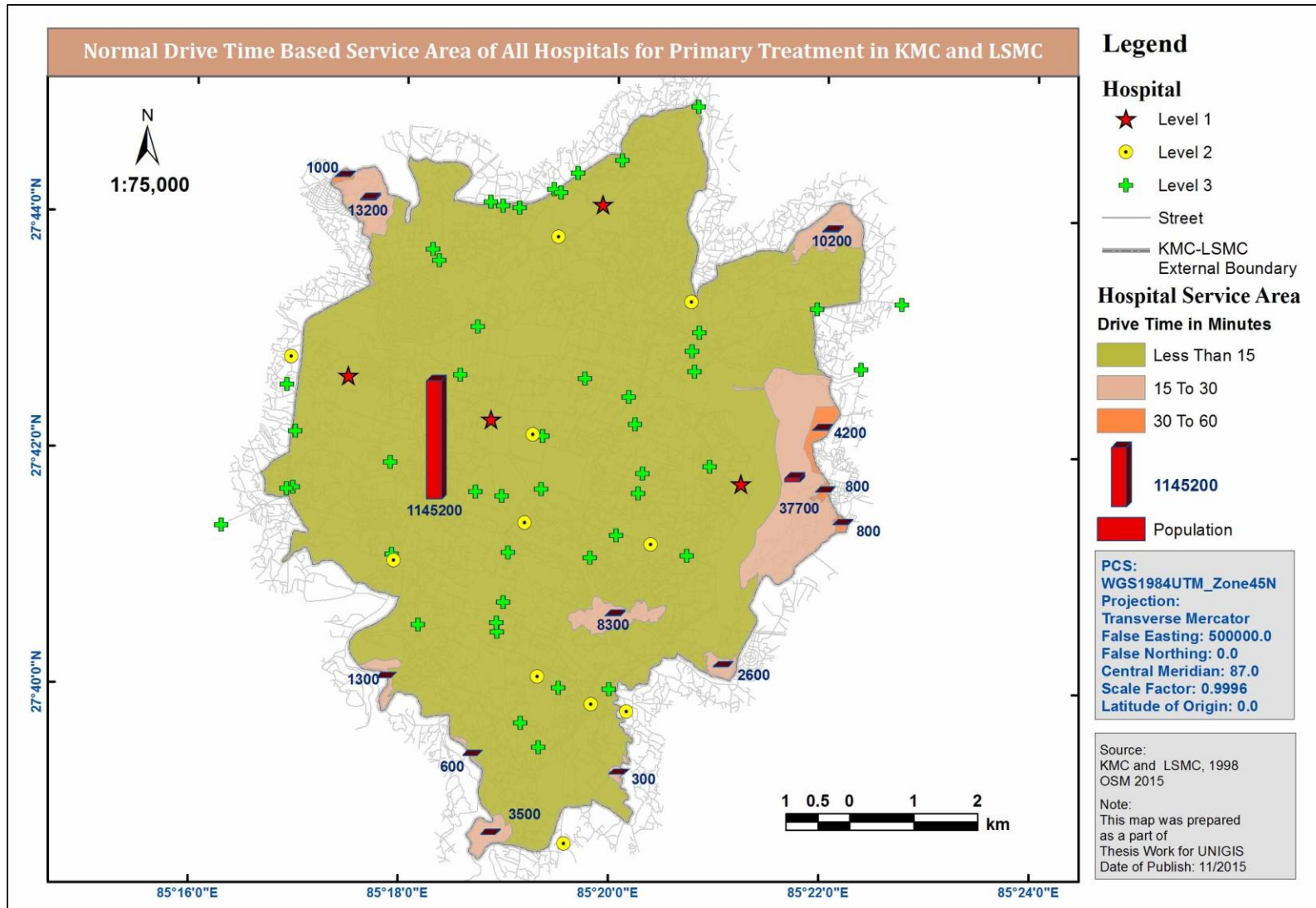
**Map 8: Drive Time Based Service Area of Each Level 1 Hospital, Its Population & Treatment Capacity**



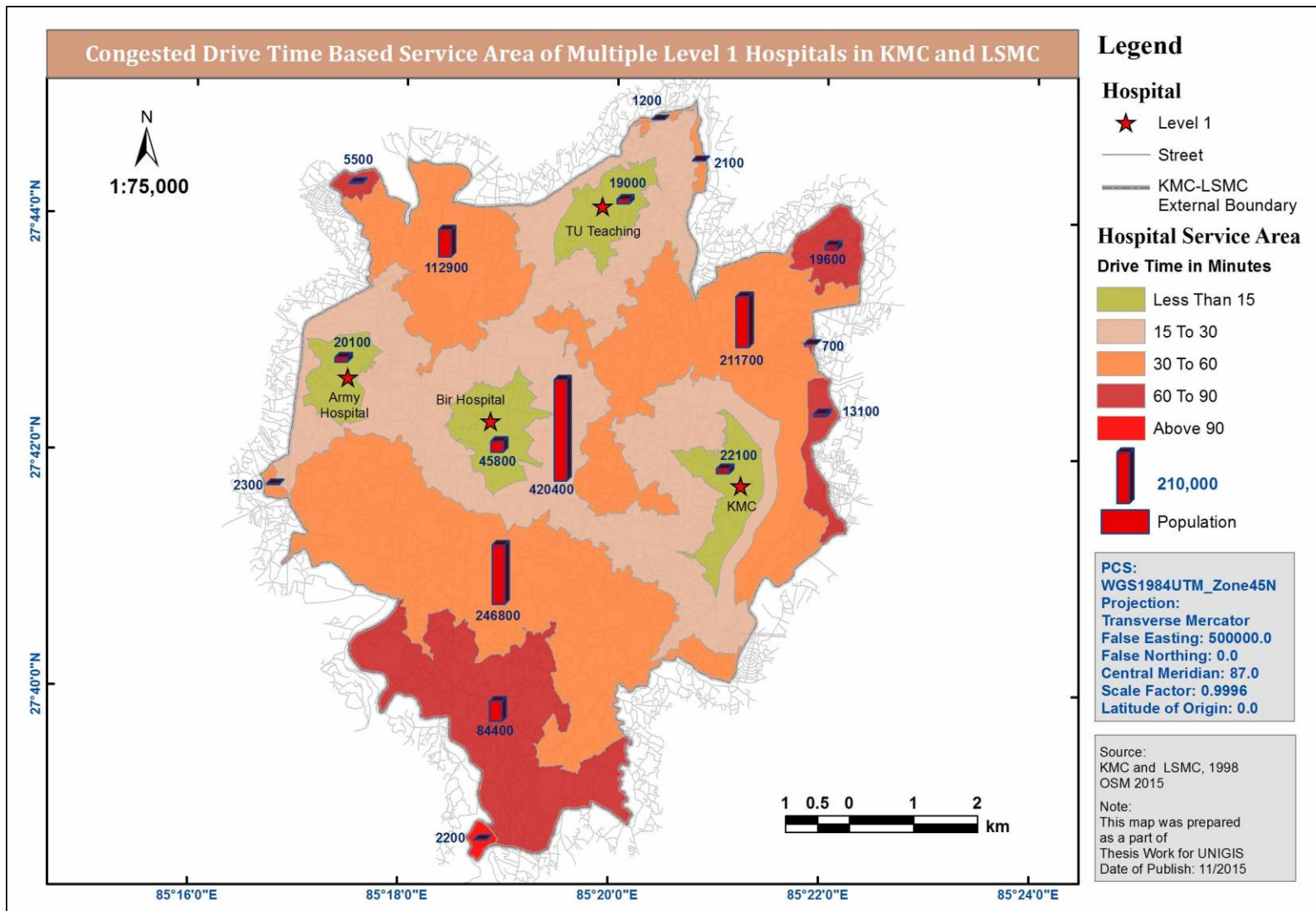
**Map 9: Drive Time Based (Normal Traffic) Service Area of Multiple Level 1 & 2 Hospitals in KMC and LSMC**



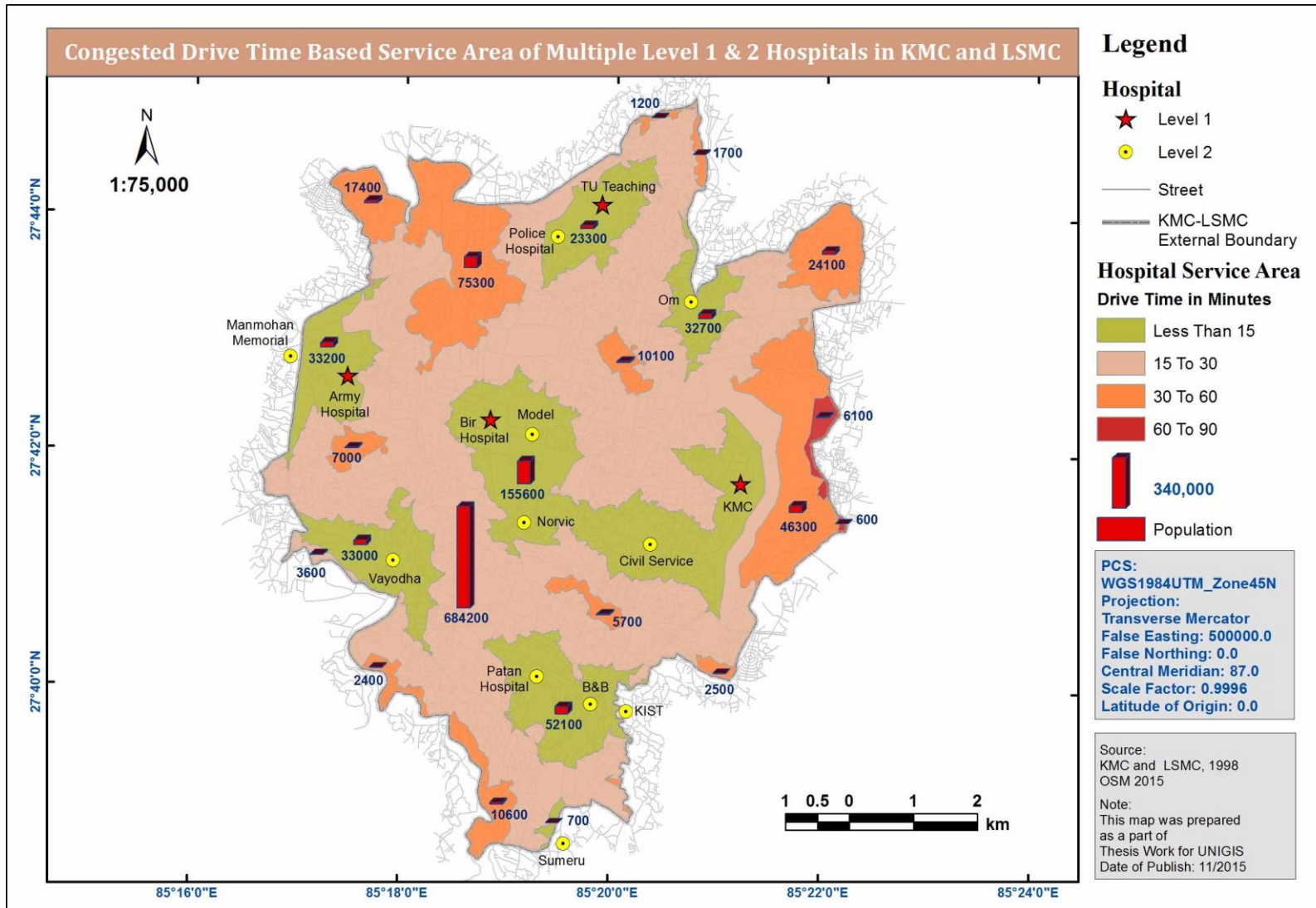
Map 10: Drive Time Based Service Area of Each Level 1 & 2 Hospital, Its Population & Treatment Capacity



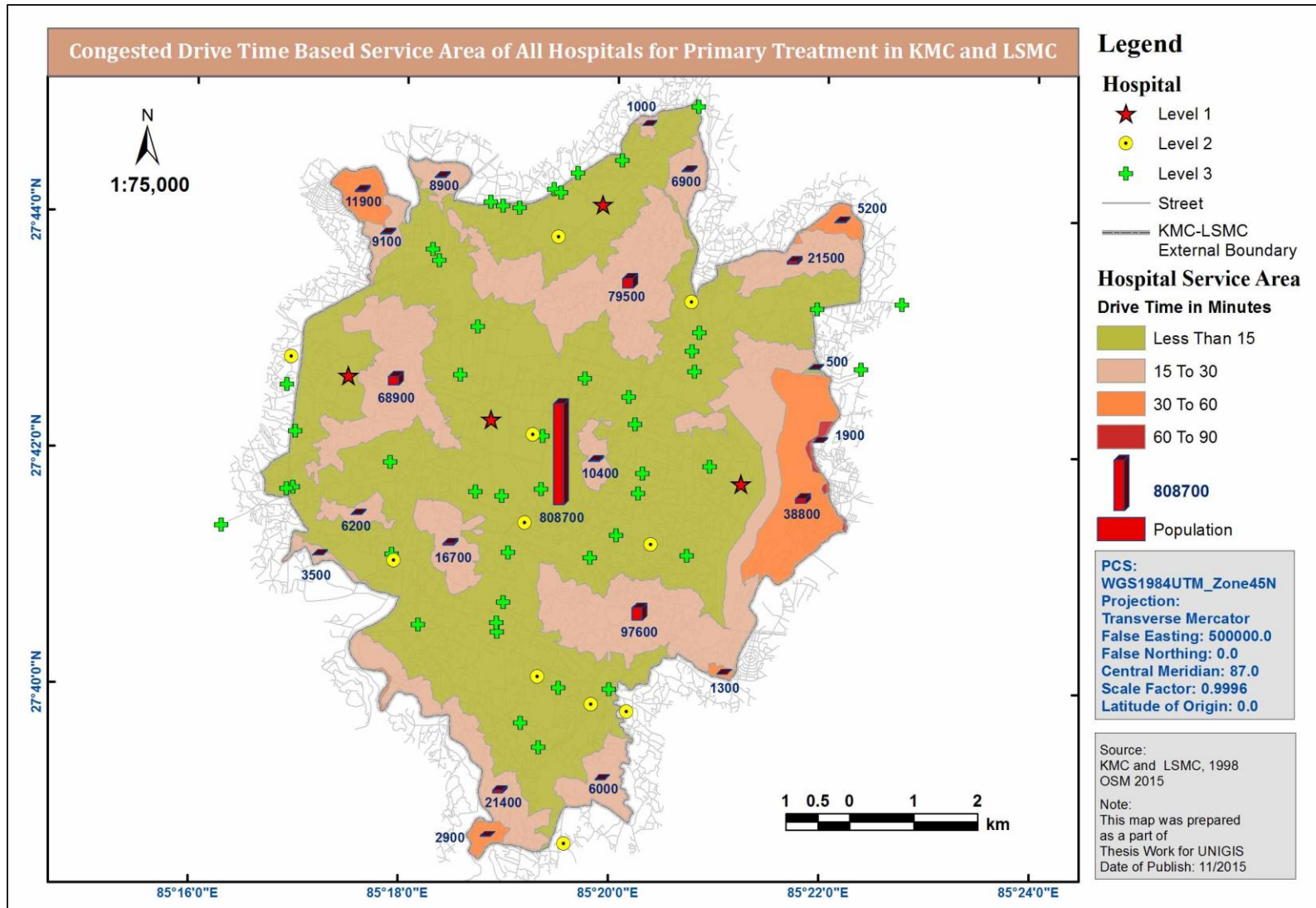
**Map 11: Drive Time Based (Normal Traffic) Service Area of All Hospitals in KMC and LSMC**



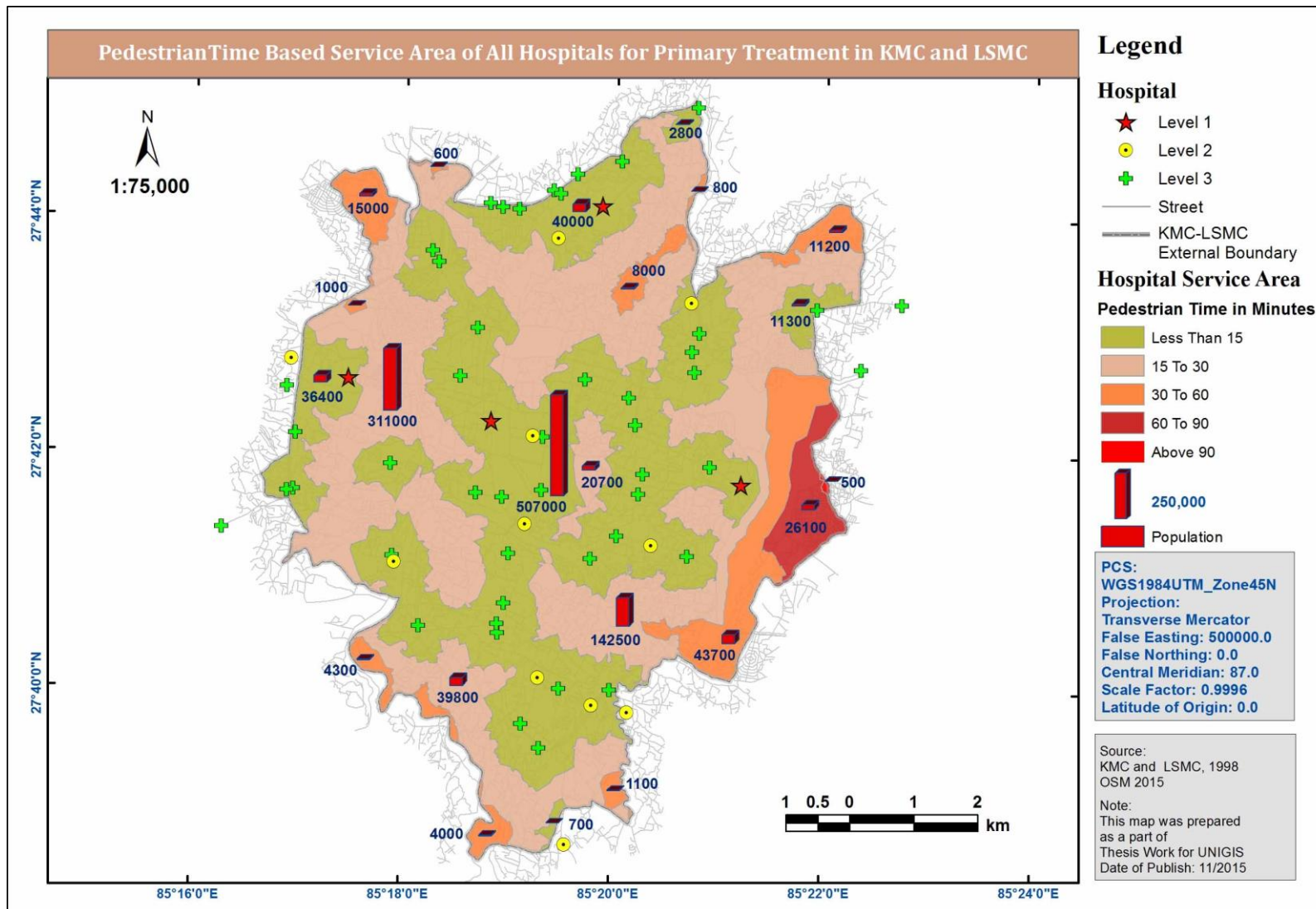
Map 12: Drive Time Based (Congested Traffic) Service Area of Multiple Level 1 Hospitals in KMC and LSMC



Map 13: Drive Time Based (Congested Traffic) Service Area of Multiple Level 1 & 2 Hospitals in KMC and LSMC



**Map 14: Drive Time Based (Congested Traffic) Service Area of All Hospitals in KMC and LSMC**



Map 15: Pedestrian Time Based Service Area of All Hospitals in KMC and LSMC

### 3.6. Assessment of Emergency Scenario of Hospitals on 25<sup>th</sup> April, 2015 Earthquake

Earthquake scenario was assessed based upon the service status, number of emergency patients and building condition of hospitals.

#### 3.6.1. Building Condition

The building condition of hospitals, including 4 hospitals which were not surveyed because of their non-operational status can be summed up as follows

**Table 3.6.a: Building Condition of Hospitals after 25<sup>th</sup> April 2015 Earthquake**

Building Condition	Count	%
Collapsed	1	2%
Currently Non Operational	3	5%
Severely Damaged	1	2%
Partially Damaged	19	29%
Safe	41	63%
Total	65	100%

The 40% of the hospitals have suffered some form of damage due to earthquake, with 10% hospitals having serious damages (Table 3.6.a).

#### 3.6.2. Service Status

Out of 62 hospitals surveyed, only one hospital was unable to offer its service due to collapse of adjacent building. However, it was found that none of the hospitals were able to give its service inside its building, other than in ground floor due to effect of continuous aftershocks of earthquake. Therefore, the emergency service was offered by setting up tents in the nearby available open space. The hospitals had to spent considerable time in

evacuating the inpatients and arranging for alternate space before resuming emergency service.

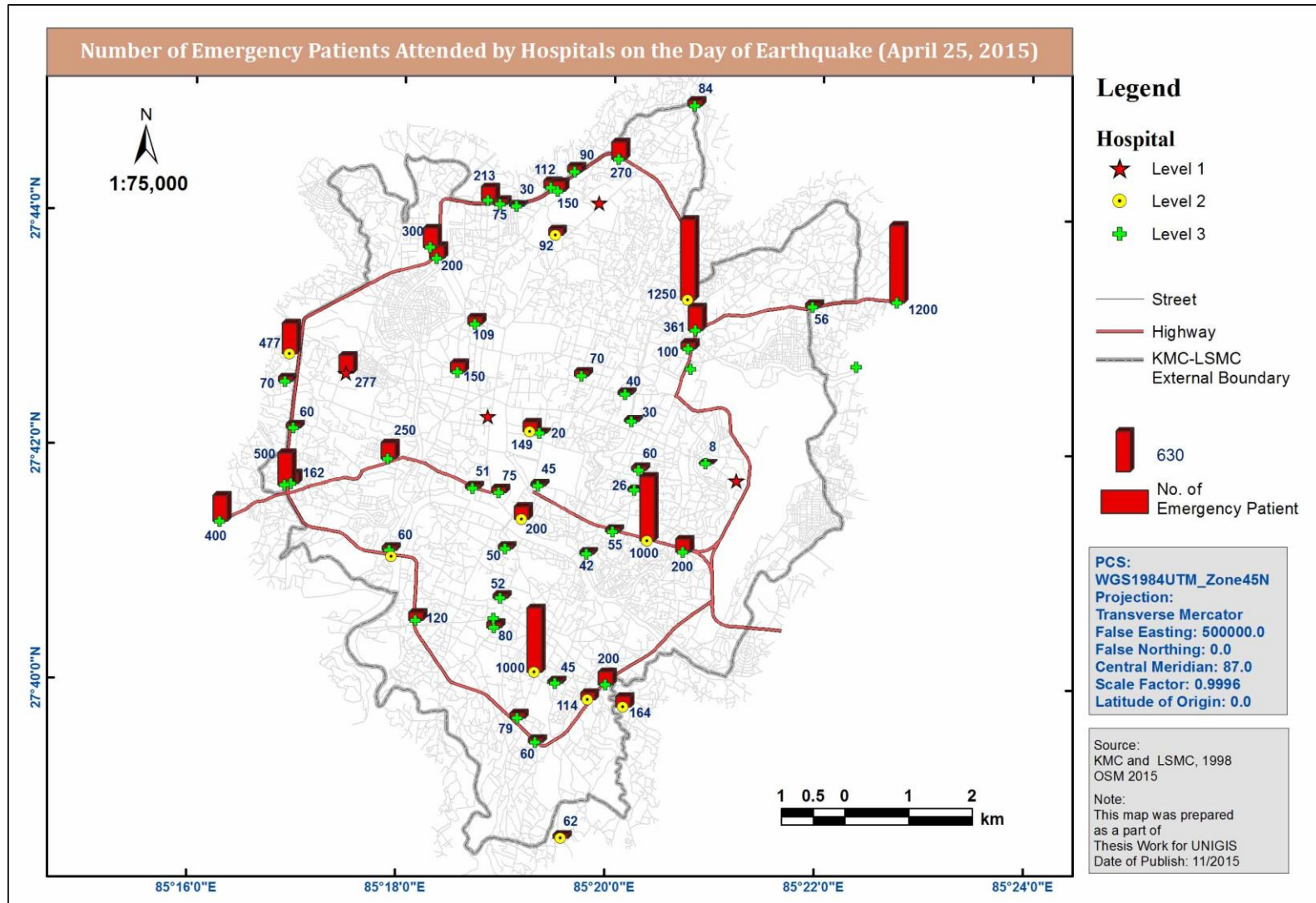
### 3.6.3. Number of Emergency Patient Reported

Out of 62 hospitals, the records of emergency patients were made available from 57 hospitals, which can be tabulated as follows

**Table 3.6.b: Emergency Patients in Hospitals on 25<sup>th</sup> April 2015 Earthquake**

Number of Emergency Patients	Count
Above 1000	4
400-500	3
300-400	2
200-300	8
100-200	11
50-100	19
20-50	9
Below 20	1
Total	57

The maximum number of patients reported was 1250; however the average number of patients can be considered as 200 (Table 3.6.b & Map 16). The total number of emergency patients reported was around 14,000 approximately, which is 1% of the total population of the study area. It was observed that the number of patients reported in each hospital was not uniform, and was highly reliant upon the proximity to site of casualty, irrespective of the type of hospital. Mainly the hospitals on the north east side of KMC have higher emergencies, and it can be attributed to the mass casualty of nearby Sankhu area.



**Map 16: Number of Emergency Patients Attended by Hospitals on the Day of Earthquake (April 25, 2015)**

## Chapter- 4. Discussion

The spatial distribution of hospitals within KMC and LSMC can be considered abundant; especially its distribution along the highway is prominent. Almost all the hospitals are accessible by good roads; with 41 out of 62 hospitals being near the highways and primary roads. However, the scenario becomes gloomy when we focus mainly on tertiary treatment required for trauma related to earthquake. Only 4 out 62 hospitals are deemed to have all the necessary human resources, equipment and supplies, whereas other 11 hospitals have enough resources but limited human resources to cater for burn and neurosurgical cases.

Even though the number of tertiary treatment is limited to 15, they are accessible to victims within one hour drive time. The primary level of treatment can be reached within 15 minutes drive time. During the congested traffic scenario, the accessibility of hospitals is still within one hour drive time. However, if the **Level 1** hospitals are to be accessed, a small portion of population within the study area has to drive more than 60 minutes. This puts the 10% of the total population at the risk of not being able to access the desired emergency service. In case of road blockage, the nearest available hospital can be reached within 30 minutes on foot; he/she can then be transferred to **Level 1** hospital after getting initial stabilization. Therefore, the spatial accessibility of hospitals can be considered reasonably good.

Next, the HTC of hospitals is a matter of concern; it is less than 0.1% of the total population. The catchment / service area of each **Level 1** hospital accommodates population of 200000 to 400000. On the other hand, **Level 1** and **Level 2** hospitals taken jointly have catchment area of population as low as 1500 and as high as 180000,

indicating their uneven spatial distribution. This situation further becomes grave, as the hospitals having high population catchment have lowest HTC.

During 25th April 2015 earthquake, the average number of emergency patients reported stands at 200 and maximum number at 1000. The average HTC for trauma support care was identified as 6 patients per hour, which is 3% and 0.6% of average and maximum number of emergency patients reported. Therefore, these factors suggest that the availability of emergency service to the victims will be questionable even though they reach the hospitals within one hour drive time. Further, for this recent earthquake, the total number of emergency patients reported is only 1% of the total population. So if this number increase by slight margin say another 1%, the scenario will be totally different or in other words, extremely serious.

The emergency preparedness of hospitals was found to be reasonable with up to 60% of hospitals having emergency plan and surge capacities. However, it was also observed that 40% of the hospital buildings were damaged due to April earthquake. In such scenario, the primary concern of emergency management would be diverted to the safety of hospital inpatients as well as managing of alternate care site. Therefore, the ability of hospitals to provide prompt emergency service becomes doubtful. Further, the damage of 40% hospitals, irrespective of degree of damage, is a matter of serious concern regarding the safety of hospital buildings. Mainly the hospitals are offering their service in rented buildings not designed for the purpose of hospital, so it is not known what the structural quality is. Also it is not clear whether self constructed hospital buildings have followed engineering standards and municipal regulations. Therefore, for the emergency preparedness, the stability of hospital buildings and setting up of alternate care site should be a top priority.

## Chapter- 5. Conclusion

Considering the past history of large earthquakes in Nepal, the susceptibility of the region to future earthquakes and its damaging effects is unavoidable. The need of research in better emergency preparedness for earthquake scenario is thus crucial. Since disaster situation can be mapped and analyzed using GIS, it plays a central role in emergency management and related studies. The study was performed with the perspective of implementing GIS to model the drive time based catchment areas of hospitals, and thereby recognize its accessibility to the percentage of population that is mostly likely to depend upon it for emergency services during earthquake.

The study mainly focused on

- The availability of hospitals with necessary human resources and equipment for trauma related to earthquake, their categorization for different levels of treatment and their treatment capacity.
- The accessibility of hospitals through road network via four wheelers like car, van, jeep etc. as well as pedestrian mode for various traffic scenarios.
- The comparison of catchment area population of different level of hospitals and their treatment capacity.
- The emergency preparedness of each hospital.
- The actual emergency service scenario in hospitals on 25th April, 2015 earthquake.

The study has been conducted by gathering appropriate data, thereby organizing and analyzing them using GIS software and tools. The study has come up with results and maps necessary for better emergency preparedness in coming days. Though the earthquake scenario modeled in the study may not exactly match the actual emergency

situation, it has been able to portray the overall scenario of accessibility of hospitals; highlight shortcomings in emergency services and emergency preparedness.

The study has demonstrated how change in drive time affects the accessibility of hospitals, and on the other hand, the most easily accessible hospital may not be the suitable one for the treatment of earthquake related trauma. Though there are overwhelming numbers of hospitals within the study area i.e., KMC and LSMC; when the need for tertiary level of care arises, these numbers drop down to 4 and up to 15 with some limitations. Overall, the hospitals in the study area are accessible through well paved roads and within drive time of one-hour, which is considered vital for saving the trauma victim's life. Only 10% of total population is at higher risk, as their drive time to the hospitals takes more than 60 minutes during congested driving scenario. The time required to access the nearest available hospital on foot is also less than 30 minutes. Therefore, the spatial accessibility of hospitals can be considered reasonably good even during disaster scenario like earthquake. However, even though hospitals are physically accessible, the other three factors a) medical staffs, b) emergency preparedness and c) the impact of earthquake are largely limiting the accessibility to the first aid measures or trauma life support. The most important factor that has surfaced from this study is that 75% of the hospitals did not have full time surgeons and anesthesiologists necessary for trauma treatment, despite having necessary equipments and supplies. The HTC for tertiary level of treatment was found to be 0.03% of total population. Also the average HTC per hour of major hospitals can cater for only 3% of the average number of emergency patients reported on the day of 25<sup>th</sup> April 2015 earthquake. On the other hand, the total number of emergency reported on that day is only 1% of the total population. Therefore, even the slightest increase of 1% casualties in future earthquakes will create a chaotic emergency scenario. The limitation within the tertiary level of treatment is thus a matter of serious concern that needs to be addressed immediately. Further, the observed

impact of earthquake on 40% of hospital buildings makes the functioning and stability of hospitals in such scenario questionable. In such scenario, the management of inpatients and setting up alternate care site demanded more attention compared to the catering of emergency patients. However, the intake of emergency patients is also of equal importance if not higher. Therefore, the emergency preparedness should give top priority in setting up alternate care site, managing inpatients, catering of emergency patients and safety of hospital buildings.

Overall the accessibility of hospitals in terms of spatial access is good and the availability of supplies and equipments can be considered satisfactory. However, the necessity to increase the Hospital Treatment Capacity and embrace better disaster management practices is largely felt. The need of better emergency preparedness therefore demands not much; but the availability of full time surgeons and related medical staffs at the hospitals, well-constructed hospital buildings and an emergency plan to swiftly evacuate inpatients and setting up alternate care site.

To conclude, the maps of this study can be utilized by government officials and planners, health care providers, emergency response teams and general public to understand the location specific situation during earthquake scenario. Mainly the general public and emergency response team can identify the location of their interest, and the accessibility of suitable hospitals based upon one's need from that point. The health care providers can identify the overall catchment area of their hospital, the population it commands, and the necessary improvements required to cater the likely demand. The government officials and planners can understand the existing emergency service scenario, and thereby formulate the policies and take measures to improve the overall emergency preparedness in coming days. Finally, the information garnered from this study is also extendable to other surgical emergency cases, but not to medical emergencies.

## Chapter- 6. Limitations of the Study

The study has been conducted within the short duration of time with available primary data of hospital information and GIS related secondary data. The field survey for the collection of hospital information had been done within the period of 13<sup>th</sup> July to 4<sup>th</sup> August, 2015. Therefore, any additional information or changes occurring past these dates have not been covered in the study.

Hospital information was collected from the related officials, doctors and matron, and has been used in the study as provided. The information that was not disclosed and considered inappropriate for public sharing, have not been incorporated in the study. For instance, the human resource details of Army hospital has not been included in the study as well as number of emergency patients on the day of earthquake was unavailable from few hospitals. Almost all the hospitals that could be located within the study area have been surveyed, except two hospitals which declined to give necessary information.

The study has not been carried out from the perspective of medical research. Therefore, it deals with medical details superficially based upon the literature review. No field verification has been done to validate the method of calculation of hospital treatment capacity and other tools used in the study as well as the results obtained from their use.

For network data, the Open Street map data has been used and its verification and update has been done based on Google Earth image. Because speed limit data were not available for roads of Kathmandu and Lalitpur, travel speeds were estimated by first categorizing the road into different hierarchies. However, no uniform methods were available for classification of urban roads, so the liberty has been taken to classify the road according to the necessity of study. Identification of the type of the roads was done

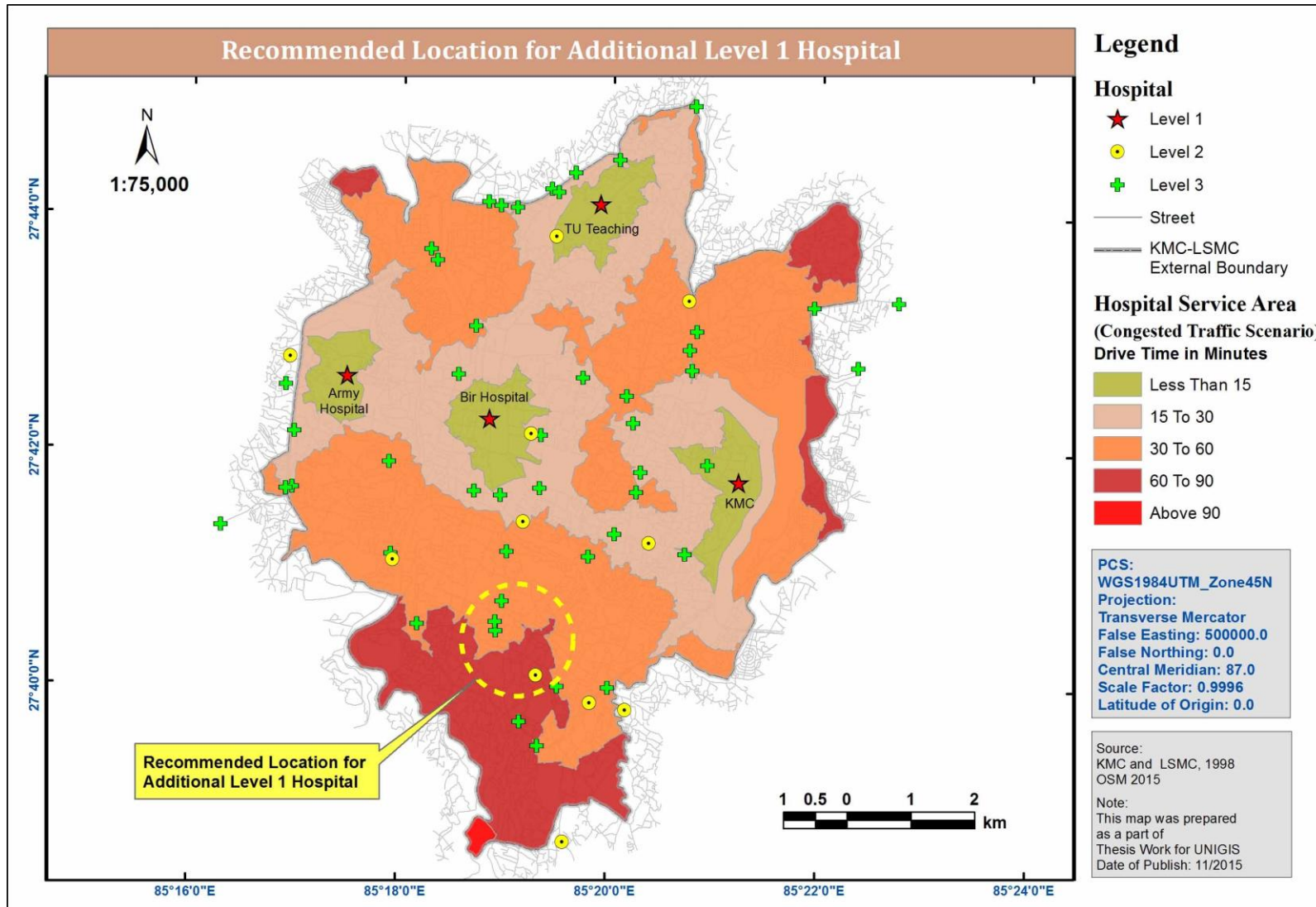
based upon the information provided by the local residents of respective areas, and the observed and anticipated traffic volume. The estimation of true speed of each segment of road based upon road surface type is beyond the scope of this study. However, when the travel time between various points within the study area was tested, it gave fairly accurate timing for normal traffic scenario.

The service area of hospitals calculated in the study is based upon network analyst tool available in ArcGIS. Though this method is considered fairly accurate, it is not without uncertainty. Therefore, the service area polygons constructed from the network based data model can be considered as approximation for the given travel speed. Also the total population count of the study area varied slightly over different traffic scenario due to inconsistencies along the boundary of service area formed.

## Chapter- 7. Recommendations

On the basis of this study, the following recommendations can be made for the better accessibility of emergency services during earthquake

- The nonexistence of fulltime doctors in most of the hospitals has made the accessibility of emergency service questionable even though the hospitals are reachable within an hour's time. But still the presence of hospitals which are well equipped can be considered overwhelming in numbers. Therefore, the provision of at least one or two full-time doctors such as surgeons, orthopedics and other specialist doctors necessary for trauma treatment in these hospitals would make the emergency service largely accessible. The government officials should bring out policy to make this provision mandatory based upon the size and capacity of hospitals. On the other hand, hospitals should look forward in this direction to make their emergency services more adept and promptly available. Further, the availability of **Level 1** emergency service for the people in the southern block of LSMC is critical. Therefore, either existing hospitals should be upgraded or a new hospital should be established for **Level 1** emergency service in the mid southern part of LSMC (Map17).
- During mass casualty scenario of earthquake, the victims have to be transported to hospitals mainly through onsite available either private or public vehicles. This not only overcomes the problem of availability of limited number of ambulances, but also saves time of transportation as time required for ambulance to reach the patient can be cut down. Therefore, the government should come out with measures to make the passage of these vehicles swifter in emergency scenario. This can be done by making it mandatory for all the vehicles to carry temporary emergency sirens, so that they can be identified and given priority in case they are carrying the victims. Next, prohibiting traffic aftermath of earthquake will enable emergency vehicles to move freely.



**Map 17: Recommended Location for Additional Level 1 Hospital**

- It was observed that no hospitals could operate inside their existing building due to regular aftershocks of earthquake. Therefore, the provision of alternate care site such as tents and mobile treatment units should be made in each hospital. The focus of emergency preparedness training should be also on setting up alternate care site and evacuating the inpatients. Since it would be difficult to setup alternate operation theaters, it should be made mandatory that while constructing the hospitals, these important units be made more earthquake resistant.
- Since most of the hospitals are operating under rented buildings constructed for the residential purpose, their stability during earthquake is highly questionable. The retrofitting techniques must be adopted for these buildings to make them more resilient during earthquakes. Also government should come up with proper standard for hospital building construction and strictly enforce it. However, it would be unfair to impose only rules and regulations from government side; the government should also provide enough subsidy and resources to make it practically viable.
- The uneven distribution of emergency patients in the hospitals on 25th April 2015 earthquake showed that victims approached the nearby hospitals irrespective of their treatment capacity and capability. Therefore, for better emergency preparedness, the public should know in advance about the nearest hospital suitable for the treatment of type of injury they have incurred. The maps prepared in this study or the better one should be made available to the public to create awareness about the type of hospital, their capacity and proximity based on drive time. Next, each hospital should have sufficient primary stabilization kit sufficient for at least 50 to 100 patients. Further, the nearby hospitals should have good networking with each other, so that critical patients can be referred to **Level 1** or **Level 2** hospitals, and not so critical patients to **Level 3** hospitals. This will help to uniformly distribute the patients among the hospitals within particular geographical limit; avoiding over burdening on single hospital. Since most of the **Level 3** hospitals have ambulance service, they should

have prior knowledge about the nearest **Level 1** and **Level 2** hospitals for them. This would enable speedy transfer of critical patients for tertiary care after primary stabilization.

## References

**ArcGIS Desktop Help 10.0, 2015**, *About the ArcGIS Network Analyst tutorial*. [Online] Retrieved August 13, 2015, from [http://help.arcgis.com/EN/ArcGISDesktop/10.0/help/index.html#/About\\_the\\_ArcGIS\\_Network\\_Analyst\\_tutorial/00470000005r000000/](http://help.arcgis.com/EN/ArcGISDesktop/10.0/help/index.html#/About_the_ArcGIS_Network_Analyst_tutorial/00470000005r000000/)

**Aydan, Ö., & Ulusay, R., 2015**, *A Quick Report On The 2015 Gorkha (Nepal) Earthquake and Its Geo-Engineering Aspects*. [Online] Retrieved September 11, 2015 from [http://www.iaeg.info/wp-content/uploads/QuickReport\\_2015NepalEarthquake\\_Aydan\\_Ulusay\\_IAEG.pdf](http://www.iaeg.info/wp-content/uploads/QuickReport_2015NepalEarthquake_Aydan_Ulusay_IAEG.pdf)

**Boer, D. J. de, & Dubouloz, M., 2000**, *Handbook of Disaster Medicine*. [Online] Retrieved September 22, 2015 from <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2763653/>

**Burrough P. A., McDonnell, R. A., 1998**, *"Principles of Geographical Information Systems"*, pp.11.Oxford University Press, New York. [Online] Retrieved September 26, 2015 from <http://dds.cepal.org/infancia/guide-to-estimating-child-poverty/bibliografia/capitulo-IV/Burrough%20Peter%20A%20y%20McDonnell%20Rachael%20A%20%281998%29%20Principles%20of%20geographical%20information%20systems.pdf>

**CBS, 2014: National Population and Housing Census 2011**. [Online] Retrieved November 26, 2014 from [http://cbs.gov.np/wp-content/uploads/2012/11/VDC\\_Municipality.pdf](http://cbs.gov.np/wp-content/uploads/2012/11/VDC_Municipality.pdf)

**Chokotho, L., Jacobsen, K. H., Burgess, D., Labib, M., Le, G., Lavy, C. B. D., & Pandit, H. , 2015**, *Trauma and orthopaedic capacity of 267 hospitals in east central and southern Africa*. [Online] Retrieved September 28, 2015 from [http://doi.org/10.1016/S0140-6736\(15\)60812-1](http://doi.org/10.1016/S0140-6736(15)60812-1)

**Cinnamon, J., Schuurman, N., & Crooks, V.A., 2008**, *A method to determine spatial access to specialized palliative care services using GIS*. [Online] Retrieved June 29, 2015 from <http://www.biomedcentral.com/1472-6963/8/140>

**DeBoer, J., 1995**, *"Order in Chaos: Modeling medical disaster management"*, pp.7-159. [Online] Retrieved July 7, 2015 from <http://www.eird.org/isdrbiblio/PDF/Order%20in%20chaos.pdf>

**Delamater, P. L., Messina, J. P., Shortridge, A. M., & Grady, S. C., 2012**, *Measuring geographic access to health care: raster and network-based methods*. *International Journal of Health Geographics*, 11(1), pp. 15. [Online] Retrieved June 29, 2015 from <http://doi.org/10.1186/1476-072X-11-15>

**DeLia, D., 2007**, *Hospital capacity, patient flow, and emergency department use in New Jersey*. Rutgers Center for State Health Policy. [Online] Retrieved September 6, 2015 from [http://newjersey.gov/health/rhc/documents/ed\\_report.pdf](http://newjersey.gov/health/rhc/documents/ed_report.pdf)

**Department of Roads, 2013**, *Nepal Road Standard*. [Online] Retrieved June 28, 2015 from <http://www.dor.gov.np/documents/Nepal%20Road%20Standard%20-2070.pdf>

**Development of Trauma Center in Nepal, n.d.** [Online] Retrieved September 22, 2015 from <http://www.healthnet.org.np/article/orthopedic/rks.html>

**Dewar, R., 2002,** *Pedestrians and Bicyclists, Human Factors in Traffic Safety.* Lawyers & Judges Publishing Company, Tucson, AZ. [Online] Retrieved September 26, 2015 from <https://www.fhwa.dot.gov/publications/research/safety/pedbike/05085/chapt8.cfm>

**Dinh, M. M., Bein, K., Roncal, S., Byrne, C. M., Petchell, J., & Brennan, J., 2013,** *Redefining the golden hour for severe head injury in an urban setting: The effect of prehospital arrival times on patient outcomes.* *Injury*, 44(5), pp.606–610. [Online] Retrieved September 6, 2015 from <http://doi.org/10.1016/j.injury.2012.01.011>

**ESRI 2015,** *Algorithm used by the ArcGIS Network Analyst Extension.* ArcGIS 10.2 Help: Release 10.2 Redlands, CA: Environmental Systems Research Institute

**ESRI 2015,** *Network Analysis.* ArcGIS 10.2 Help: Release 10.2 Redlands, CA: Environmental Systems Research Institute

**ESRI 2015,** *Service Area Analysis.* ArcGIS 10.2 Help: Release 10.2 Redlands, CA: Environmental Systems Research Institute.

**Fatalities per district as of 28.04(10.30am), Nepal Government Figures, 2015.** [Online] Retrieved October 7, 2015 from <http://www.earthquake-report.com/wp-content/uploads/2015/04/Screen-Shot-2015-04-28-at-12.35.14.png>

**Fresh List of Medical Centers in Nepal - iCareNepal, 2015.** [Online] Retrieved July 10, 2015 from <http://icarenepal.com/medical-directory/clinics/57-fresh-list-of-medical-centers-in-nepal>

**Government of India - UNDP DRM Programme, 2008,** *"Guidelines for Hospital Emergency Preparedness Planning."* pp.8-28. [Online] Retrieved July 2, 2015 from [http://sdmassam.nic.in/pdf/publication/undp/guidelines\\_hospital\\_emergency.pdf](http://sdmassam.nic.in/pdf/publication/undp/guidelines_hospital_emergency.pdf)

**Gongal, R., & Vaidya, P., 2012,** *Responding to the need of the Society: Nepal Ambulance Service.* *Journal of Institute of Medicine*, 34(1), pp.1. [Online] Retrieved June 28, 2015 from <http://www.nepjol.info/index.php/JIOM/article/download/9114/7482>

**Government of Nepal, Ministry of Home Affairs, 2015.** [Online] Retrieved July 2, 2015, from <http://www.moha.gov.np/home>

**Govt approves 72 new municipalities (with list), 2014.** [Online] Retrieved September 19, 2015 from [http://www.setopati.net/society/1583/Govt-approves-72-new-municipalities-\(with-list\)/](http://www.setopati.net/society/1583/Govt-approves-72-new-municipalities-(with-list)/)

**Haupt, M. T., Bekes, C. E., Brill, R. J., Carl, L. C., Gray, A. W., Jastremski, M. S., ... Md, M. H., 2003,** *Guidelines on critical care services and personnel: Recommendations based on a system of categorization of three levels of care\*: Critical Care Medicine*, 31(11), pp. 2677–2683.[Online] Retrieved July 2, 2015 from <http://doi.org/10.1097/01.CCM.0000094227.89800.93>

**Hudsal, J., 2011**, *Network analysis – raster versus vector – A comparison*. [Online] Retrieved July 2, 2015 from <http://www.hudsal.com/1999/10/11/network-analysis-raster-versus-vector-a-comparison-study/>

**In Wikipedia, 2015**, *Golden hour (medicine)*. [Online] Retrieved April 18, 2015 from [https://en.wikipedia.org/w/index.php?title=Golden\\_hour\\_\(medicine\)&oldid=657019584](https://en.wikipedia.org/w/index.php?title=Golden_hour_(medicine)&oldid=657019584)

**In Wikipedia, 2015**, *Trauma center*. [Online] Retrieved June 19, 2015 from [https://en.wikipedia.org/w/index.php?title=Trauma\\_center&oldid=667681185](https://en.wikipedia.org/w/index.php?title=Trauma_center&oldid=667681185)

**In Wikipedia, 2015**, *Walking*. [Online] Retrieved September 17, 2015 from <https://en.wikipedia.org/w/index.php?title=Walking&oldid=681462544>

**Joseph, A. E., & Phillips, D. R., 1984**, *Accessibility and Utilization: Geographical Perspectives on Health Care Delivery*. [Online] Retrieved July 1, 2015 from <http://onlinelibrary.wiley.com/doi/10.1111/1467-9566.ep10831418/pdf>

**Khan, A., Zafar, H., Naeem, S. N., & Raza, S. A., 2010**, *Transfer delay and in-hospital mortality of trauma patients in Pakistan*. *International Journal of Surgery*, 8(2), pp.155-158. [Online] Retrieved September 6, 2015, from <http://doi.org/10.1016/j.ijisu.2009.10.012>

**Longley, P., Goodchild, M., Rhind, D., & Maguire, D., 2011**, "*Geographical Information Systems and Science (3rd Edition)*", pp.16, J.Wiley & Sons Ltd., USA.

**Mock, C., 2004**, "*Guidelines for essential trauma care. Essential Trauma Care Project (World Health Organization)*", World Health Organization, International Society of Surgery, & International Association for the Surgery of Trauma and Surgical Intensive Care. [Online] Retrieved July 2, 2015 from [http://www.who.int/violence\\_injury\\_prevention/publications/services/en/guidelines\\_trauma\\_care.pdf](http://www.who.int/violence_injury_prevention/publications/services/en/guidelines_trauma_care.pdf)

**Nadeem, Q., 2012**, *Best Living Neighborhood in the City*. [Online] Retrieved June 26, 2015 from <http://www.lebret-irfed.org/spip.php?article787>

**Nepal Earthquake 2072: Situation Update as of 11th May, 2015**. [Online] Retrieved July 2, 2015 from <http://drrportal.gov.np/uploads/document/14.pdf>

**OpenStreetMap Wiki, 2015**, *Nepal/Roads*. [Online] Retrieved September 25, 2015 from <http://wiki.openstreetmap.org/wiki/Nepal/Roads>

**Nicholl, J., West, J., Goodacre, S., & Turner, J., 2007**, *The relationship between distance to hospital and patient mortality in emergencies: an observational study*. *Emergency Medicine Journal : EMJ*, 24(9), pp.665–668. [Online] Retrieved September 25, 2015 from <http://doi.org/10.1136/emj.2007.047654>

**Paudel, T., 2011**, *A Report on Earthquake in Nepal*. [Online] Retrieved July 2, 2015 from <http://www.lebret-irfed.org/spip.php?article787>

- Ritzen, Y., 2015**, *Timeline: Nepal earthquakes - Al Jazeera English*. [Online] Retrieved July 2, 2015 from <http://www.aljazeera.com/indepth/interactive/2015/04/timeline-nepal-earthquakes-150425115801610.html>
- Schuurman, N., Fiedler, R.S., Stefan CW Grzybowski, S., & Grund, D., 2006**, *Defining rational hospital catchments for non-urban areas based on travel-time*. [Online] Retrieved July 2, 2015 from <http://www.ij-healthgeographics.com/content/5/1/43>
- Shah, M. T., Bhattarai, S., Lamichhane, N., Joshi, A., LaBarre, P., Joshipura, M., & Mock, C., 2015**, *Assessment of the availability of technology for trauma care in Nepal*. *Injury*, 46(9), pp. 1712–1719. [Online] Retrieved September 24, 2015 from <http://doi.org/10.1016/j.injury.2015.06.012>
- Thapa, A.J., 2013**, *"Status Paper on Road Safety in Nepal"*, pp.14-15. [Online] Retrieved June 28, 2015 from [http://www.dor.gov.np/documents/Status\\_Paper%20\\_2013.pdf](http://www.dor.gov.np/documents/Status_Paper%20_2013.pdf)
- Trodd, N., 2005**, *Network Analysis*. [Online] Retrieved September 15, 2015 from [http://www.gisknowledge.net/topic/spatial\\_operations/trodd\\_network\\_analysis\\_05.pdf](http://www.gisknowledge.net/topic/spatial_operations/trodd_network_analysis_05.pdf)
- USGS, 2015**, *M7.8 - 36km E of Khudi, Nepal*. [Online] Retrieved July 2, 2015 from [http://earthquake.usgs.gov/earthquakes/eventpage/us20002926#general\\_summary](http://earthquake.usgs.gov/earthquakes/eventpage/us20002926#general_summary)
- Walsh, S. J., Page, P. H., Gesler, W. M., 1997**, *Normative Models and Healthcare Planning: Network-Based Simulations Within a Geographic Information System Environment*. 32(2), pp: 247. Health Services Research 1997. [Online] Retrieved September 15, 2015 from <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1070185/>
- WHO: Emergency preparedness pays off as Kathmandu hospitals respond to earthquakes, 2015**. [Online] Retrieved July 2, 2015 from <http://www.who.int/mediacentre/news/releases/2015/nepal-second-quake/en/#content>
- WHO: Hospital Emergency-Response-Checklist, 2011**. [Online] Retrieved July 7, 2015 from [http://www.euro.who.int/\\_data/assets/pdf\\_file/0008/268766/Hospital-emergency-response-checklist-Eng.pdf](http://www.euro.who.int/_data/assets/pdf_file/0008/268766/Hospital-emergency-response-checklist-Eng.pdf)
- WHO: Tool for Situational Analysis to Assess Emergency and Essential Surgical Care, 2008**. [Online] Retrieved July 7, 2015 from <http://www.who.int/surgery/publications/QuickSitAnalysisEESCsurvey.pdf>
- Zeiler, M., 1999**, *Modeling our world*. [Online] Retrieved September 11, 2015 from <http://www.nlcsk.sk/files/330.pdf>

# Annex

## A. Survey Form used for Hospital Survey

Form No:		Hospital Emergency Service Earthquake Preparedness Assessment Form				KAFCOL/UNIGIS, Salzburg	
Hospital Name						Date	
Address						Lat	Long
Respondent Name					Contact Number		
Type	Government	Community	Private	Mission/NGO	Teaching	Others	
Emergency Service		Hospital Capacity					
Medical/ Surgical/Both	No. Emergency Beds	No. of Beds	No. Surgical Beds	No. ICU beds	Occupancy	No. Oper.Theaters	
Lab							
Haematology	Biochemistry	X-Ray	Ultrasound	CT-Scan			
Supplies							
Medicine Storage	Blood Bank	Oxygen Supply	Electricity Backup	Sec. Water Supply			
Other Capacities							
Ambulance	Morgue	Burn Care	No. of Ventilators	Hospital Networking With			
Human Resources in No.							
Surgeons	Anaesthesiologist	Orthopedics	Neuro Surgeon	Gynecologist	Nurses		
Medical Officer	Other Surgical Specialists						
Method of Earthquake Emergency Management (EM) in the hospital							
EM Plan	EM Committee	Training	Drill	Alternate Care Site	Tents/Accessories	Surge Capacity	
Building Condition Post Disaster 2015							
Safe	Partially Damaged	Severely Damaged					
Activity during Earthquake 25 April 2015							
ER service given or not given on the day of EQ, April 25:				If yes, no. of patients on that day.			
Remarks/ Suggestions:							
* Type of Injuries observed during recent EQ, their percentage etc.							

**B. List of Hospitals Surveyed and the Level of Emergency Service Provided**

S.N.	Hospital	Level
1	Alka Hospital (1&2)	3
2	All Nepal Hospital	3
3	Annapurna Neurological Institute	3
4	B&B Hospital (College of Physicians & Surgeons of Pakistan)	2
5	B.P. Memorial Community Co-Operative Hospital	3
6	Bharosa Hospital	3
7	Bir Hospital-Trauma Center	1
8	Bluecross Hospital	3
9	Capital Hospital	3
10	Chetrapati Free Clinic Hospital	3
11	Chirayu National Hospital	3
12	City Center Hospital	3
13	Civil Service Hospital	2
14	Clinic Health Care Center 24 Hrs Nursing Home	3
15	Dirghayu Guru Hospital	3
16	Everest Hospital	3
17	Ganesh Man Singh Memorial Hospital	3
18	Global Hospital	3
19	Green City Hospital	3
20	Helping Hands Community Hospital	3
21	Himal Hospital	3
22	Hospital for Advanced Medicine and Surgery (HAMS)	3
23	Jana Maitri Hospital	3
24	Jyoti Hospital	3
25	Kantipur General and Dental Hospital	3
26	Kantipur Hospital	3
27	Kathmandu Hospital	3
28	Kathmandu Medical College Teaching Hospital(KMC)	1
29	Kathmandu Model Hospital	2
30	KIST Medical College & Teaching Hospital	2
31	Laligurans Hospital	3
32	Mahendra Narayan Nidhi Memorial Hospital	3
33	Manmohan Memorial Community Hospital	3
34	Manmohan Memorial Medical College & Teaching Hospital	2
35	Mega Hospital	3
36	Midat Hospital	3
37	National Institute of Neurological & Allied Science	3
38	Nepal Bharat Maitri Hospital	3

S.N.	Hospital	Level
39	Nepal Police Hospital	2
40	Nidan Hospital	3
41	Nobel Hospital	3
42	Norvic International Hospital	2
43	Om Hospital	2
44	Om Samaj Hospital	3
45	Patan Academic of Health Sciences (Patan Hospital)	2
46	Sahid Memorial Hospital	3
47	Sarwanga Swasthya Sadan Hospital	3
48	Shankarapur Hospital	3
49	ShivaJyoti Hospital	3
50	Shree Birendra Hospital (Army Hospital)	1
51	Siddhi Binayak Hospital and Maternity Home	3
52	Stupa Community Hospital	3
53	Sumeru City Hospital	3
54	Sumeru Samudaik Hospital	2
55	Suvekchya International Hospital	3
56	Swacon International Hospital	3
57	T.U. Teaching Hospital	1
58	Vayodha Hospital	2
59	Venus International Hospital	3
60	Vinayak Hospital and Maternity Home	3
61	Welcare Hospital	3
62	Yeti Hospital	3

### C. List of Hospitals Not Included in Survey

S.N	Hospital	Status
1	Omakar Hospital	Collapsed
2	Family Health Care Hospital	Not Operational
3	Omni Care Hospital & Research Centre	Not Operational
4	People's Medical College	Emergency Service Not Operational
5	Medicare National Hospital & Research Centre	Data Not Provided
6	Star Hospital	Data Not Provided