Indian Journal of Spatial Science Vol - 6.0 No. 2 Winter Issue 2015 pp. 40 - 46

Indian Journal of Spatial Science

EISSN: 2249 - 4316 homepage: www.indiansss.org ISSN: 2249 - 3921

Rectification of Base Map using RS and GIS — a case study of Chandernagore Municipal Corporation, West Bengal

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Article Info

Article History
Received on:
12 June 2015
Accepted in *Revised Form* on:
14 August 2015
Available *Online* on and from:
23 September 2015

Key Words
Geographic Information System (GIS),
Ground Control Points (GCPs),
Positional and Graphical Rectification

Abstract

The proliferation of Geographic Information System (GIS) in diligence and research has led to the need for converting the available analog geospatial data to digital form. Though maps can be scanned, but they cannot be used directly in a GIS system without processing. Many investigations have been done on the accuracy and methodology for generating appropriate base map. Preparation of the accurate digital base map of Chandernagore Municipal Corporation (CMC) is necessary because the map provided by the CMC is showing more than 16.42% error after vectorisation and has been found to be inappropriate for further geospatial work on it starting from Land Use/Land Cover change detection to land resource area planning . The positional accuracy is an indispensable factor for future resource-area planning. For these purposes, the map has been rectified based on positional and graphical rectification. After rectification, the area of CMC has been calculated maintaining maximum accuracy and the error has been reduced to 0.64%.

Introduction

Over the past 50 years, the pace of technological advancement has far exceeded the impact of industrial revolution. Technological advancement has led to the introduction of the Geographic Information System (GIS) in the late 1960's and early 1970's, which requires digital maps for processing. GIS is defined by Gottfried Konecny (2003) as, "*A computer system for the input, manipulation, storage and output of digital spatial data. It is a digital system for the acquisition, management, analysis and visualization of spatial data for the purpose of planning, administering and monitoring the natural and socio-economic environment*"(Dharmaraj, 2005)

Paper maps are very important in the field of surveying and any kind of spatial analysis, like-Land Area Planning (LAP) and Land Use Planning (LUP) needs proper geographically accurate base map of the particular areas. Technological advancement has led to introduction of the GIS in the late 1960's and early 1970's, which requires digital maps for processing. Automatic algorithms are required for faster and reliable conversion of maps and operator is required only for verification. Methods for automatic vectorization of scanned maps deal with polygons, lines and points where Ground Control Points (GCPs) are essentially required for the rectification of Remote Sensing (RS) images and georeferencing map database in GIS. GIS is typically used to represent maps as data layers that can be studied and used to perform analysis. In today's society, there is a greater emphasis on digital data than on paper maps. This corresponds to the proliferation of GIS in industrial and research environment. This has lead to the need to transform pre-existing paper maps to digital maps. Like if the hardcopy of historical maps are getting vectorised with the help of GIS corresponding different layers of attributes then it would very easy to access that map form any corner of the world and making different spatial analysis would be easier. It makes the information transfer effortless as the size of a vector data is smaller than a raster one.

Although there are several practical difficulties in image processing (Dai et al., 2010, Woodcock et al., 1987) for urban areas, digital image classification (DIC) has been an important and popular method for extracting geo-spatial data. It is the process of sorting of pixels into number classes through statistical techniques by using computer aided software (Lillesand and Keifer, 2008; Haque and Bandyopadhyay, 2013).

Conceptual Background

A Map is the greatest of all epic poems. Its lines and colours show the realization of great dreams - NGS, 2002

1) Conversion of Maps/ Vectorisation

Raster data is defined as an abstraction of the real world where spatial data is expressed as a matrix of cells or pixels, with spatial position implicit in the ordering of the pixels. A raster map is stored as a regular array of cells. In GIS, vector data refers to the positional data in the form of points, lines and polygons, expressed in x and y coordinates having varying topological relationship, locations and attribute features related with each other (Dharamraj, 2005). Vector data format having the advantage of relatively lower data volumes has better spatial resolution and ensures prevention of topological data relationships with better network analysis (Lillesand and Keifer, 2008). Vectorisation involves digitization of the paper map and adding attribute. Its major advantages include —

i.) Map scale can be enlarged or reduced to any desired limit and the area of any closed polygon can be calculated accordingly.

ii.) Different layers of the map can be created and can be switched on or switched off to view only the desired layers which make the map more readable and less complex.

iii.) The width of the lines, arc, circles etc. can be measured and may be transferred to any desired scale.

iv.) Updating map and image-to-image rectification and its verification become easier.

2)The UTM Grid Coordinate System

The United State Geological Survey (USGS) uses a measurement system called the ***Universal Transverse Mercator*** (UTM) grid coordinate system, which divides the earth into a perpendicular grid with constant linear surface distances, in meters between each of its grid lines in all directions. It was developed in order to reduce the complexity of calculation needed to transfer a location on the spherically-shaped planet Earth to a flat surface (Mebratu, 2009).

The Transverse Mercator Projection, which divides the earth like the slices of an orange and flattens the slices, introduces a negligible amount of distortion in map scales typical of most topographic maps. The UTM Grid Coordinate System superimposes a perpendicular grid over this earth slices with constant linear surface distance values between each of its grid lines in all directions.

3) UTM Measurements and Coordinates

In Eastings each UTM zone is 6° wide, and uses the central meridian as a reference. Zone numbers designate 6° longitudinal strips extending from 80°S latitude to 84°N latitude, for a total of 60 zones. For example, the Zone 10 extends from 126° W to 120° W Longitude. The central meridian is 123°, halfway (3°) from the bounding meridians.

Northings are measured from the equator. The Zone characters designate 8° zones extending north and south from the equator. Each zones is divided into (Basic Map Skill, NGC, 2002) sections of latitude that are 8° in height. Again, the Eastings indicate the number of meters of longitude within the numbered zone the same easting coordinate value will repeat for each zone. The Eastings are specified as six-digit numbers. Northings specify the absolute number of meters from the Equator and are specified as seven-digit numbers.

4) Positional Accuracy

As a GPS (Global Positioning System) receiver provides accurate measurement of coordinates on the same ellipsoid as Google Earth, it was used to check the accuracy of Google Earth. The Root Mean Square Error (RMSE) for horizontal coordinates was found to be only 1.70 m. It was found that the positional accuracy changes only when the images are updated and gets improved, but the elevation remains unaltered. Google Earth portrays the earth as it looks from an elevated surface with the General Perspective project system which is similar to Orthographic projection. Its file format is known as KML (Keyhole Mark up Language) which uses 3D geographic coordinates - longitude, latitude and altitude, the positional accuracy being projected by the World Geodetic System of 1984 (WGS84) (Mohammed, Gazi and Mustafa, 2013).

Objectives

The major objectives of the present study are to —

(i) rectify the map and related data collected from the CMC office, and

(ii) prepare a base map of CMC.

Materials and Methods

To construct the present study the following materials have been collected are as follows—

(i) A base map of CMC area, (ii) CMC old area (1851, 1986, 2006,); CMC added area (2006), (iii) Toposheet-79B/5 (SOI), NF 45-7(Series-U502, 1-AMS Edition), (iv) Satellite Image [IRS-P6 LISS-IV Mx (5.8 M) November, 2011], Google Earth Image (8th July, 2014), (v) Software -ArcGIS 9.3 Version 9.3 (Esri Developers Summit, 2008), Erdas Imagine 9.1, Microsoft Office Excel and Word '07 , (vi) CMC Report (2010), Primary Census Handbooks, Govt. of India (2001&2011).

The work was done to rectify the Ward Map of Chandernagore Municipal Corporation (CMC) collected from the CMC office. There are mainly two kinds of data base which have been assembled for the accomplishment of the study—

a) RS/GIS data sets regarding the specific characteristics of the study area, and

b) Attribute data sets, i.e., statistics of written text, tables etc.

After collecting the Ward map from the Municipal Corporation georeferencing has been done using ArcGIS 9.3. In this process, the map has been converted to UTM projection to minimize the map distortion and to activate the grid option. After digitization, the total area of the Municipal Corporation has been extracted from the attribute table of the main layer which comes out with an error of 16.42% (Fig.10 and 12) with the Census data (2011) regarding the total area of the Municipal Corporation.

For further rectification of the map, image to image registration (with the help of geo-referenced map) and re-projection have been done. Google Earth measured co-ordinates of points have been collected to convert the base map containing the basic information such as road networks, ward boundaries ((Fig.7 and 8) of the study area. In the eastern part of CMC the wards have mostly been delineated following the road networks and in the western part the edges of agricultural fields and *Bund* played a key role for the demarcation of wards. Afterwards, the KML file from Google Earth Imagery has been taken to the ArcGIS 9.3 for re-projection and further digitization through which the area of CMC has been calculated maintaining maximum accuracy where the error has been reduced to 0.64% (Fig.11 and13) in comparison to the Census record (2011).

The Study Area

A. Historical Account: Chandernagore Municipal Corporation (CMC) is one of the six Municipal Corporations of West Bengal and a major urban settlement articulated by its own tradition in West Bengal. It scripted a separate chapter in the history of alien rule in India (Mukhopadhyay and Chakraborty, 2003).When the whole of Bengal was under British rule, Chandernagore was under the French rule (French East India Company) under the name of the person Duplessis in the year 1673 (Chandernagore Heritage, 2014). Though the first reference to the name of Chandernagore is found in a letter written to the then Director, French East India Company and signed by Martin, Deslandes and Pelle on November 21, 1696, it grew up during the French regime covering mainly three villages — *Borokishanpur, Khalisani and Gondolpara* (Mukhopadhyay and Chakraborty, 2003; DHDR, Hooghly 2011).

The French took the ownership of Chandernagore in 1688 where it took almost 10 years for the British East India Company to take a similar licence on the city of Calcutta (Banerjee, 2012). The Chandernagore changed hands throughout the 18th century, with several periods of English occupation: 1757 – 63; 1778 – 83; 1793 – 1802. It is only from 1816 onwards that it enjoyed continuous French rule till November 1947, when the French declared Chandernagore a free city and handed its charge over to local residents. Following a referendum in June 1949, Chandernagore became a part of India on 2nd February, 1950 through De jure Transfer. It was named as 'Francedongi' in 1757 and became popular with the name of 'Farasdanga'.

B. Situational Perspective: The geographical location of the Municipal Corporationlies between 88^{0}19' E to 88^{0}24' East and 22^{0}50'N to 22^{0}53' North. It is under Chandernagore sub-division of the district Hooghly. Being a Class - I town, the total population and population density of CMC were 162187 and 7362/km^2 in 2001 that increased to 166867 and 7575/km^2 in 2011.

The Chandernagore sub-division holds the second position in the district in terms of percentage share of urban population after Serampur sub-division (Table-2) and with its glorious past and tradition within its small urban unit Chandernagore enjoys a position of esteem amongst the major urban units of West Bengal, comprising an area of 22.03km^2 (Census, 2011), sharing small areal percentage in the eastern part of Singure Block. River Ganges flows down the eastern part of the town by making a shape of the crescent moon, which is one of the main reasons behind the name 'Chandernagore', coming from *Chandra* (moon) (Mukhopadhyay and Chakraborty, 2003).It has two distinctive areas as follows—

(a) ***Old Area*** *(Ward 1-26 and 27):* It is the old and main part of the town since the French rule and at the same time it is the heart of all commercial, institutional (academic and administrational) residential units, covering an area of 9.5 km^2. Though the ward 27 is an integral part of the main town but from the very beginning, it is lying as an "administrative handicapped" encompassed by *Champdani Municipality* as an isolated unit.

(b) ***Added Area*** *(Ward 28-33):* The added area of CMC was initially under the jurisdiction of *Khalisani Gram Panchayet* and had come under the governance of CMC after 31st December, 1994, comprising an area of 12.53km^2.

Results and Discussion

The vectorized base map of Chandernagore Municipal Corporation shows an area of 21.89 km^2 though the Census record is 22.03km^2(Table- 4). The Draft Development Report (2012 - 13, 2016 - 17) of the Municipal Corporation shows it as 24.51km^2 (Table-3). The percentage area of each Ward has been calculated from 22.03km^2 but the total comes to 109.8% instead of 100%.The old part of town and the added area which has been added after 31st December, 1994 comprising the western part of CMC beyond the railway station was formerly under the jurisdiction of *Khalisani Gram Panchayet* (Fig. 4). For the fulfilment of the first objective the rectification of the map of CMC has been done by observing an error 16.41%. After correction the accuracy level has reached more or less 100% by reducing the error up to 0.63% from 11.26% (DDP) (Table-4,5 and Fig.12).

Conclusion

It is apparent from Fig. 12, that Ward no. 28, 29, and 30 have the maximum percentage share in terms of area of the total municipal corporation but according to the Draft Development Plan (DDP) of the Corporation it's been calculated as around 11%, 2% and 13% of the total area which is the same as could be seen in the case of Ward no. 17 and 18 showing the same assessment (Table-3). But these wards do not comprise that much percentage share of the total area as it has been reported in the 2nd generation DDP of CMC. The picture is evident from Table - 3 and 4. The rectified map, hopefully, will be useful for various stakeholders.

Acknowledgement

The authors express their profound gratitude to Prof. Ashis Sarkar of Chandannagar College for his encouragement, cooperation and valuable advice. They would also like to thank Arijit Majumder, Ex-Ph.D. Research Scholar (CSIR-SRF) and Prasanta Ghosh, Ph.D. Research Scholar (State Funded) of Department of Geography, The University of Burdwan, for their help in preparation of this article.

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Table - 1: History at a Glance

19th June,1949	Date of Referendum
2nd May,1950	'De facto' Transfer
2nd February,1951	'De jure' Transfer, Treaty of Cession signed by France and India
11th April,1952	Ratification of the Treaty of Cession by the Franch National Assembly
2nd October,1954	Integration of Chandernagore with the state of West Bengal.

Source: Chandernagore Heritage Archives (Mukhopadhyay & Chakraborty, 2003)

Sub-division	% of Urban Population in 1991	% of Urban Population in 2001
Sadar	27.31	26.71
Chandannagar	37.17	39.61
Serampur	54.11	59.84
Arambag	4.57	5.02
Hooghly District	31.19	33.47

Source: Census, 1991 & 2001

Table - 2: Composition of Chandannagar

Table - 3: Area Computation of the CMC

Ward No.	Area in km²	% of Area to Total
1	0.34	1.5
2	0.29	1.3
3	0.21	1
4	0.32	1.5
5	0.1	0.5
6	2.5	11.3
7	0.45	2
8	3.06	13.9
9	0.46	2.1
10	0.32	1.5
11	0.12	0.5
12	0.34	1.5
13	0.29	1.3
14	0.21	1
15	0.32	1.5
16	0.1	0.5
17	2.5	11.3
18	0.45	2
19	3.06	13.9
20	0.46	2.1
21	0.32	1.5
22	0.12	0.5
23	0.34	1.5
24	0.29	1.3
25	0.21	1
26	0.32	1.5
27	0.1	0.5
28	2.5	11.3
29	0.45	2
30	3.06	13.9
31	0.46	2.1
32	0.32	1.5
33	0.12	0.5
Total	24.51	109.8

Table - 4: Area of CMC after DD Plan

Ward No.	Area in km²	% of Area to Total (21.89 km²)
1	0.69	3.15
2	0.51	2.32
3	0.44	2.01
4	0.34	1.55
5	0.21	0.96
6	0.12	0.55
7	0.27	1.23
8	0.67	3.06
9	0.43	1.96
10	0.26	1.18
11	0.15	0.68
12	0.32	1.46
13	0.42	1.91
14	0.45	2.05
15	0.51	2.32
16	0.28	1.27
17	0.13	0.59
18	0.60	2.74
19	0.42	1.92
20	0.3	1.37
21	0.53	2.42
22	0.34	1.55
23	0.3	1.37
24	0.21	0.95
25	0.15	0.68
26	0.15	0.68
27	0.11	0.5
28	4.37	19.96
29	3.77	17.22
30	2.5	11.42
31	1	4.50
32	0.44	2.01
33	0.5	2.28
Total	21.89	100

Tabel - 5: Picture of Area Correction

Source	Area (km²)	Error (%)
Census (2011)	22.03	-
Draft Development Plan of CMC	24.51	[{(24.51-22.03)/22.03}*100] =11.26
Map Provided from the Department of Urban Planning, CMC (Before Rectification)	25.65	[{(25.64671-22.03)/22.03}*100] =16.42
After Rectification	21.89	[{(22.03-21.89)/22.03}*100] = 0.6354

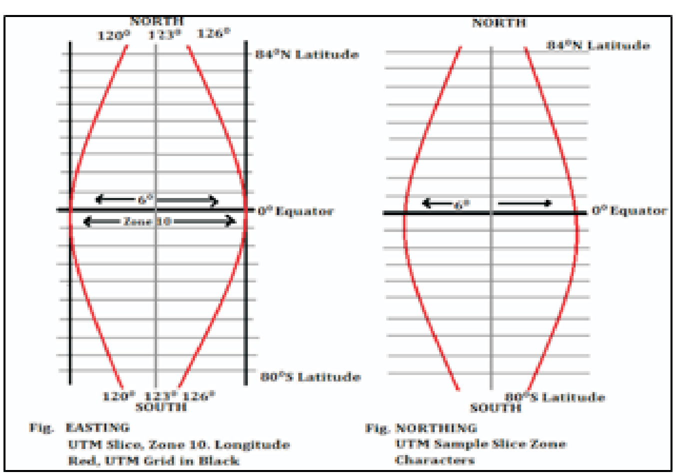

Fig. 1: UTM Measurements and Coordinates (afterNGC, 2002)

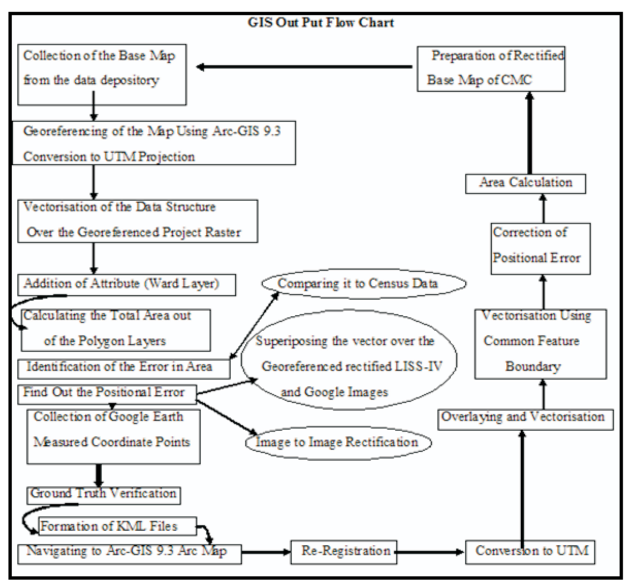

Fig. 2: Flowchart of the GIS Output Method

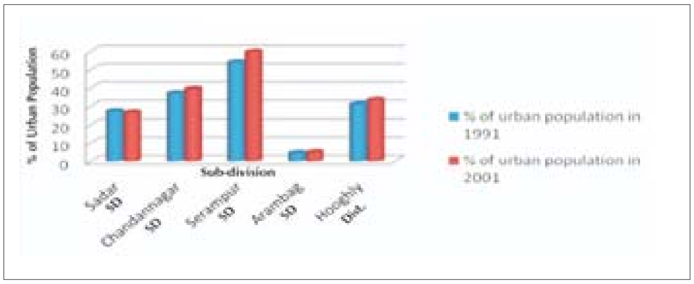

Fig. 3: Level of Urbanisation (HDI Report of Hooghly, 2009)

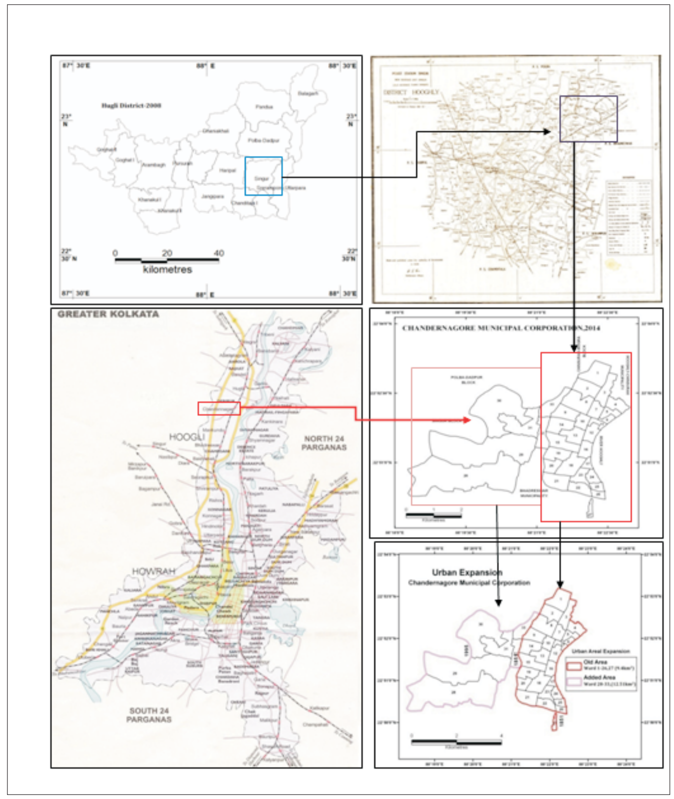

Fig. 4: Location of the Study area

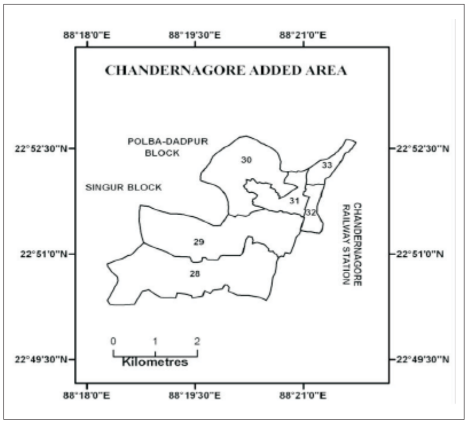

Fig. 5: The Added Area (Previous), CMC

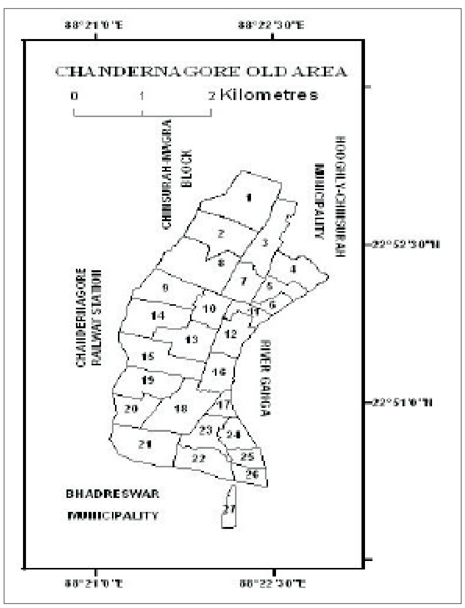

Fig. 6: Old Area (Next) of CMC

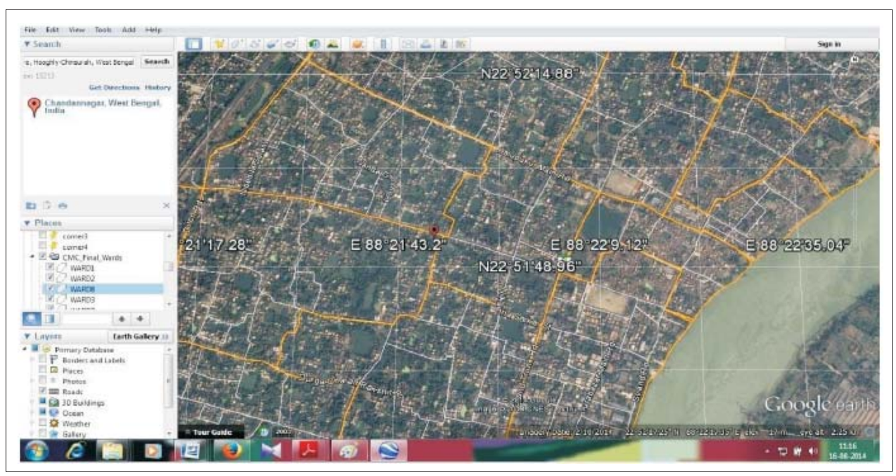

Fig. 7: Identification of Location of GCPs in the Field

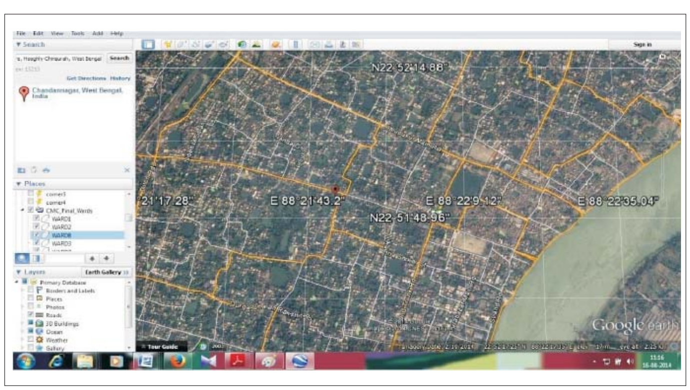

Fig. 8: Fig.8: The Old CMC Ward Demarcation Along the Road Networks, Vectors with Specific Topology (Feature Extraction for Generation of Digital Base Map on Satellite Image)

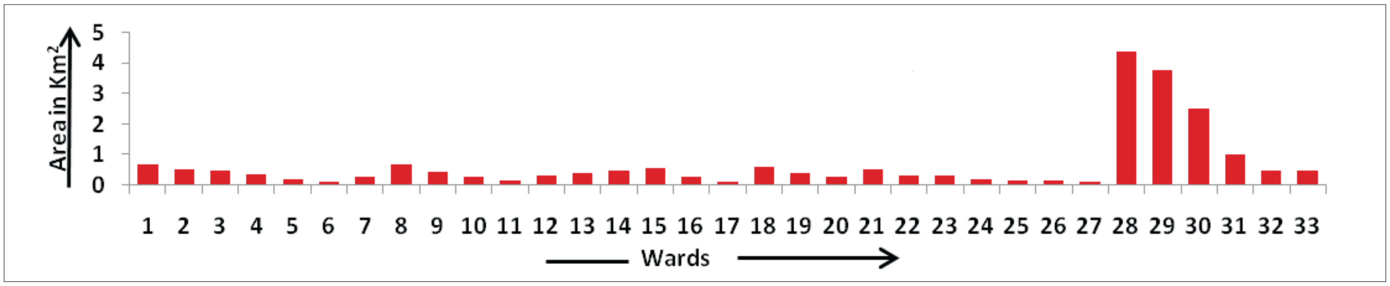

Fig.9: Ward Wise Distribution of Area CMC

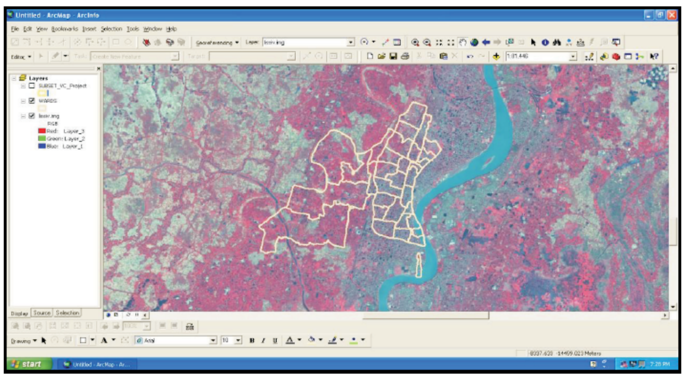

Fig. 10: Overlaying Vectorised Feature on Georeferenced Satellite Image (Before Rectification)

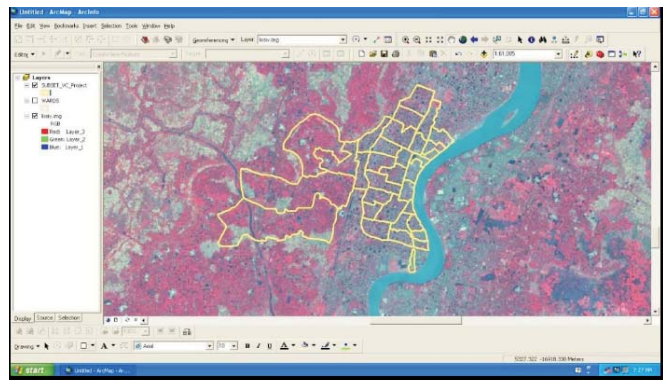

Fig.11: Overlaying Vectorised Feature on Georeferenced Satellite Image (After Rectification)

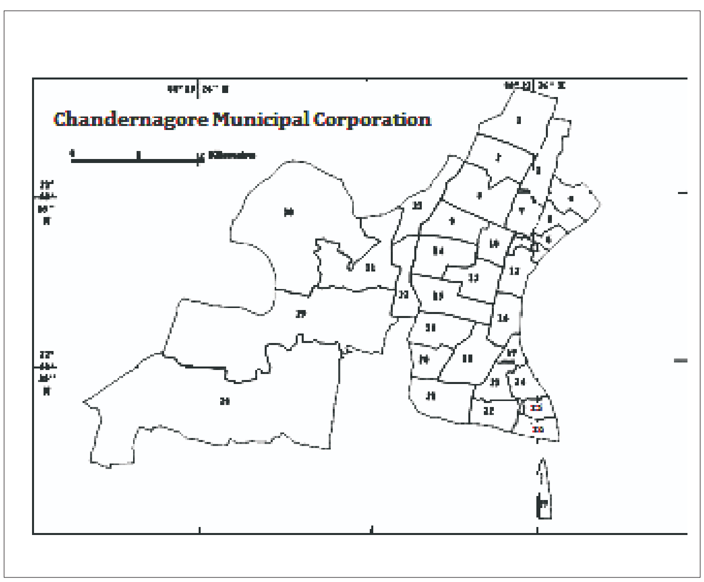

Fig. 12: Before Rectification

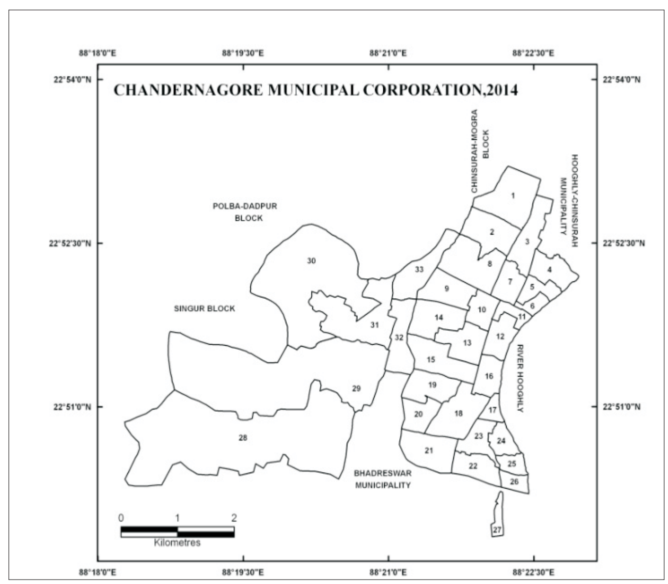

Fig. 13: After Rectification

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