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Location–Allocation Model Applied to Urban Public Services: Spatial Analysis of Fire Stations in Mysore Urban Area Karnataka, India

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Abstract

Urban fire is one of the most disturbing problems even in modern times with the development of technology designed forfire prevention and suppression, they continue to damage life and properties. Thus, effective handling of fires requires an effective planning response system on a regional scale.Network analysis models were applied to find out the parts of the city having poor coverage within a pre-defined impedance cutoff of time and also to provide the sites wherefrom all demand points will be covered within a predefined impedance cutoff of time of five minutes as recommended by Standard Fire Advisory Council (SFAC). The served and under-served areas of fire service on the basis of time have been generated by taking the response time 5 minutes. The result indicates that 42.09 percent of city area in the Southeast and Southwest remains under-served within the response time five-minute. Location-allocation model has been applied for theallocation of additional facilities wherefrom the uncovered area will be served within the prescribed time of five minutes.Two approaches have been adopted to fulfill the requirements of such emergency facility;by preventing the existing facilities and by relocating the existing facilities. In both cases nine fire stations are required to cover the entire city effectively. Hence, it is advisable to adopt the second method that is, establishing six new fire stations without relocating existing three fire stations, which would be cost effective.

Key words: *Fire Stations, GIS, Population, Served area,Time, Distance,Location-allocation*

Introduction

Today fire has an important place among the causes of loss of life and property. It should therefore be intervened as soon as possible to eliminate the destructive outcomes. Effectiveness of the intervention is directly linked with instant access to the fire accident spots. Information Technologies (IT) that have developed rapidly in recent years are being used in fire relief management and the application ofGeographic Information Systems (GIS) specifically, in fire accident management can achieve efficient results. Since GIS can analyzeexhaustivespatial and non-spatial datait is highly effective in responding to spatial queries. Physical accessibility for fire service in an urban area is exceptionally important in spite of the hindrances like transportation that reflects the ease for travel. Accessibility is a combination of two elements: spatial location of a phenomena suitable destination, and the accessibility based ontransportation network linking points on that surface (Vickerman,

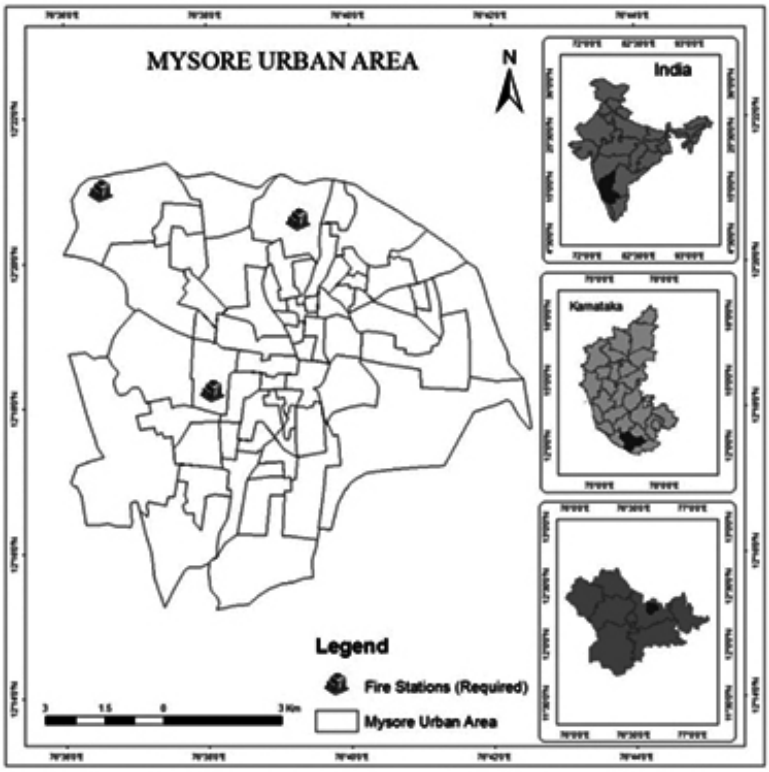
R.W. 1974). The distance, travel time, transportation, and the associated cost are the geographical dimension'saccessibility. Measures of access often focus on spatial location of service "supply" and the population "demand" in based on time and space(Ghosh, A. & Rushton, G. 1987). The location-allocation models have been applied to form structural form of services of facilities to fulfill the demands in optimal way (Algharib S M. 2011).Location-allocation model is the process in which distribution of demands are taken into consideration to selects the optimal location for facilities from a set of available locations (Drezner, Z.1995).

The demand and supply are the basic determinants of the optimal location and allocation of facilities (Yeh, A. & Chow, M. 1997). The integration of GIS and location-allocation act as a tool for public facilities planning for developing a spatial decision support system (Valeo, C. et.al., 1998).The location-allocation models can be helpfulfor the spatial planners to choose the optimal locations of public facilities(Rahman, S. & Smith, D. 2000). Location-allocation models are important in the location of new facilities as well as to evaluate and improve the efficiency of prevailing location decisions(Plastria, F. 2001).There are methodologies designed to place a limited number of stations(Mon, H. et.al., 1998), and others designed to place whatever number of stations necessary to address all demands (ReVelle .C.S and Swain R, 1998). Identifying and establishing fire station at an optimal location is one the important concerns of planners and researchers, especially in the cities where the population has been growing significantly (Aktas.E. et.al., 2013; Catay B, 2011). To achieve an effective and reliable emergency response system, the location of rescue facility plays a major role, the fatalities and disabilities caused by natural and manmade disasters can be significantly reduced through an effecting planning of location (Basar A et.al., 2012). It is important to assure that; the fire stations are not only located at the place from where it can serve large area but also strategically placed so as to minimize the response time to accident spots (Liu N et.al., 2006). There are several methods have been used to identify the suitable location for establishing facility canters by researchers (Murray A.T, 2013; White et.al., 1974), among them Geographical Information System (GIS) based assessment method is popular in recent days (Forkua et.al., 2013; Isa U.F, 2016). GIS provides real time simulation of transportation network accompanied with high level of accuracy as it uses actual travel distance, speed of vehicle and time delays (Kazemi M, et.al., 2013). A GIS based analysis is likely to offer a straighter forward approach than conventional mathematical models (Park, P.Y, 2016). Hence, the present study adopted GIS based approach to assess the location based emergency service of existing fire station in Mysore city, in which the service area of each fire station and unserved area is identified and suitable places for establishing new fire station and allocation of existing fire stations was assessed.

Study Area

Mysore is one of the popular cities in southern Karnataka located from 12°18'N to 12°30'N latitude and 76°39'E to 76°65'E longitude, and has an average altitude of 770

meters (2,526 ft.), covering 89.71 sq. km area. According to Census of India 2011, the city has been divided in 65 wards for administration purpose and the population of the city has been growing rapidly followed by spatial extension of settlements in all the directions. The city contains of three fire stations located at SaraswathiPuram, Bannimantap and Hebbal to secure the population from the fire incidents. Fire outbreak is a one of the major problems in the city which has been occurred oftenthe number of fire incidences occurred in the city has been increasing over the years from 246 in 2003 to 416 in 2013. The cost of property damage also has increased from 4.1 million in 2013 to 11.24 million in 2013. Hence, the result of present study would help to understand whether the existing fire stations can cover entire city, if not what are the necessary steps to have to be taken to protect whole city.



Map 1: Study Area

Methodology

The methodology has been framed to examine three research questions as follow.

- Which demand areas are not being served from existing facilities within the response time of 5 minutes?
- Where are the optimal locations for placing an additional facility to address the unmet needs? And
- What are the locations having appropriate building conditions, optimal distance, optimal time, population, facility capacity, optimal cost etc. in relation to fire station etc.

The present paper deals with the physical accessibility of fire stations to the different areas in Mysore urban area. To attain the objectives of the study, fire incident data was collected from 2003 to 2013 related to number/prevalent of incidence. The information regarding existing road networks of city was collected from Mysore Urban Development Authority and it has been digitized in ArcGIS. The location of existing fire stations was collected through the GPS survey using Garmin etrex 10. The available sites to set up a fire station was identified using land use and land cover map that has been prepared from Landsat 8 satellite image. Service area and location analysis have performed using network analysis extension in ArcGIS software. The drive time was assumed depending upon the vehicular traffic supposed to ply on the respective roads, road hierarchy, land use in the vicinity, road width, nature of road, traffic bottle necks, etc. and does not take into consideration traffic signals, because of permission to emergency vehicles to pass off in traffic signal points. The drive-time is valid only in the normal traffic conditions and it does not apply in circumstances where unexpected situations of traffic jams, or other barriers such as tree falling, road accidents, road blockades, etc. occur. The Standing Fire Advisory Committee (SFAC) recommendations for area, population and travelling time has been taken into consideration for the service area of fire station.

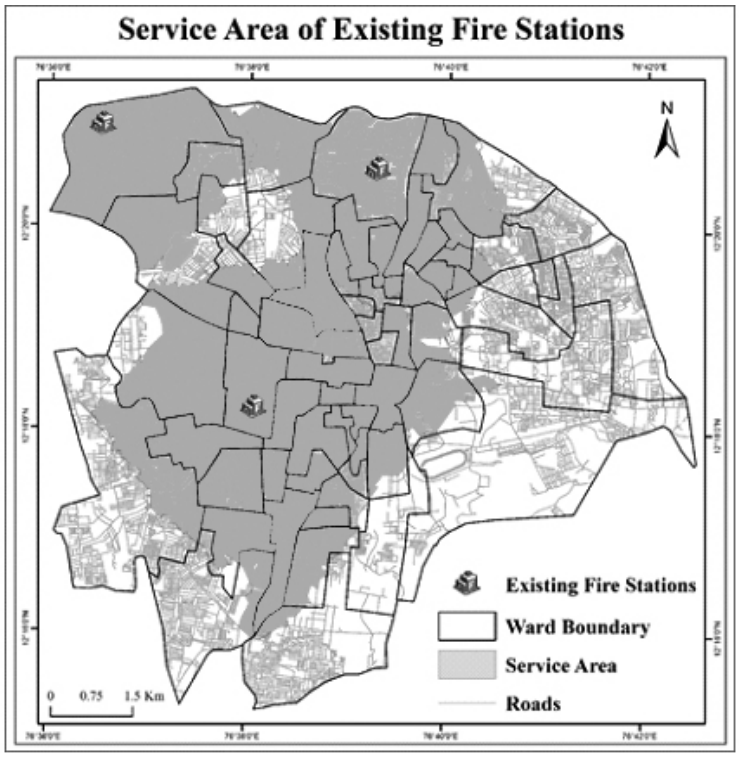
Results and Discussion

Analysis

The service area of existing fire stations in Mysore city was examined within reaching time of 5 minutes in ArcGIS (Map: 1), and areal extension of coverage shown in table 1.

Table: 1 Service Area of Existing Fire Stations within 5 Minuteswithin Mysore Urban area

Category	Area	Area (%)
Service Area	50.16	57.91
Non-Service Area	36.46	42.09
Total	86.62	100.00



Map 2

The result of service area depicts that the existing fire stations cover only 50.16 Sq. Km of city area while 36.46 sq.km are not covered within the time of 5 minutes. From the result it is obvious that the fire vehicle has to travel more than adequate time to reach non-service areas, which may cause loss of life or higher damage of property due to longer time travel to incident spots.

Location Analysis of Fire Stations

As the result of service area indicated that the existing fire stations cannot cover around 42.9 percent of city's area, thus, it is necessary to make proper plan to protect the non-service area. Hence, two strategies can be implemented to overcome this problem such as a) establishing new fire stations without consideration of existing fire stations and b) establishing new fire stations without changing the location of existing fire stations, both these assessments can be performed in ArcGIS Network Analysis environment. The network analysis works based on the interconnected elements, such as edges (lines) and connecting junctions (points), that represent possible routes from one location to another (ESRI). Hence, the study has performed both the techniques using transportation network of Mysore city to identify the optimal location for new fire stations.

Further, it is necessary to identify available space in city that is suitable for establishing a fire station or allocate an existing fire station, therefore the study has

followed National Disaster Management Authority, Government of India 2012 guidelines (Basic Requirement for Setting Up A Fire Station, Annexure – 1B) for identifying available places that is suitable for set up a fire station. In total, 81 sites were found within city limit that is suitable for establish a fire station (to construct office, watch room, store, work room, rest room, drill tower, petrol store, hoe washing through, smoke chamber, drill ground with other facilities).

First, location analysis was carried out without consideration of existing fire stations in ArcGIS as available 81 sites are facility (facility refers the option in Network Analysis, from where service will be provided) and settlements are demand points (demand points refers the option in Network analysis, the area requires service).

The result represented that, among the available sites 9 sites are found optimal as shown in Map 3 (see page 9). Then using these selected 9 sites, service area assessment was carried out, the result represents that, the chosen 9 sites such as 7, 19, 27, 29, 34, 56, 61, 67 and 77 (Map 4 legend) (see page 9) can cover all the settlements in the city.

Secondly, location analysis was carried out with existing fire stations, as 3 existing fire stations are essential locations and other 81 available sites are optional in facility and location of settlements are demand points.

The result shows among the available locations 9 locations are optimal including existing fire stations such as Bannimantap, Hebbal, and Sarawathipuram; available sites 7, 19, 27, 29, 56 and 61. From the assessment of including and excluding fire stations in the location and service area analysis, it is clear that, in both cases 9 fire stations are required to cover the entire city effectively. Hence, it is advisable to adopt the second method that is, establishing 6 new fire stations without allocating existing 3 fire stations, which would be cost effective.

Conclusion

This paper proposed a method of gradual optimization of urban fire station plan based on GIS location allocation model. The analysis revealed that the fire stations in the study area are less in number with intentof itsmaximal coverage within the minimum impedance time concerned. Emergency services need to be planned in such a way that it caters to most areas/locations within quickest possible time as the fire service mission is to protect life and property from fire.The main goal of the spatial planners around the world is the selection and finding the optimal site for facilities. Location allocation model provides the solution for spatial decision not to find the optimal locations for locating the emergency service facilities but also acts as tool to determine where and how many facilities are in need to fulfill the all requirements . The location - allocation model helps planners to locate facilities and also to support them in taking a decision about where to locate facility or facilities inside a chosen location. The result of both analyses revealed that, a total of 9 fire stations are required to cover the entire city within 5 minutes. Therefore, the present study suggests to adopt second method, that is establishing 6 new fire stations without allocating existing fire stations which would be cost effective.

Acknowledgement

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References

1. Aktas, E., Ozaydın, O., Bozkaya, B., Ulengin, F., &Onsel, S. (2013): Optimizing fire station locations for the Istanbul metropolitan municipality. Interfaces, 43(3), 240-255.
2. Algharib S M. (2011): Distance and Coverage: An Assessment of Location-Allocation Models For Fire Stations in Kuwait City, Kuwait, A dissertation submitted to Kent State University in partial.
3. Basar A, Catay B and Unluyurt T, (2012): A taxonomy for emergency service station location problem. Optimization letters 6 (6), 1147-1160
4. Catay B, (2011): Siting new fire stations in Istanbul: A risk-based optimization approach. Operational Research Society Ltd 24 (2), 77-89
5. Drezner, Z. (1995): Facility Location A Survey of Application and Methods. New York: Springer.
6. Forkuo, Eric K., and Jonathan A. Quaye-Ballard, (2013): GIS based fire emergency response system. International Journal of Remote Sensing and GIS 2 (1), 32-40
7. Ghosh, A. & Rushton, G. (1987): Spatial Analysis and location-Allocation Models, New York: Van Nostrand Reinhold Company Inc.
8. Isa U F, Liman M A, Mohammed M U, Mathew O S and Yayo Y R, (2016): Spatial Analysis of Fire Service Station in Kano Metropolis, Nigeria. IOSR Journal of Humanities and Social Science 21 (9.1), 45-52
9. Kazemi M, Kunt M M, Aghayan I and Larijani R J, (2013): Optimization Model for Fire Station Location Based on GIS and Python: A Case Study in North Cyprus. Applied Mechanics and Materials 330, 1059-1064
10. Liu N, Huang B, and Chandramouli M, (2006): Optimal Siting of Fire Stations Using GIS and ANT Algorithm. Journal of Computing in Civil Engineering 20, 361-369
11. Mon, H. Jayaraman V and Srivastava, R. (1998): Combined Location-Routing Problems: A Synthesis and Future Research Directions, European Journal of Operational Research, 108: 1-15.
12. Murray A T, (2013): Optimising the spatial location of urban fire stations. Fire Safety Journal 3 (2), 1-8
13. Park, P. Y., Jung, W. R., Yeboah, G., Rempel, G., Paulsen, D., &Rumpel, D. (2016): First responders' response area and response time analysis with/without grade crossing monitoring system. Fire Safety Journal, 79, 100-110.
14. Plastria, F. (2001): Continuous Covering Location Problems, In: Drezner, Z. and Hamacher, H.W., eds. Facility Location: Applications and Theory. Berlin: Springer-Verlag, 37-79.
15. Rahman, S. & Smith, D. (2000): Use of Location-Allocation Models in Health Service Development Planning in Developing Nations, European Journal of Operational Research, 123: 437-452.
16. ReVelle .C.S and Swain R. (2013): Central facilities location. Geographical Analysis, 1970, 2: 30–4
17. Valeo, C., Baetz, B., &Tsanis, I. (1998): Location of Recycling Depots with GIS. Journal of Urban Planning and Development, 124 (2): 93-99

18. Vickerman, R.W. (1974): Accessibility, attraction and potential: A review of some concepts and their use in determining mobility" Environment and Planning, 6 (6): 675-691.

19. White, John A., and Kenneth E. Case (1974): On covering problems and the central facilities location problem. Geographical Analysis 6 (3), 281-294

20. Yeh, A. & Chow, M. (1997): An integrated GIS and location-Allocation approach to Public Facilities Planning-an Example of Open Space Planning. Elsevier Science, 20 (4/5): 339-350.

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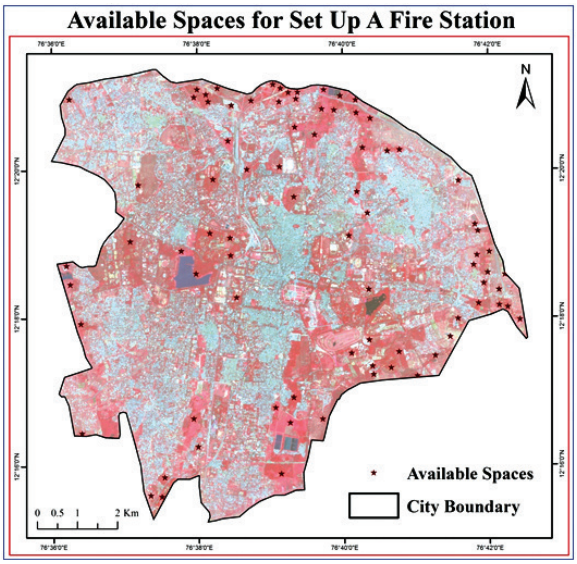
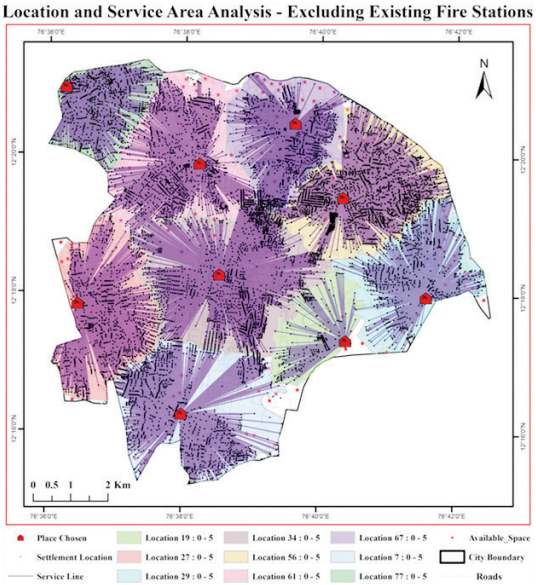
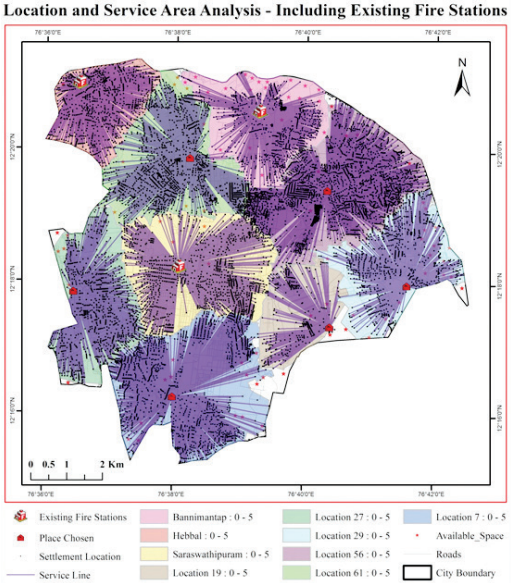


Map 3 (see page 6)



Map 4 (see page 6)



Map 5 (see page 6)

Terrace at Wayangani (see page 15)

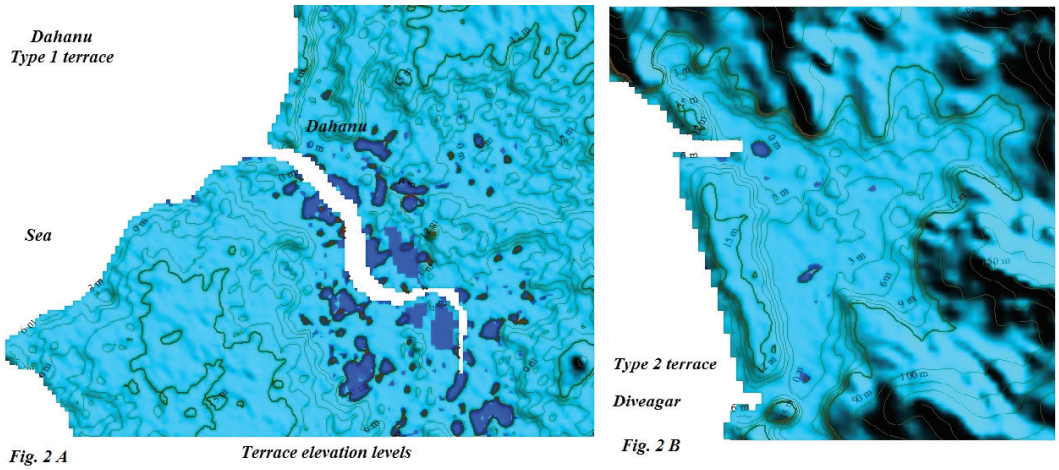


Fig.2.A: Elevation levels of Type 1 terrace at Dahanu
Fig.2.B : Elevation levels of Type 2 terrace at Diveagar

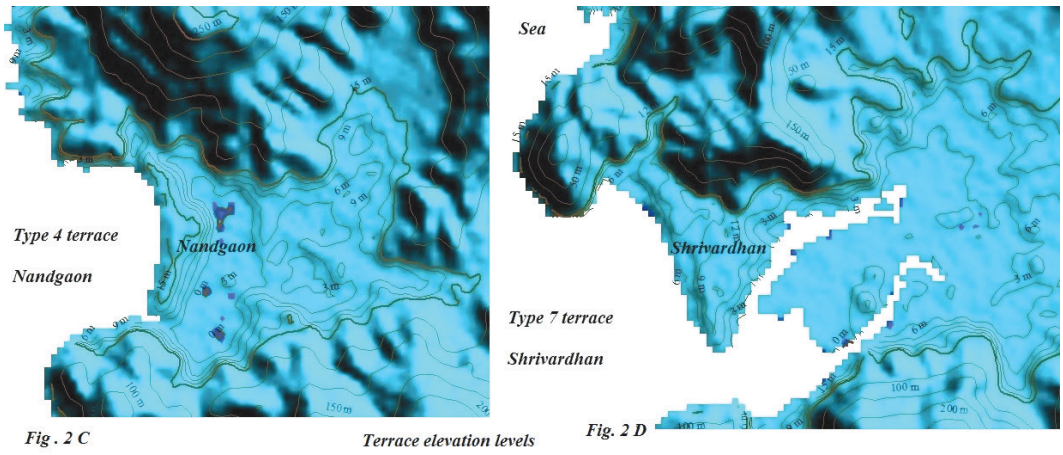


Fig.2.C: Elevation levels of Type 4 terrace at Nandgaon
Fig.2.D: Elevation levels of Type 7 terrace at Shrivardhan

(For Fig.2 (A,B,C and.D) ....See page 16)

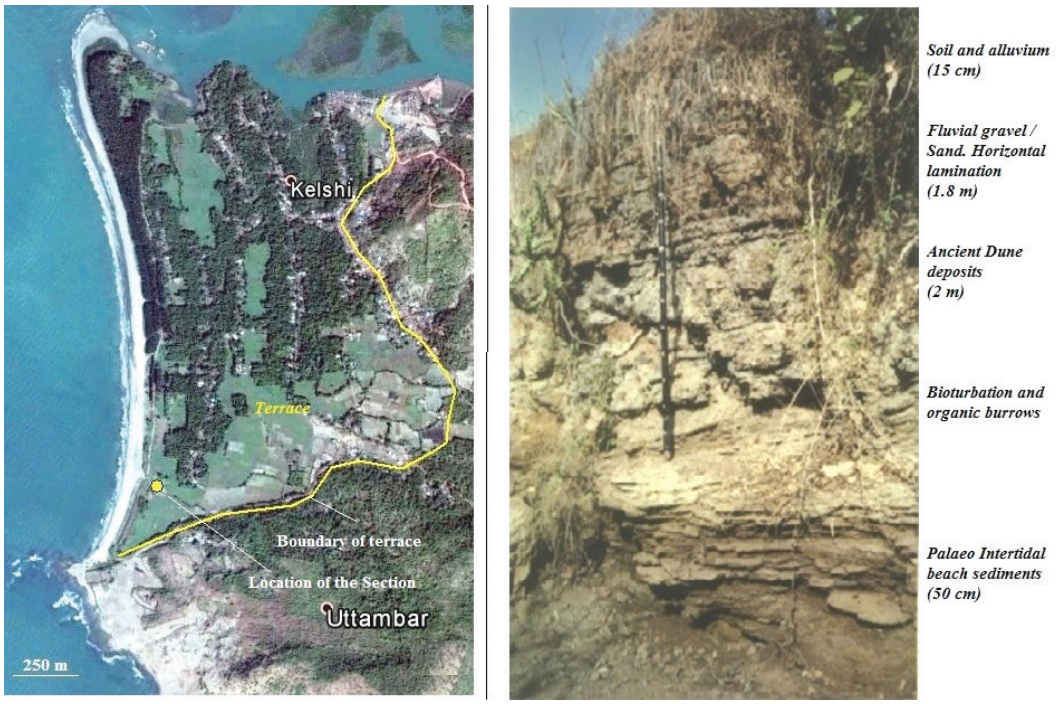


Fig.3: Stratigraphy exposed at seaward side of Littoral terrace at Kelshi

Fig.4: Stratigraphy exposed at seaward side of Littoral terrace at Kolthare

(Fig.3 and 4: See page 18)