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FEASIBILITY ANALYSIS OF KALYAN-DOMBIVLI SMART CITY USING ANALYTIC HIERARCHY PROCESS

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ABSTRACT

A Smart City is a complex mesh of systems across sectors based on providing basic amenities to its citizens 24*7 with all-inclusive policy and eco-friendly measures. The twin cities of Kalyan-Dombivli, designated as smart city by central government were selected from Maharashtra. The cities falls within the Thane District under the jurisdiction of Kalyan-Dombivli Municipal Corporation with an areal extent of 39.44 sq. Km. This ancient city has a glorious history, rich heritage and culture. Implementation of information technology in the governance and dissemination of its functions would play a significant role in creation of a smart city. It is also necessary to understand the existing conditions, in terms of physical characteristics of the land, its infrastructure that will eventually lead the city to become smart. A clear picture of this analysis was brought out by making use of the Analytic Hierarchy Process (AHP) technique and weighted overlay technique in a GIS Environment. The results, highlight those wards with the highest and least propensity to becoming smart.

Keywords: Kalyan-Dombivli, wards, AHP, weighted overlay technique, physical variable, rank, suitability

Introduction

A smart city comprises of interconnected systems and facilities of public convenience across various sectors such as; water, power, sanitation, transportation, education, healthcare, security and the like. By managing these sectors, a smart city enables the development of intelligent infrastructures, public convenience, social management, optimized industry structures, and employment. Since times immemorial, man has been living and gainfully utilizing the 'Land' resource to his own advantage. Every portion of land, whether rural or urban that exists on this planet Earth, has certain pockets that prove to be highly suitable, whereas, others are moderately suitable or least suitable for carrying out certain types of activities, In order to perform this task of decision making, about the extent of suitability of the site and feasibility of the activity to be performed in any given area, understanding the ground reality is a prerequisite. Once this understanding is developed, the

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performance of a site suitability analysis with the help of the concerned variables, shall acquaint us with the characteristics of that portion of land. In the twin city of Kalyan-Dombivli, under Kalyan-Dombivli Municipal Corporation, it is certain that, there exist certain physical factors that exert an influence on the area and the urbanization process. This study has been conducted taking into cognizance only the majorly urbanized wards in the city's domain, inclusive of Ward B, C, D in Kalyan and F, G, H in Dombivli. The total areal expanse of all the six wards is 39.44 Sq. Km. Furthermore, these wards are in the process of experiencing the developmental activities with respect to creation of the smart city.

Objectives

The main agenda and objective behind conducting this study is the creation of maps such that these highlight the ward-wise suitability (based on physical parameters) of the six selected wards in Kalyan-Dombivli, using the AHP technique which in turn shall help in determining whether the twin city fulfils the requisite conditions of feasibility for becoming a full-fledged smart city.

Scope

It is imperative from the research point of view that the physical parameters are given their due importance such that they can be systematically analyzed and interpreted to bring about a clear description of the study area with specific relevance to the provisioning of new facilities. This in turn, shall prove to be of considerable worth to the planners, who at their end, prepare the City Development Plans and Master Plans to understand the nature of land, its use, cover, slope as well as how development needs to be undertaken.

Study Area

The twin city of Kalyan-Dombivli is situated in the Kalyan tehsil which is governed by the Kalyan-Dombivli municipal corporation (KDMC), an urban local body, located in the Thane district of Maharashtra. It spans an area of 39.44 sq. Km. it stretches from 19°4' to 19°14'N latitude to 72°9' to 73°10'E longitude. Ulhas Creek marks its northern boundary and it stands amidst the Thane Corporation, Ulhasnagar Corporation and Navi Mumbai Corporation (Revised City Development Plan, 2012). Today, KDMC, encompasses 8 major township settlements, namely- Kopar, Dombivli, Thakurli, Kalyan, Vithalwadi, Shahard, Ambivli and Titwala. Out of which, Kalyan and Dombivli have witnessed maximum development and serve as a dormitory township for a huge number of people who have their offices in Greater Mumbai and Mumbai Suburban. (Revised City Development Plan, 2012).

Materials used

Data was collected and in some cases acquired from several sources within the study area and also from online sources whose details are mentioned underneath. (Table 1 and 2)

Table 1: Details of Landsat 8 OLI/TIRS images

S. No.	Satellite	Path and Row	Date of Pass	Characteristics
1.	Landsat 8 OLI/TIRS	148 and 047	30th January, 2017	Spatial resolution= 30 m No. of bands= 11

Source: USGS, Earth Explorer website, NASA.

Land use and cover classification (Unsupervised) along with the Normalized Difference Vegetation Index Calculation was attempted, making use of the Landsat 8 OLI/TIRS image.

Table 2: Other Materials Used

S. No.	Material
1.	SRTM-DEM (1Arc-Second/ 30 m resolution) obtained from USGS website
2.	Shapefile of Study Area with ward boundaries, obtained from KDMC Headquarters in Kalyan
3.	Portions of Kalyan delineated for Area Based Development, obtained from KDMC website

Source: Data collected by Researcher

Softwares Used

ERDAS IMAGINE 2014 software is an essential and user friendly application for carrying out various techniques of remote sensing.

ARCMAP VERSION 10.2.1 is a user friendly software application, primarily used to create maps, perform spatial analysis and manage geographic data in an automated scenario.

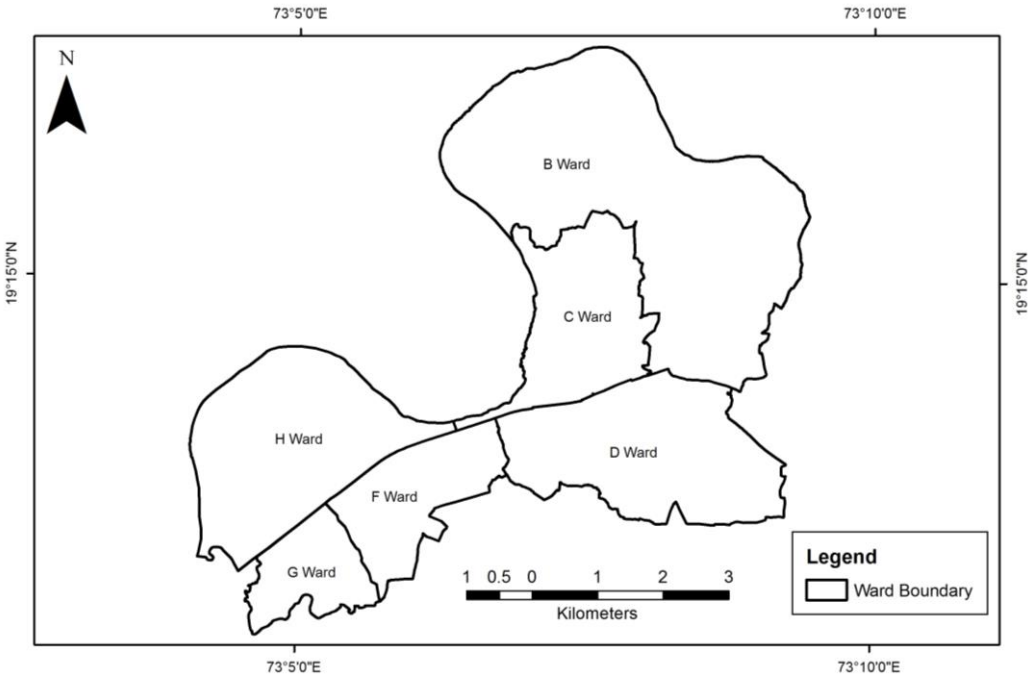
Methodology

For the purpose of easing out the task of decision making for the planners so that they can come up with favorable developmental strategies, the Analytic Hierarchy Process (AHP) is a worthwhile consideration. It has far reaching effects and can be easily applied to any scenario that involves several variables for decision making. Thus, AHP carried out on the basis of expert opinion, combined with the Weighted

Overlay Technique (WOT), which is a method of modelling the suitability of the area, have been primarily used to perform the site suitability analysis. The successful completion of the aforementioned techniques is dependent on the careful selection of the variables that exert a direct influence on the study area. These can be classed under the physical parameter which encompasses four variables including Land-use/Land cover, Normalized Difference Vegetation Index or NDVI, Slope and the digitized portions of Kalyan that have been covered under Area Based Development Plan of KDMC.

Method and Procedure

Three wards in Kalyan (i.e. B, C, D) and three wards in Dombivli (i.e. F, G, H), as shown in figure 1 were taken into consideration.



Source: Shapefile, KDMC

Fig. 1: Map Indicating Ward-Boundaries of Kalyan Dombivli

First of all, work was initiated with the physical parameter. The DEM of the study area, obtained from the USGS website, was converted into a slope map and the area of interest was clipped. Secondly, the area of interest was also clipped from the land-use/land cover and NDVI maps. Further, the map indicating the portions of Area Based Development (ABD) was prepared after digitizing from the one given on the KDMC website. After all the variables were cast into maps, the process of rank allocation on a scale of 1 to 5 was undertaken on the basis of which their respective weight categories were decided ranging between Very High Suitability, High Suitability, Moderate Suitability, Low Suitability and Very Low Suitability. The

highest i.e. rank 5 was allocated to the Very High Suitability category, so on till the last rank.

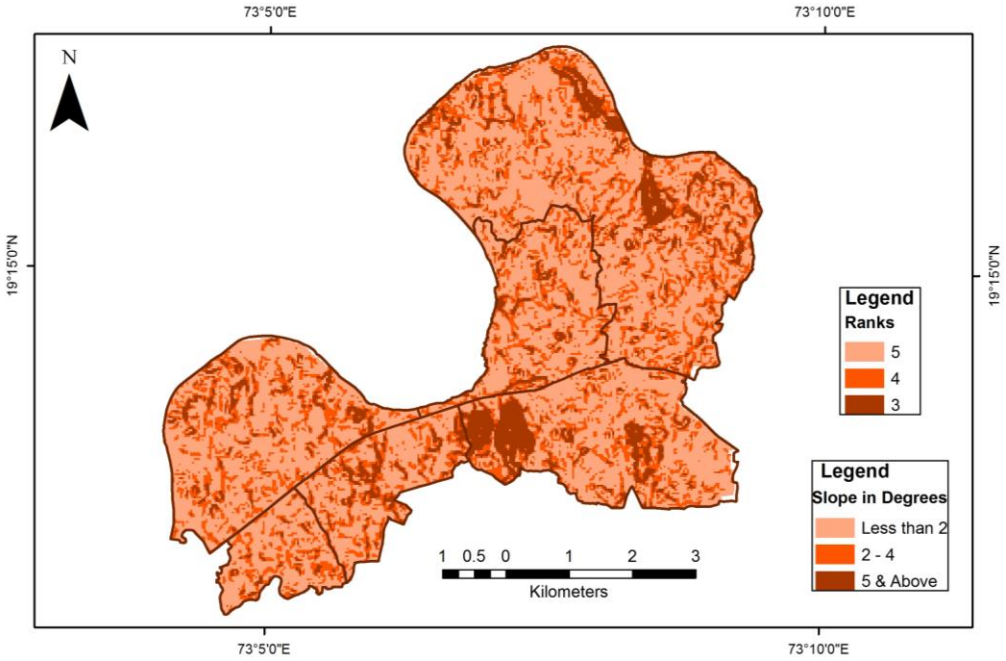
Beginning with the procedure of giving ranks to the variables, this was fundamentally based on experts' opinion and citings from authentic references.

Physical Parameter

Four variables have been selected for studying this parameter.

Slope

The slope of an area denotes its gradient or in other words, rise and fall in the surface of land. The SRTM-DEM (Shuttle Radar Topographic Mission-Digital Elevation Model) of Kalyan-Dombivli was downloaded from the United States Geological Survey (USGS) website and it was converted into a slope map after clipping the study area. Since it is a coastal area with the Ulhās Creek marking its northern boundary, the general gradient of land is pretty gentle, most of which varies between 0 to 6 degrees though a few places have a steeper gradient of more than 6^0 the maximum slant goes up to 26.25^0. Thus, depending upon suitability three categories were formed namely; slope between 0^0-2^0 (rank 5), 2^0-4^0 (rank 4) and 5^0 & above (rank 3). These ranks were decided on the basis of 'Urban and Regional Development Plans Formulation and Implementation Guidelines' (URDPFI), 2015 which indicates, lesser the gradient of land, higher is its suitability for undertaking construction and developmental activities (Fig. 2).

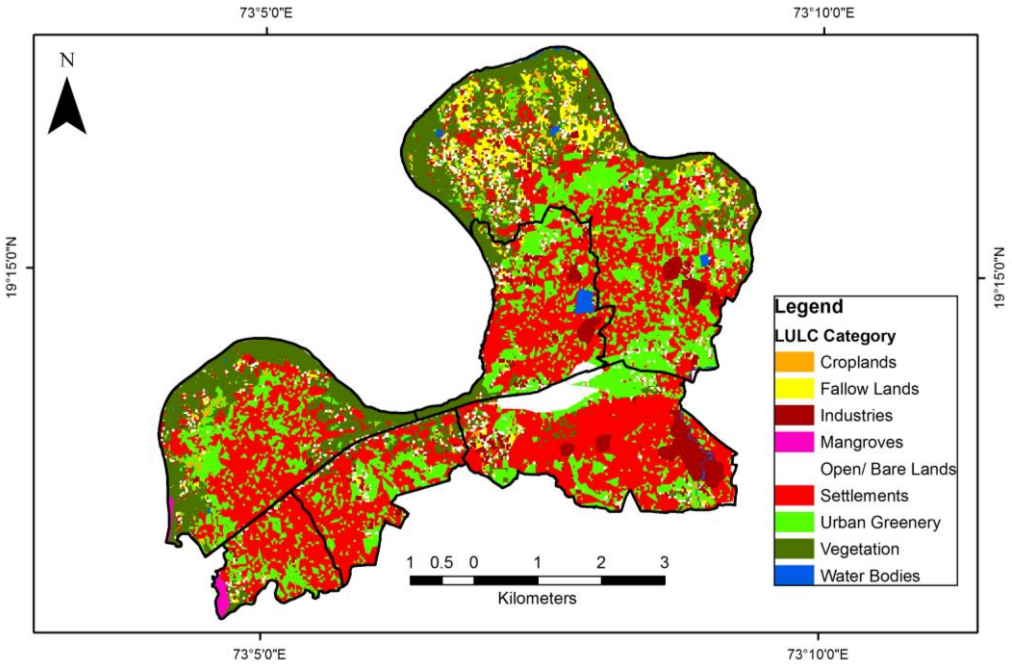


Source: SRTM-DEM, USGS

Fig. 2: Slope Map of Kalyan-Dombivli with Suitability Ranks

Land-use/Land-cover

The term 'Land-cover' refers to the physical character of land and the naturally occurring phenomena whereas 'Land-use' pertains to human utilization of land according to his needs. An Unsupervised Hybrid Pixel Classification of Kalyan-Dombivli was attempted, using the satellite image downloaded from the USGS Website and suitability ranks were allotted to each class of the nine classes of land-use/land-cover (LULC). Figure 3 illustrates the LULC classification.

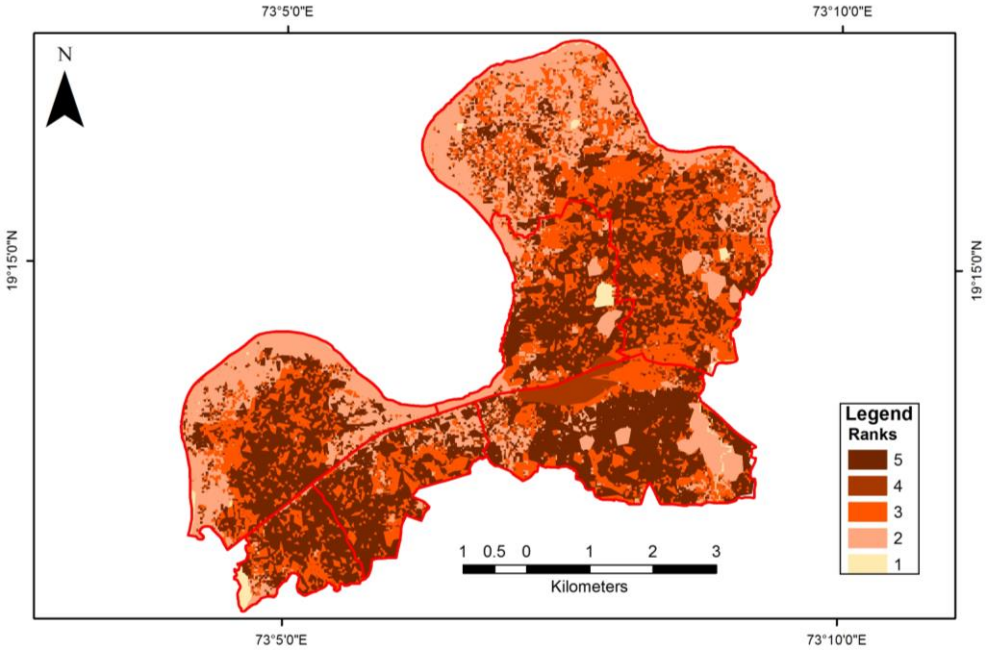


Source: Landsat 8 OLI/TIRS, USGS

Fig. 3: Land-use/Cover Map of Kalyan-Dombivli, 2017

The ranks on the scale of 1-5 were decided on the basis of functionality and capacity of that class to either support any new construction or renovation of the existing structure. Categorically, since it is not advisable to alter through human interference, the mangroves and water bodies, so these were given rank 1 which means 'very low suitability'. The class of croplands and vegetation was given a rank of 2, meaning 'low suitability', considering the fact that these need to be protected by the government and Urban Local Bodies but may be considered vulnerable to human interference to some extent. The class of Industries was also kept under the same rank as, once constructed, these are hard to shift to other locations, though they may be improvised in-situ, depending upon availability of space and resources. Thirdly, fallow lands and urban greenery were assigned rank 3 of 'moderate suitability' as these lands may be considered for developmental activities by the urban planners if these aren't yielding sufficient returns in terms of Gross Domestic Product. This is although done keeping environmental sustainability at the forefront. Rank 4, denoting areas of 'high suitability' was assigned to open and bare lands as these areas have a high potential of being put to valuable commercial or residential use,

these being unutilized lands. Finally, the 'very high suitability' i.e. rank 5 was allotted to the class of settlements as these are the most potent areas in terms of pursuing refurbishment, retrofitting and construction activities. The trick in the smart cities is to make the present structures smart while paving the way for newer facilities. Figure 4 represents the map of most suitable to least suitable categories of land uses and covers on the basis of their respective ranks.



Source: Landsat 8 OLI/TIRS, USGS

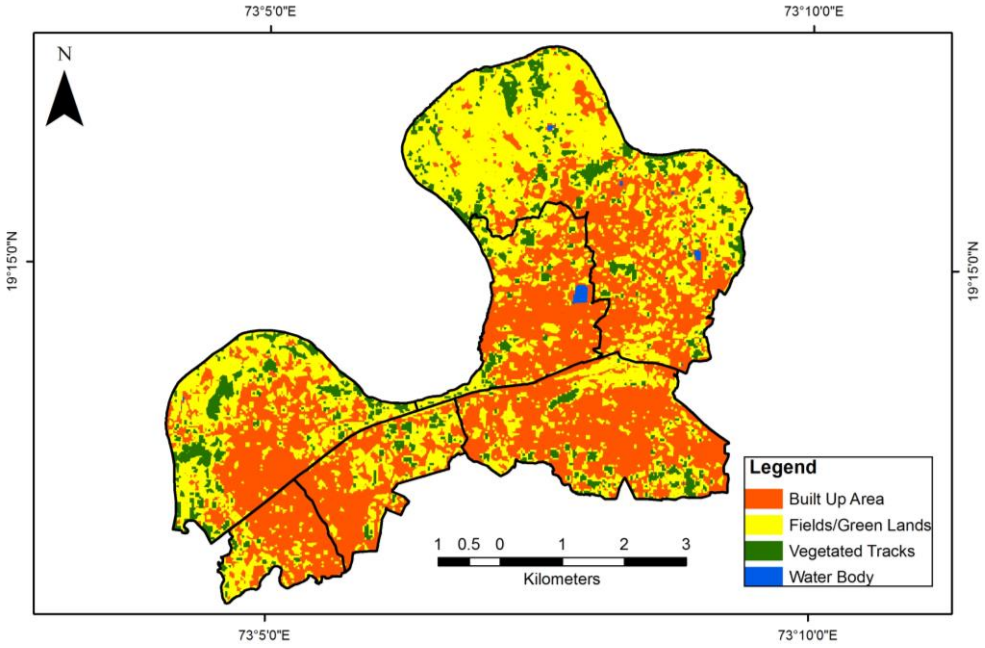
Fig. 4: Land-use/Cover Map with Suitability Ranks

Normalized Difference Vegetation Index (NDVI)

This is a numerical indicator, having widespread use in studies concerning presence or absence of vegetation or forested tracts and to determine the extent of green density on a portion of land as the leaf chlorophyll absorbs between 0.4 to 0.7 µm of visible sunlight whereas, the leaf cell reflects the Near Infrared light (NIR), i.e. between 0.7 to 1.1 µm. Thus, higher the NIR reflected light, higher is the density of vegetation. It is calculated using the formula:

NDVI= (NIR - VISIBLE RED) / (NIR + VISIBLE RED)

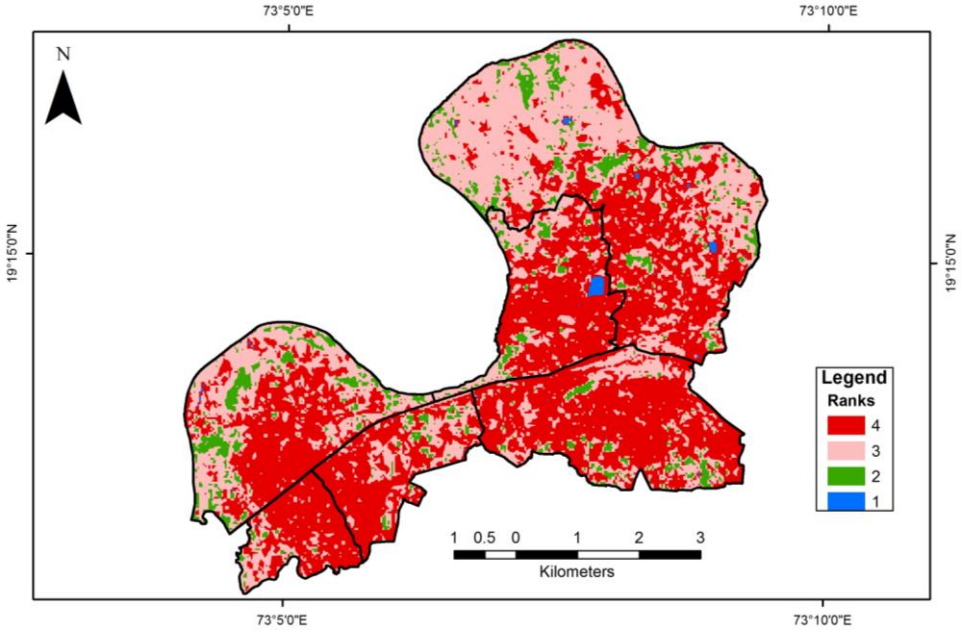
The answer is always a number that falls between minus 1 and plus 1. If there are absolutely nil green leaves then, the value recorded is zero and on the other hand, a very high density of green leaves leads to a value which is close to +1 i.e. 0.8 or 0.9 (Holme et. al, 1987). NDVI has been included in the list of physical parameters as it helps in understanding the extent of presence of vegetation in the study area and also leads the planners to design plans of action wherein the green cover is promoted rather than being compromised. NDVI, after calculation was projected as a map, thereafter the area of interest was clipped and the vegetated tracts were segregated from the built-up area, agricultural/green lands and water bodies. (Fig. 5).



Source: Landsat 8 OLI/TIRS, USGS

Fig. 5: Normalized Difference Vegetation Index of Kalyan-Dombivli, 2017

On completion of NDVI computation, the ranks of suitability were assigned to the four classes i.e. rank 1 (very low suitability) was given to water bodies as these are least appropriate for carrying out any sort of activity apart from beautifying the area where they are located. Rank 2 (low suitability) was given to the vegetated tracts for the simple reason that they should not be meddled with, since they are protectors of the overall environment. Rank 3 (moderate suitability) was assigned to agricultural fields, open lands and lands covered with urban greenery as they may be put to fruitful use in accordance with government regulations. Rank 4 (high suitability) was given to the portions covered with buildings. Figure 6 depicts the areas within the six wards designated as most suitable to least suitable for designing development related projects.

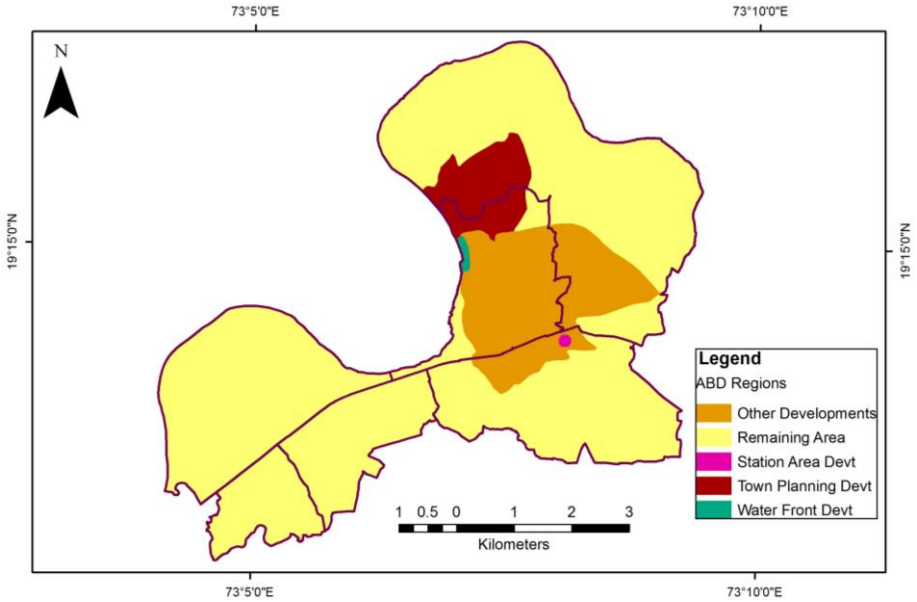


Source: Landsat 8 OLI/TIRS, USGS

Fig. 6: Normalized Difference Vegetation Index, Kalyan-Dombivli with Suitability Ranks

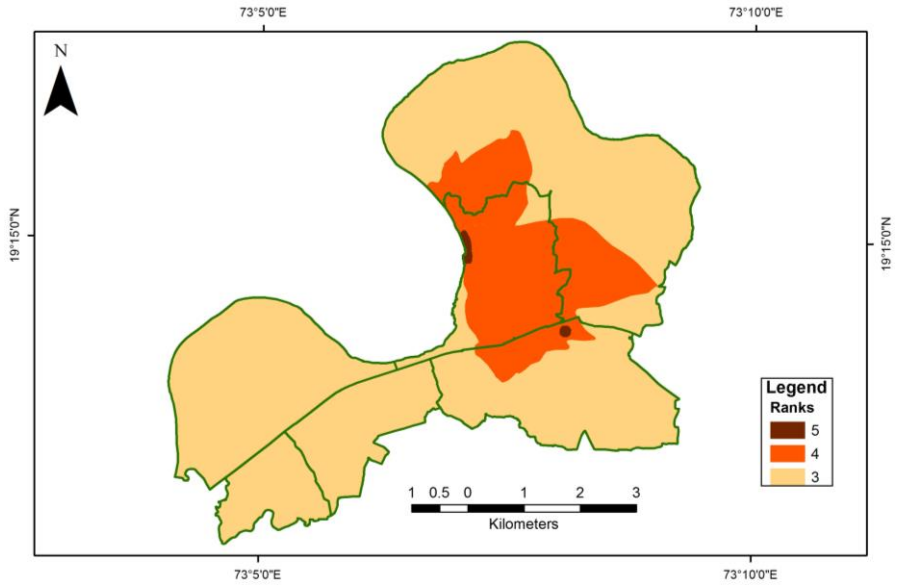
Area Based Development (ABD) Region

This is an area within the city, which was delimited by KDMC, after a series of deliberations, thorough desk-research, analysis and discussions with prominent citizens. This ABD site spreading over an area of 2054 acres, was decided on the basis of its appropriateness for performing either of the two proposed types of developments namely; 'Retrofitting' (1512 acres) and 'Greenfield Development' (542 acres). (Smart City Proposal SCP, Annexure 3, 2016) As a final outcome, the area shall entail within itself all the essential infrastructural facilities and amenities, as have been prescribed under the Mission Guidelines as well as some other elements like 'Redevelopment' that may be deemed imperative from the Smart City point of view. Thus, the ABD region was digitized after geo-referencing the map available on the KDMC's official website. The region is divided into four parts inclusive of area under town planning development, area considered for other developments, water front area and the station area (SCP, Annexure 3). Consequently, three ranks were allotted in all, depending upon their level of suitability. Rank 5 of 'very high suitability' was given to the waterfront area and the station area. Rank 4 was allocated to the area under other developments and town planning development. These ranks were decided after holding concrete discussions with the KDMC officials in Kalyan. Whereas, rank 3 of moderate suitability was given to the remaining area. The following two maps (Fig 7 and 8) clearly depict the ABD region as well as the suitability ranks.



Source: Smart City Proposal, KDMC

Fig. 7: Area Based Development Site in Kalyan



Source: Smart City Proposal, KDMC

Fig. 8: ABD site with Suitability Ranks

Calculation of Weights, Physical Parameter

The completion of the task of map making led to the series of calculations involved in the Analytic Hierarchy Process (AHP). It is important to state here that, the total number of variables selected under either of the two parameters i.e. physical and socio-economic should not be more than 9 as there is an absence of Random Indices given in the Random Consistency (Table 8), prepared by Thomas Saaty in 1977, beyond nine selections. These indices are mandatory for calculating the Consistency Rates C.R. (discussed in the following paras). Chronologically speaking, the pairwise

comparison matrix (table 5) was prepared after taking note of expert opinion of six respondents, regarding the level of significance of one variable, in comparison with another. The values in the matrix were established on the basis of the Scale of Preference (table 4). In case, the second variable was preferred over the first one then the reciprocal of the value mentioned in the scale was given for that particular comparison (for instance; in A1 vs A2 if the first variable is preferred the value will be *'n'* but if the second one is preferred the value will be *'1/n'*). For these values, the average was calculated, column wise, and noted in the 'blue' triangular portion of Table 6 whereas, the reciprocal of these (average) values were noted in the 'green' triangular portion of the same table. In other words, it can be said that, half of the values in this matrix are simply a comparison of the variables mentioned in the left column with the ones mentioned in the topmost row and the other half are those values that are the reciprocals of the first half and the middle diagonal is filled with the numerical '1' (1 signifies Equal Importance) as these depict the comparison of one element with itself. Further, the weights were calculated in Table 7 by dividing each figure in table 6 by the sum-total. This was done column-wise. Thereafter, the average of the figures mentioned in column 3 to 6 (row-wise) was calculated so as to derive the final 'weights' also called as *'Local Priorities'* (according to Thomas Saaty, 1977) and are generally listed on the right hand side, as mentioned in column 7 in table 7. The consistency values were then computed in order to assess the rate of consistency between the selected variables under the physical parameter. In case of perfectly consistent judgements, the Consistency Rate (C.R.) is equal to 0. Since the rate of consistency came out to be 0.09, which is less than 0.1 it is understood that the variable selection is good and there exists an optimum level of intra consistency among them. If the C.R. is too high, or there exists inconsistency within the judgements, (C.R. = > 0.1) then the result becomes biased by a sizeable error.

After calculating the Consistency value for each of the selected variable, an average of these values was obtained, which is known as the *'Lambda value'*. The total number of selected variables, under the physical parameter, which is 4, was then subtracted from the Lambda value i.e. 'Lambda – n' (4.25 – 4 = 0.25). This figure was then used for calculating the Consistency Index (C.I.) using the formula: "C.I. = Lambda Value / n-1"

Where, n = the number of variables selected under the physical parameter.

Next, the consistency rate (C.R.) was computed using the formula:

C.R. = C.I. / R.I.

Where, C.I. is the Consistency Index and

R.I. is the Random Index which is a numerical value adopted from the Random Consistency Table (given by Thomas Saaty, 1977) depending upon the '*n'* (number of selected variables). The R.I. thus adopted from table was 0.9 for n = 4.

Therefore, the Consistency Rate came out to be 0.09 and since this value is less than the prescribed value of 0.1 thus, it is considered relevant for further consideration.

Table 3: Physical Variables Selected for Calculation

Physical Variables	
Series	**Categories**
A1	Slope
A2	ABD
A3	LULC
A4	NDVI

Source: Variables selected by the Researcher

Table 4: Scale of Preference (1-9)

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
3	Moderate Importance	Experience and judgement slightly favor one activity over another
5	Strong Importance	Experience and judgement strongly favor one activity over another
7	Very Strong Importance	An activity is favored so strongly, its dominance is demonstrated in practice
9	Extreme Importance	The evidence favoring one activity over another has the highest possible affirmation.
2, 4, 6, 8	For compromise between the above values	Sometimes a compromise judgement needs to be given due to absence of a good description
Reciprocals	Inverse Value	It is used for inverse comparison

Source: Saaty, 1977

Table 5: Pairwise Comparison Matrix (on the basis of Scale, in table 4)

Respondents	A1 vs A2	A1 vs A3	A1 vs A4	A2 vs A3	A2 vs A4	A3 vs A4
First	9.00	0.14	0.20	0.13	0.17	0.25
Second	3.00	0.20	5.00	0.16	4.00	7.00
Third	1.00	0.13	0.14	0.13	0.13	6.00
Fourth	1.00	0.14	0.14	0.14	0.17	5.00
Fifth	1.00	0.20	0.12	0.25	0.20	5.00
Sixth	9.00	0.20	0.13	0.14	0.17	0.20
Average	**4.00**	**0.17**	**0.96**	**0.16**	**0.80**	**3.91**

Source: Inputs provided by Experts and Average Calculated by the Researcher

Table 6: Computation on the basis of Pairwise Comparison

Series	Variables	A1	A2	A3	A4
A1	Slope	1.00	4.00	0.17	0.96
A2	ABD	0.25	1.00	0.16	0.80
A3	LULC	5.94	6.34	1.00	3.91
A4	NDVI	1.05	1.24	0.26	1.00
	Sum	**8.23**	**12.59**	**1.58**	**6.67**

Source: Calculated by the Researcher

Table 7: Computation of Weights

Series	Variables	A1	A2	A3	A4	Weights	Consistency Value
A1	Slope	0.12	0.32	0.11	0.14	0.17	4.43
A2	ABD	0.03	0.09	0.10	0.12	0.09	3.75

A3	LULC	0.72	0.50	0.63	0.59	0.61	4.47
A4	NDVI	0.13	0.10	0.16	0.15	0.13	4.34
	Nr. Sum	1	1	1	1		4.25

Source: Calculated by the Researcher (Note: Nr. Means Normalized)

Table 8: Random Consistency Table

n	1	2	3	4	5	6	7	8	9
R.I.	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45

Source: Thomas Saaty, 1977

Values obtained after calculation from the preceding tables are listed below.

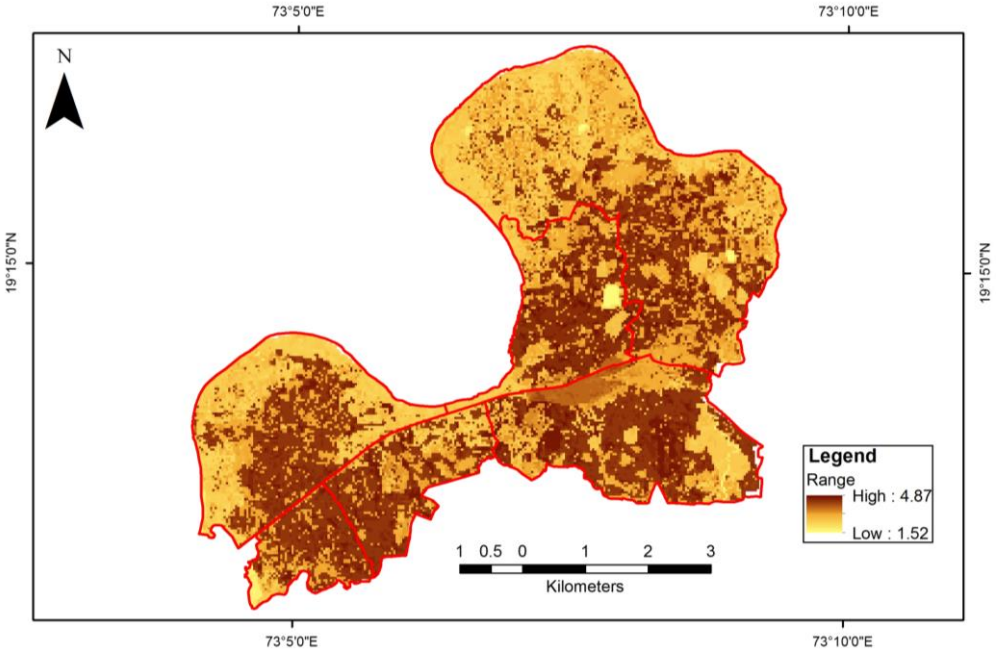
Lambda = 4.25, Lambda - n = 0.25, Consistency Index = 0.08, Random Index = 0.9, Consistency Rate = 0.09

Weighted Overlay Technique (WOT), for Physical Parameter

After derivation of the weights for the above variables, it becomes imperative to accomplish the target of performing the 'Weighted Overlay Analysis' in order to understand the site suitability of Kalyan-Dombivli (Saaty and Vargas, 2012). Thus, after prioritizing the suitability ranks and calculating the respective weights to be allotted to the inputs, the vector maps (shapefiles), as shown above were converted into raster layers, as the WOT only accepts the inputs in the form of rasters that have been reclassified as integers. Further, the weights calculated in table 7 were assigned to all the variables, so as to stack together, all the created layers along with their respective ranks of suitability, and generate an output with these layers overlaid onto each other. This was done using the following algorithm, while arranging the variables in descending order of their weights:

LULC * 0.61 + Slope * 0.17 + NDVI * 0.13 + ABD * 0.09.

This culminated in the formation of a final layer, which was then portrayed as a map (fig. 9) that systematically illustrated those areas within the study area that can be considered for redevelopment by the planners based on the requirement of the site. The map vividly highlights those areas (Dark-Brown with a suitability value of 4.87), within the different wards of Kalyan and Dombivli, that are the most suitable as far as the development of the existing and new infrastructural facilities is concerned, owing to the flat nature of the land, absence of crop lands, vegetated or mangrove tracts and the presence of open/bare lands and settlements. On the contrary, those areas in the lightest shade of brown and a range value of 1.52, are considered the least suitable as these are covered by either water bodies, cultivated/vegetated areas or industrial belts. The remaining areas are moderately suitable though.



Source: Prepared by the Researcher on the basis of calculated weights

Fig. 9: Weighted Overlay of Physical Variables

Conclusion

It can be concluded that the wards that project higher suitabilities are the ones that support higher densities of population. This sufficiently points to the realization that people in general, utilizing their intelligence, almost always choose to live in those areas, where they find maximum resources, lower costs of living, safer environments, good infrastructure. Therefore, D ward in Kalyan and G and F wards in Dombivli are more congested as compared to the other wards. These can be considered for retrofitting amenities and refurbishment of the existing facilities. Whereas, the wards like B and H where more open areas are available due to lesser concentration of population can be considered for schemes of redevelopment. According to the municipal corporation officials, portions of ward B that face the water body have already been covered under the 'water front area development scheme' and the city of Kalyan, is covered under the Area Based Development Scheme, thus, the twin city of Kalyan-Dombivli is very much feasible to become a full-fledged smart city, as designated under the 'Smart City Mission' because the corporation officials are busy with the provisioning of the infrastructural amenities to the masses coupled with citizen participation.

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