Multi Criteria Based Land Suitability Analysis Using GIS

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Abstract - *The process of Urban Planning is highly complex in nature given the multiple parameters and layers of information that is required while deriving a plan. These range from geographical features such as slopes, watersheds, soil characteristics to physical features such as roads, utility lines, rail lines etc. Standard means of planning becomes restricted in its capacity to perceive the interaction of multiple features and in deriving the best proposals. As an alternative approach, the paper establishes an alternative methodology to leverage GIS to conduct land suitability analysis. Analytical Hierarchy Process is used to weigh multiple layers of information and a composite map for the suitability is generated.*

Key Words: **GIS, Analytical Hierarchy Process, Land Suitability Analysis,**

1. INTRODUCTION

Land Use Planning is an important step in developing an urban planning scheme. Any given region is a complex mix of various landuses allocated by the planner judiciously as per the analysis and regulatory requirements applicable for the proposed typology of development. The allocation ensures an even distribution of resources, population and opportunities to result in a development, which is efficient and optimized. There are multiple factors that have to be considered while allocating these land uses. Traditionally an urban planner will generate various maps and layouts highlighting each of these features and then process hem manually while trying to arrive at the best fir proposal.

This exercise becomes increasingly challenging when the area of study becomes larger and complexity of interaction multiplies.

Leveraging GIS the process of Land Suitability Analysis is digitalised which can handle large and complex datasets easily. The method of land suitability analysis is divided into four major sub sectors mainly, developable land based on natural features, suitable land for urban development based on developable land map derived after considering natural features and other factors, suitable land for polluting and non-polluting industries.

2. Multi Criterion Analysis

To determine the best location for various zones inside the estate multi-criterion analysis is conducted. Analytic Hierarchy Process (AHP) is used to calculate the weightages for selected 5 main criterions identified based on which the zones will be placed. AHP is a structured technique that used to make complex decision based on mathematical relations and psychology. This takes into consideration multiple factors and perceived weightages against each other based on Saty's comparison index.

2.1 Proximity to railway line

Railway corridor divides the whole site into two major halves. Along the railway corridor, few industries have come up. This nature of development, coveys that, apart from road networks, rail networks are also necessary for the residential development. The cost of transportation for daily commuters is improved in this case. Majority of residential zones which have been proposed for future development lies outside the spine of 1500m from the railway line.

2.2 Proximity to railway station

This criterion is very important for urban development. The areas surrounding railway stations are densely populated. The primary reason for this is access to means of transport from other parts of the city or region, which allows workforce to get in and out. A 750 m buffer has been taken for high-density development. The land parcel within the radius of 750m is most preferable to be developed as transit oriented development.

2.3 Proximity to major roads

Roads are the most important elements in development of any settlement. Every settlement develops along certain corridors. Proposed roads act as guides to the growth of the development in a certain way. The major buffers are taken as 100m, 300m, 500m, 750m from the roadways for urban development. In most of the cases, unorganised development and mixed use developments come up near the roads. This criterion is important in determining the location of the residential and mixed areas of the urban development. Proximity to centres City centre is always an important factor for urban development which act as an magnet for growth and causes high property values leading to densification of development and population. Historically the commercial activities are focused around such centres.

2.4 Proximity to Water Channel

The drain channels are one the defining geographical features of the site and nearness to it is not desirable for locating the residential zones. Contrasting to this fresh water channels become desirable when zoning residential zones. Buffers along these have been taken in order to get the non-buildable zone near the river-bed.

2.5 Proximity to Industrial Park

Location near the industrial park becomes important while siting the industry as it possess potential to create a shared system of utilities, logistic systems and other resources such as services, electric sub-stations, ETPs, CETPs etc. At the same time the residential areas won't be desirable to be located there.

4. Process of calculation

Once the parameters to be considered are established, the next step is to assign weightages to each factor. These weightages are based on expert opinions and different inputs normalized into average.

$$A = \begin{bmatrix} a_{11} & \cdots & a_{16} \\ \vdots & \ddots & \vdots \\ a_{61} & \cdots & a_{66} \end{bmatrix}$$

$$A/w = \sum_{j=6}^{j=1} a_{ij} . w_j^{-1} = \begin{bmatrix} a_{11} & \cdots & a_{16} \\ \vdots & \ddots & \vdots \\ a_{61} & \cdots & a_{66} \end{bmatrix} . [1/w_1 \quad \cdots \quad 1/w_6]$$

Table -1: Parameter Characteristics

Parameter	Development Constraint	Buffer Considered	Ranking
Nearness to roads	Areas nearer to transportation network have higher potential for development. Development of infrastructure near the road saves cost and time for transportation.	< 100 m	10
		100-300 m	8
		300-500 m	6
		500-700 m	4
		>700 m	2
Nearness to Railway line	Areas near to railway has high potential for industrial development	<150m	10
		150-300m	8
		300-500m	6
		500-1000m	4
		1000-1500m	2
		>1500m	1
Distance from Water Bodies	Needs conservation for future	50m	2
		150m	5
Distance from Residential Areas	Areas away from residential area is suitable for hazardous industrial development	Areas outside 1 km Buffer	10
		750-1000 m	8

A Pair wise comparison between each factor defining its importance. This helps in allocating the relative importance while calculating the weightages of individual factors.

Table -2: Pair wise comparison of factors

		Important	Scale
A	**B**	**- A or B**	**(1-9)**
Proximity to residential area	Proximity to major road	A	7
	Proximity to drain channel	B	7
	Proximity to railway line	A	8
	Proximity to Industrial Park	A	8
Proximity to major road	Proximity to drain channel	B	6
	Proximity to railway line	A	7
	Proximity to Industrial Park	B	8

Proximity to drain channel	Proximity to railway line	A	6
	Proximity to Industrial Park	A	5
Proximity to railway line	Proximity to Industrial Park	A	6

The above pair wise comparison table can be summed up into a matrix as under:

Table -3 Consolidated Pair Wise Comparison

Factors	1	2	3	4	5
Proximity to residential area	**1**	7	1/7	8	8
Proximity to major road	1/7	**1**	1/6	7	1/8
Proximity to drain channel	7	6	**1**	6	5
Proximity to railway line	1/8	1/7	1/6	**1**	6
Proximity to Industrial Park	1/8	8	1/5	1/6	**1**

Normalized principal eigenvector, to get weightages for each identified parameter.

$$W_j = \frac{1}{n}\sum_{j=6}^{j=1} a_{1j}/w_j = \begin{bmatrix} a_{11}/w_1 & \cdots & a_{16}/w_6 \\ \vdots & \ddots & \vdots \\ a_{61}/w_1 & \cdots & a_{66}/w_6 \end{bmatrix} . \begin{bmatrix} 1 \\ \vdots \\ 1 \end{bmatrix} . n^{-1} = \begin{bmatrix} \frac{1}{n}\sum_{j=6}^{j=1} a_{1j}/w_1 \\ \vdots \\ \frac{1}{n}\sum_{j=6}^{j=1} a_{6j}/w_6 \end{bmatrix}$$

Table -4 Weightages of Each Parameter

Pair Wise Comparison Matrix	P.R.A.	P.M.R	P.D.C.	P.R.L.	P.I.P.	Weightages
Proximity to residential area	1.00	7.00	0.14	8.00	8.00	27.7
Proximity to major road	0.14	1.00	0.17	7.00	0.13	9.3
Proximity to drain channel	7.00	6.00	1.00	6.00	5.00	43.3
Proximity to railway line	0.13	0.14	0.17	1.00	6.00	9.2
Proximity to Industrial Park	0.13	8.00	0.20	0.17	1.00	10.6

These factors are integrated as property values into the rasterized images generated for each of the parameters using the GIS software like ArcMap.

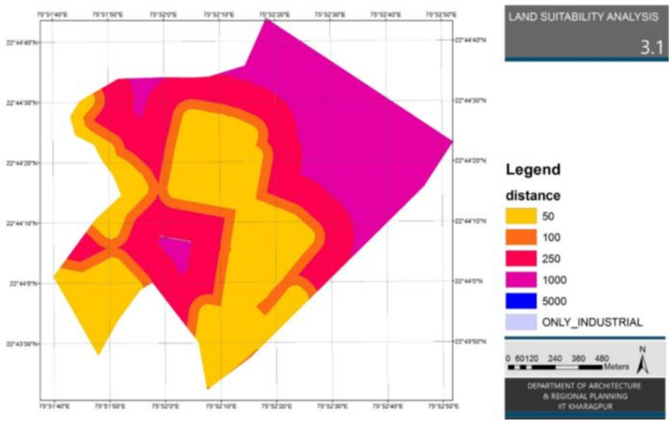


Fig -1: Proximity to Industries

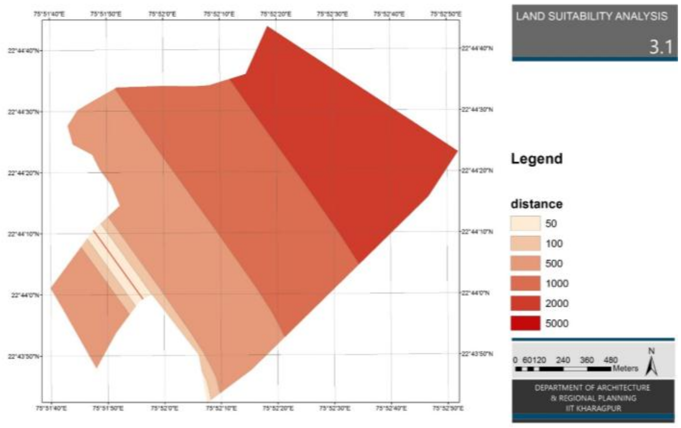


Fig -2: Proximity to Rail Lines

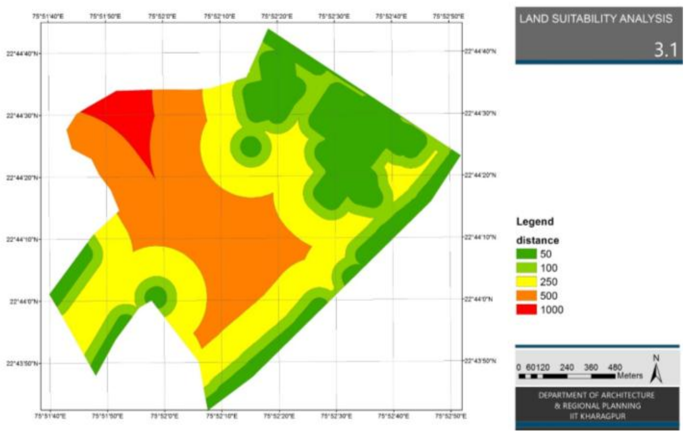


Fig -3: Proximity to Residential Areas

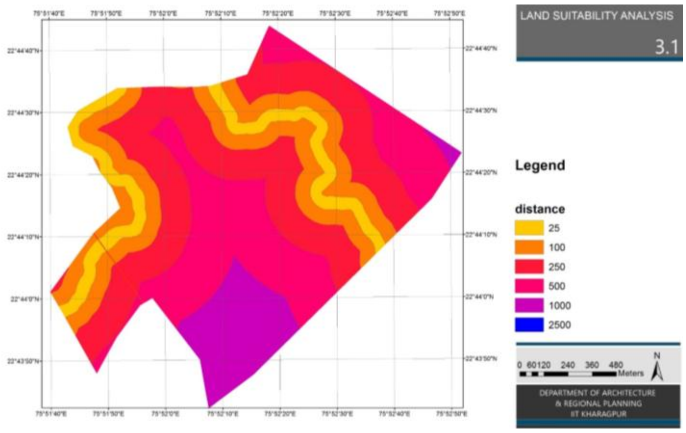


Fig -4: Proximity to Drain Channels

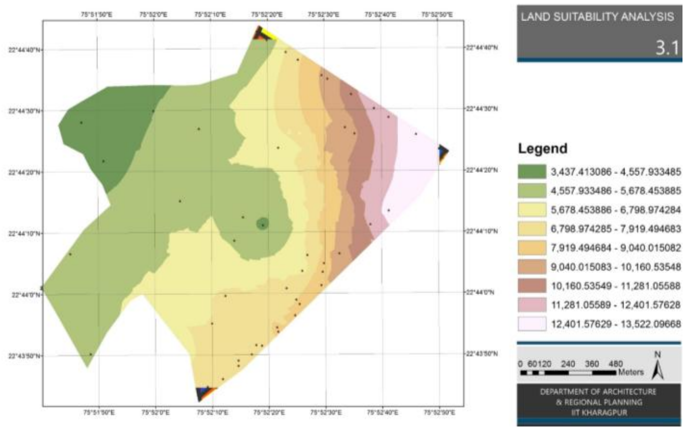
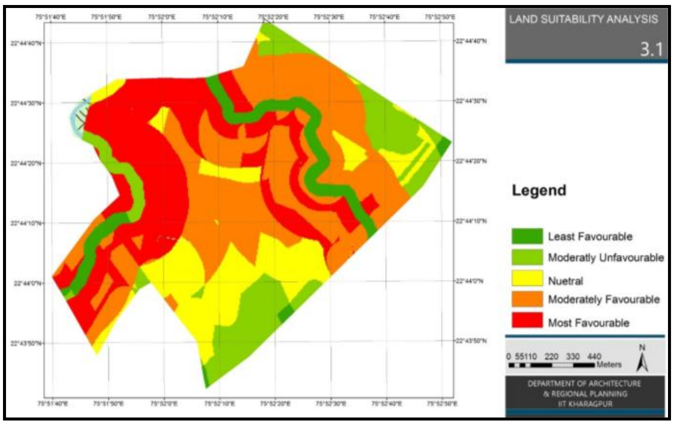


Fig -5: Land Value Map (Proximity to Road)

4. CONCLUSION

The land suitability map shows an integrated map generated by overlaying all the pertinent parameters taking into account the various weightages and respective factors. The red zones are areas that are most favorable for development into industrial zones. While the green areas are those which are to be developed as residential and commercial areas.



5. Way Forward

The process of Land Suitability analysis can be utilized effectively in the ongoing project by MSRDC of new town developments.

Fig -6: Samruddhi Mahamarg Infographic

The Hindu Hrudaysamrat Balasaheb Thackeray Maharashtra Samruddhi Mahamarg, the flagship project of Government of Maharashtra, has now placed emphasis on the development of new towns along the route. The Mahamarg, that connects Mumbai to Nagpur in Vidarbha, will develop more than 19 new towns along the 701 km expressway. A network of industrial hubs will also be weaved along the expressway, benefiting the state. The state Government has undertaken policy level inititatives to establish growth centres and committed to develop economic hubs along the Mahamarg to ensure planned development.

MSRDC has been appointed as a New Town Development Authority (NDTA) under the provisions of the sub sec (1) and sub sec (3A) of section 113 of the MR & TP Act, 1966, for the development and growth of Nodes, which is also coined as 'Krushi Samruddhi Nagar.' MSRDC has proposed 20 New Towns at the intersection of Samruddhi Marg and national and state highways at an average distance of 30 to 40 km from each other. The objective to develop such towns and villages is to enrich the lives of the farmers residing there. The town will witness great opportunities in terms of better agro-based industrial production, trade, commercial facilities. These towns will be developed and promoted as centres of wider regional economics. Each Nagar developed by this initiative will have an area of approximately 1000-1500 ha.

The sheer size of developments indicate the need for a more robust process to plan the best possible solutions & planning proposals for these towns for the benefit of the land owners as well as the government. The process of land suitability analysis thus can be utilized to evaluate the conditions at each of these locations and aid the government, stakeholders as well as consultants to arrive at appropriate land use strategies for development.

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