GIS-based Industrial Land Suitability Analysis for locating Industrial Parks in Raipur and Nava Raipur

Ankur Baghel
Assistant Professor, Department of Planning and Architecture
National Institute of Technology Rourkela, Odisha, India
baghela@nitrkl.ac.in

Abstract This paper offers an integrated approach towards the preparation of a mechanism for allocation of land for the industrial parks assessing the land potential for different uses to regulate and manage the use of land and improve the surrounding environment. An Industrial land Suitability Analysis has been carried out to allocate suitable land parcels for industrial development. An Analytical Hierarchy Process (AHP) with the integration of Geographic Information System based Multi-criterion decision-making (MCDM) was adopted for weighing the parameters. With the pairwise comparison matrix, the establishment of the weights was carried out and based on obtained weights, overlaying was carried out in the GIS interface to generate outputs for the most suitable and least suitable areas for industrial land use with a synthesized suitability map. The final results showed that the prominent locations for future industrial development came mostly near roads and railway routes. Since the utilization of vacant and wastelands with preservation of agricultural fields were prime concerns while deciding on the ranking of the criteria, the suitability results showed lesser agricultural areas than in other areas.

1. Introduction
As per the Chhattisgarh Industrial Policy 2019-2024, the investment climate plays an essential role in the region's industrial development. Raipur district is widely known for its rice mills, cement, and steel plants. Raipur district has a rare distinction of having the most significant number of large and small cement plants. Raipur and Nava Raipur have emerged as prominent and essential destinations for industrial and commercial activities (Mohan et al., 2012). This development of a favourable industrial climate has led to rapid industrialization in areas near Raipur and Nava Raipur (Bhojwani & Bagga, 2016).

Alternatively, this has made Raipur one of India's critically polluted cities, as per a study from the Centre of Science and Environment (CSE, 2011). There exists a severe lack of the development of industrial estates, which is required for better growth (Verma, 2014). Being the new Capital and acting as one of India's largest steel manufacturing hubs lying in the industrial corridor due to expressway connectivity; The PM2.5 show a rise of 50% between 1998 and 2014 (Gutikunda, Pant, Nishadh, & Jawahar, 2019). Thus, it is essential to provide suitable land parcels for future industrial development in this region.

Suitability analysis is a valuable tool for assessing land suitability for specific purposes. It aims to utilize the land for the best possible use appropriate to the needs and preferences. Since this is a decision-making process involving the land's capacity for supporting a specific service and considers the other vital aspects like socio-economic and environmental features thus, the weighing of the criteria under consideration becomes difficult. A multicriteria decision-making process has been adopted to assist in the weight calculation to overcome this issue. This method can analyze problems, producing alternatives.

Integrating AHP used for multicriteria analysis and GIS in land suitability analysis is suitable for this study. Both these tools were used along with the mapping of existing land uses, and appropriate land parcels were found for future industrial development (Cengiz & Akbulak, 2009).
2. Methodology

2.1 Study area

The study area is situated in the fertile plains of the Chhattisgarh Region. This region is between 22° 33' N to 21°14'N latitude and 82°6' to 81°38'E longitude (figure 1). District Bilaspur surrounds the North, District Bastar and part of Odisha state in South, District Raigarh and part of Odisha state in East, and district Durg in West.

Road connectivity is an essential development determinant of any upcoming economy of the region. The Raipur Region is strategically positioned and crosses numerous critical national highways, including the Great Eastern Road (Bombay – Kolkata) and Raipur-Dhamtari-Vishakhapatnam. Aside from that, it has air connections to the country's major cities. National highways (NH-6, NH-43, and NH-200) and three state highways connect the region (SH-2, 7, and 9). In Bilaspur, the South Eastern Railway Headquarters manages the region's railway network. All of the lines run practically parallel to National Highway and State Highway. Raipur is located on the Bilaspur-Durg portion of the South-Eastern Railways' Mumbai-Howrah broad gauge line. Over the region, the railway lines and stations offer mass communication and goods movement.
2.2 Criteria to be considered for the Land Suitability Analysis

An Industrial land Suitability Analysis has been carried out to allocate suitable land parcels for industrial parks. The areas with maximum susceptibility of action were considered in terms of industrial suitability, which were thus generated with the help of the land-use suitability method and included specific criteria. The criteria provided with respective scales based on expert opinions and reviews are as follows:

Table 1. Importance to different criterion

| Criteria                        | Scale |
|---------------------------------|-------|
| Utilization of Wastelands       | 10    |
| Utilization of Vacant land       | 9     |
| Accessibility to Road            | 8     |
| Accessibility to Railways        | 7     |
| Preservation of Agricultural Field | 6    |
| Distance from Residential Areas  | 5     |
| Distance from Water bodies       | 4     |
| Distance from Core City area     | 3     |

2.3 Weighted Index Model

Saaty's 'Analytical Hierarchy Process' is the most widely accepted method for scaling the weights of different criteria (Jie, Jing, Wang, & Shu-Xia, 2010). A pairwise comparison matrix was made based on a scale of essential intensities. Ranks were given to criteria Factors after considering the expert's opinions.

Table 2. Saaty's intensity of importance on an Absolute Scale

| Intensity of importance | Definition                              | Explanation                                           |
|-------------------------|-----------------------------------------|-------------------------------------------------------|
| 1                       | Equal importance                        | Two activities contribute equally to the objective    |
| 3                       | Moderate importance of one over another | Experience and judgment moderately favour one activity over another |
| 5                       | Strong importance                       | Experience and judgment Strongly favour one activity over another |
| 7                       | Extreme importance                      | An activity strongly favoured                         |
9 Extreme importance The evidence favouring one activity over another is of the highest possible order of affirmation
2.4,6,8 Intermediate values between the two adjacent judgment When compromise is needed

2.4 Computation of criterion weight:
After forming the Pairwise Comparison Matrix, criterion weight has been calculated. The steps followed are as follows:

- The sum of each column of the pairwise comparison matrix has been found.
- Each element of the pairwise comparison matrix is divided by the column sum, which results in the formation of a normalized matrix.
- The average of all elements in each row of the normalized matrix is calculated and divided by some criteria. The averages that come out are the relative weights of the corresponding criteria.

Table 3. depicts the Pairwise comparison matrix

| TABLE 3 | | | | | | | |
|---------|---|---|---|---|---|---|---|
| W   | 1.00 | 2.00 | 3.00 | 3.00 | 4.00 | 7.00 | 9.00 |
| V.L. | 0.50 | 1.00 | 2.00 | 3.00 | 5.00 | 7.00 | 8.00 |
| A.R | 0.33 | 0.50 | 1.00 | 2.00 | 4.00 | 5.00 | 6.00 |
| A.Ry | 0.33 | 0.33 | 0.50 | 1.00 | 4.00 | 5.00 | 4.00 |
| Aw | 0.25 | 0.20 | 0.25 | 0.25 | 1.00 | 4.00 | 6.00 |
| R.A | 0.14 | 0.14 | 0.20 | 0.20 | 0.25 | 1.00 | 2.00 |
| C.C | 0.11 | 0.13 | 0.17 | 0.25 | 0.17 | 0.50 | 1.00 |
| W.B | 0.25 | 0.20 | 0.25 | 0.25 | 0.50 | 0.50 | 1.00 |
| 2.92 | 4.50 | 7.37 | 9.95 | 18.92 | 30.00 | 36.50 | 24.00 |

Table 4. shows the Normalized matrix for criteria weights

| TABLE 4 | | | | | | | | |
|---------|---|---|---|---|---|---|---|---|
| W | 0.34 | 0.44 | 0.41 | 0.30 | 0.21 | 0.23 | 0.25 | 0.17 |
| W.B | 0.294 |
2.5 Calculation of the Consistency Ratio

Calculating a consistency ratio to assess the consistency of the judgments is the next critical step. An identity matrix is multiplied by the normalised matrix. The consistency vectors are created by multiplying the reciprocal values of the final matrix by a matching relative weight.

The sum of all consistency vectors is calculated to get $\lambda_{max}$. Consistency Index is measured from the following formula:

**Equation 1.** Consistency Index calculation

$$C.I = (\lambda_{max} - n)/(n-1)$$

**Table 5.** Calculation for Consistency vector

| V.L | A.R | A.Ry | Ag | R.A | C.C | W.B | $\lambda_{max}$ |
|-----|-----|------|----|-----|-----|-----|-----------------|
| 0.17 | 0.11 | 0.11 | 0.09 | 0.05 | 0.04 | 0.09 | 2.63            |
| 0.22 | 0.14 | 0.07 | 0.04 | 0.03 | 0.03 | 0.04 | 2.17            |
| 0.27 | 0.20 | 0.10 | 0.03 | 0.02 | 0.02 | 0.03 | 1.47            |
| 0.30 | 0.21 | 0.21 | 0.01 | 0.01 | 0.03 | 0.01 | 1.16            |
| 0.26 | 0.17 | 0.17 | 0.05 | 0.03 | 0.03 | 0.02 | 0.69            |
| 0.23 | 0.16 | 0.16 | 0.13 | 0.08 | 0.08 | 0.03 | 0.33            |
| 0.22 | 0.17 | 0.17 | 0.16 | 0.08 | 0.08 | 0.04 | 0.26            |
| 0.21 | 0.17 | 0.17 | 0.16 | 0.08 | 0.08 | 0.04 | 0.30            |
| | | | | | | | 1.00 |

$\sum{C.I} = 8.78$
Consistency Index provides a measure of departure from consistency. For the determination of the goodness of C.I, the analytical hierarchy process compares it with Random Index, and the result we get is consistency ratio (C.R)

**Equation 2.** Consistency ratio

\[ CR = \frac{CI}{RI} \]

Here C.R. is Consistency Ratio, CI is consistency index, and R.I. is Random Index.

The C.R is designed so that if C.R< 0.1, the ratio indicates a reasonable level of consistency in a pairwise comparison. If C.R>0.1, then the ratio is indicative of inconsistent judgments. In such cases, one should reconsider and revise the original values in the pairwise comparison matrix (Franek & Kresta, 2014).

| Table 6. Random Index Table (Wedley, 1993) |
|-------------------------------------------|
| \( \begin{array}{cccccccccc}
| N & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 \\
| \hline
| RANDOM INDEX & 0 & 0 & 0.58 & 0.9 & 0.12 & 1.24 & 1.32 & 1.41 & 1.45 & 1.49 \\
| \end{array} \) |

| Table 7. depicts the obtained CI and CR |
|----------------------------------------|
| \( \begin{array}{c}
| CONSISTENCY INDEX (CI) \\
| CI = \frac{\lambda - n}{n-1} \\
| \hline
| CI & 0.11 \\
| \end{array} \) |

| \( \begin{array}{c}
| CONSISTENCY RATIO (C.R.) \\
| CR = \frac{CI}{RI} \\
| \hline
| CR & 0.0795 \\
| \end{array} \) |

| Table 8 shows the Obtained Criteria weights |
|--------------------------------------------|
| \( \begin{array}{ll}
| Criteria & Obtained Criteria Weight \\
| \hline
| Utilization of Wastelands & 0.294 \\
| Utilization of Vacant lands & 0.236 \\
| Nearness to road & 0.158 \\
| Nearness to Railways & 0.126 \\
| Preservation of Agricultural fields & 0.077 \\
| Distance from Residential Areas & 0.039 \\
| Distance from water bodies & 0.031 \\
| Distance from Core City area & 0.035 \\
| \end{array} \) |
Once the weights were found out, the "Overlaying" method was employed in the GIS interface; with more than one parameter affecting the region’s future development, this technique is most appropriate.

The generated output depicts the most suitable and least suitable areas in the Raipur region. Utilization of vacant and wasteland with preservation of agricultural fields were prime concerns while deciding on criteria ranking. Hence the suitability shown by agricultural areas was comparatively lesser than in other areas.

**Table 9 Physical Parameters considered for land suitability analysis**

| Parameter                          | Constraint                          | Development Constraint                                                                 | Buffer/ Factors Considered | Ranks |
|-----------------------------------|-------------------------------------|-----------------------------------------------------------------------------------------|-----------------------------|-------|
| Accessibility to Roads            | Infrastructure, Transport mode       | Areas nearer to the transportation network have a higher potential for industrial development. | < 300 m                     | 10    |
|                                   |                                     | Growth of infrastructure near the road saves cost and time for transportation             | 300-500 m                   | 8     |
|                                   |                                     |                                                                                         | 500-800 m                   | 6     |
|                                   |                                     |                                                                                         | 800-1000 m                  | 4     |
|                                   |                                     |                                                                                         | > 1000 m                    | 2     |
| Accessibility to Railways         | Transportation                       | Areas near to railway have a high potential for industrial development                   | < 500 m                     | 10    |
|                                   |                                     |                                                                                         | 500-800 m                   | 8     |
|                                   |                                     |                                                                                         | 800-1500 m                  | 6     |
|                                   |                                     |                                                                                         | 1500-1800 m                 | 4     |
|                                   |                                     |                                                                                         | > 1800 m                    | 2     |
| Distance from water bodies        | Environmental Pollution              | Needs conservation for future                                                             | Other Areas                  | 10    |
|                                   |                                     |                                                                                         | Waterbody buffer of 500 m   | 5     |
| Distance from Residential areas   | Environmental Pollution              | Areas away from residential areas are suitable for hazardous industrial development       | Areas outside 1200 m Buffer | 10    |
|                                   |                                     |                                                                                         | 800-1200 m                  | 8     |
|                                   |                                     |                                                                                         | 600-800 m                   | 6     |
|                                   |                                     |                                                                                         | 400-600 m                   | 4     |
|                                   |                                     |                                                                                         | < 400 m                     | 2     |
| Distance from Core City area      | Infrastructure, Environmental Pollution | Areas away from City core areas are suitable for hazardous industrial development                | 13000-17000 m               | 10    |
|                                   |                                     |                                                                                         | 10000-13000 m               | 8     |
|                                   |                                     |                                                                                         | 7000-10000 m                | 6     |
|                                   |                                     |                                                                                         | 3500-7000 m                 | 4     |
|                                   |                                     |                                                                                         | < 3500 m                    | 2     |
| Preservation of Agricultural fields | Agricultural Productivity | Productive agricultural and reserved green areas should not be considered for development | Other Areas                  | 10    |
|                                   |                                     |                                                                                         | Areas under Agriculture     | 5     |
| Utilization of Wastelands         | Developmental cost, Environment protection | Wastelands are the most suitable areas for industrial development | Other Areas                  | 10    |
|                                   |                                     |                                                                                         | Areas under Wasteland       | 10    |
|                                   |                                     |                                                                                         | Other Areas                  | 5     |
| Distance from vacant lands | Developmental cost, Environment protection | Vacant lands are more suitable for industrial development | Areas under vacant land |
|----------------------------|---------------------------------------------|----------------------------------------------------------|-------------------------|
|                            |                                             |                                                          | 10                      |
|                            |                                             |                                                          | Other Areas             |
|                            |                                             |                                                          | 5                       |

**Figure 2.** Existing Landuse map for the study area
Figure 3. Generated map for distance from primary roads

Figure 4. Generated map for distance from Railway lines

Figure 5. Generated map for waterbodies with buffers

Figure 6. Generated map for distance from residential areas
3. Results
The generated output depicts the most suitable and least suitable areas for industrial development in the Raipur and Nava Raipur region. In the entire region, the most prominent areas or the most suitable areas with a higher probability of future industrial Estates or parks are mostly near roads and railways.
Utilization of vacant and wasteland with preservation of agricultural fields were prime concerns while deciding on criteria ranking. Hence the suitability shown by agricultural areas was comparatively lesser than in other areas.

4. Conclusion:
The present study attempts to improve the prevailing environmental condition in the Raipur and Nava Raipur region, keeping in mind that industrial growth cannot be restricted. Still, it can be carried out in a planned and systematic manner that creates a win-win situation for the industries and residents and healthily improves the ecosystem, enhancing the standard of living for the people under constant health risks. A solution for any urban issue, locating industries or minimizing pollution, must be convincing and follow logical steps, meaning more scientific tools and techniques.

Figure 11. Map depicting Land Suitability for Industrial Development
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