# Economic Suitability Mapping – a New Trend in Establishing Economic Suitability of Project Site

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**Abstract:** Selection of promising site for construction project is essential since it has strong linkage with service life of the project. Recent fast developments in construction technology demands a matching method for finding economic suitability since it has a strong connection with overall suitability of the project site; and when we characterize a site suitable for construction we definitely mean economic suitability, besides construction suitability. This research is about creation of economic suitability map of an area few kilometers north of Islamabad. A multi-prong comprehensive research methodology was adopted to accomplish the task. Subsurface soil investigation was done for complete 1 km x 1 km area to obtain geotechnical suitability of the site, thereafter, through economic evaluation of the project site was carried out and finally, based on economic factors, an economic suitability map was created for the area with the latest and state of the art computer software. The research is first of its kind to map the applied features of a social science.

**Key words**: Economic suitability, geotechnical suitability, construction suitability, subsurface, soil investigations, economic factors.

## Introduction

Overall construction suitability of a project site is comprised of geotechnical suitability and economic suitability (Calyton and Mathews, 1995). Geotechnical suitability is the aptness of a project site based on subsurface geotechnical parameters of soil strata whereas economic suitability is the worthiness of project site in terms of economic considerations. Over the years, this has been overlooked to find out a relationship between the two kinds of suitability, though, it is realized that one definitely effects the other. In the same context, geotechnical and economic suitability of a selected site located few kms north of Islamabad, Pakistan was determined to ascertain whether there is any relationship between the two different discipline (*geotechnical engineering and economics*) while dealing with same project site. Soil properties were obtained through conventional laboratory testing of soil samples. Thereafter, bearing capacity, which is the load carrying capacity of soil (Codutu, 1998), was calculated in kilopascal (kPa) from where a geotechnical suitability map was drawn for the site. Basing on tangible factors like cost of material, digging, soil improvement, labour and transportation of material to the site, an economic model was developed to carryout an economic evaluation of the complete site. Surprisingly, there was close similarity between geotechnical and economic suitability maps for the project site.

**Study Area**

The study area was located close to Risalpur Town, located north of Islamabad, Pakistan. It was measuring 1 km x 1 km and was characterized with a flat topography, having numerous paved and unpaved tracks. A satellite map of the area is shown in Figure 1.

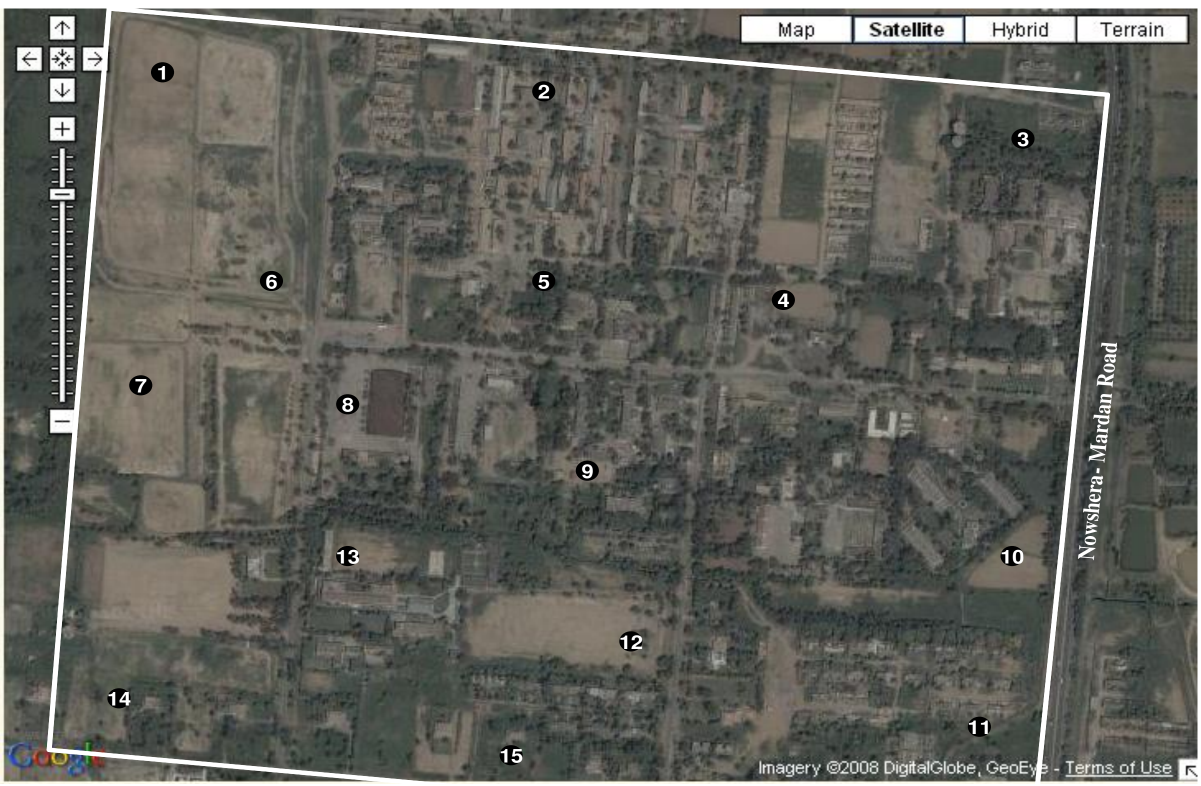


Figure 1: Thematic satellite map of the study area in the vicinity of Risalpur Town. The study area is indicated by square enclosed by white lines on the map. 15 randomly selected points are indicated as black spots and labeled on the sketch. (www.googlemaps.com).

**Research Methodology**

The methodology evolved for investigations comprised following steps:-

- ***Step 1***: Collection of disturbed and undisturbed soil samples from 15 randomly selected points of the study area.
- ***Step 2***: Laboratory tests on soil samples to find out geotechnical properties of soil.
- ***Step 3***: Calculation of bearing capacity based on the sub surface soil properties.
- ***Step 4***: Making of geotechnical suitability map of the study area.
- ***Step 5***: Economic evaluation at the same 15 selected points of the selected site.
- ***Step 6***: Making economic suitability map of the study area.
- ***Step 7***: Comparison of geotechnical and economic suitability maps.
- ***Step 8***: Conclusions.

**Collection of Soil Samples**

Samples were collected from 15 randomly seelcted locations of the study area to yield an estimate of subsurface profile. These samples were undisturbed. Undisturbed samples are those which represent natural conditions (Clayton, 1995). These were collected with Shelby tubes, which are the best sampling apparatus to collect undisturbed soil samples (Das, 2002). Now to get these samples, 15 boreholes were made with motorized earth auger, which is a tool to make the bore hole in soil (Das, 2004). Thereafter, 15 soil samples were collected from depth of 1.5, 3 and 4.5 meters each. Total of 45 samples were collected.

**Laboratory Investigations**

Conventional geotechnical laboratory tests were performed on undisturbed soil samples to infer the subsurface geotechnical properties. Individual samples varied in properties. Most of the samples were classified as fine soil and very few as coarse soils as shown in Table 1. The difference between the coarse and fine soil depends upon whether their particles are visible to naked eye or not (Das, 2004). For example particles of gravel and sand are easily visible, so these are coarse soils, whereas the particles of silts and clays are hardly visible, so these are fine soils. The percentage composition of the soil is reflected in the Figure 2. Moisture content varied from 6 – 10%. Soil moisture was determined in the laboratory by performing standard natural moisture content test using oven dry technique. In this method, difference in weight of undisturbed soil sample before and after the oven drying is the quantity of moisture present in that particular sample (Das, 2002). The above data indicates that the subsurface stratum was in medium dense state (Das, 2007).

Table 1: Interpretation of subsurface soil stratum from laboratory investigation.

| Depth (m) | Strata | | | | Total |
|---|---|---|---|---|---|
| | ML | CL | CL – ML | SM | |
| 1.5 | 5 | 2 | 3 | - | 10 |
| 3 | 4 | 3 | 2 | 1 | 10 |
| 4.5 | 4 | 2 | 3 | 1 | 10 |
| Total Points | 13 | 7 | 8 | 2 | 30 |

*Note: ML is silt, CL is clay, CL-ML is sandy silty clay and SM is silty sand.*

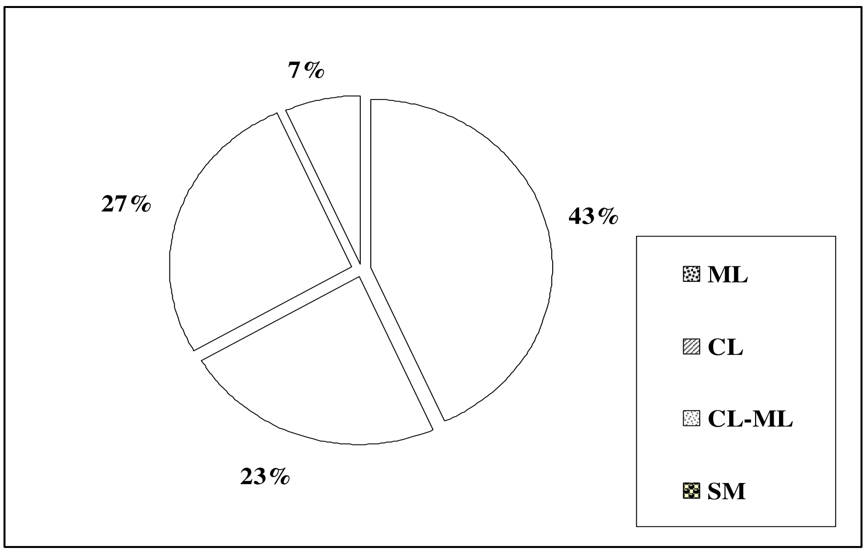


Figure 2: Percentage composition of subsurface strata

**Calculation of Bearing Capacity**

Allowable bearing capacity values were calculated with general bearing capacity equation (Das, 2007) for each depth level. Summary of the bearing capacity calculated is reflected in Table 2. Bulk of the area is having bearing capacity values between 50 – 200 kPa which is the range for silts, clays, sandy silts and sandy clays (Fang, 2001). The above table clearly indicates variation in bearing capacity of subsurface strata across the study area. If we read this table in conjunction with Figure 1, we will see that points selected in the centre of the project site are having more bearing capacity, and hence, more strength. Graphically this variation can be seen in Figure 3.

Table 2: Summary of bearing capacity of 15 randomly selected locations at the project site.

| Point | Bearing Capacity (kPa) | | | Average Bearing Capacity (kPa) |
|---|---|---|---|---|
| | 1.5 meter depth | 3 meter depth | 4.5 meter depth | |
| 1. | 88.67 | 65.87 | 71.55 | 75.36 |
| 2. | 220.45 | 326.70 | 302.80 | 283.32 |
| 3. | 65.29 | 81.45 | 93.45 | 80.06 |
| 4. | 215.11 | 265.31 | 243.12 | 241.18 |
| 5. | 267.87 | 254.90 | 281.34 | 266.03 |
| 6. | 115.65 | 217.82 | 181.23 | 173.57 |
| 7. | 260.41 | 276.72 | 312.85 | 285.66 |
| 8. | 65.29 | 181.45 | 93.45 | 116.06 |
| 9. | 235.14 | 265.33 | 343.19 | 284.22 |
| 10. | 217.87 | 259.90 | 291.34 | 259.7 |
| 11. | 288.61 | 265.17 | 271.59 | 278.79 |
| 12. | 188.27 | 365.57 | 271.51 | 279.12 |
| 13. | 120.41 | 126.73 | 92.10 | 117.41 |
| 14. | 65.49 | 81.41 | 193.25 | 118.05 |
| 15. | 211.19 | 261.39 | 343.15 | 276.91 |

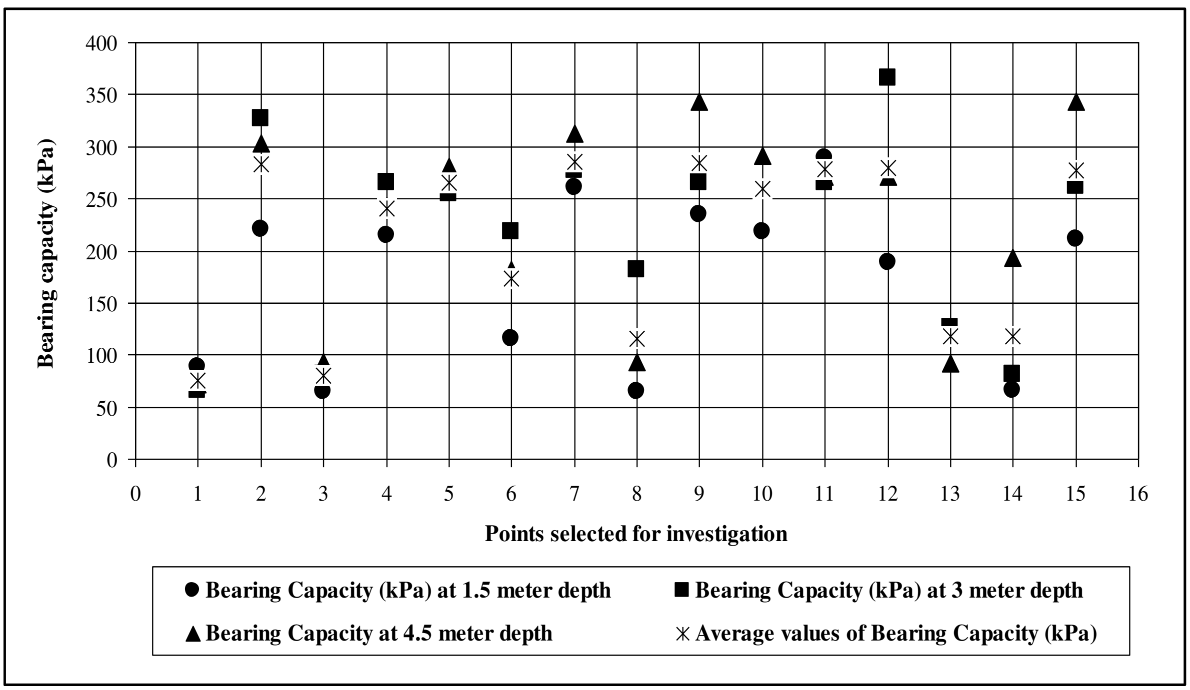


Figure 3: Scatter of bearing capacity (kPa) along the depth of subsurface strata.

## Geotechnical Suitability Map

Geotechnical suitability map is the most important outcome of the whole process of geotechnical site investigation. This is the map which shows the suitability of a project site from geotechnical point of view. The steps adopted to make a geotechnical suitability map were as under:-

- The values of bearing capacity were calculated at each depth level as shown in Table 2.
- Bearing capacity values were averaged. This again is shown in Table 2.
- SURFER Mapping Software was used to create geotechnical suitability map. Such map for the study area is given in Figure 4. SURFER is versatile mapping software which can create variety of maps and models for different purposes (www.rockware.com).

As evident from the key given with the map, area in the middle extending towards south eastern corner is most suitable for construction from geotechnical point of view. The feasibility decreases towards the edges of the study area; becoming minimum at the north western and eastern corners.

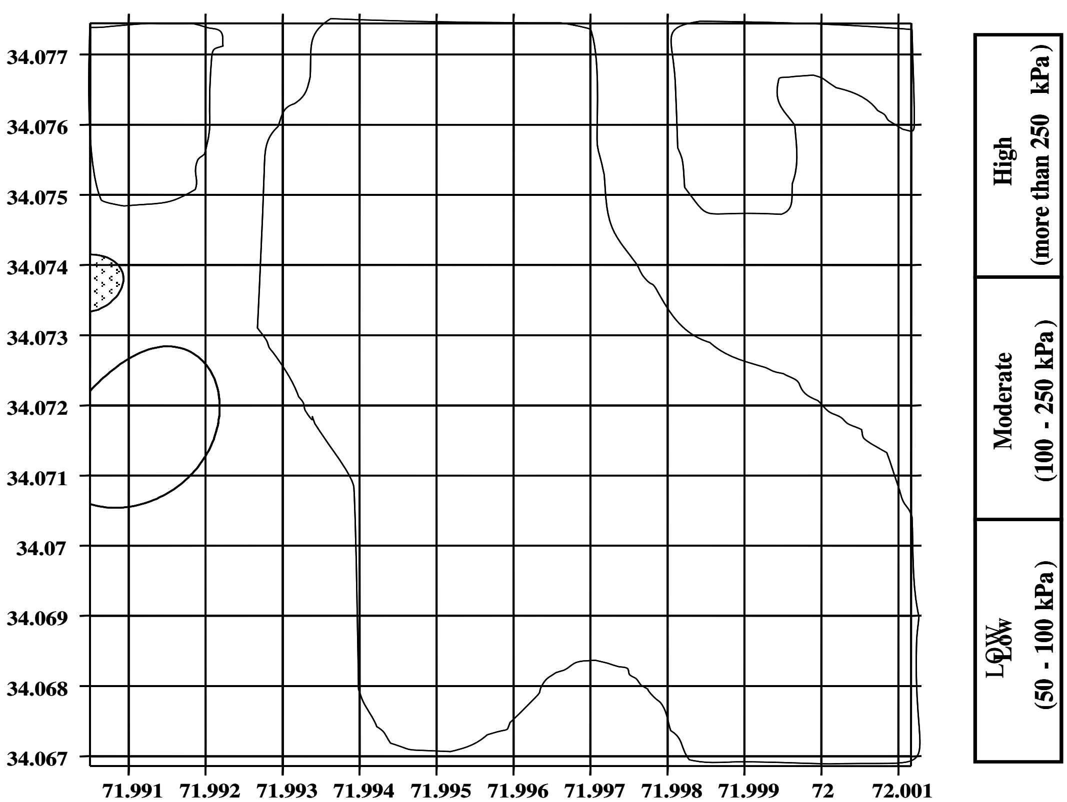


Figure 4: Geotechnical suitability map for the study area.

## Economic Evaluation Process

Engineers are tasked with providing safe and cost effective solutions. Essential to this, is the economic evaluation of the project site relative to engineering performance and construction needs (Kleinfeld, 1998). Economic evaluation directly affects the level of conservatism to which projects are designed and also project costs (Raffia, 1997). Economic demands on infrastructure in recent years have accentuated the need for economic construction and long performance (Thausen and Fabrycky, 2002). Economic evaluation of the project site is a process through which we assess the feasibility of a project site from economic point of view. It is done by analysis of each selected economic factors thoroughly. Each factor is given a corresponding weight according to its prevalence intensity and after considering weight obtained by all the factors, an economic solution is concluded (Zeleny, 1982).

After establishing geotechnical suitability of the selected site, economic evaluation was carried out using tangible economic factors. Same 15 spots were selected for this evaluation. The procedure adopted for economic evaluation was as under:-

- Five simple but very important factors were considered. These factors included cost of material, soil treatment required to improve the site, transportation of material, lobour charges and maintenance requirement of the construction facilities in the future.
- Each factor was given specific marking from 0 to 5 depending upon its prevalence or validity in ascending order.
- Factors were applied to each selected point and analysis was carried out.
- Trend was deduced for the complete study area.

Based on above narrated modus operandi, an economic evaluation matrix was developed which is given in Table 3. Since cost of material and labour charges remains the same, these factors have been given equal marks for all 15 spots.

The graphical representation of economic evaluation matrix is reflected in Figure 5. Note that investigation points selected in the central and south eastern side of the project area are more economical for undertaking the construction activities. Similarly, the north western and eastern corners are less suitable for construction activities from economics point of view.

Table 3: Economic evaluation matrix.

| Point | Cost of Material | Soil Treatment | Transportation of Material | Labour Charges | Maintenance | Average Score |
|---|---|---|---|---|---|---|
| 1. | 4 | 3 | 3 | 4 | 4 | 3.6 |
| 2. | 4 | 0 | 3 | 4 | 2 | 2.6 |
| 3 | 4 | 4 | 1 | 4 | 5 | 3.6 |
| 4. | 4 | 1 | 2 | 4 | 4 | 3.0 |
| 5. | 4 | 0 | 2 | 4 | 2 | 2.4 |
| 6. | 4 | 1 | 3 | 4 | 3 | 3.0 |
| 7. | 4 | 0 | 3 | 4 | 1 | 2.4 |
| 8. | 4 | 1 | 3 | 4 | 2 | 2.8 |
| 9. | 4 | 0 | 3 | 4 | 1 | 2.4 |
| 10. | 4 | 1 | 2 | 4 | 2 | 2.6 |
| 11. | 4 | 0 | 2 | 4 | 1 | 2.2 |
| 12. | 4 | 0 | 3 | 4 | 1 | 2.4 |
| 13. | 4 | 1 | 3 | 4 | 2 | 2.8 |
| 14. | 4 | 1 | 4 | 4 | 2 | 3.0 |
| 15. | 4 | 0 | 3 | 4 | 1 | 2.4 |

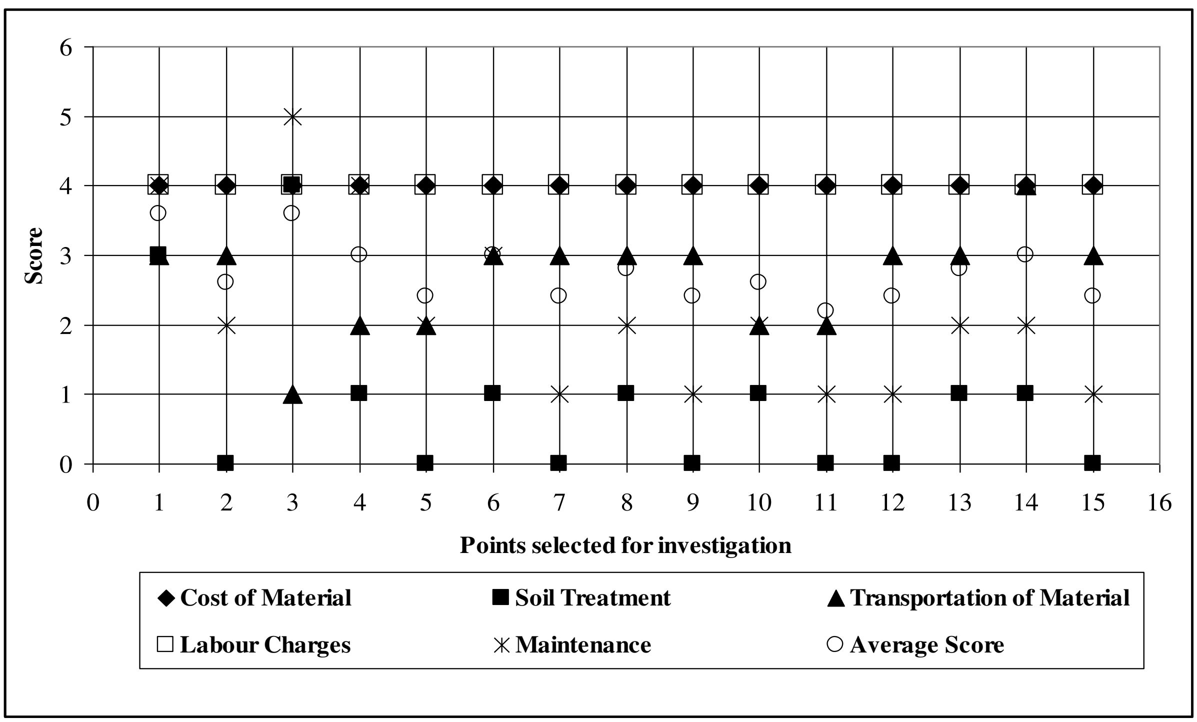


Figure 5: Economic evaluation of the project site.

**Economic Suitability Map**

Economic suitability mapping is a relatively new field which remains unexposed mainly due to large variations in economic conditions and absence of accurate tool to draw correlation between geotechnical and economic parameters for the same project site. The subject of economic suitability mapping is, however, very important and highly significant for engineers as it hold the promise for rapid and relatively inexpensive economic characterization of the site.

Based on the economic evaluation, an economic suitability map, shown in Figure 6, was created for the study area with the SURFER software. The map is essentially a contour map with contours showing variation in the economic suitability across the study area.

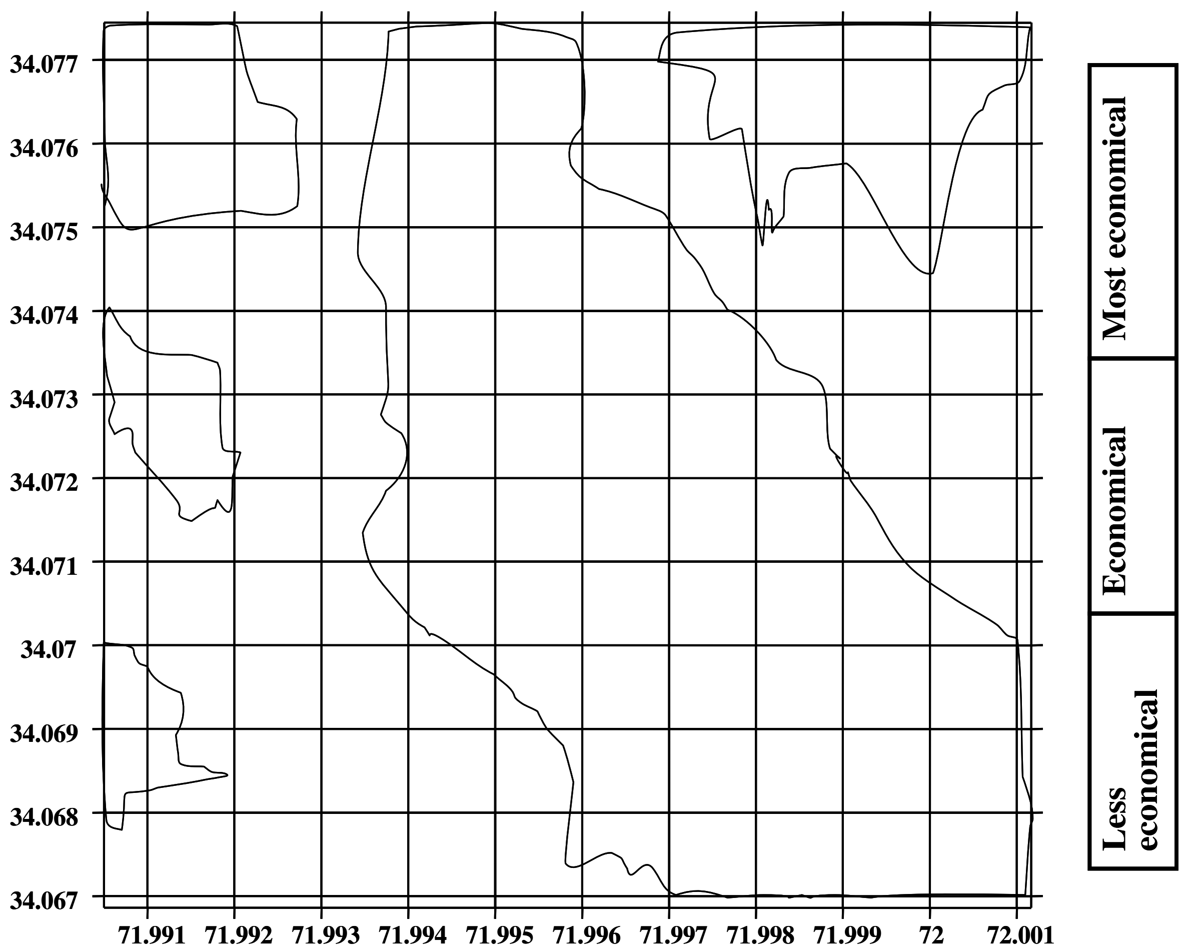


Figure 6: Economic suitability map of the project site.

**Comparison of Geotechnical and Economic Suitability**

By mere looking at geotechnical and economic suitability maps, one can easily make about the close similarities between the two types of maps. A view of both maps together side by side is shown in Figure 7.

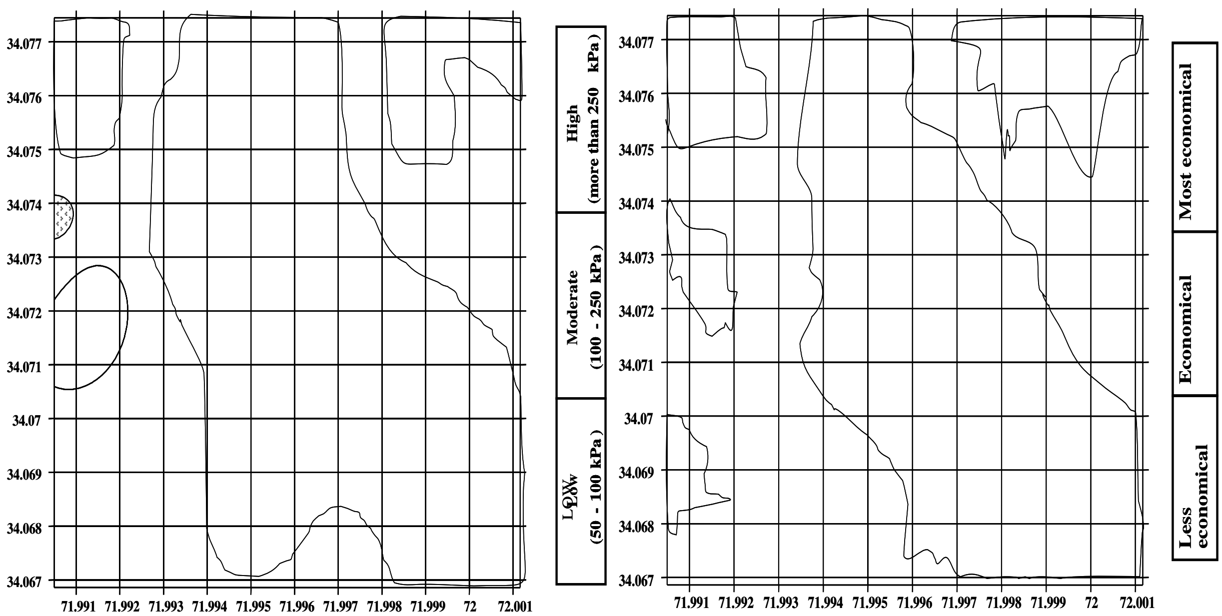


Figure 7: Geotechnical and economical suitability maps for the study area.

Trends shown in these maps can be summarized as under:-

- Both the map shows that region in the centre of the study area extending towards south east is the most suitable for construction both from economics and geotechnical point of view.
- The areas in the north east and west are less suitable for the construction activities both from economics and geotechnical point of view.
- There exists a suitable region on the western edge of the study area as shown in both the maps, however, the size of this region is bigger in case of economic suitability map than the geotechnical suitability map.
- There exists a dissimilarity in the two maps which is about location of less economical region on the western edge of the study area. The location of this region indicated on

geotechnical suitability map is in the middle of western edge while the same is shown in the south western side of the study area on the economic suitability map.

- The most economical region is broader on the geotechnical suitability map while the same is comparatively narrower on the economic suitability map.
- Contours of geotechnical suitability map are smooth while the same are sharp on the economic suitability map indicating that economics believes in sharp precision.

**Conclusions**

Overall there is a similarity and agreement between geotechnical and economic suitability maps, though there are some minor dissimilarities of ignorable nature. If we have economic suitability maps, we can immediately assess whether construction on a particular site will be economical or not. Economic suitability maps would require effort for its long term improvement and updation since economic factors changes with time. However, a map once made can be updated easily and it seems that economic suitability map shall render essential services for a greater span of time than expected. A careful study of these maps indicates that:-

- These maps are easily interpretable / comprehendible.
- Contours show variation of properties.
- These are acceptably reliable and accurate.

Owing to its usefulness and wide applicability, there is a need to undertake making of geotechnical and economic suitability maps (like other maps) at large level. These maps will be helpful for planners, designers and builders to select safe / appropriate locations for buildings and communication infrastructure.

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