CHAPTER 16

VISUAL IMPACT ASSESSMENT METHODOLOGY FOR INDUSTRIAL DEVELOPMENT SITE REVIEW IN SPAIN

Santiago G. Alonso, Miguel Aguilo,
and Angel Ramos
INTRODUCTION

This chapter addresses directions and techniques to follow in landscape studies undertaken as a requisite for official approval of industrial developments.¹

The landscape is assessed for three qualities: Visibility, Visual Quality and Fragility. This is not a division corresponding to an analytic process that identifies different components which integrate into one reality, but three separate approaches or points of view. A complete analysis of the hypothetical visual impact produced by an industrial installation is achieved by: (1) a determination of what is actually seen; (2) consideration of its aesthetic value; and (3) a valuation of the capacity of response to impact, which, simultaneously, provide guidance to possible modifications or choices in case of conflict.

These approaches are first developed conceptually and then followed by an evaluation model for the possible visual impact. The techniques used in the application of these principles are described in the original report (Alonso et al. 1983). The landscape constraints are summarized in Table 16.1.

VISUAL FRAGILITY

The visual fragility concept addresses the whole of the characteristics of the landscape related to its capacity of response to the change of its specific properties. It is a concept associated with visual quality, although clearly independent. A territory of low visual fragility will preserve its landscape quality even if it suffers some modification that would have altered the quality of any other landscape with high fragility.

It constitutes an intrinsic territorial characteristic dependent on the conditions of the environment. The same industrial installation will offer the greatest visual impact where the fragility is high. The fragility being equal, the impact will be the highest where the activity of the largest amount of development is located. The fragility of the landscape or, more precisely, its visual vulnerability, carries a strength component or resistance capability independent of the landscape quality and the impacting activity.

The concept of visual fragility corresponds reciprocally to the capability of visual absorption, understood as “an ability of the territory to visually absorb the modifications or alterations without any loss of its landscape quality.” The capability of visual absorption is a positive evaluation of the landscapes potential in regard to its use, opposite to the negative approach that corresponds with visual fragility.

Visual fragility is taken then as a quality or property of the land that helps in locating possible industrial installations or their elements, producing the lowest visual impact. It is not, therefore, a quality that is going to be affected by the future activities but is a guide for the location of those activities. Normally, the factors influencing visual fragility can be considered as belonging to three classes (Aguilo 1981):

- Biophysical factors, mainly related to the slope, orientation, and land cover, determining the visual fragility in every point itself.
- Perceptual factors, responsible for the readability or visual insight into the landscape and therefore defining the fragility conditions of the viewing point related to its environment.
- Historic and cultural factors, explaining the character and shape of the landscape in terms of its historical process and determining the future compatibilities with the proposed activities.

These landscape qualities should be complemented by considering the real possibility that the activity could be seen by any observer. This theoretical or potential fragility becomes operational upon adding the concept of potential accessibility of the observation.

Potential accessibility depends, at the same time, on two factors: the distance from the “sources” of possible observers, or places where these can be gathered, and the visual accessibility of the territory from these sources, that is to say, the visibility from them. The most usual nuclei or sources of observers are the roads and the urban areas.

In the following paragraphs, the importance of the definition of every previously mentioned factor, its significance related to visual fragility, and the parameters or methods normally used to

¹It is a part of a broader document, including ecological aspects, written by the same authors and supported by the Spanish Ministry of Industry (Alonso et al. 1983).
<table>
<thead>
<tr>
<th>Affected Characteristics, Qualities or Processes</th>
<th>Parameters of measuring and contrast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual fragility of the spot</td>
<td>- Vegetation density</td>
</tr>
<tr>
<td>Biophysical factors</td>
<td>- Chromatic contrast ground-vegetation</td>
</tr>
<tr>
<td></td>
<td>- Vegetation's height</td>
</tr>
<tr>
<td></td>
<td>- Number of layers</td>
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<td></td>
<td>- Chromatic contrast within the vegetation</td>
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<td></td>
<td>- Vegetation seasonality</td>
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<tr>
<td></td>
<td>- Slope</td>
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<td></td>
<td>- Orientation</td>
</tr>
<tr>
<td>Visual fragility of the spot's environment</td>
<td>- Viewed areas</td>
</tr>
<tr>
<td>Perceptive factors</td>
<td>- Percentage of hollow or shadow areas</td>
</tr>
<tr>
<td></td>
<td>- Stretching of the shape</td>
</tr>
<tr>
<td></td>
<td>- Observation position (in height)</td>
</tr>
<tr>
<td>Inherited fragility. Historical and cultural characteristics</td>
<td>- Global character of the landscape</td>
</tr>
<tr>
<td></td>
<td>- Particular elements</td>
</tr>
<tr>
<td>Acquired fragility. Accessibility</td>
<td>- Proximity to villages, towns or roads</td>
</tr>
<tr>
<td></td>
<td>- Visual exposure from villages and roads</td>
</tr>
<tr>
<td>Visibility. Viewshed</td>
<td>- Visual scope or reach</td>
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<tr>
<td></td>
<td>- Distance areas</td>
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<td></td>
<td>- Angle of visual incidence</td>
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<tr>
<td></td>
<td>- Visual intrusion</td>
</tr>
<tr>
<td></td>
<td>- Properties of the viewshed, shape, eccentricity, compactness, surface, etc.</td>
</tr>
<tr>
<td>Visibility. Susceptibility</td>
<td>- Number of observers</td>
</tr>
<tr>
<td></td>
<td>- Observer's attitude</td>
</tr>
<tr>
<td>Quality. Landscape components</td>
<td>- Water and land. Morphology, topography, slopes, water courses, lakes, etc.</td>
</tr>
<tr>
<td></td>
<td>- Vegetation. Trees, bushes and vegetal cover</td>
</tr>
<tr>
<td></td>
<td>- Human activity. Land uses, buildings</td>
</tr>
<tr>
<td>Quality. Visual elements</td>
<td>- Color contrast, shape, line, texture</td>
</tr>
<tr>
<td></td>
<td>- Scale dominance</td>
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<td></td>
<td>- Intrusion by position</td>
</tr>
<tr>
<td>Quality. General character</td>
<td>- Lack of compatibility of the uses. Global character</td>
</tr>
<tr>
<td></td>
<td>- Unique elements. Areas to protect</td>
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</tbody>
</table>
measure them are precisely described. The consideration of the visual (perceptual) factors is developed in the section devoted to visibility. The concepts applied to the industrial installation as a single viewpoint here are extended to a whole of the territory, describing its general conditions of visibility.

To clarify the role of every factor in the visual fragility analysis, an evaluation is included, with ordinal scales from 1 to 5 in which the increasing values correspond to situations of increasing visual fragility.

**Visual Fragility: Biophysical Factors**

**Soil and Land Cover**

The authors considered the possibilities of camouflage or enhancement that the combinations of soil and vegetation in the landscape offer as a support to future activity. The parameters or variables normally used include vegetative density, chromatic contrast of soil and vegetation, vegetative height, diversity of vegetative strata, chromatic contrast within the vegetation, and seasonal changes of vegetation, slope and orientation.

<table>
<thead>
<tr>
<th>TABLE 16.2</th>
<th>Evaluation and Percentage of Land Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation</td>
<td>Percentage of Land Cover</td>
</tr>
<tr>
<td>1</td>
<td>80 &lt; x ≤ 100</td>
</tr>
<tr>
<td>2</td>
<td>50 &lt; x ≤ 80</td>
</tr>
<tr>
<td>3</td>
<td>30 &lt; x ≤ 50</td>
</tr>
<tr>
<td>4</td>
<td>15 &lt; x ≤ 30</td>
</tr>
<tr>
<td>5</td>
<td>0 &lt; x ≤ 15</td>
</tr>
</tbody>
</table>

**Vegetative density**

The more vegetative density, expressed by the percentage of soil covered by the horizontal projection of the woody species, the less the intrinsic visual fragility:

**Chromatic contrast of soil and vegetation**

The intrinsic visual fragility increases with the amount of color contrast between soil and vegetation. The highest color contrast furnishes the best camouflage or absorption.

**Vegetative height**

The power of vegetation to screen man-made structures increases with the vegetation's density and size. The largest vegetative sizes correspond to the least amount of visual fragility:

<table>
<thead>
<tr>
<th>TABLE 16.3</th>
<th>Evaluation and Vegetative Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation</td>
<td>Highest Size of the Upper Stratum of Plant Cover (in Meters)</td>
</tr>
<tr>
<td>1</td>
<td>10 &lt; x</td>
</tr>
<tr>
<td>2</td>
<td>3.0 &lt; x ≤ 10.0</td>
</tr>
<tr>
<td>3</td>
<td>1.0 &lt; x ≤ 3.0</td>
</tr>
<tr>
<td>4</td>
<td>0.5 &lt; x ≤ 1.0</td>
</tr>
<tr>
<td>5</td>
<td>0 &lt; x ≤ 0.5</td>
</tr>
</tbody>
</table>

**Diversity of vegetative strata**

The land cover vegetative structure and organization determines its visual absorption capacity. As the complexity of this structure and the number and definition of vegetative strata increases, the visual fragility level decreases. It is necessary

<table>
<thead>
<tr>
<th>TABLE 16.4</th>
<th>Evaluation and Land Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetative Cover Character</td>
<td>Characterization of Land Cover</td>
</tr>
<tr>
<td>Evaluation</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Entirely organized vegetation: trees, shrubs, and herbaceous strata.</td>
</tr>
<tr>
<td>2</td>
<td>Vegetation generally lacking the shrub stratum, or if it exists, is very little defined.</td>
</tr>
<tr>
<td>3</td>
<td>Half-organized vegetation, normally with a thick tree stratum, a sparse shrub layer, and herbaceous stratum. Or, if the intermediate strata are well structured, they go with a poor tree layer.</td>
</tr>
<tr>
<td>4</td>
<td>Poorly organized monospecific vegetation: a well-defined tall-tree stratum, being accompanied only, as such a continuous stratum, by a low herbaceous layer.</td>
</tr>
<tr>
<td>5</td>
<td>Vegetation with no upper strata than small shrub layer; at most, some trees are scattered in open plantations or geometrically organized.</td>
</tr>
</tbody>
</table>
to point to the dominance of some of the strata upon the others related to the quantification of this fragility: the existence of a given number of the upper strata prevails upon that of the same number of the lower strata.

Chromatic contrast within the vegetation

The chromatic diversity within the land cover itself favors the “camouflage” of the human activity, especially if the large range of colors does not suit a clearly defined pattern and it is distributed in a chaotic way.

So the highest visual fragility situations are defined by the monochromatic spots (constants through the seasons—pinewoods—or changeable—dry farming land). Areas of intermediate visual fragility are composed of distinct homogeneous color, while the least fragile or most absorbive areas correspond to the heterogeneous colored vegetation masses.

Seasonal change of vegetation

The loss of the opacity—the reduction of the screen effect which the deciduous leaves imply—is a factor that increases the visual fragility in areas that support deciduous vegetation even if it is a temporary effect in autumn and winter.

<table>
<thead>
<tr>
<th>TABLE 16.5. Evaluation and Vegetation Seasonal Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>3</td>
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<tr>
<td>5</td>
</tr>
</tbody>
</table>

All the above-considered factors do not have the same importance in the fragility evaluation. They are listed from the most important to the least in a hypothetical scale:

Vegetation density.
Chromatic contrast of soil and vegetation.
Vegetation height.
Strata diversity within the vegetation.

Chromatic contrast within the vegetation.
Seasonal change of vegetation.

Slope

The slope is the most important element in determining visual absorption capacity because it defines the visual angle of incidence of the observer. The increase of slope is intrinsically tied to the increase of visual fragility. If there are no physiographic factors to be considered, slope can be considered as a multiplier of the rest of the factors. A typical classification of slope and a possible evaluation could be:

<table>
<thead>
<tr>
<th>TABLE 16.6. Slope Classification and Evaluation</th>
</tr>
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<tbody>
<tr>
<td>Class and Classification of the Slope</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
</tbody>
</table>

Orientation

Orientation is directly related to the landform configuration. Its importance is not the same in a rugged landscape with well-defined exposures as in the gentle, ridged ones. It is related to visual fragility by a two-sided criterion:

The highest illumination provides the highest visual fragility since it emphasizes possible contrasts. In this sense, the southern and western exposures are more fragile than northern and eastern exposures.

Observation with backlighting. The areas to be normally observed opposite to the sunlight offer very little definition.

Taking into account both of these factors, the most fragile area would be the southern orientation, combining strong sunshine with the highest position of the sun when the observer is looking toward the landscape. The least fragile would be
the north-northeastern exposure, receiving sunlight with a low angle of incidence.

Visual Fragility: Perceptual Factors

The visual relationship of each viewing point with its surroundings is complex and requires a sound definition. This can be approached through the study of the properties of viewed or visual basin (see section on the viewed).

Area Viewed

A stronger visual fragility is normally associated with larger areas viewed. Activities such as refuse disposal, for instance, will require sites of minimum visibility (small fragility).

Percentage of “Hollows” or Shadow Zones

Fragility decreases with percentage increase; the lack of shadow zones makes difficult the proper location of undesirable activities, that is, to hide them.

Shape of the Viewshed

Elongated shapes are more sensitive to visual impacts; visual intrusion tends to be emphasized within them, while in panoramic views only a sector is disturbed.

Position (in Altitude)

Position in altitude is a controversial matter. Some authors maintain that fragility is stronger when the point is seen from a higher position, but others maintain just the opposite. Both approaches may be reconciled insofar as a point is more fragile when it is clearly higher or lower than its viewed. The “mean angle of incidence” is, then, the key parameter: With level visual rays, observation will be imperfect and fragility low; complete observation requires greater angles of incidence.

Historic and Cultural Factors

The accounting of historic and cultural characteristics, essential to the understanding of the landscape in its testimonial role and its formation process, is made in a double sense.

Global Character of the Landscape

Landscape character has its roots in the historical development of the landscape that has determined specific uses that give it its own sense. The history of the process of land taking, the beginnings of the different settlements, and the evolution of the man-environment relationship (especially farming systems and woodland uses) are essential to the understanding of the future problems of compatibility of land uses.

Special-Value Areas and Sites

Special-value areas and sites have a historical, cultural, traditional, and archaeological interest and function as focuses of experience, organizing the man-environment relationship and giving the special sense that transforms nature into landscape. These historical and cultural values, associated with specific sites or elements, are preserved by means of including them in protected areas. The criteria for selecting these sites, elements, or areas to protect are:

- **Uniqueness.**
  - Buildings, monuments or places of unique or rare character.

- **Tradition.**
  - Areas with strong significance at the local level, used as common references and being themselves regional symbols.

- **History.**
  - Relevant monuments in the regional history.

- **Aesthetics.**
  - Buildings, monuments, and areas recognized by their inhabitants and visitors to have aesthetic value.

Accessibility

In order to take into account possible observers, the concept of accessibility is introduced as an external modifier of the intrinsic fragility of the landscape. It is normally determined by two properties, proximity and visual exposure, related to the production nuclei of possible observers.
Proximity to Villages and Roads

The landscape’s fragility increases in points close to places where a great number of observers can concentrate. It is necessary to take into account the number of visitors or observers related to the population in urban areas and the average intensity of the daily traffic on roads. In some cases, it is convenient to use a weighting system for different areas or districts of a nucleus, giving these areas a treatment according to their intensity of use.

Visual Exposure

As well as the number of potential observers, it is relevant to know the possibility of each point being seen. It is then a question of calculating and superimposing the viewsheds of nuclei and roads, projecting the zone exposed to the observers. For the roads, it is necessary to define a distance between viewpoints according to the road class and its traffic flow.

VISIBILITY

Apart from the inherent characteristics of the landscape and its sensory and cultural significance as defining elements of the visual quality of the landscape, it is absolutely necessary to determine the zone visually affected by the future man-made structure or industrial structure installation. Then the possible visual impact can be explicitly stated, with the severity of the impact defined in precise terms with regard to both its extent and the possible number of affected persons. The basic instrument for this analysis is the viewshed of the future installation. In the following paragraphs, this concept and the methods to determine it are explained. Nevertheless, it is advisable to apply the process with realism and rationality. The viewshed will be precisely defined but it must not be forgotten that it is only a simple means to predict, in relation to the visual effects, the area of influence of the installation.

In the same way, the parameters that control its extent, as well as the attributes used in the evaluation, ought to be applied on a trial-and-error basis. Their function is always to detect possible impacts. Their use in the opposite direction, that is, to prove the nonexistence of impacts, must be made with great care. For instance, if a maximum distance of visibility of 5 km is fixed to determine the visual impact, and there is a possible point of conflict at 5.5 km from the installation, the analysis is being improperly used. The values must be flexible enough to include possible abnormal or conflicting situations that must be always analyzed.

The methods, the values of the parameters, and the properties that are going to be explained must be taken into account in this sense, not being valid as a proof by themselves.

The Viewshed

The key element in a study of visibility conditions is the visual basin or viewshed. The viewshed, from a given point, is defined as the portion of the landscape seen from that point. By extension, this definition is applied to elements with appreciable physical dimensions, such as a dam or an industrial installation. The visual basin of these structures would be the sum of viewsheds of all their points.

The premises for these visibility analyses having been established, it could be interesting not only to include the building itself but auxiliary elements too, as access roads or the possible buildings that are surely going to appear near the main structure. Sometimes the effects of the installation ought to also be included in the analysis, as in the case of the steam clouds of the power station visible from several miles away.

EXAMPLE 1:  Techniques for the Determination of the Visual Basin

DIRECT IN-SITU DETERMINATION (LITTON 1973)

The observer places himself or herself at the point from which the visual basin has to be determined, in order to transfer to a map the limits of his or her observations. The aim is to estimate the relative positions of the start and finish of shadowed areas with respect to accidents or characteristics of the terrain which are shown on the map, linking them to establish visible and shadowed areas, using a similar process to that used to fix the position of a real point on the map.
A scale around 1:25,000, where the localization of visual limits can be carried out with relative accuracy, is frequently used. Smaller scales yield better accuracy, but on the other hand will frequently require the use of many maps, which are difficult to handle, for in-field studies.

The process has to be carried out in the most advantageous conditions as far as illumination and visibility are concerned. Whenever possible, working in orientations with lateral illumination, as well as visiting the place at different times of the day would be preferred. Front or rear light tends to alter the shape of the terrain, thus introducing large errors in the determinations.

This is a fast technique (around one hour is a reasonable time for a normal determination) and enables a better knowledge of the terrain by the observer. Personal errors of the observer and characteristics of the area, however, yield variable reliability as a disadvantage. Errors tend to overestimate the visible area.

Summit lines are currently taken as vision limits, but they are not actually visible due to the convexity of the terrain; and limits are found far earlier.

**MANUAL DETERMINATION BY PROFILES**

This is the more common and simplest method to determine the visual basin. It can be used as a single procedure or in combination with the previous one, especially if available maps are thought to have inaccuracies. The procedure is as follows:

A visual direction, for example, north, is plotted on a map at the appropriate scale.

The transverse profile which corresponds to that visual direction is obtained by computing the intersections with the height curves (it is convenient to enlarge the vertical scale).

Visual rays are plotted in such a way that points, increasingly farther away from the observation point, are linked with this by rays of increasing slope in order to maintain visibility. When a point such as F in Figure 16.1 is linked to the observer O, an initial ray OF is found which lies below another ray, thus indicating a point in an invisible area. In that way, points A, B, C, D, E indicate starting and finishing points for shadowed regions.

The points are plotted on the base map.

The visual ray is tilted a given angle, and all three previous points are repeated. The previous step is repeated until the area of interest is scanned, and the corresponding points A, A, B, B, ... are linked to find the shadowed areas.

When accuracy is needed, 5° intervals are required; but, generally speaking, some 16 profiles are sufficient (22.5°).

Spacing of different profiles is frequently useful, according to topographic conditions in individual areas. Determinations without noticeable difficulties allow fewer profiles without loss of accuracy, while potentially conflictive areas may require an increase in their number.

The most important difficulty lies in the limitation to include restrictions of visibility due to vegetal formations or buildings. Thus, it would be advisable for this, as well as for any other group method, to improve the determination by means of in-situ observation to account for likely deviations. A standard determination may take about 90 minutes without any special training.

**HEBBLETHWAITE METHOD**

A somewhat faster, manual procedure was developed by Hebblethwaite (Clark 1976) for the calculation of the visual impact for power plants. In order to use this method, a map with adequate scale, as well as two transparent plastic pieces, 10 to 15 cm wide and long enough to cover the maximum visible distance, are needed. For a typical 1:25,000 scale, 50 cm will generally be adequate. One of the pieces will have a straight line marked to indicate the visual line. The other piece will have parallel equidistant horizontal lines to represent different heights with the same distance as shown in the map. Parabolas or other curves may be preferred to account for curvature and refraction effects.

The procedure is as follows (Figure 16.2).
400ft LINE ON MARKER PLATE PLACED ON INTERSECTION OF SIGHT LINE AND 400 ft CONTOUR

The visual line plotter is based on the observation point according to a preset direction.

The height plotter is placed in such a way that the observation point coincides with the corresponding height line up to the height of that point (a in the figure).

The crossing point between the visual direction and the height curve is identified. The height plotter is guided in such a way that the height line which corresponds to that height curve coincides with the crossing point.

Following the visual direction, a point is reached where the next height curve is intersected. When this one and the height line cross above the visual direction, the point will be visible. Otherwise, the point will not be visible (b in the figure).

When an invisible point is reached, the latest visible point has to be taken again and the height plotter placed so that in that point visual line, height curve and height line cross (c in the figure).

The procedure is repeated with this location. All visible points are recorded until another invisible point is reached, and the height plotter is placed again there as described above.

The visual line is followed to the visibility limit.

The process is repeated at 5° or larger intervals.

When all visible points have been recorded for a given interval, they are linked in order to construct the visual basin or visual influence area.

**AUTOMATIC METHODS**

When the topography of the terrain is represented by a matrix of altitudes associated to a superimposed network, it is easy to identify visible and invisible areas by means of several simple routines. Several methods have become available since the VIEWIT program (Travis 1975) was set up, which are more or less efficient according to the aims of the project. Some of them do only identify the visible points in the network whilst several other methods may plot the visible areas and can compute several parameters which are associated with visual basins.

Well-known methods include VIEWIT, predetermination of cells in the visual ray, sectorial search, and cell-by-cell search.

**Viewit**

The procedure is similar to the manual procedure indicated in the section discussing manual determination by profiles. The program plots a visual direction, identifies cells which are intersected by that direction, and determines which of them are visible and which ones invisible. This implies a criterion for
visibility to be defined. In fact, some of the visual rays might section a profile which allows visibility, and others may not be able to reach the network, leaving it in the shadow. It is thus reasonable to set up the condition that the visual ray segment, which is intercepted by the network, have a minimum length. When this is fulfilled, the network is considered to be visible from the observation point. A different condition could be that of the number of rays which are intercepted by the network. This has the drawback, however, that cells are discriminated according to distance, since the separation between rays increases with distance. It would be simpler to assume that a cell is visible whenever any of its points become so; this is not fully accurate but requires fewer additional operations.

The program will then store a 1 for visible cells and a 0 for invisible ones. If the number of times a point can be seen from a given set of points is larger, the program will place different origins and add another 1 to the corresponding memory. When all required origins have been scanned, the memory which corresponds to every cell will have stored the number of points from which the area is visible. The results are automatically plotted in numerical form or converted to a grey level scale.

**Predetermination of Cells in the Visual Rays**

This program, developed by Steinitz et al. (1974) for a visual quality model, acts in a different way. The area around the origin cell is divided into eight octants which are scanned by several beams in order to obtain a more efficient search algorithm. The user may select which octants and the number of rays he or she wants to use for the search; for example, he or she may select searching in the north-northeast octant with three visual rays and 26 cells range, which would mean reducing the search to some 70 cells instead of all 240 cells within 2.6 km in the octant (cell side, 100 m). With this, accuracy is lost in the interest of speed; but if the search is to be carried out from a set of origins, cells disregarded by an observation point will usually be taken into account by another one. Thus the loss of accuracy will be smaller. The program allows the land use for visible cells to be plotted and the search to be organized according to the land uses of the origin or other sought-after cells. This capability is very useful for identifying sensitivity levels for visible cells and allows the possible number of observers, as well as qualification of their attitude, according to the use to be computed (Figures 16.3, 16.4, and 16.5).

**FIGURE 16.3.** Predetermination of cells. Rays in octant, 3. Reach, 15 cells.

**Sectorial Search (Aguilo 1981)**

This is the automatic version for the manual method using profiles discussed previously. The search process is organized by means of rays which are made to scan the area under study from the origin or observation point. In every ray, which is considered to be representative of the corresponding circular sector, visible and invisible points are recorded. Also, the slope of the straight line linking every such point with the observation point is compared with slopes computed for previous points. If that
slope is larger, the point—and thus its surrounding zone—will be visible; otherwise, it will have been covered by a previous point along the same ray.

Parameters which rule the process are the angle between two consecutive rays and the radius with which every ray is scanned up to the maximum visual range. Accuracy is regulated with these parameters; thus it is lower for more distant areas since the trapeze which is assigned to every point increases in area with distance from the observation point. This loss of accuracy, however, is similar to that which takes place from the physiological point of view and the process is accordingly well adapted to real conditions.

If a plotter is available with the computer, drawing of the basin can be carried out on a transparency which, placed on a conventional topographical map, will allow the identification of visible areas and their associate use. The program allows the shape and eccentricity parameters to be easily determined, as well as the calculus of maximum and minimum radii and diameters which are difficult to obtain with other means.

When the basin is plotted from a set of beams starting at the observation point but which are not drawn at the invisible areas, the strong relationship between the observation point and the visible areas is enhanced. Viewsheds are areas clearly focused, and it is advisable to employ a graphical representation which maintains such quality.

**Cell-By-Cell Search**

The search can be organized as a systematic scan of cells lying in the visual range circle. It is customary to scan only the central square submatrix around the observation point and size $2a \times 2a$ where $a$ is the range; every point is subject to a distance test $d < a$, and then to a visibility test.
This one is very simple. The observation point is linked with the center of the corresponding cell, and the straight line is followed comparing the altitudes on it with actual values for the terrain. If only a single point lies above the straight line, the center of the cell will not be visible. Only if the process is carried out without finding a point of more altitude will the cell be visible from the observation point. Drawing of the visual basin can be carried out then by means of a printer. The plot will be schematic, however, and will have the supplementary difficulty of inaccurate and generally different vertical and horizontal scales due to normalization conditions in the printers. Identification of visible areas will thus have to be carried out by manually translating them to a topographical map (Figure 16.6).

Taking into account the reciprocity of the visual fact, the viewshed includes all the possible observation sites from where the activity will be visible. Its fixing will mark the boundaries of the environment of the possible visual impacts of the installation with two main consequences:

1. To alter the view from all these observation sites by inserting a new artificial element, and
2. To modify the visual conditions of the landscape altering the visual flows produced by the almost simultaneous perception of viewsheds, crossing their different points, especially at a high speed.

This second effect requires the prior fixing of the visibility characteristics of the sites, especially given by the parameters stated in preceding sections.

Methods of drawing the viewshed can be found in Litton (1973), Hebblethwaite (1973), Clark
(1976), Travis (1975), Steinitz et al. (1974), Aguilo (1981), and Alonso (1983). They include simple manual methods to use in situ or at the office and more complex computer methods in case they would be needed.

To be considered next are the different qualities of the viewshed that can become altered by an industrial installation.

EXAMPLE 2: Selection of Observation Points

The visual impact of the new industrial plant reaches all the points in its visual basin, as has already been shown, and has a global character. As a complement of the evaluation of that global impact, which is analyzed when the effect on the character and the quality of the affected landscape is studied, it is very useful to select the points from which a more detailed analysis of the possible impact has to be continued.

The key observation points to carry out the analysis of the proposed activity are those which will more likely be used by possible observers. The aim is not to select a point from which the plant is best seen or its complete layout better understood. The purpose is to better establish a relationship between possible visual alterations and the people who have to suffer them, by an identification of its number and observation conditions, through the most representative points for every factor.

The procedure for the selection of these points requires a good knowledge of the project and the area where it is planned. Possible candidates should be selected according to three main criteria:

1. Number of observers. Population nuclei and roads are compulsory observation points and should always be considered. Parameters here will be number of inhabitants and average traffic density. Recreational areas are measured by the number of users or visitors.

2. Previsible attitudes and reactions. The use the observer makes of the visually affected area strongly influences the appreciation of the impact. Plants whose characters are strongly in disagreement with the use from which they are seen are valued very negatively. That is the case for recreational and cultural uses. Areas where such utilization is produced have to be very carefully considered since they are areas of potential conflict. Another important factor will be the special sensitivity of some social groups of potential observers, independently of the use they make of the area at the moment of the observation.

3. Observation conditions. They are related to the observer, the observed territory and atmospheric conditions and, together or separately, favor aesthetic behavior which is highly influential on the observation. These can be pointed out:

   a. Duration of the view on the spot. This applies especially to roads and railway lines. When the observer sees the plant for a limited amount of time, the corresponding impact will be much smaller because the time to detect contrast and misplacement is also limited.

   b. Single or repeated views. When the observation, for example, from the road, allows repeated views of the plant from different points, the appreciation of the impact will be more conscious and the plant-environment interaction will be more globally understood. On the other hand, the impact of a single view can be mitigated by the use of small modifications on the project, for example, screens.

   c. Seasonality. Both the appearance of the modifications that will be introduced by the future installation and the attitude of the observers can be modified by seasonal reasons. That is the case of snow, which can alter completely the relationship between the observer and the environment. A vegetal screen with nonperennial leaves will act in a completely different way according to the season by attraction, filtering, or repulsion of the view.

   d. Illumination. The season of the year as well as the time of the day may substantially alter visibility conditions and thus exert an influence on the selection of possible observation points. Views in the northern direction, for example, are characterized by a better illumination which enhances the contrast between the installation and its surroundings. In that direction, the observer will never be looking against the sun. An eastern view may yield a situation similar to sunset on a western view, but the average observer will scarcely see that view at sunrise time. On the contrary, the western view is more...
likely to be appreciated and thus to have a larger implication with the surroundings.

e. Spatial composition. Some landscapes direct or point the view in predetermined directions, and the visual flows in those directions are more likely to strengthen or weaken the attraction caused by the modification on the perceived landscape. A typical case could be the existence of a given point of special interest such as the top of a mountain. Possible observation points along the line linking such a singular point with the plant under evaluation are potentially confictive. A similar case will take place when the installation obstructs the visual lines emerging from a valley, and the enhanced contrast will yield an increased effect.

f. Parameters of the visual basins and situation within them. They collect the influence of topography of the surroundings of every possible viewpoint on the organization of the territory, as seen from every point, and from the plant with respect to the position of the basin. Shape, eccentricity, compactness, and relative height of the basin will have an important role as qualifiers of the possible viewsheds with strong importance in the process of appreciation of the match of the installation with its surroundings. Distance, angle of incidence, degree of intrusion with which the installation is seen have also their share.

These three groups of criteria will allow a careful selection of the viewpoints which are considered necessary for a detailed evaluation of the likely visual impact of the installation. The required number of points may vary according to the territory and the project under evaluation. If the project is small or the observation conditions are very uniform, a single point may suffice. More complicated projects may require two or more points to offer different aspects of the likely impact. In some cases, the impact produced by the project will only be ascertained by the use of a given sequence of points.

When the selection of points to be carried out is aimed at the evaluation of industrial actions of dispersed localization, for example, power lines, lineal transport systems, pipelines for oil or gas, or large area developments, visual data will be obtained with the use of the parameters of the visual basins and selection of the more typical views among them.

This process requires the use of computerized methods due to the large number of basins and parameters to be determined and is very similar to the one used for the establishment of the visual control points (Agulu 1981) which are used to evaluate the visual fragility of the landscape in a given territory. It is advisable (Smardon, Sheppard, and Newman 1984) to take into account the following:

1. Most critical points with respect to the number of observers or the crossing of areas of conflicting use, as stated above.
2. Most representative views at the main landscape types affected by the installation.
3. Any special characteristic of the project or the landscape which may prompt higher visual attraction such as river crossings, mountain tops, substations, and so forth.

In any case, for localized as well as for disperse localizations, the number of selected viewpoints should be small enough to allow the simulation processes to be carried out. If the characteristics of the project or the territory do not allow the selection of two or three viewpoints as a maximum, it is convenient to structure them in such a way that the accuracy of the simulations can be easily graded according to the importance of the viewpoints.

Visible Area

In an absolutely flat area, an object can be clearly seen until there is a distance from the observer in which the corrections by the earth’s curvature and light refraction are equal to the object’s height (size). The height reduction in meters, related to the distance in kilometers in refraction normal conditions, would be (Hubblethwaite 1973):

<table>
<thead>
<tr>
<th>Distance in km</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height in m</td>
<td>0.07</td>
<td>0.27</td>
<td>0.61</td>
<td>1.08</td>
<td>1.69</td>
<td>2.43</td>
<td>3.31</td>
<td>4.32</td>
<td>5.47</td>
<td>6.75</td>
</tr>
</tbody>
</table>
(Example: Taking an object 8 m high, placed 10 km far away in a constant altitude area, only the 8 \( - 6.75 = 1.25 \) upper meters could be seen.)

If one were working in rough areas or at small scale, this reduction normally has no importance. In flat and large areas, it can be essential. Lighthouses are extreme examples of this problem. The processing of the visibility average conditions made to determine their range establishes the best approach to the problem (Soler Gaya 1972). In general and for reasons that we will explain, it is not necessary to take into account this effect, the range is fixed by trial and error, taking into account the effect of distance whose definition follows.

**Loss of Sharpness at Distance**

As objects are moving away from the observer, their details become unnoticeable. This fact has two immediate consequences:

The quality of the visual perception decreases as the distance increases.

It is possible to fix a distance, related to the conditions of the territory and the object to be seen, from where it is not interesting to pursue the visibility analyses.

The loss of sharpness in the distance can be represented by a function inversely proportional to the distance or its square (Aguilo 1981), though for practical purposes it could be enough to distinguish three zones of distance and apply decreasing weights to each one. Usually (Litton 1972; Burke 1968) three zones are considered:

1. **Foreground**: up to 200 or 500 meters. Observers have direct participation. They receive impressions from the near details. They realize color hue and chroma that will be lost far into the distance. They value all the architectural details of the man-made structure that take priority over any other considerations.

2. **Middle distance**: from the previous limit up to 3 or 5 km. It is the most critical zone to observe the activity environment system. This zone suffers all the adjustment or impact problems. Nearer, the detail has the priority, but further, the whole appears somewhat blurred. The attributes of the landscape group together and makes its character. "The hills become mountains, and the trees, forests" (Litton 1972). The industrial installation is not perceived as an isolated element and inserts itself into its environment.

3. **Background**: starting from 3 or 5 km. This threshold is the most variable. It is the outline that is emphasized. Color becomes indistinguishable. Masses and patches, against which the characteristics of the two other zones are detached, are perceived as a background.

The critical points to be considered for detailed analysis of the installation and its environment are found in the middle distance zone. Its boundaries, unavoidably vague, depend also on landforms and on the scale of the installation related to its environment. The concept of dominance plays an essential role.

**Angle of Visual Incidence**

If every point within an area is characterized by its normal vector, our impression of reflected light can be studied as a function of the angle formed by this vector and the view from the observation point. The smaller the angle, the nearer we are to the frontal observation of this area and the better we can value it. Big angles imply a level line of sight, of little significance.

In respect to the man-made structure itself, the angle of incidence has less significance in the quality of the observation since the facing is normally vertical. The only problems of level line of sight occur on the horizontal level and rarely in several faces at the same time. On the land, however, they reach great importance because this type of sight not only makes it impossible to perceive the landforms, but it also magnifies the structure by outlining its shape against the background.

**Properties of Viewshed**

Although it is common to use only the amount of area viewed as the sole parameter of visibility, the understanding of visual conditions of a piece of land can be improved by exploiting the possibilities offered by a more detailed study of the viewshed.
First, it is highly useful to investigate the land shape of the visual basin, that is, the geometrical shape of its delimitation in plan as a categorizing element of the land’s visual conditions. Even though the visual basin cannot be directly related to the views, it contains a great deal of information. In the terminology of Gibson (1950), the visual basin would correspond to the visual world and views would form part of the visual field. The visual basin thus constitutes the objective land seen which, through a sensory organization process, we transform into a three-dimensional space sensed. Therefore, there is no direct, immediate relation, but the relation clearly exists. In fact, the shape, as one of the basin’s spatial properties, explains how observation from a point is linked with the land’s morphology, inasmuch as the view is supported or impeded by the content of the surroundings (Appleton 1975).

These concepts can be directly transferred to the study of the visual basin’s shape drawn in plan. With the study of these shapes, numerous visual properties are inferred, not only of the observation point but of the land itself.

A circular shaped visual basin with its observation point near the center suggests a balanced position, either in an unstable way, as would happen if the observer were positioned at the top of a peak, or in a stable manner, if the observer is on the flat. In the latter case, it is possible to talk of an undifferentiated position, since the absence of obstacles to the views suggests that a displacement in either direction would not radically alter the land contemplated.

The elongated shape, with an observation point centered on the longest axis, is favored by the presence of side obstacles running parallel. These are the typical visual basins of valley bottoms. These basins will be characterized by the existence of long “diameters,” that is, directions allowing large reaches in both senses.

When the morphology is not so clear and valleys cannot be clearly seen, the typical slope situations arise with very broad and highly off-centered visual basins. The typical shape is semicircular, with the observation point near the circle’s center. Obstacles exist, the basin narrows and turns into a more or less closed view, depending on the reach. Something will always be seen toward the top of the slope, but it will be diminished.

Highly irregular basin edges are typical of highly blurred topography with a profusion of obstacles in all directions. The observation point usually has the close views restricted in some direction. This edge configuration is usually frequent in high-point visual basins on the slopes of land with rough topography, with basins in the shape of an irregular fan, cut off a great deal for a whole sector of the views.

Another main feature of visual basins as flat areas is the existence of “hollows” or shadow zones, which are not visible, inside the perimeter formed by the furthest viewed points. In general, the basins appear fragmented by innumerable intermediate obstacles which provide shadow zones but whose silhouette is drawn on a visible background, giving rise to a whole series of intermediate silhouettes. These silhouettes are taken by landscape drawers as points of support to build the land’s morphology, and their perception constitutes the clearest sign of relief.

Visual basins full of “holes” are typical of very rough land. Moving from one observation point to another within them may mean a huge reduction in the areas viewed. Very nearby zones may be the zones with minimum or maximum visibility, thus in this kind of land the analyses of intervisibility are highly useful for locating actions.

Of the two ways mentioned earlier for calculating the visual basin, the one operating by visual rays is the most suitable, from a graphic point of view, for analyzing the shape of the edges and the presence of interior shadow zones. If a plotter is available, it is possible—with minimum modifications to the program—to draw the visual basins from a beam of rays originating at the observation point and break off in the shadow zones. With the grid division, the basins can also be drawn, but to a certain extent the strong link existing between each point and the observation point or pole is lost. Visual basins are clearly focalized areas, and it is advisable to use a representation that keeps and highlights this feature.

By representing this beam of rays on a survey graph with contour lines, recognition of obstacles or depressions giving rise to shadow zones is immediate, and rays “passing” between a group of obstacles reaching the furthest zones are easy to locate. Besides, this kind of representation needs no auxiliary symbolism to highlight the pole enhanced by the beam arising therefrom.

Very compact visual basins—whose visual rays
are not interrupted until they end—are typical of highly diaphanous land where everything is easily visible and the edges are clearly defined. They are zones with a high fragility. Everything done therein will have an immediate visual repercussion. There are no possibilities for hiding it since the shadow zones are scarce or do not exist.

The presence of hollows or shadow zones is, then, an important factor when the time comes to analyze the visual basin of a point. It constitutes an index of “roughness” of a landscape, as a feature defining its morphology, on a lesser scale than that anticipated by the overall shape of the visual basin.

The drawing of the visual basin on the topographical map not only enables the land viewed to be understood and to be related to the morphology, but it also anticipates the character of the land as it is observed from a certain point.

In Figure 16.7, representing a coastal area, four visual basins of a different character have been drawn. That of point (6,19) corresponds to a long view where the nearby land disappears under the feet. A sensation of being overhead, on a balcony, will be felt. The observer will be tempted to advance toward the edge in order to see the sea crashing onto the rocks.

Observation point (23,15) offers a very clear example of a panoramic view not very much broken in the whole circle. The foregoing phenomenon is repeated somewhat toward the left-hand side, but the same does not happen toward the right, where the sight is continuous from the feet to the limit of visual extension.

Point (8,7) has a typical hillside basin, very much closed. It is inside a crevice, and so its view toward both sides is small as it also is upwards, and it immediately stumbles into the once-again ascending contour lines which shut off the views thereof. Point (30,6), finally, has a somewhat irregular basin with certain nearby shadow zones, reaching cohesion when arriving at the sea.

Finally, although the amount of area viewed does not adequately reflect the whole of visual conditions, this simplified intervisibility measure is useful in regional planning studies and site analysis. It helps to find maximum visual repercussion sites, not only to see from (a fire tower’s location, for example) but also to be seen (sites for a monument, a signal, or lighthouse).

**FIGURE 16.7**. Viewsheds of four different points. NOTE: for figures 6 and 7. Class 1: cells outside the study area. Class 2: cells not seen from the observation point. Class 3: cells seen from the observation point.
Susceptibility

Apart from the viewed areas and their qualification, it is interesting to introduce the active subject of contemplation. It is clear that the visual impact will be more intense as long as the maximum number of observers will be capable of understanding it as it is. This interest or relation between the landscape and the observer is considered by means of two parameters: the number and the attitude of the possible observers.

1. Number of observers is usually proportional to the frequency of use of a particular area. The areas capable of producing observers are, generally, the inhabited areas, roads, and internal use places attracting a lot of people. The standard of observers can be quantified by managing the amount of population, the average intensity of daily traffic, and the population density per hectare.

2. The observer's attitude or reaction related to the degree of interest toward the landscape shown by the observer. The expected behavior of an average observer, in relation to site land use, is considered as a possible approach to the individual behavior. The people who drive along a rural or forest road during their free time or those who use a recreational area are expected to show a higher interest in the landscape than those who ordinarily travel or are forced to work in that place. It is a parameter difficult to evaluate and only its positive sense should be considered, as a further precaution standard in order to admit other possible spectators sincerely interested in the landscape because of its peculiar characteristics. It has special significance in tourist places and routes.

Supposing both parameters are measurable in three levels: high, medium, and low—or 3, 2, and 1—the following aggregation matrix can be established (USDI, B.L.M. 1980):

<table>
<thead>
<tr>
<th>Number of observers</th>
<th>3 3 2 1 3 2 1 2 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attitude</td>
<td>3 2 3 3 1 2 2 1 1</td>
</tr>
<tr>
<td>Susceptibility</td>
<td>High Medium Low</td>
</tr>
</tbody>
</table>

An average number of observers (2) with an attitude of high interest in the landscape (3) give place to an area of high susceptibility.

Thus the possible visual impact can be magnified or decreased in relation to the area where it takes place. As will be explained later, this may compel more careful evaluation and modification of the design or the location of the industrial plant.

The notion of susceptibility is always relative and it should be considered in that sense. For example, a province or state with a high tourist potential will have more problems when placing an energy plant than those scarcely visited. Moreover, the different regions and areas of that same province or state will possibly have a variable flow of visitors. In each case, the concept is applicable in relative terms.

**VISUAL QUALITY EVALUATION**

The landscape's quality is an important element to be considered when placing an industrial plant. Quality evaluation is usually a comparative exercise, and it is not easy to determine the quality of a certain place independently. There are many methods for the evaluation of visual quality, but on the whole, they are all based on the classification of the land in comparative terms. The option for an industrial location will be determined by planning, and visual quality will be an element of the land's capacity models used. Nevertheless, the methods are useful as a strategy of approach of that complicated reality, the landscape, and also as indicators of the components, elements, and techniques to be used in each case. There is plenty of literature on compilation of methods (Dunn 1974; Aguilo et al. 1982; Blanco and Aguilo 1981) in which the principal series of methods are summarized in order to facilitate the appreciation of each one of them.

The landscape, in its double role as a sensitive mediator with the environment and as witness of man's historical activity, is capable of giving clear signs of acceptance or rejection toward our performances by adjusting the forms and contents of what is intended to the actual situation. The evaluation of this adjustment is not unanimous, but there are enough available methods so as to try.

Usually the evaluations of the landscape's quality are considered as subjective. It is clear that the subjective component plays an important role. The acquired education, the affective bonds, and the tastes represent a considerable part of the evaluating process, and it is unreasonable to ig-
nore them. It is not so much a matter of leaving out the subjective component as a submission and rationalization of it, so that the evaluating process may be understood by the general public and not only by the operator. Still, there is no other way but to trust qualified professionals who are trained to face these problems as in many other fields of human activity.

Another of the great topics on the evaluation of the landscape's quality is the real value of the analysis systems which work through aggregation when the landscape is basically perceived as a whole. There is plenty of literature on this subject that implies the revision of the evaluating methods we have mentioned before. “The whole is not just a result of the addition of its parts.” This is a powerful reason supporting the methods of direct and global evaluation, but we cannot deny the progress attained by the analytic methods in the gradual understanding of the landscape.

With the aim of helping to improve subjective and/or global evaluations, an orientative list of landscape components is given below. Its purpose is not to propitiate independent evaluations that can be later added up into one single value; on the contrary, it is meant to facilitate the approach to a complicated problem, making clear the several shades of that sole reality.

**Landscape's Components**

The landscape’s components are the physical factors that form the landscape. They can be assembled in three groups:

**Water and Land.** Terrain’s morphology, topography, slopes, rocky outcrops, ground surfaces, lakes, ice, snow, and so forth.

**Vegetation.** Trees, bushes, plant cover—all of them as individual tridimensional elements and also as homogeneous compounds or in contrast with the ground.

**Human Performance.** The various uses of the ground, structures, and buildings. Punctual character (buildings), linear (roads, railways, energy transport lines), or superficial (big installations, crops, and so forth), which gives out most of the testimonial function, which will determine the adjustment of the contents.

Sometimes, these components are intrinsically important, especially when certain conditions are present: scarcity, special characteristics of the component, aesthetic value, historical concern, and so forth. Usually, a component’s importance for the evaluation depends more on its interactions with other elements originating compositions that provoke aesthetic emotions. The components as well as the compositions, or even the whole landscape, have their visual characteristics or basic elements organized in a certain way. On the other hand, the installation which we pretend to place there has its own visual characteristics, and the analysis of the presumable impact tries to determine the agreement or disagreement between both groups of visual basic elements.

Usually, a new industrial plant modifies several components of the actual landscape and supplies new ones, with particular visual characteristics. These components are also assembled in three groups, similar to those referred to above. For example (Smardon, Sheppard, and Newman 1984):

**Water and Land**
- Altered or uncovered soils
- Earth tracks and paths
- Embankments
- Rocky outcrops
- Flooded areas
- Refuse disposal areas

**Vegetation**
- Sown fields or new plantations
- Pruned or cut trees
- Pruning remnants
- Vegetation clearings

**Structures**
- Buildings
- Water pipes, wells, transmission towers
- Concrete asphalt roads
- Contention walls and complementary works
- Basic material stores and uncovered manufactured products
- Waste material

All of them play their part in the impact’s evaluation. In many cases, the installation’s secondary elements (belonging to any of these groups) produce a greater visual impact than the one produced by the principal building of the installation.
itself. And there is a further problem because these secondary elements are not carefully evaluated or designed, due to hasty and careless improvisations. It is necessary to insist on giving special attention to the work leading to the construction of the industrial installation—access, quarries, earth dumps, and so forth—which are generally ignored when evaluating, even if they are potentially capable of very serious alterations.

**Basic Visual Elements**

Any landscape or industrial structure may be described in visual terms by means of the basic elements: color, shape, line, texture, scale, and spatial character.

**Color**

Property of reflecting the light with a certain intensity and wavelength. It is defined by its tinge: red, blue, yellow; shade: light, dark; brightness: bright and dull. It is the most important visual property of a surface. The luminous and bright colors prevail over the dark and dull ones. They lose brightness with the distance acquiring a blue tinge.

**Shape**

Limited surfaces or volumes so as to acquire unity. It is explained in terms of geometry, complexity, and orientation. It depends on the observation’s visual angle and is modified by the illumination.

**Line**

The border or limit perceived when there are different colors or textures. The special configuration or unidimensional arrangement of the objects. It is distinguished by its complexity, orientation, and strength—very intense, weak, and so forth. The strong and vertical lines tend to prevail over the weak and horizontal.

**Texture**

An aggregate of small combinations of shapes and colors forming a continuous superficial configuration. It is studied in terms of relative dimensions of the superficial variations and density or degree of surface scattering and regularity.

**Scale**

Relation of size between an object and its environment. Intimately related to the notions of dominancy and contrast. It is altered by the distance, the configuration of external space, and the relative position of the observer—considering his or her height.

**Space**

Determined by the tridimensional arrangement of solid bodies and empty spaces. Distinguished by the spatial composition which gives place to panoramic, closed, or focal landscapes, dominated by one particular component. Its perception is closely connected with the observer’s position in relation to the landscape, vertically as well as horizontally.

**Visual Impact Assessment**

In addition to what we have already mentioned about the effects of the visibility conditions of the area, the industrial plant can produce a visual effect capable of altering the two ways by which the landscape displays itself: its role of sensorial measurement and its testimonial role.

The first is essentially displayed by a lack of adjustment, or by an excessive contrast between the visual elements of the components introduced by the installation. For example, consider the contrast of shapes and lines established between the building’s geometry and the mild contours of the land, or the different scales or the chromatic contrast.

The contrast between the visual elements of the environment and the installation can be provoked by one or several of those elements. Its influence on the global impact can be classified in the following order: color, shape, scale, line, and texture. As a suggestion (Smardon, Sheppard, and Newman 1984), certain weights could be assigned: 3, 2, 2, 1, and 1, respectively. The impact can be graded into four classes which can act as multipliers of what has been mentioned before: null, low, medium, or high impact (0, 1, 2, 3).

As well as the visual contrast, the impact on the sensorial role becomes apparent by the visual dominancy of the introduced elements in relation to those already existent, especially in terms of scale and position in space. Frequently, it is the
most important factor in the production of a possible visual impact. It is closely related to the visual characteristics of the land and the notion of visual intrusion already mentioned.

The dominance of scale is determined by the relative occupation of the viewshed in terms of area of the invaded visual plane. In order to appreciate this effect, the observation spot has to be situated at an appropriate distance so as to perceive the surrounding landscape (its morphology, organization, and imbrication in the region’s geography) and simultaneously appreciate the installation. Spots must be chosen at medium distances, where these effects are observed in their real magnitude. The installation’s components become directly connected with the components of the surrounding landscape. In some cases, the landscape can annul or diminish them, showing a dominant power. In other cases, the installation has such energy that it diminishes the resulting landscape, transforming itself into its most fundamental characteristic and blotting out the environment.

The visual intrusion depends on the situation of the industrial plant in relation to the dominant components of the landscape, or of the visibility conditions of its morphology. In areas with regular and defined parameters (viewsheds always stretched and in the same direction, for example), the visual flows are compelled to canalize the direction of the vistas and the observation positions. In this case, the presence of an industrial installation can provoke a fracture of the visual flow system, occupying prominent positions in most of the viewsheds of that area’s spots. The problems of maximum intrusion, because of this reason, are normally found in narrow valleys when the installation is rather big and occupies a position near the center.

The spatial relation with certain principal components of the landscape is another source of potential problems. If a landscape is dominated by a mountain or a crest line, the partial or total hiding of the mountain or the interruption of the crest line will produce a strong visual impact. Even if the hidden components are artificial, the impact can be equally strong. The concealment of a village from an outstanding view spot is a clear example of it all. The effect, in this case, can be enhanced depending on the aesthetic quality of the components that have been hidden, interrupted, or altered. It also depends on the significance of the observation points.

Usually, and without considering the importance of the observation points that have been chosen, the most vulnerable landscapes in this sense are the focal landscapes (where all lines converge in one point), those dominated by a particular component (an interesting or isolated tree, a waterfall, and so forth) and the very closed-up landscapes. There are two other kinds of landscapes which suffer milder impacts: the panoramic landscapes with a predominant horizontal composition and without definite delimitation, or those landscapes dominated by a certain characteristic or component that is not very strong. The least vulnerable are the vague landscapes or those without any specific meaning.

In regard to position, the prominence of the installation is bigger when situated on top of a hill or half-way down a slope. When situated in a plateau (plain and high area with clearly defined borders) or in undulating open valleys or beside the foot of a hill, then the problem is usually less important. The background against which we observe the installation can increase or reduce the effect of dominance because of position. The outline of the structures or buildings against the sky or the water have more relevance than with a background of vegetation.

In relation to the landscape’s testimonial role, the impact is basically due to a lack of compatibility between the historical land uses which have conformed it and the meaning of the installation in that place. An agricultural landscape, for example, typified by certain crops, acquires a peculiar morphology on which all further human activities have been registered.

Roads, paths, tracks, irrigation systems, agricultural buildings, houses—all interrelate and influence one another, giving place to a real cultural possession of the environment. With the passing of the years, the activity adjusts itself to the environment, generating new ways of behavior. For example, roads always use the “cuestas” to communicate the productive high lands with the bottom of the valleys, and the latter are spared because of their fertility, restricting the buildings to the border of the productive area. Fences’ orientation is also determined by the morphological conditions. If in a landscape of this kind a road is built neglecting the context, or electric posts
are set which have nothing to do with the place, or if the bottom of a valley is damaged by a building that does not profit from it, then the incongruity with the traditional use of the surrounding land becomes clear.

Finally, the respect for those singular elements which are for any reason positively valued by the local life, because of their uniqueness, history, or aesthetics (see prior section on fragility). Any building, monument, or component of the landscape possessing any singularity of this kind must be protected. Its use and enjoyment must be guaranteed, and the environment, as well, cannot suffer any change capable of altering the service it renders to the community.

**OPERATIVE PROCESS**

In order to determine the convenience of a certain location for an industrial plant, we have to evaluate its possible impact on the qualities and characteristics mentioned in the preceding pages. Depending on the magnitude and the conditions of the installation and on the characteristics of the chosen place, the evaluation will be more or less complete. We now describe the necessary stages to follow when it is a complicated case. Each stage may be submitted to detailed analysis, implying long time and procedures, or, it may be a simple estimation elaborated with good sense. In any case, as we are trying to elude future problems, it is convenient to trust qualified professionals when considering the landscape's problems.

If we already have a duly documented plan of the chosen area, this will provide information about the visual quality of the different landscape units of the area. If there is no available plan, and if the area has landscape value, or is being used for activities which are potentially incompatible with those intended, it will then be necessary to do a previous study of fragility or visual vulnerability in order to support the first decisions about the selection of optional and alternative locations. From these previous studies, valuable suggestions for the external design of the installation will be obtained, also reducing future problems.

Unfortunately, it frequently happens that the consideration of conflicts begins when the principal characteristics of the installation and the location are totally decided. It is then necessary to evaluate the possible impact on the landscape and to propose the appropriate measures to mitigate impacts according to the following steps:

1. Information about the project, including built volumes, spatial organization, building materials, auxiliary elements, and so forth. Illustrated documents of the installation.
2. Description of the surrounding landscape. Identify its principal uses. Sketch of historical process. Identify all particularly interesting elements, and so forth.
3. Definition of the area visually affected by the installation. Viewshed. Calculation of the visual parameters (see Example 1).
4. Selection of observation points. Places which will probably concentrate observers. Probable visual elements to be affected. Routes, and so forth (see Example 2).
6. Fulfill a simulation from the chosen spots.
7. Definition of the probable impact, based on the simulation, studying (see Table 16.1): Contrast between the visual elements of the installation and the environment: lines, color, shape and texture. Scale dominance Disturbance of the visual parameters
8. Evaluation. With the following possible results: Acceptable impact. Installation is authorized. Nonacceptable impact, requiring a change of location. Go back in the process to Steps 3 or 2. Impact which can be corrected. Proposal of changes. Go back in the process to Steps 6 or 7. In some cases, it is necessary to reform from Step 3.

**EXAMPLE 3: Figures 16.8, 16.9 and 16.10.**

The following three computer programs to calculate visibility were written in BASIC computer language to be run on an HP-85 microcomputer. The approach taken by each is generally described in Ex-
PROGRAMA DE VISIBILIDAD.
METODO DE G. STEINITZ.

10 REM PROGRAMA DE VISIBILIDAD SEGUN STEINITZ.
20 CLEAR
30 OPTION BASE 1
40 DIM A(100)
50 DIM INTEGER Z(39,60)
60 DIM L(1,2,3,4)
70 V=1-L1
80 INTEGER A(67,9),C(36,60),R(17,17)
90 CMD W4
100 DISP "PROGRAMA DE VISIBILIDAD STEINITZ"
110 PRINT "Visibilidad. STEINITZ"
120 DISP "LONGITUD MAXIMA DEL RAYO: 67 cuadrículas"
130 ASSIGN 1 TO "V1"
140 READ C(,)
150 ASSIGN 1 TO * 
160 FOR I = 1 TO 30
170 FOR J = 1 TO 60
180 C(I,J)=0
190 NEXT J
200 NEXT I
210 DISP "NUMERO DE RAYOS(3,5,9)"
220 INPUT A
230 DISP "LONGITUD DE LOS RAYOS"
240 INPUT B
250 DISP "COORDENADAS DEL PUNTO DE OBSERVACION (X/Y)"
260 INPUT F,G
270 U1,W2=0
280 FOR I = 1 TO 17
290 FOR J = 1 TO 17
300 R(I,J)=0
310 NEXT J
320 NEXT I
330 FOR C = 1 TO B
340 T=0
350 IF C=1 THEN M,N=1
360 IF C=4 THEN M=1 @ N=-1
370 IF C=5 THEN M=-1 @ N=-1
380 IF C=8 THEN M=-1 @ N=1
390 IF C=2 THEN M=1 @ N=1 @ T=1
400 IF C=3 THEN M=1 @ N=-1 @ T=1
410 IF C=6 THEN M=-1 @ N=1 @ T=1
420 IF C=7 THEN M=-1 @ N=-1 @ T=1
430 IF A=3 THEN V=4
440 IF A=5 THEN V=2
450 IF A=9 THEN V=1
460 LB=G
470 LG=L7=1 @ LB=9
480 IF INT(C/2)=C/2 THEN L7=U+1 @ LB=9-U
490 FOR J=L7 TO LB STEP V
500 S=-100
510 FOR I=1 TO B
520 X1=IP(A(I,J)/100)
530 Y1=IP(A(I,J)/100)*100
540 L=SQR(X1^2+Y1^2)
550 IF L<7 THEN 770
560 IF T=0 THEN 570 ELSE 570
570 Y=G+X1*N
580 X=F+Y1*M
590 GOTO 620
600 Y=G+Y1*N

FIGURE 16.8.
610 X=F+XI*M
620 IF Y(L3 OR Y)L4 THEN 770
630 IF Y(L3 OR Y)L4 THEN 770
640 IF X(L1 OR X)L2 THEN 770
650 IF Z(Y,X)=-1 THEN 770
660 WZ(Y,X)=Z(G,F)
670 Z=W/L
680 S=MAX(Z,S)
690 IF Z)=S THEN 700 ELSE 760
700 IF AHS(X-F)<-1 AND AHS(Y-G)<-1 THEN C(Y,X)=1 0 GOTO
710 W1=W1+1 0 C(Y,X)=1
720 GOTO 760
730 T1X=F+9
740 T2Y=G+9
750 R(T2,T1)=1
760 NEXT I
770 NEXT J
780 NEXT C
790 FOR I=1 TO 17
800 W2=W2+R(I,J)
810 NEXT J
820 NEXT I
830 NEXT I
840 PRINT "Puntos X:";F;"Y=";G
850 W3=IP((W1+W2)*100)/100
860 PRINT
870 GOSUB 1130
890 PRINT USING 900
920 IMAGE 3/7
930 FOR I=L4 TO L3 STEP -1
940 A1(I)=VAL$(IP(I/100))
950 A2(I)=VAL$(IP(FP(I/100)*10))
960 A3(I)=VAL$(FP(I/10))
970 FOR J=1 TO L2
980 IF I-G AND J-F THEN A5(I+6+V)="A" 0 GOTO 1000
990 IF Z(I,J)=-1 THEN A5(I+6+V)=" " 0 GOTO 1000
1000 IF C(I,J)=0 THEN A5(I+6+V)="." 0 GOTO 1000
1000 FOR I=1 TO 1000
1010 FOR J=1 TO 1000
1020 A5(I+6+V)=A5(I+6+V)+"A"
1030 A5(I+6+V)=A5(I+6+V)+"A"
1040 A5(I+6+V)=A5(I+6+V)+"A"
1050 PRINT A5
1060 NEXT J
1070 NEXT I
1080 PRINT USING 1080
1090 IMAGE 3/7
1100 GOSUB 1130
1110 GOSUB 1270
1120 GOTO 160
1130 STOP
1140 FOR J=1 TO L2
1150 A5(J+6+V)=VAL$(IP(J/100))
1160 NEXT J
1170 PRINT A5
1180 FOR J=1 TO L2
1190 A5(J+6+V)=VAL$(IP(FP(J/100)*10))
1200 NEXT J
1210 PRINT A5
1220 FOR J=1 TO L2
1230 A5(J+6+V)=VAL$(FP(J/10)*10)
1240 NEXT J
1250 PRINT A5
1260 RETURN
1270 PRINT USING 1280
1280 IMAGE 1/1
1290 D=.1
1300 PRINT "CILES"
1310 FOR I=1 TO 3
1320 PRINT TAE(3+7*I),I;
1330 NEXT I

FIGURE 16.8. (continued)
Visibilidad por cuadrículas

10 REM "CUADR1". VISIBILIDAD POR CUADRÍCULAS, CON CORRECCION DE ALTITUDES.CINTA 2, 14.X1.81.
20 CLEAR
30 OPTION BASE 1
40 COM INTEGER Z(30, 60)
50 COM L1, L2, L3, L4
60 COM U4
70 U61-L1
80 INTEGER A(30, 60)
90 DIM A$(100)
100 DEF FNZ(Y)
110 IF X+1)L2 OR Y+1)L4 THEN FNZ=Z(Y, X) & GOTO 180
120 IF Z(Y+1, X+1)=1 THEN FNZ=Z(Y, X) & GOTO 180
130 IF E=R THEN 140 ELSE 160
140 IF Z(Y, X+1)=1 THEN FNZ=Z(Y, X) & GOTO 180
150 FNZ=Z(Y, X)*((1-E)+Z(Y, X+1)*((E-R)+Z(Y+1, X+1)*R & GOTO 180
160 IF Z(Y+1, X)=1 THEN FNZ=Z(Y, X) & GOTO 180
170 FNZ=Z(Y, X)*((1-R)+Z(Y+1, X)*((R-E)+Z(Y+1, X+1)*E
180 FN END
190 DISP "ALC,SOBRELPASO"
200 INPUT A, S, P
210 DISP "COORDENADAS DEL PUNTO DE OBSERVACION (X, Y)"
220 INPUT X, C
230 Y=G & X=F
240 IF Z(G, F)=1 THEN PRINT "PUNTO FUERA DE LA ZONA DE ESTUDIO" & GOTO 210
250 E, R=.5
260 Z1-FNZ(Y)+S
270 D=0
280 FOR I=1 TO 30
290 FOR J=1 TO 60
300 A(I, J)=0
310 IF Z(1, J)=1 THEN 490

FIGURA 16.9.
```plaintext
320 IF F=1 AND G=1 THEN 490
330 T=SQR((F-J)^2+(G-I)^2)
340 IF T>A THEN 490
350 H=(1-G)/T
360 N=(J-F)/T
370 Q=Z*(1,J)-Z1
380 FOR U=1 TO T STEP P
390 Z=D*Q+T+Z1
400 X=Q*N+P, Y=E-X=INT(X) @ X=INT(X)
410 Y=Q*M+P, E=Y-INT(Y) @ Y=INT(Y)
420 IF X>L1 OR X>L2 THEN 490
430 IF Y<L3 OR Y>L4 THEN 490
440 Z=INT(Y)
450 IF Z=Z THEN 450 ELSE 490
460 NEXT U
470 A(I,J)=1
480 D=D+1(1,J)
490 NEXT J
500 NEXT I
510 PRINT "Visibilidad cuadrícula a cuadrícula."
520 PRINT "ALCANCE:;A;" SUBREL:;S;" PASO:;P"
530 PRINT "=IA=X;=IF;Y=";G
540 B=IP(b+100)/100
550 PRINT USING 560
560 IMAGE /
570 GOSUB U20
580 PRINT USING 590
590 IMAGE /
600 FOR I=L4 TO L3 STEP -1
610 AS(I)=VAL$(IP(I/100))
620 AS(I+2)=VAL$(IP((FP(I/100)*10))
630 AS(I+3)=VAL$(IP((FP(I/100)*10))
640 FOR J=L1 TO L2
650 IF F=1 AND G=1 THEN AS(I+J+6)="A" @ GOTO 690
660 IF (I,J)=-1 THEN AS(I+J+6)=" " @ GOTO 690
670 IF A(I,J)=0 THEN AS(I+J+6)=" " @ GOTO 690
680 AS(I+J+6)=VAL$(1)
690 NEXT J
700 AS(L2+7+V,L2+9+V)=" "
710 AS(L2+10+V)=AS(I)
720 AS(L2+11+V)=AS(I+2)
730 AS(L2+12+V)=AS(I+3,3)
740 PRINT AS
750 NEXT I
760 PRINT USING 770
770 IMAGE /
780 GOSUB B20
790 GOSUB 1600
800 GOTO 190
810 STOP
820 FOR J=L1 TO L2
830 AS(J,3)="+++"
840 AS(J+5)=" "
850 AS(J+6+V)=VAL$(IP(J/100))
860 NEXT J
870 AS(L2+10+V,L2+12+V)="+++"
880 PRINT AS
890 FOR J=L1 TO L2
900 AS(I+J+6+V)=VAL$(IP((FP(J/100)*10))
910 NEXT J
920 AS(L2+10+V,L2+12+V)="+++"
930 PRINT AS
940 FOR J=L1 TO L2
950 AS(J+6+V)=VAL$(IP((FP(J/100)*10))
960 NEXT J
970 AS(L2+10+V,L2+12+V)="+++"
980 PRINT AS
990 RETURN
1000 PRINT USING 1010
1010 IMAGE /
1020 D="",1"
1030 PRINT "CLASES";
1040 FOR I=1 TO 3
```

FIGURE 16.9. (continued)
VISUAL IMPACT ASSESSMENT METHODOLOGY FOR INDUSTRIAL DEVELOPMENT SITE REVIEW IN SPAIN

```
1050 PRINT TAB(5+7*I),I;
1060 NEXT I
1070 PRINT "-----------------------------
    ======
1090 FOR I=1 TO 100
1100 A(I)=" "
1110 NEXT I
1120 FOR I=1 TO 4
1130 FOR J=1 TO 4
1140 A(I+J,11+J)=D(I,J)
1150 A(I+11+J)=D(I,J)
1160 A(I+25+J)=D(I,J)
1170 NEXT J
1180 PRINT A6
1190 NEXT I
1200 PRINT "-----------------------------
    ======"
1210 PRINT "Frecuencia";TAB(19),W4-D;TAB(26),D
1220 PRINT USING 1230
1230 IMAGE /;
1240 PRINT "Clase 1: cuadrículas fuera de la zona de est 
    ocio";
1250 PRINT "Clase 2: cuadrículas no vistas desde el punt 
    o de observacion";
1260 PRINT "Clase 3: cuadrículas vistas desde el punto de 
    observacion"
1270 RETURN

FIGURE 16.9. (continued)

VISIBILIDAD POR RAYOS.

10 REM PROGRAMA DE VISIBILIDAD POR RAYOS.
20 CLEAR
30 OPTION BASE 1
40 COM INTEGER Z(30,60)
50 COM L1,L2,L3,L4
60 COM W4
70 DEF
80 DISP DIR,AMPL,ALC,PASO,ANG,SOBR
90 INPUT A1,A2,A3,A4,A5
100 DISP "X,Y DEL PUNTO DE OBSERVACION"
110 INPUT F,G
120 H=Z(C,F)+A5
130 R,T=0
140 FOR W=A1-A2/2 TO A1+A2/2 STEP A4
150 B=cos(w) & C=sin(w) & E=tan(a4/2)
160 S=-100
170 FOR D=P TO A3 STEP P
180 X=D+B+F
190 Y=C-D*C
200 X=INT(X)
210 Y=INT(Y)
220 IF X(l1 OR X)l2 THEN 330
230 IF Y(l3 OR Y)l4 THEN 330
240 IF Z(Y,X)=1 THEN 330
250 L=Z(Y,X)-H
260 M=L/D
270 R1=(2*D*P-P*P)*E
280 S=MAX(M,S)
290 IF M>S THEN 300 ELSE 310
300 R=R+R1
310 T=T+R1
320 NEXT D
330 NEXT W

FIGURE 16.10.
```
340 PRINT "Punto: x=";F;",y=";C
350 PRINT USING 360; "Cuenca visual real: ",R," cuadrículas"
360 IMAGE K,2X,DDDD.DD,X,K
370 PRINT USING 380; "Cuenca real esperada: ",T," cuadrículas"
380 IMAGE K,2X,DDDD.DD,X,K
390 PRINT USING 400; "Cuenca relativa: ",R/T*100," cuadrículas"
400 IMAGE K,2X,DD.DD,X,K
410 GOTO 100
420 STOP

FIGURE 16.10. (continued)