Appraisal of environmental impacts and mitigation measures through mathematical matrices

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Interaction matrices are widely used in environmental impact assessments (EIAs). However, this technique is considered an illustrative approach, since its analytical power is deemed to be insufficient for effectively handling complex decision-making. It can be argued that the misuse of interaction matrices has (in some instances) contributed to flawed EIAs, which have been deliberately misrepresentative and have been used for endorsement of projects. Consequently, an alternative for better EIAs in the short term is to enhance the matrix approach, so that a more rigorous evaluation of impacts can be achieved. The approach presented here is based upon mathematical matrices to determine the significance of impacts; specifically it encompasses the use of minimum link matrices, interpretative structural models and exponential and linear equations. This method allows users to systematically weight all possible cause-effect interactions and pathways, and to consider primary and secondary impacts identified in a matrix. Consequently, the approach increases the effectiveness and rigor of matrices in handling complex data and predicting environmental impacts in a strict and traceable way.

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Introduction

Environmental impact assessments (EIAs) are regarded as integrative analyses by which sound inferences can be derived in relation to the effects of development projects. Their objective is to enhance rationality in decision-making and provide information in an environmental conflict resolution process. Furthermore, they are tools for public scrutiny of development enterprises, enabling the evaluation of possible technical and environmental options of original proposals. In practice, this implies that an EIA should include a meticulous treatment of how to mitigate the negative impacts, otherwise, it becomes a futile endeavour (Hollick, 1981; Organisation of American States (OAS), 1987; Wright and Greene, 1987; Harashina, 1995).

The most generalized impact assessment technique is the interaction matrix. This technique has been advocated in a wide variety of EIA procedures around the world (Munn, 1975; Holling, 1978; Wright and Greene, 1987; Shopley and Fuggle, 1984; Bojórquez-Tapia, 1989; Shopley *et al.*, 1990; Zeiss, 1994). However, matrices present several drawbacks that limit their effectiveness in impact assessments (Holling, 1978; Lawrence, 1993). In Mexico, for example, extensive application of matrices has resulted in deficient and vague impact assessments. On the other hand, the matrix approach yields satisfactory results if used properly (Holling, 1978). Therefore, a practical way to achieve better EIAs is to improve matrices so that users can benefit from their advantages and appraise impacts more rigorously.

The objective of this paper is to present an enhanced matrix procedure which facilitates a systematic evaluation of environmental impacts. This approach reduces the matrices' weaknesses and allows users to assess the efficiency of contemplated impact mitigation measures. In essence, the technique is based upon a set of six impact indicators (Duinker and Beanlands, 1986; Bojórquez-Tapia, 1989)

measured in an ordinal scale. These indicators are combined into two indices through mathematical matrices, by applying exponential and linear equations. The approach is illustrated by a case study: La Venta-Colegio highway project in Mexico City. The corresponding EIA evaluated of the potential effects of the project (a 23·3 km, four-lane toll road) on urban development, groundwater recharge, flora and fauna extinction, air pollution and travelling time during rush hours.

Results demonstrate that the use of mathematical matrices allow users to assess both primary and higher order interactions (*sensu* Shopley *et al.*, 1990) in an orderly and traceable way. Furthermore, the approach increases the effectiveness of the analysis in handling a variety of conditions and kinds of data.

Limitations and enhancement of impact matrices

An impact matrix consists of a grid diagram in which two distinct lists—environmental factors and project activities—are arranged along perpendicular axes. An interaction between components on opposing axes is marked and scored in the cell common to both. The original approach, the Leopold Matrix, was designed to assess the impacts generated by large infrastructure projects. Its usage has been justified on the following grounds (Munn, 1975; Holling, 1978): (1) they are easy to employ; (2) they constitute a comprehensive—although qualitative—summary of a large number of impacts; (3) they promote an interdisciplinary examination of a project; and (4) they simplify communication of what the impacts might be.

However, interaction matrices are considered as a descriptive rather than an analytical approach, because they are deemed to be ineffective in handling complex decision-making and appraising the importance of mitigation measures (Holling, 1978). From an analytical point of view, those problems arise from the limitations of the original approach (Holling, 1978; Lawrence, 1993). First, matrices are not necessarily comprehensive or systematic. Second, their format is unrealistic: sequential impacts are difficult to identify since only binary interactions are considered. Third, interactions between project activities and environmental attributes may rely on unsubstantiated judgments. Fourth, matrices tend to be subjective and biased because the significance of impacts is not explicit. Finally, they inhibit scrutiny inasmuch as the process by which interpretations and conclusions are reached cannot be reproduced.

A consequence of the drawbacks of the matrix approach is that it can easily be misused. Results can then be manipulated to endorse projects, mainly because it is almost impossible to track back to the rationale behind particular conclusions. In such cases, EIAs are severely limited as a decision-making tool, and are certainly useless for environmental conflict resolution (Dickman, 1991; Lawrence, 1993; Ross, 1994).

Consequently, a crucial requirement for enhancing the matrix approach is to require users to justify their judgment; that is, to methodically clarify the rationale behind the value assigned to each particular cell in a matrix. This requires a technique to be found by which experts can formalize even subjective judgments and intuitions about relationships among poorly-defined variables (Holling, 1978; Lawrence, 1993).

Mathematical matrices can address the limitations associated with Leopold's original approach by forcing an explicit formulation of value judgments and opinions about an interaction. Mathematical matrices are rectangular arrays of quantities upon which algebraic operations can be performed (Shopley and Fuggle, 1984). Mathematical operations constrain the basic assumptions about an interaction to a set of weights or impact significance criteria, which involve the transformation of data into a common scale. Thus, the interactions can be organized by impact classes and the sensitivity of the experts' judgments to alternative perceptions can be evaluated.

Evaluation procedure

Environmental impact assessments should be based on a procedure designed for a comprehensive and systematic appraisal of all

foreseeable environmental impacts of development projects. In general, this appraisal is achieved by following steps: (1) project description and environmental characterization; (2) identification and prediction of impacts; and (3) evaluation of impact significance. In this paper, the authors will concentrate in the application of mathematical matrices at each step, since other details on the procedure have been described elsewhere (Munn, 1975; Holling, 1978; Wright and Green, 1987; Bojórquez-Tapia, 1989).

Steps 1 and 2

Project description and environmental characterization are carried out as detailed in Bojórquez-Tapia (1989) and Wright and Green (1987). Then, both the project activities and the environmental factors are incorporated into a binary matrix to depict the direct dependencies. Up to this point, it is sufficient for the experts to determine which activities interact with the environmental factors. Thus, interactions are marked in the corresponding cell as either 0 (absent) or 1 (present).

Next, a flow diagram is generated from the matrix to simplify the examination of both direct cause-and-effect relationships, and higher-order interactions. Higher-order interactions are those generated by interdependence between the system's components that are not directly connected, such as indirect feedback linkages and causal chains (Shopley et al., 1990). Likewise, the analysis of higher-order dependencies is facilitated through the development of a minimum-link matrix that renders the shortest connection between variables in an indirect causal chain (Shopley et al., 1990). Since the number of interactions in a matrix can be considerable, flow charts can become complex and hard to outline. Hence, it is convenient to use a systematic scheme to delineate causal chains. Interpretative structural models rank the variables hierarchically, so flow diagrams are more easily constructed (Vizayakumar and Mohapatra, 1989, 1992). Both the interpretative structural model and the minimum-link matrix are generated by means of a similar process: the binary matrix is exponentially elevated to the nth power,

where n is the highest-order interaction (Hein, 1995).

Another tool that helps experts to refine their judgments is through qualitative simulation models, such as KSIM (Kane, 1972; Kane et al., 1973; Holling, 1978). These models help the analysis of interactions because they reveal the dynamic behaviour of the system components. Moreover, sets of scenarios can be generated to detect the sensitivity of the variables to different circumstances.

At this point, it is expected that the experts be able to define the project activities and the environmental factors with respect to a set of environmental indicators. An indicator is a measurable property of environmental change (Munn, 1975). Thus, experts have to specify the proper variables for baseline conditions and interactions. The indicators are indeed formal postulates about the effects of one activity over one environmental component.

Step 3

The significance of an interaction in the matrix is then assessed by means of a set of basic, supplementary and quality criteria (Duinker and Beanlands, 1986; Bojórquez-Tapia, 1989). Basic criteria include magnitude or intensity, spatial extent and duration. Supplementary criteria entail synergism between variables, cumulative effects and controversy surrounding the interaction. Quality criteria encompass information that supports the prediction of an impact, its probability of occurrence, confidence in the prediction and existence of environmental standards. Thus, basic criteria are those that are indispensable for defining an interaction, while the supplementary criteria are those that complement that description, but which can be missing from the description of an interaction. Likewise, quality criteria serve to judge the rationality of the assessment.

The criteria are valued on an ordinal scale corresponding to expressions related to the effect of an activity on the indicator variable of the environmental component. While valuation of most of the criteria is straightforward, synergycal and cumulative effects require the consideration of the dynamic simulation and the higher-order dependencies.

The expressions and their value in the ordinal scale are: null (0), null to low (1), very low (2), low (3), low to moderate (4), moderate (5), moderate to high (6), high (7), very high (8), and extremely high (9). An exception, in terms of the quality criteria, is the existence of environmental standards, which are rated as present or absent. When uncertainty exists on determining the value of a criterion, it is assigned the highest figure. This rule is consistent with a precautionary rationale for environmental conflicts (Crowfoot and Wondolleck, 1990); that is, lessening the chance of underestimating an impact, and which minimizes the risk to the public (Shrader-Frechette and McCoy, 1993).

Since the maximum value in the ordinal scale is 9, a basic index (MED_{ij}) and a supplementary index (SAC_{ij}), describing the effects of variable j on variable i can be obtained through the following equations:

$$MED_{ij} = \frac{1}{27}(M_{ij} + E_{ij} + D_{ij}) \qquad (1)$$

$$SAC_{ij} = \frac{1}{27}(S_{ij} + A_{ij} + C_{ij}) \qquad (2)$$

where: M_{ij} = magnitude, E_{ij} = spatial extent, D_{ij} = duration, S_{ij} = synergy effects, A_{ij} = cumulative effects and C_{ij} = controversy. As the basic criteria cannot be absent (i.e. the magnitude, the spatial extent and the duration have to be different from zero for an impact to exist) their minimum value should be one. Thus, the ranges of the indexes are as follows: $(3/27) \le MED_{ij} \le 1$ and $0 \le SAC_{ij} \le 1$.

From these two indices (basic and supplementary) the qualitative impact of an interaction between two variables i and j can be estimated. It is easy to see that the impact of j on i will be proportional to the value of the basic impact index (MED_{ij}), but that this impact will be synergized by the value of the supplementary criteria (SAC_{ij}). In short, the impact (I_{ij}) should be equal to MED_{ij} if the value of SAC_{ij} is zero, but it should be higher than MED_{ij} when SAC_{ij} is greater than zero (Figure 1). In mathematical terms, this relationship can be written as:

$$I_{ij} = MED_{ij}{}^{\varphi} \qquad (3)$$

where $\varphi = 1 - SAC_{ij}$.
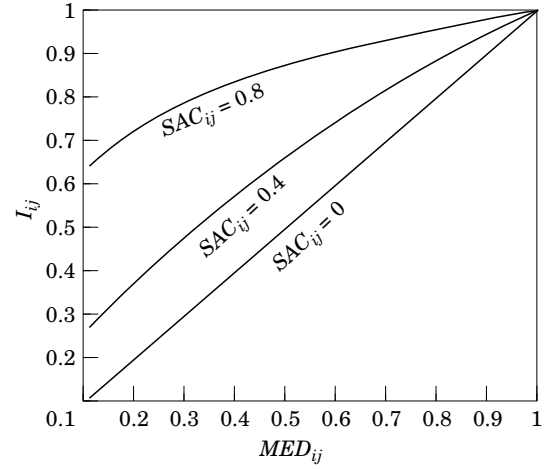
Figure 1. Impact index values (I_{ij}) as a function of the non-linear combination of the basic (MED_{ij}) and supplementary (SAC_{ij}) index values. $I_{ij} = MED_{ij}$ when $SAC_{ij} = 0$; and $I_{ij} > MED_{ij}$ when $SAC_{ij} > 0$.

Additionally, the significance of the interaction (G_{ij}), which takes into consideration the mitigation measures (T_{ij}), is obtained from the following equation:

$$G_{ij} = I_{ij} \cdot [1 - (T_{ij}/9)] \qquad (4)$$

Since basic criteria cannot be valued as null, then: $(3/27) \le G_{ij} \le 1$. Mitigation measures are assessed on an ordinal scale similar to that for the basic and supplementary criteria. Costs have to be taken into account to discern their relative importance and chances of implementation before a mitigation measure is fully evaluated.

Finally, the values G_{ij} are ranked in four impact significance classes: low (0–0·25), moderate (0·25–0·49), high (0·50–0·74) and very high (0·75–1·00). The efficiency of the mitigation measures is then evaluated by observing the magnitude in the reduction of an impact's significance, as well as the number of impacts that are ameliorated, directly or indirectly, by a single mitigation measure.

Case study

Steps 1 and 2

The La Venta-Colegio Militar project consisted of the construction and operation of

a 23·3 km, four-lane toll road. The project, located on the south-west section of Mexico City, was designed to complement the western portion of a projected external transit loop for the city. It encompassed 233 ha and included the construction of several bridges over the principal water courses, numerous runoff underpasses and one tunnel.

The study area was divided into geomorphic regions, following a hierarchical classification approach (Cendrero and Diaz de Teran, 1987; Bos, 1993). Two main geomorphic units, that contained six ecological landscapes, were identified. The former corresponded to the mountainous ranges west of Mexico City, while the latter included valleys, hillsides, alluvium deposits with different vegetation, soil, slope, human influence and hydrology. The project intersected 18 watersheds. The regional environmental and socio-economic characteristics were associated to the landscapes, since natural land cover has been fragmented by urban development, and illegal human settlements were scattered along the projected route.

Major concerns of both the public and the Government related to the effects of the project on: (1) inducing urban development into natural areas; (2) deforestation during the construction of the highway; (3) increasing risks of extinction of flora and fauna; (4) reduction of groundwater recharge; and (5) higher local air pollution. On the other hand, the principal benefit of the project, according to the developers, were a decrease in travel time during rush hours, and a reduction of automobile air emissions within Mexico City.

The potential environmental impacts were categorized with respect to the concerns recognized during environmental characterization. This allowed the assessment process to address the environmental conflicts more likely to be generated by the project. For that reason, it was necessary to employ three different scales: small (the whole of the metropolitan area); medium (the mountainous ranges); and large (a fringe of 1 km at both sides of the highway). In essence, the potential impacts that were assessed at each were the following: (1) small scale, changes in traffic and air pollution within Mexico City; (2) moderate scale, local and regional extinction of biologically valuable species; and (3) large scale, modification of

natural cover, urban growth induced by traffic, reduction of infiltration and water and air pollution.

Subsequently, the initial binary matrix was prepared utilizing the list of the project activities during the construction and operation phases and a list of the most relevant environmental factors. Although the matrix resembled the one in Leopold's approach, in this case all the variables were specifically defined according to the data gathered during the characterization. Next, a structural model and a KSIM qualitative simulation were generated to facilitate the examination of higher-order interactions and the system's dynamic behaviour.

A final interaction matrix was prepared taking into consideration all the information base attained to this point. It is important to note that this matrix was smaller than that expected from a traditional Leopold's approach, because it was limited to those project activities that specifically interacted with the environmental factors (either ecological, physical or socio-economic) likely to be affected by the project. Moreover, the description of each interaction was precise, since it was associated to one indicator variable as a minimum. As a result, the matrix included 33 environmental factors, 25 project activities and 274 interactions.

Step 3

Estimations of change for each of the indicators were derived from diverse sources, in addition to the previous analyses. Thus, selecting the appropriate values for basic, supplementary or quality criteria required repeated consultations to the baseline data, the structural model, the qualitative simulation and also a series of interdisciplinary discussions. Taking the major concerns as an example, the selection of a criterion's value were derived mainly from: (1) an urban growth simulation model and the KSIM to analyse urban development rates at the large scale; (2) remotely-sensed data and geographical information systems to measure the area to be deforested and the presence of important habitats at the large and medium scales; (3) a water balance model for each watershed at the medium scale to estimate variations in infiltration; and (4) a network

Table 1. Example of the application of the basic, supplementary, impact and significance indices for the assessment of environmental impacts of La Venta-Colegio Militar highway project in Mexico City

i	*j*	M_{ij}	E_{ij}	D_{ij}	S_{ij}	A_{ij}	C_{ij}	T_{ij}	MED_{ij}	SAC_{ij}	I_{ij}	G_{ij}
Urban growth rate	Highway operation	3	5	7	3	2	9	6	0·56	0·52	0·75	0·25
Loss of natural cover	Construction/ roadwork	6	2	9	2	2	9	7	0·63	0·48	0·79	0·17
Flora and fauna extinction	Deforestation	2	2	1	3	3	7	6	0·19	0·48	0·42	0·14
Groundwater recharge	Highway surface	1	1	9	0	2	9	9	0·41	0·41	0·59	0·00
Air pollution	Construction and transit	1	1	6	3	1	3	0	0·30	0·26	0·41	0·41

i, environmental factor or effect on; *j*, activity or cause over; M_{ij}, magnitude; E_{ij}, extention; D_{ij}, duration; S_{ij}, synergy; A_{ij}, cumulative effects; C_{ij}, controversy; T_{ij}, mitigation measure; MED_{ij}, basic index; SAC_{ij}, supplementary index; I_{ij}, impact; G_{ij}, significance.

flow assignment model and an air pollution simulation model, coupled with the KSIM, to determine expected transit demands and air pollution estimates at small and large scales.

Each interaction in the final matrix was assessed by the equations described in the 'Step 3' section. Agreement between the experts was difficult because of the wide spectrum of information utilized to support a particular judgment. Consequently, a criterion could be modified as necessary to explore the sensitivity of the assessment to different opinions. That is, discussions about the criteria values focused on the values assigned within the ordinal scales, so different judgments were tested by changing the corresponding values of the indicators. For example, the interactions shown in the first two rows of Table 1 resulted in very high I_{ij}, this value was counterbalanced by high T_{ij}. In this situation, it would be necessary to reduce T_{ij} to a very low value in the ordinal scale (3) to obtain a G_{ij} of equivalent of high class. Thus, the experts could discuss whether such a reduction was reasonable or could be justified with the data. Furthermore, the controversy criterion could be evaluated in the light of the heavy weighting. On the other hand, the remaining interactions in Table 1 had comparatively low index values, and it would require either an increase of any of the basic or supplementary criteria, or a reduction of the mitigation measure criterion. Thus, the relevance of any disagreements could be explored and resolved easily. Nonetheless, there were instances when disagreements persisted, so additional research was necessary to discern the final values of the criteria.

The overall results showed that the majority of the interactions were judged as having moderate values for the basic criteria and low values for the supplementary criteria (Table 2). Likewise, about one-third of the impacts were judged as very high or high, while the rest were moderate. The final significance values demonstrated that the relevance of the majority of those impacts was reduced to either low or moderate after the mitigation measures were considered in the analysis.

Since the results included both positive and negative impacts, each project activity was examined to identify its specific negative effects, and to determine the efficiency of the mitigation measures. A total of 72 negative impacts with high and very high values were detected for 16 of the project activities (Table 3). When considering the significance values, that is, after the mitigation measures were included in the analysis, the resulting number of high and very high values was reduced to 14.

It was concluded, therefore, that while most of the negative effects could be avoided, some of them could not be lessened. Examination of the databases revealed the cause-effect relationships for each of those interactions: they were generated by land acquisition, clearing of trees, excavation, slope protection, land cuts/embankments, tunnel and bridges, power lines and construction and operation of junctions. The predicted effects involved changes in life style and land use patterns, habitat loss, landscape alteration and increased local transit at the large scale of analysis. Because of both the large scale and

Table 2. Percentage of the total number of interactions considered for the environmental impact assessment of the La Venta-Colegio Militar highway project

| Criteria | Value class | | | |
	Low	Moderate	High	Very high
Basic	1	64	25	9
Supplementary	67	18	9	6
Impact	0	64	14	21
Significance	27	60	8	5

Value classes are the following: low $(0 \cdot 11 \leq L < 0 \cdot 25)$, moderate $(0 \cdot 25 \leq M < 0 \cdot 50)$, high $(0 \cdot 50 \leq H < 0 \cdot 75)$, and very high $(0 \cdot 75 \leq VH)$.

Table 3. Number of interactions by value class per project activity of the La Venta-Colegio Militar highway project

| Project activity | Impact (I_{ij}) | | | | Significance (G_{ij}) | | | |
	L	M	H	VH	L	M	H	VH
Land acquisition	0	0	5	6	7	2	1	1
Access roads	0	10	0	2	2	10	0	0
Clearing of trees	0	5	1	13	13	5	1	0
Soil removal	0	6	0	1	3	4	0	0
Excavations	0	5	0	4	3	4	1	1
Soil compaction	0	4	0	0	0	4	0	0
Slope protection	0	4	1	0	0	4	1	0
Land fillings	0	5	0	0	1	4	0	0
Land cuts/embankments	0	8	0	5	3	8	2	0
Liquid-waste disposal	0	5	0	0	1	4	0	0
Explosions	0	9	1	0	8	2	0	0
Mining of materials	0	6	0	0	2	4	0	0
Tunnels and bridges	0	6	0	3	3	5	0	1
Walls	0	4	0	0	0	4	0	0
Junction (construction)	0	4	2	0	1	4	1	0
Reforestation	0	4	0	0	0	4	0	0
Pavement (building)	0	4	1	0	0	5	0	0
Power lines	0	0	1	0	0	0	1	0
Traffic	0	5	8	4	9	7	1	0
Energy and fuel	0	0	3	0	3	0	0	0
Services	0	0	4	1	4	1	0	0
Junctions (operation)	0	0	3	2	2	1	2	0

Value classes are the following: low $(L < 0 \cdot 25)$; moderate $(0 \cdot 25 \leq M < 0 \cdot 50)$; high $(0 \cdot 50 \leq H < 0 \cdot 75)$; and very high $(0 \cdot 75 \leq VH < 1 \cdot 00)$.

the high relative weight of one criteria (controversy), it was considered that the related environmental costs were acceptable. This conclusion was supported by the following considerations: (1) the predicted faster traffic flow would benefit the city; (2) the availability of large habitat areas in the mountainous range would effectively cancel out any losses; (3) the agricultural land to be affected consisted of a small area of low productivity, so did not constitute a great loss; (4) the effects on landscapes were mainly visual; and (5) the effects on life style were both positive, because of faster transit in the city and the creation of temporary jobs during construction, and negative, because of changes in the rural settlements. On the other hand, the study rejected the developer's claims of the reduction of air pollution in the city.

Discussion and conclusions

Impact assessments are not scientific endeavours, but decision-making exercises. Thus, their goal is to gain an understanding about the effects of a project on which to base

decisions (Holling, 1978), and their results should always be balanced by a broad-minded application of experience and intuition (Dykstra, 1984). Since, EIAs are usually included in broader governmental or private decision-making processes, the key issue is how well decisions on a project are substantiated (Beattie, 1995; Lawrence, 1993). Therefore, the contribution of an EIA in decision making is in providing factual data for supporting environmental conflict resolution processes (Crowfoot and Wondolleck, 1990; Harashina, 1995). This implies an examination of different kinds of data, which may be either quantitative or qualitative in character, or perhaps even derived from perceptions and assumptions. Hence, EIA methods must permit multiple viewpoints and perspectives to be considered.

In practice, the different viewpoints and perspectives with respect to a project are represented by the different backgrounds and judgments of the members of the interdisciplinary team that usually perform the assessment (Canter, 1991). Environmental impact assessments can be enhanced by including these prerequisites more rigorously, as shown by this case study. The effectiveness of an assessment is increased by using mathematical matrices. The initial binary matrix has to take into account the issues, interests and perceived conflicts of the different stakeholders. Mathematical matrices can increase the effectiveness of EIAs in handling data, mainly because users are forced to explicitly define the direct interactions and higher-order interdependencies between variables (Holling, 1978; Shopley *et al.*, 1990). Moreover, the use of impact indices, such as the ones used in the La Venta-Colegio Militar case study, yield significance values for impacts consistent with the precautionary principle of minimizing the public risk (Shrader-Frechette and McCoy, 1993). Different project alternatives can be compared through the significant scores.

The case of the La Venta-Colegio Militar impact assessment demonstrates that the use of indices facilitates the manipulation of different kinds of data, ranging from direct field measurements, quantitative simulation models and even expert knowledge or intuition. Factual data, more easily obtained for the basic criteria, can be separated from the more subjective value judgments for the supplementary criteria. Furthermore, the results allow the interdisciplinary team to estimate the efficiency of the mitigation measures and to easily explore alternatives.

However, impact statements are often criticized for not considering the 'right' alternatives. The EIA of La Venta-Colegio Militar highway project, for example, has been questioned by some local-interest groups. Such criticism shows that different people are going to consider different alternatives depending upon their preferences, their concerns, what they have at stake and their perception of what constitutes a good outcome (Crowfoot and Wondolleck, 1990).

No theory exists for making a value-neutral determination of when enough alternatives have been considered (Beacon, 1980). Judgment on the significance of environmental impacts is not merely a scientific or technical matter to be decided by experts, but rather socio-economic, ethical, aesthetic, political and cultural determination by the people (Shrader-Frechette and McCoy, 1993). Therefore, the public has the right to scrutinize the conclusions of an EIA as part of a conflict settlement process. The role of EIAs is to help information exchange among interest groups (Harashina, 1995).

The advantage of the matrix procedure presented here is that information is organized in a simple format, while judgments on impacts are systematic and traceable. Settlement of environmental conflicts is facilitated because the rationale behind the assessment can be verified. In a sense, the approach allows one to follow the advice of Loomis (1993) that, in good environmental planning, 'the analyst job is to let the analysis speak for itself.'

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