A DECISION SUPPORT SYSTEM TO ASSIST IN THE PREPARATION AND APPRAISAL OF SCHEME OPTIONS

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INTRODUCTION

The design and appraisal of individual schemes is central to the way in which overall transport policies are translated into reality. As a consequence, considerable effort has been devoted over the years to ways of facilitating good design and to supporting the appraisal of alternative designs. Rather less attention has been given to the importance of the relationship between the two processes. Essentially, it is this with which the present paper is concerned.

In the paper, we outline a recently developed decision support system which uses simple multicriteria analysis principles and sensitivity testing to help in the preparation and appraisal of scheme options. The system, known as *MASCOT* (Multicriteria Analysis of Scheme Options in Transport) runs on a PC and employs user-friendly interactive facilities and graphics. *MASCOT* has been developed in consultation with UK local highway authorities, but was designed also to facilitate its use by members of the concerned lay public (politicians, pressure groups, etc.), as well as by transport professionals.

In the first main section, we outline the background to the development of *MASCOT*, emphasising the importance of matching the structure of any decision support tool to the administrative and social context in which it will operate. We next give a brief overview of the structure of the program before going on, in Section 3, to describe in more detail the way in which its components work. The final section of the paper reviews practical experience to date and outlines our plans for further development.

1. BACKGROUND

Two opposing views emerge among transport planners and decision makers concerning how the planning system operates. At one pole, there are those who regard planning as an essentially political exercise in which planning constitutes the procedures necessary to implement on the ground a set of proposals whose general form has already been specified, for example by reference to higher level national transport goals or through local debate. Attempts at "rational" planning, especially at the level of individual schemes are, from this perspective, of limited consequence.

Alternatively, the opposite pole, while not denying the political dimension within all planning activity, would argue that both in terms of practicality and perhaps professional ethics, it is essential to try to undertake an analysis based on such "objective" facts about a scheme as are available. *MASCOT* has evolved from a sympathy with the latter view, but also from a recognition that formal analysis must be matched to the realities of appraisal in practice. These include: lack of time and money for full analysis; the possibility that a scheme might not be important enough to justify the expenditure of a large amount of appraisal effort; the existence of many impacts arising from transport schemes which are difficult to quantify and even harder to evaluate; the existence of political pressure groups and competing viewpoints on the importance of different scheme impacts; and, finally, the possibility that some professionals themselves may, as noted earlier, be less than completely sympathetic to the notion of formal, essentially quantitative approaches to transport planning.

The planning model on which *MASCOT* is based takes it that a "problem" has been identified for which a transport *scheme* is thought to be the appropriate solution. Typically, there are a number of alternative *options* through which the scheme could be implemented. These might, for example, be different designs for a given stretch of road, or perhaps different versions of a traffic management scheme. The aim of the planning exercise is to find the "best" option. The selection is likely to involve balancing the positive and negative impacts of the options against their financial costs in some appraisal of comparative value for money. It may also require that each option be assessed against the extent to which it meets performance objectives. These may be either specific to the scheme or have been established by the planning authority as relevant to all schemes for which it has responsibility.

Identification and specification of options may not be straightforward. In principle, any option that might conceivably be the "best" should be specified and evaluated at a level of detail sufficient to confirm its superiority or to eliminate it from consideration. In practice, time and cost constraints will usually prevent this. There is a real need to try to assist an effective allocation of effort, ensuring that neither too many options are investigated (thus wasting resources on options which will not be adopted) nor too few (thus increasing the risk of failing to locate the best one).

It is important therefore to try to aid the planner to establish, as early as possible in the planning sequence, which options can reasonably be rejected and which have a realistic chance of being optimal. This judgement has to be made in the face of considerable uncertainty. Both the performance of any option and the relative importance which will be attributed to its various impacts may be unclear early in the planning process. It can also be the case that different interest groups will bring quite different value judgements to the process of ranking options. Environmentally oriented groups may view things differently from local businessmen, say, or local residents. It may sometimes be possible to satisfy all points of view, but compromises will usually be necessary. It is clear also that, even among planners predisposed to formal evaluation processes, there would be little sympathy for evaluations which were excessively rigid or prescriptive. Decision support for transport decision making is just what it says it is. It is support, aid for the judgements which, between them, professional planners and politicians must make. It is not a black box with output to be followed unquestioningly.

2. AN OVERVIEW OF *MASCOT*

2.1 The Model Structure

The working environment within which any decision support system for option specification, appraisal and ranking must operate needs to accommodate the practicalities set out in the previous section. In our view, it is particularly important that such a system positively encourages an exploratory attitude of mind in the early stages of option generation, with feedback from initial designs to revised versions based on insights deriving from initial valuations. *MASCOT* is designed to encourage this type of process.

MASCOT is not a forecasting model. It requires the user to generate such traffic and other forecasts as are necessary to provide an estimate of each option's performance with respect to all specified impact dimensions. In the first instance, the estimates of impacts need not be particularly accurate. MASCOT is designed to accept uncertainty about the true level of different impacts and not to seek greater accuracy unless this is critical to ranking the options under investigation. Its mode of operation is to accept "first cut" range estimates of impact scores and to evaluate options using this full range of scores. It also uses differing sets of value judgements about the relative importance of the impacts. Thus, at early stages in the planning process, the planner can put in quite vague estimates as a basis for preliminary evaluation.

Once this data is input, *MASCOT* endeavours to highlight those features of options which are critical to their relative performance. In this way, the intention is to target further preparation and analysis effort most effectively. *MASCOT* can also help users to explore the robustness of option ranking to alternative political priorities. Aspects of schemes which may prove contentious can be identified. More positively, options likely to attract support, albeit for diverse reasons, from groups with differing viewpoints can be identified.

The underlying evaluation model for *MASCOT* is a simple multicriteria one, the linear additive form:

$$E_{op} = \sum_{i=1}^{n} W_{ip} S_{io}$$

where

E_{op}	=	the effectiveness of option o judged using the weight set p;
W_{ip}	=	the weighting given to impact i in weight set p;
S_{io}	=	the score of option o for impact i.

The use of this particularly simple and inevitably evaluation model is justifiable for a number of reasons. One important one is transparency to non-specialist users; a second is ease of calibration. Perhaps the most important is the frequent empirical observation from a range of multicriteria applications (e.g., Dyer and Larsen, 1985) that linear models appear to provide an approximation to more complex value structures which is very robust. Given the nature of much of the data likely to be used in appraisal exercises of this type, the inevitable uncertainties and disagreements about values (weights) and the time pressures under which the analysis is likely to be carried out, this seems to be by far the most sensible basis on which to try to construct decision support for the transport option design and ranking problem.

It is also worth noting (Watson and Buede, 1987) two further general findings from the multicriteria literature that support this approach. One is that the substantial issue in multicriteria decision analysis is more often to ensure that all the relevant impacts have been built into the model, rather than the precise scores or weights that are used. The second is that interested parties to decisions can often exhibit marked differences of principle in how they would go about assessing hypothetical options. However, when faced with specific options to compare, their rankings are often much closer than their divergent principles would suggest and the potential for compromise greater than might be suspected. In these circumstances, a decision support framework which, like *MASCOT*, encourages users to design new options which try to exploit the strengths and avoid the weaknesses of initial designs is particularly useful.

MASCOT allows the user to explore the performance of options in a number of ways:

- Users may specify target levels of achievement for individual impacts and can subsequently check the percentage achievement of those targets by each option.
- Users may compare the overall effectiveness of individual options and can identify the major contributions to overall performance for each one. This may be done for any of a number of assumptions about what exactly are the scores achieved by each option and for any of three different weight sets.

- *MASCOT* can identify options which, even under assumptions most favourable to them, have no hope of becoming the best performing option. It is then normally reasonable to exclude such options from further consideration.
- *MASCOT* can examine the sensitivity of any option's overall effectiveness to changes in individual weights or scores and can establish and rank what changes in weights or scores would be necessary to move an option to the top of the current ranking.

Identifying the "best" option is not where *MASCOT's* focus lies. Its aim is to highlight the contribution of individual impacts to each option's performance, in both absolute and relative terms. Using the various forms of sensitivity analysis available, the user can identify impacts where uncertainty (either about weights or scores) is critical to option ranking and explore the benefits of reducing that uncertainty. Equally important, where the uncertainty doesn't matter, the user is guided not to waste effort on unnecessarily refining information. Finally, by highlighting critical impacts, some guidance is provided as to where revised design specifications might prove most effective.

2.2 The User Interface

MASCOT has a hierarchical menu structure, with some on-screen help available. It does not require significant computer literacy on the part of the user. It makes extensive use of graphical displays and is able to output selected graphs and tables as hard copy for use in discussions with other interested parties or for inclusion in formal reports.

Data input is often a tedious process in many support packages. There is no escaping the fact that data needed for the analysis has to be entered from the keyboard. However, considerable efforts have been made to facilitate the process while not at the same time making it so easy that the user is tempted not to think about the data on which the rankings of options will be based. To this end, the data entry module in *MASCOT* incorporates maximum use of defaults and templates, so that the process of setting up a new option is made as quick as possible. Normally, the data will have been prepared in advance; however, *MASCOT's* ability to test rapidly to assess the consequences of uncertainty about scores or weights makes it quite feasible to input ball-park estimates initially without off-line preparation. If the degree of uncertainty is critical, effort can be devoted to narrowing the range. If not, then effort need not be wasted on it. This facility for rapid interactive testing should be particularly valuable during the initial stages of developing options for a scheme in order that a shortlist of possibilities deserving detailed attention can be established.

3. THE COMPONENTS OF *MASCOT*

MASCOT consists of two main elements, each with sub-components.

3.1. The Data Entry Component

When initially defining an entirely new scheme, the user first gives it a name and indicates its approximate scale ("small", "medium" or "large" - currently defined as having costs <£500k, £500k - £1m, or over £1m respectively). *MASCOT* uses the information about scheme scale to select an appropriate set of default impacts and scores. For example, a small scheme will have a default list of impacts which is shorter and default scores that are smaller than a larger scheme.

The relevant impact list is presented on the screen and the user is given the opportunity to delete any impacts judged irrelevant to this particular scheme. Similarly, at this stage, extra impacts may be added. For example, a particular scheme may be such that no option is likely to yield any change in visual intrusion (hence all intrusion impacts could be deleted - see Table 1). However, it may involve the possibility of access difficulties to a local hospital over and above those that would show up through other impacts already considered. This would suggest the addition of an appropriate impact.

Once the impact list is established, the user has the opportunity to establish the weights associated with three different value systems. Default values are provided for all the impacts on the original list, which broadly correspond to "environmentalist", "official" and "commercial, market-oriented" points of view. The user may accept these as they stand or modify them to suit the circumstances of the appraisal. Where user-defined impacts have been added, the user must, of course provide his/her own weights. The weights effectively translate each unit of impact into a common unit of benefit, which may be taken as £k, although no particular unit of measurement need be specified. Note that, unlike conventional cost-benefit analysis, there need be no link to market prices when specifying the weights. Neither in principle within the linear additive multicriteria framework is it necessary for unit changes in scores on a given impact to have equal marginal values independent of their base level. However, *MASCOT* as it is presently set up does make this assumption.

With this scheme-level information on impacts now specified, the user is asked to estimate scores for each option on each impact. Three scores are required - "best estimate", "pessimistic" and "optimistic". *MASCOT* does provide default scores for all impacts on the original list, but it is likely that the user will normally need to replace them with values established specifically for the option under consideration. Options may be scored relative to a "do-nothing" option or relative to a base-year measure. In the latter case, the do-nothing option would normally be included explicitly as a design option and evaluated.

Initial option scores may, of course, be edited at any stage in the light of subsequent information, as can weights. Existing options can be used as templates from which to enter new options which are minor variations on an existing design.

At the time of data entry, the user may also specify target levels of achievement for any impact For example, it might be to reduce travel time by at least 20% for the stretch of road in question; or there may be a cost target - capital cost < £300k.

3.2. Scheme Evaluation Component

MASCOT acts as both a data base and a decision support device. It stores data on all previously evaluated options unless the user consciously deletes them. It is not usually necessary to evaluate all options. The first thing the Evaluation component establishes from the user is which options are to be evaluated. *MASCOT's* evaluation can comprise one or more of four sub-components.

3.2.1 Overview of Weighted Scores

This provides aggregate and disaggregate information on the weighted and unweighted scores achieved by options. The user first sees a display of the aggregate weighted scores for each option using whichever of the three weight sets A, B and C he/she chooses (Figure 1). The figure automatically includes the scores for "best", "pessimistic" and "optimistic" estimates. The availability of analysis in terms of each of the weight sets gives a view of how different interest groups may view the options. Analysis in terms of the three scores gives an indication of robustness.

After each graphical display a disaggregate tabular display of the weighted scores by impact for each option is given, using the best score estimates (Figure 2). This indication of each option's strengths and weaknesses is an important element in investigating revised design specifications.

Screen dumps for either graphical or tabular displays provide hard copy for later reference.

3.2.2. Rank Reversals

A unique feature of *MASCOT* is the facility it provides to explore the robustness of the first ranked ("topdog") option to weights and scores other than the official weights and the best estimate scores. Having identified the topdog option using the official weights and best estimate scores, *MASCOT* explores the range of scores given by the user and the three alternative weight sets to see whether any of the other options ("underdogs") could conceivably outperform it. It uses the uncertainty in the data to show the underdogs in the best possible light and hence establishes the extent to which topdog is vulnerable to challenge as a result of the imperfect data set and the differences of opinion about impact importance. This is done by assuming the most pessimistic scores for all impacts for the topdog and then, considering each underdog in turn, for each impact assuming its most optimistic score and then applying the weighting which is most favourable to the underdog. The results are displayed firstly as an aggregate graph (Figure 3) showing for each underdog the underdog favoured scores for the topdog and the underdog. If, after being shown in this way in its most favourable light, an underdog still does not outscore topdog, it is reasonable to conclude that it can be deleted from further consideration.

Two further graphical displays amplify this information on the extent to which the balance of preference could in principle be shifted against the topdog. This can then be explored in more detail for any particular underdog by a tabular disaggregation of the contributions to rank reversal. The table displays (Figure 4) for each impact the percentage of the original lead of topdog over underdog which could be eliminated if (a) the weight or (b) the score were to be changed to most favour underdog.

The disaggregate display thus focuses the user's attention on those specific impacts which are the main sources of ambiguity in the ranking of options. It also indicates whether it is ambiguity about weights or about scores which contributes the most. This information could encourage the user to seek more accurate estimates of certain data. Alternatively, it could lead to a redesign, avoiding a serious difference in performance with respect to an impact where there are clearly divergent views as to its importance.

3.2.3 Sensitivity Testing

This component of *MASCOT* permits conventional sensitivity testing. Starting again with the topdog option which ranks highest using the official weights and the best scores, *MASCOT* provides a number of ways to explore what changes in individual weights or scores would be sufficient to nullify the topdog's advantage. One option considers all impacts and all underdogs simultaneously. For each change in score from the best estimate score and for each change in weight from the official weight, it identifies the change which would be just large enough to bring underdog and topdog to parity. These changes are then ranked according to their likelihood of occurrence as judged by the percentage which the required change is of the range on the input data. Although ranked in percentage terms, the display indicates the absolute changes required to achieve parity (Figure 5). Clearly it is then for the user to interpret the list to identify whether or not the required change is likely in fact.

Similarly sensitivity tests can be undertaken on all impacts for a selected underdog (if the performance of that underdog were the subject of particular attention); for one impact across all options (if one impact is particularly contentious); or for one particular impact/underdog combination (for detailed questions about how much a particular underdog would have to change on a named impact).

3.2.4. Target Achievement

MASCOT summarises target achievement by tabulating for each option, using the best score estimates, the absolute extent to which target levels of achievement are exceeded or not. Impact/Option combinations where target levels are not achieved are highlighted (Figure 6). Presenting target achievement summarised in this way can be particularly useful if targets are changed after the initial data input. Such a change could easily occur after a political change in the group responsible for planning decisions or if new options are created after the initial data input.

4. PRACTICAL EXPERIENCE AND FURTHER DEVELOPMENTS

A number of local authority officers and consultants have contributed to *MASCOT's* development by using versions of the software on case studies. The main changes which have followed from this testing have been presentational. A number of the graphical and tabular displays have been adjusted to provide information in a form users have indicated would be more intuitive or helpful. The decision to provide default lists of impacts and increased ease of editing impact lists to add new ones after the initial phase of impact specification was also a direct response to user feedback.

Development of *MASCOT* is continuing. The next anticipated change is to introduce the facility to link together "families" of impacts for purposes of sensitivity and rank reversal testing. The argument here is that, notably because they may all be linked to a single driving variable such as traffic growth, a number of impacts are likely to be correlated with each other. If one increases, others will increase and vice versa. Circumstances in which members of the same family of impacts move in opposite directions are implausible. At present, this is not acknowledged by the sensitivity and other post-optimality analyses undertaken by *MASCOT*. The user will be allowed to nominate groups of impacts likely to have a shared direction of change. For such groups, *MASCOT* will not allow sets of changes in scores which are seen as mutually contradictory. By restricting the range of changes in this way, the ability of the package to discriminate options and to indicate a likely ranking between them should be somewhat increased. A second planned development envisages providing a weight derivation component which will give structured support to the user in developing his/her own sets of relative weights for impacts.

REFERENCES

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ACKNOWLEDGEMENTS

We should like to express our appreciation for the helpful comments of many individuals during the development of *MASCOT*, particularly Howard Wyborn, formerly Director of Highways and Engineering, Leeds City Council.

Table 1: Default Impacts and Weights for a Small Scheme

Impact	Units	Loweight	Weight	Hiweight
Preparation Cost	K	-1	-1	-1
Land Acquisition Cost	K	-1	-1	-1
Construction Cost	K	-1	-1	-1
Severe Visual Intrusion	Properties	-4	-7	-21
Significant Visual Intrusion	Properties	-2	-4	-10
Slight Visual Intrusion	Properties	0	-2	-3
Noise Increase	Properties	-2	-4	-7
Noise Reduction	Properties	1	2	4
Severe Vibration	Properties	-500	-7	-21
Significant Vibration	Properties	-20	-4	-10
Slight Vibration	Properties	-3	-2	-3
Fatal Urban PIA	Accidents p.a	-500	-695	-1200
Serious Urban PIA	Accidents p.a	-20	-27	-54
Slight Urban PIA	Accidents p.a	-3	-4	-7
Zero PI Urban PIA	Accidents p.a	-1	-1	-2
Car Work Time Saving	K Veh Hrs p.a	13	11	6
LGV Work Time Saving	K Veh Hrs p.a	11	10	5
HGV Work Time Saving	K Veh Hrs p.a	20	7	4
Bus Work Time Saving	K Veh Hrs p.a	37	37	37
Car Non Work Time Saving	K Veh Hrs p.a	4	4	1
Bus Non Work Time Saving	K Veh Hrs p.a	10	13	10
Pedestrian Time Saving	K Hrs p.a	0	7	2
Additional Distance Cars	K Kms p.a	-0	-0	-0
Additional Distance LGVs	K Kms p.a	-0	-0	-0
Additional Distance HGVs	K Kms p.a	-0	-0	-1
Additional Distance Buses	K Kms p.a	-0	-0	-1
Pollutants Emitted	K Tons p.a	-50	-100	-1000
Land Take Private.	Hectares	0	0	-100
Buildings Take Minor	Buildings	0	0	-10
Land Value Increase	K	1	1	0
Construction Delay	K Veh Hrs	-10	-10	-5
Construction Nuisance	Index	-1	-10	-20
Community Severance	Index	-1	-10	-20
Environmental Improvement	Index	10	100	400
Economic Activity Increase	K Trips p.a	0	0	0

Figure 1: Aggregate Weighted Scores

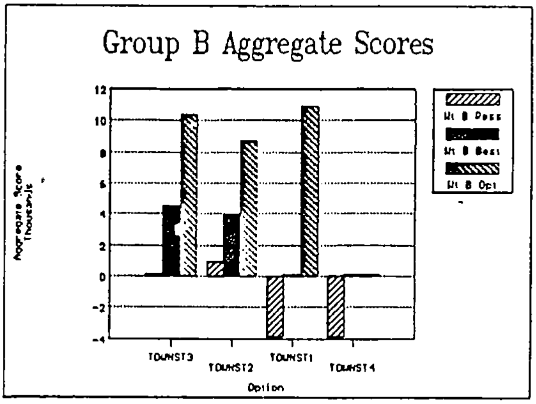

Figure 2: Disaggregate Weighted Scores

WEIGHTED BEST ESTIMATE SCORES

IMPACT NAME	TOWNST1	TOWNST2	TOWNST3	TOWNST4
LAND ACQUISITION COST	-50	0	-50	-50
CONSTRUCTION COST	-200	-100	-400	-200
ACCIDENT URBAN (FATAL)	695	695	1390	695
ACCIDENT URBAN (SERIOUS PI)	164	164	328	164
ACCIDENT URBAN (SLIGHT PI)	36	36	72	36
ACCIDENT URBAN (D.0)	47	47	93	47
NOISE INCREASE	0	-11	-18	0
NOISE REDUCTION	0	4	20	0
COMMUNITY SEVERANCE	-1000	1000	1000	-1000
ENVIRONMENTAL IMPROVEMENT	500	2000	2000	500
ENFORCEMENT COST	-30	-10	-10	-30
RETAIL TURNOVER INCREASE	-75	150	150	-75
VEHICLE TRAVEL TIME SAVING	10	-20	-20	10
TOTAL	96	3955	4556	96

Figure 3: Underdog Favoured Aggregate Weighted Scores

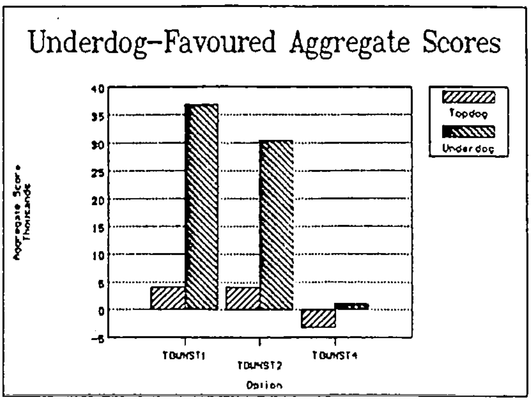

Figure 4: Components of Rank Reversal (Disaggregate)

IMPACT CONTRIBUTIONS TO RANK REVERSAL FOR TOWNST1

IMPACT NAME	CHANGE IN WEIGHTED SCORE DUE TO		
	WEIGHT CHANGE	SCORE CHANGE	WEIGHT+SCORE CHANGE
LAND ACQUISITION COST	0	70	70
CONSTRUCTION COST	0	650	650
ACCIDENT URBAN (FATAL)	2020	5300	5495
ACCIDENT URBAN (SERIOUS PI)	107	336	380
ACCIDENT URBAN (SLIGHT PI)	29	88	94
ACCIDENT URBAN (D.O)	54	147	147
NOISE INCREASE	35	35	53
NOISE REDUCTION	5	5	15
COMMUNITY SEVERANCE	8100	11000	12800
ENVIRONMENTAL IMPROVEMENT	9600	12950	14300
ENFORCEMENT COST	0	30	30
RETAIL TURNOVER INCREASE	2100	3075	3225
VEHICLE TRAVEL TIME SAVING	3	21	22
TOTAL	22052	33706	37280

Figure 5: Sensitivity Analysis: Ordered List of Changes Sufficient to yield Parity

OPTION	IMPACT	REQUIRED CHANGE	UNITS
TOWNST2	ENVIRONMENTAL IMPROVEMENT	6.003	INDEX
TOWNST2	ACCIDENT URBAN (FATAL)	-.864	ACCIDENTS
TOWNST1	COMMUNITY SEVERANCE	-44.596	INDEX
TOWNST2	RETAIL TURNOVER INCREASE	40.020	K
TOWNST1	ENVIRONMENTAL IMPROVEMENT	44.596	INDEX
TOWNST1	ACCIDENT URBAN (FATAL)	-6.417	ACCIDENTS
TOWNST2	ACCIDENT URBAN (SERIOUS PI)	-21.989	ACCIDENTS
TOWNST2	CONSTRUCTION COST	-600.300	K
TOWNST2	COMMUNITY SEVERANCE	-6.003	INDEX
TOWNST2	ACCIDENT URBAN (D.O)	-645.484	ACCIDENTS

Figure 6: Target Achievement Table

TARGET ACHIEVEMENTS

IMPACT NAME	UNITS	TOWNST1	TOWNST2	TOWNST3	TOWNST4
CONSTRUCTION COST	K	50	150	-150	50
ACCIDENT URBAN (SERIOUS PI)	ACCIDENTS	-2	-2	4	-2
NOISE REDUCTION	PROPERTIES	-2	0	8	-2
ENVIRONMENTAL IMPROVEMENT	INDEX	-5	10	10	-5
ENFORCEMENT COST	K	-30	-10	-10	-30