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Rationalizing social policy: evaluation and viability

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In this article, it is argued that only a small fraction of social expenditures actually reaches the poor. Diverse social policy weaknesses which account for leaks and ineffective use of resources are reviewed, and the authors maintain that it will only be possible to overcome those deficiencies if serious *ex ante* and *ex post* evaluations of social programmes and projects are made.

Three different analytical procedures are then discussed: cost-benefits; cost-effectiveness; and impact evaluation. A methodology is proposed which seeks to take advantage of all three approaches: cost-impact analysis, which takes into account the special features, especially those connected with public investment, which make social projects different from other types of projects. The establishment of information systems (also called social project data banks) for the evaluation of social projects is proposed, and the differences between these and other similar systems are noted.

Finally, the possibility of using the proposed instruments to rationalize social policy is analysed.

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I

Social policy weaknesses

Social policy in Latin America today faces a crucial problem: the low proportion of resources allocated to aid the poorest sectors. A few examples will suffice to illustrate this problem. In 1987, only one dollar of every 7.83 dollars spent on social programmes reached the poorest 20% of the population in Chile, a country which for several years had made significant efforts to focus expenditure on that sector (Haindl, Buvinic and Irarrázaval, 1989). Likewise, in a confidential report it was asserted in respect of another country of the region that the suppression of all the current social programmes would not give rise to any change in the living conditions of the poorest 50% of the population.

What is the reason for this? There are two basic reasons. On the one hand, social policy has concentrated mainly on dealing with other groups: as argued in another paper, social policy is not only for the poor. On the other hand, the ineffectiveness observed is due to the prevailing social institutions, the way in which programmes are designed and implemented, and leakages which occur in those programmes.

The Latin American State provides social services through a fragmented network in which functions and services are often duplicated. This means that resources are wasted and that only a small portion of them reaches those who should be beneficiaries. It has been calculated that, in some programmes, the effective transfer to the poorest groups does not exceed 5% of the overall budget, with the rest being absorbed by bureaucratic expenses or leakages to other groups.

The common and reassuring conviction that social programmes and projects always generate at least some benefits also creates problems. It assumes that, if there is supply, there must also be impact, which will grow with increased supply. However, that correlation is not always linear. Sometimes there is only an impact when a certain threshold is passed in the provision of goods or services. The evaluation of a school nutrition programme revealed that it began to have an effect only when the daily ration exceeded 770 calories per child, which only occurred in 17% of the schools involved in the programme. When the rations provided were smaller, those resources were simply being wasted.

The investment-impact ratio is conditioned by many decisions. Results depend not only on proper selection of the beneficiary group (focussing), but also on that group's economic, social and cultural capacity to participate in the programme, and on whether or not the quantity and quality of the goods and services provided are appropriate.

A very common error which hinders the achievement of positive investment-impact ratios in practice can be observed in school lunch programmes with nutritional objectives. Universalism is commonly applied as the allocation criterion. Similar rations are given to all the students in a class, when it would be more appropriate to take actions designed to solve a specific problem –malnutrition- which does not affect all the students to the same extent. If the beneficiaries of the programme are not initially suffering from nutritional problems, then in the best of cases the effect of the rations consumed will be nil, while in the worst cases the children will become overweight. As the resources are poorly allocated, they may not have any positive effects, or if they do, these will surely be less than those which could have been obtained had the same resources been concentrated on truly malnourished children.

Errors of programme design also occur when family survival strategies are not taken into account. Thus, it has been demonstrated that beneficiaries from families with unsatisfied basic needs suffer a worsening of their nutritional situation when they begin to receive nutritional programme rations. The reason is that those programmes provide a calorie-protein supplement which is not intended to replace the nourishment supplied at home. Since no steps have been taken to communicate information on the nature and aim of the services offered, however, the poorest families exclude those of their members who eat outside the home, when sharing out the available food.

Social programmes usually also pursue secondary objectives which lower the possibilities of achieving the main objectives. The resources of some social development funds are designed to cover the outlays necessary for "social investment", without considering recurrent costs, or else by stipulating that those costs are to be met by beneficiaries; in this way, programme designers pursue something which appears to be reasonable, i.e., to promote commitment to the endeavour. However, the poorer the community is, the more remote is the probability that beneficiaries will be able to meet those expenses. Moreover, the decision to release such funds only in response to initiatives by the beneficiaries may lead to a situation in which they only benefit those who are aware of the availability of public funds and know how to negotiate administrative channels, which effectively excludes the poorest sectors. The same thing occurs when it is stipulated that the preparation of projects is the responsibility of the beneficiaries themselves, who in most cases are unable to perform that task. Likewise, bureaucratic inertia tends to allocate resources to the most easily reached areas, whose inhabitants are not usually those who are in the greatest need.

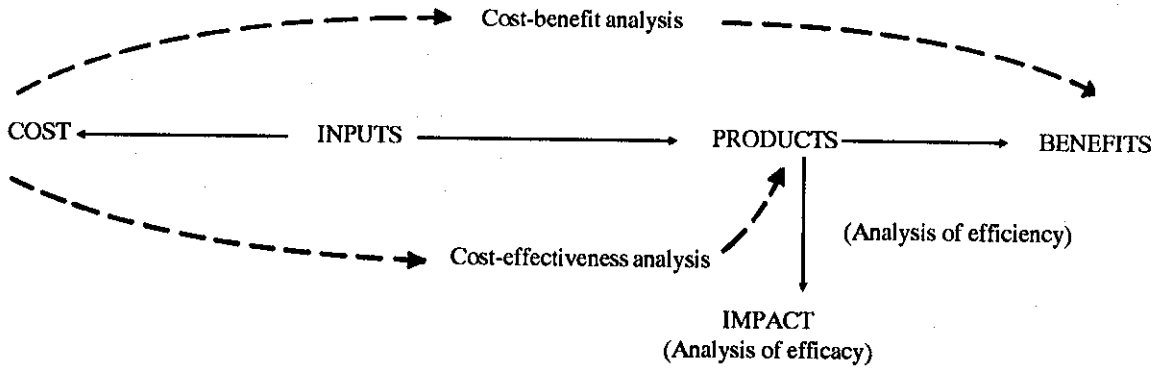
Programme and project execution decisively influences their impact. In that stage, situations often occur which lead to perverse results, even in well-designed programmes. This happens, for example, when those responsible for executing a programme designed to alleviate some crisis distribute the available food to a larger number of persons than those originally foreseen. As a result, everyone receives smaller rations which do not satisfy minimum needs, and if there are leakages to groups other than those originally designated, the impact of the programme is still further reduced.

It may be concluded from the foregoing that usually there is little or no knowledge of the real performance of programmes and projects embodying social policy objectives, and above all there is no knowledge of the impact of those activities on the population. Generally speaking, it is not known if those programmes are worthwhile or not; and if they are worthwhile, it is not known to what extent they help or to what degree they are justified. Moreover, it is not known who really benefits from them, or who is adversely affected.

It seems essential, therefore, to rationalize present-day social policy by increasing the efficiency of resource use and the effectiveness of programmes and projects. Only in this way will it be possible to satisfy the most pressing needs of the most vulnerable groups.

Figure 1

PROJECT FLOW AND THE APPLICATION OF COST-BENEFIT OR COST-EFFECTIVENESS ANALYSIS



Source: Adapted from D. Piachaud, Cost-benefit techniques and social planning, J. Midgley and D. Piachaud, *The fields and methods of social planning*, New York, St. Martin's Press, 1984.

II

The need to rationalize

In the field of social programmes and projects, rationalization is based on evaluation. Rationalizing means achieving optimum allocation of available resources –which are scarce, by definition– in order to achieve the proposed objectives. This is possible only if projects are evaluated in order to know both their costs and the impact they produce.

First of all, it is necessary to clarify a very frequent semantic confusion deriving from the different meanings of the term "social" as employed in connection with two different methodologies: the social evaluation of projects and the evaluation of social projects. In the former, the term concerns the spatial (national) area which defines the framework within which the evaluation will be performed. In the latter, on the other hand, the term is used to define the specific condition (social) of the object of the analysis (project).

Social projects can be evaluated using various methodologies, each of which has its own advantages and limitations. Figure 1 illustrates the differences among them.

1. *Cost-benefit analysis*

Cost-benefit analysis makes it possible to determine and compare project profitability by comparing the updated benefits and costs to be derived from execution of the project. [1] In order to perform this analysis, it is necessary to define an initial situation (without the project) and another one with the project.

[1] "Since resources are limited, it is necessary to choose between competing uses; project analysis is a suitable and comprehensive way of evaluating options. In essence, it weighs project benefits and costs and reduces them to a common scale of measurement. If benefits exceed costs according to that scale, then the project is acceptable; if not, the project should be rejected. In weighing the merits of different projects, the objectives of each society should be kept clearly in mind. In other words, project costs and benefits should be measured comparatively in terms of how far they help or hinder the achievement of the objectives of that society" (Squire and van der Tak, 1980).

The evaluation can be at the private level, if it concerns a specific economic unit whose costs and benefits are valued at market prices, or it can be social, if what is sought is a comparison of the relative contributions made to society by various projects involving investment in some economic sector. In this case, the benefits and costs must be valued in terms of accounting units, efficiency or social value. For cost-benefit analysis, it is essential that both costs and benefits be expressed in monetary terms.

It may happen that the private evaluation of a given project indicates a loss, whereas its social evaluation indicates that it enhances the well-being of the community.

There are two methodologies for social evaluation. The first, known as economic or efficiency evaluation, determines the profitability of a project through the correction of current prices in imperfect markets by transforming them into those which would obtain in conditions of perfect competition (Fontaine, 1984). In this case, income distribution is an aspect on which the evaluator does not give an opinion. The comparison of costs and benefits is performed without considering who bears the former, nor who receives the latter.

The second methodology, which represents social evaluation proper, explicitly incorporates the issue of distribution, assigning a central role to the target population of the project and to those who will receive benefits from it. This type of evaluation must be linked to planning, in order to reflect the current policies in the form of concrete criteria for the analysis of public investment. The integration of efficiency and equity means that it is a valuation at "social prices" (Squire and van der Tak, 1980).

In economic projects, evaluation is usually *ex ante*, since what is sought are findings which will guide the decision to implement the project or not. *Ex post* evaluations based on cost-benefit analysis may also be carried out, however. This type of evaluation, which is particularly useful for social projects, seeks to determine the usefulness of continuing projects or the appropriateness of undertaking other projects of the same type. Even when evaluating projects where political considerations prevail, "cost-benefit analysis clarifies the question of value, that is to say, what those responsible for establishing policy are willing to pay (or to give up) in order to achieve a certain type and level of benefits" (Weiss, 1982, p. 110).

Sometimes, monetary value is assigned to the extra-economic objectives of social projects, on the assumption that they are means for achieving an economic goal. The underlying reasoning is that the results obtained by these educational, nutritional, health and other projects will increase the beneficiaries' future income by a certain amount. Another way of assigning monetary value to the goods and services of a social project is to value them at market prices, as is usually done in the case of self-build or environmental sanitation projects.

However, there are social projects where it is difficult to subsume the value of their benefits in terms of economic efficiency. "In these cases, it is methodologically simpler and logically more correct to give up any attempts at monetization and use (other) indicators" (Musto, 1975, p. 116).

It should be noted that cost-benefit analysis cannot be used to evaluate programmes in which investment is nil or very small, although current expenditures may be significant, as occurs very often in the social area. Moreover, this type of analysis is not centered on the degree to which projects and programmes achieve their objectives, so that it is of little use for overcoming the weaknesses of social policy already mentioned.

2. *Cost-effectiveness analysis*

This type of analysis involves comparison of the (monetary) costs of a programme or project with the possibility of efficiently attaining goals which cannot be expressed in monetary terms (ex ante evaluation), or determination of the real differences in efficiency between various execution options having the same objectives (ex post evaluation).

Although cost-effectiveness analysis does not allow for the comparison of projects with different objectives, such comparison is possible if the projects are made compatible through the use of a common denominator, such as their likelihood of achieving the same results. Thus, a programme designed to combat malnutrition could be compared with one aimed at reducing malaria, the common element being the possibility of reducing

the number of handicapped persons and deaths in the target population.

The choice between a nutritional programme and a self-build programme for low-income groups is more difficult. In this case, the only rational criterion which can be used (independently of cost-effectiveness analysis) is that of giving priority to the most basic needs.

Cost-effectiveness analysis leaves aside the examination of objectives. It accepts that they derive from political decisions and merely seeks to ensure that they are achieved at minimum expense. In other words, it seeks to discover the way to allocate resources so as to obtain the greatest number of units of results.

To that end, it compares the degree of relative efficiency of either different projects with the same objectives, or of alternative options for the same project. A basic requisite is therefore that those options must be comparable with each other, i.e., that they have the same target population and that the goods and services generated are comparable in quantity and quality.

Traditionally, cost-effectiveness analysis examines the operational efficiency of project execution, with a view to revealing difficulties in programming, administration and control so as to correct them and thus reduce the costs due to inefficiency. It is difficult to generalize the results of this type of analysis, since in order to do so it would be necessary to address the problem of the economies and diseconomies of scale which derive from the expansion of projects.

When the product unit of the project is the same as the latter's final objective (for instance, an additional life saved), the criterion of choosing the option which will minimize unit costs is sufficient. If the products of the project are only a means to an ulterior end –for instance, the distribution of nutritional rations (the products) in order to eliminate or reduce malnutrition in a target group (the objective)– conventional cost-effectiveness analysis only guarantees efficiency through the pursuit of minimum costs, but it sheds no light on the efficacy of the project.

3. *Analysis of the impact of projects*

There are factors other than operational efficiency which may hinder or even completely prevent many social projects from achieving their goals. The purpose of impact analysis is to identify these factors. Impact is understood as the degree to which a project transforms some aspect of reality as a function of its objectives. This calls for explicit consideration of the net effects of the project, in order to eliminate changes deriving from the context in which it is executed.

Impact analysis determines the extent to which the project has achieved its objectives, the changes brought about in the target population, and the secondary effects produced (both foreseen and unforeseen).

On the whole, it may be concluded that impact analysis is a necessary, though not sufficient, condition for the evaluation of social projects. Since it seeks to measure the degree of efficacy of a project, it does not explicitly consider the costs incurred, which implies that the resources available are presumed to be unlimited. This is the result of the classical division of disciplines in evaluation activities. Economic analysis is mainly concerned with efficiency, whereas efficacy has traditionally been the main concern of specialists in the substantive areas of social projects (nutrition, health, education).

The evaluation of processes and appraisal of their impact are therefore distinguished from each other by the type of questions they answer, the decisions they affect, and the potential users of their results. The evaluation of processes looks ahead in order to suggest corrections or adjustments; impact analysis looks back to see if the project worked and to what degree it was successful. The first-named type of evaluation seeks to affect daily, operational decisions; the second type provides information for deciding on the possible continuation of the project or the design of similar ones, so that ultimately it permits the taking of policy decisions. This means that the users of one and the other type of evaluation are also different: some of them are responsible for managing projects, while others are authorities with the capacity to lay down more general guidelines on the basis of the results.

III

A comprehensive methodology: cost-impact analysis

1. *Efficiency and efficacy*

A methodology designed to overcome the current limitations of social policy must incorporate analysis of both project efficiency and efficacy (Cohen and Franco, 1992).

Efficiency is the relation between the cost of inputs and the cost of the products (services or goods) obtained. When the quantity of products to be generated is defined, the aim is to minimize the cost per product unit. When the total expenditure to be made is fixed, however, the aim is to maximize the product. Thus, both definitions mean basically the same thing.

Analysis of efficiency is undertaken both *ex ante* and during project implementation. It should not be confused with follow-up or monitoring, which is limited to comparing the actual results with the goals established in the programme.

The *efficacy* of a project is the degree to which it achieves its goals within a certain period of time, without taking the costs into account. When contextual effects are eliminated and the net effects of the project are considered, the term *impact* is used.

Impact analysis is carried out independently of the evaluation of operational efficiency (process evaluation). These two types of analysis are performed separately because some of them require more extensive collection of data than others. Reprogramming a project requires only one data collection step, in order to determine the "base line", which is a cross-section on the basis of which a diagnosis is made which permits the proposal of solutions. For impact evaluation, however, both a diagnostic "base line" and an "end line" of results are needed. Comparison of the two makes it possible to determine the magnitude of the changes which can be attributed to the project.

The base line, usually associated with the diagnosis, can be drawn at any time during project implementation. On the other hand, in order to determine the "end line" it is not always necessary for the project to have ended; in reality, it is merely another cross-section which provides information equivalent to that obtained from the base line. The time which must elapse between the collection of the initial information and that required for the end line depends on the nature of the changes pursued (nutritional, health, educational, etc.) and the degree of sensitivity of the indicators used to measure them. Those indicators should be selected by experts in the substantive areas of the project.

Impact evaluation may be carried out during execution of the project, at its conclusion, or even after it has ended, once the necessary time has elapsed for all its effects to become apparent. *Ex post* impact evaluations can be used as the basis for *ex ante* estimates for analogous projects.

2. *Central elements of the methodology*

Efficiency analysis seeks to determine which project or project option will minimize the cost per unit of product (CUP). For this purpose, it is necessary to annualize capital, operational and maintenance costs to obtain the total annual costs (TAC). At the same time, it is necessary to establish the annual services provided (ASP) by the project (in the case of new projects), or the additional annual services provided (AASP), in the event of the extension of pre-existing projects. The relation between these services and the total annual costs gives the cost per unit of product (CUP).

$$CUP = \frac{TAC}{ASP} \quad \text{or} \quad CUP^* = \frac{TAC}{AASP}$$

CUPs are indicators of operational efficiency. They are a product of the investment made. Cost-effectiveness analysis usually goes this far, that is, it tries to minimize the cost of the products of the project and assumes that the actual impact, which is more difficult to measure because it requires more time and effort, will be achieved through proper focussing on the target population. Those considerations are undoubtedly valid, especially when the alternative is the situation which usually obtains in social projects, which tend to have a loose form of programming that does not include evaluation. In such cases, the performance of cost-effectiveness analysis is obviously a significant step towards more

rational resource allocation in the social area. However, efficiency in the generation of products in a social project does not necessarily mean efficacy in the achievement of its objectives (impact).

To sum up, if the objective of the evaluation were only to analyse efficiency, it would be sufficient to determine only the minimum CUP. What is sought, however, is also to maximize the efficacy of projects, that is, their impact. Optimizing both the efficiency and efficacy of a project means making it achieve its objectives with the best possible allocation of available resources, or, in other words, maximizing its impact at the lowest possible cost. In order to determine the degree to which that purpose has been achieved, it is necessary to consider jointly, in each project or project option, the total annual costs, the impact achieved in respect of each objective, and the relative importance assigned to each of these.

The backbone of cost-impact analysis is the determination of the cost per unit of impact (CUI) ratio (see appendix). This is defined as follows:

$$CUI = \frac{TAC}{OB \cdot 100}$$

where CUI is the cost per unit of impact achieved in respect of each project objective, or the cost of achieving 1% of the impact in each objective; the numerator is the total annual cost (TAC), and the denominator is the magnitude of the impact achieved or estimated (OB), multiplied by 100.

The consideration of various technically viable options for implementing a project, by establishing their respective cost-impact ratios, will make it possible to select the alternative which minimizes the cost per unit of impact.

In *ex ante* evaluation, this procedure makes it possible to choose the best project option or to select one project from among several with the same objectives. Not only the costs, but also the products and impact are estimated. Within the margin of uncertainty inherent in every estimate, the levels of knowledge and standardization are much greater in the case of costs than in that of impact. The latter must therefore be estimated on the basis of *ex post* evaluations of analogous projects and expert judgment.

Ex ante evaluation attempts to anticipate the future, which is, by definition, uncertain. Moreover, there are always practical limitations on gathering the data needed for the analysis. Since the essence of *ex ante* evaluation is the prediction of probabilities, some degree of possible error or risk is inherent to this methodology. It is therefore necessary to determine the ranges of possible variation of the basic parameters of the project in order to define the evaluation's degree of reliability (or uncertainty). Sensitivity analysis makes it possible to determine the basic assumptions which will have significant effects on the acceptability of projects.

Ex post evaluation seeks to determine the option with the best cost-impact ratio, together with its causes, by learning from operational experience. The cost, products and net effect are revealed by the analysis of what really happened in the project. Costs are extracted from existing records, while the annual services provided, additional annual services provided, and impact emerge from measurements performed for that purpose.

The evaluation of social projects on the basis of cost-impact analysis does not calculate the rate of profitability or the contribution made by the project or programme to society as a whole. These two dimensions are subsumed in the political decision about the goals to be given priority. After that decision has been made, it remains to determine the most efficient and effective option for achieving those goals. In that respect, cost-impact analysis makes possible a rational choice.

3. *Generalizing evaluations: social project data banks*

Isolated experiences of evaluation are important because they make it possible to reprogramme the project in question and to learn from that experience for the design and implementation of future actions. However, in order to truly rationalize social policy it is necessary to evaluate every project, which can be done through the creation of information systems for evaluation or social project data banks.

The main objectives of the idea of establishing project data banks are "to facilitate, standardize and coordinate the follow-up and control tasks involved in investment projects, as well as to support pre-investment execution and planning, investment programming and the performance of *ex post* project evaluations" (ILPES, 1991). This has been done in a number of countries. In Chile, for example, this

system has been operating for years, and it is also used in Belize, Bolivia, Colombia, Guatemala and the Dominican Republic.

The methodological design of these banks permits the registration of information in each stage of the project (pre-investment, investment and implementation). In this way, the system can provide essential information for decision-making related to the programming and control of investments, thus making it possible to improve the efficiency of the latter.

Social programme and project data banks pursue similar goals. Naturally, their structure and methodology must be adapted to the particular nature of the social actions involved.

The main differences between investment project banks and social project banks are the following:

i) *Evaluation methodology.* In social project banks, cost-impact analysis rather than cost-benefit analysis is used, the impact being understood, not as the project's effect on society, but as the set of changes produced by the project in the target population, as a function of its objectives.

ii) *Predominant type of evaluation.* In public investment projects the emphasis in on *ex ante* evaluation and on physical-financial follow-up during implementation. In social projects, however, *ex ante* and *ex post* evaluations are both equally important. The latter type of evaluation serves both for reprogramming and for improving the *ex ante* evaluation of future projects.

iii) *Investment versus current expenditures.* Public investment project banks seek to help rationalize such investment. They do not include social programmes and "projects" which require little or no investment, even though the current expenditures involved may be considerable. In contrast, social project banks include both projects in the strict sense (i.e., those involving investment) and programmes which do not call for investment.

IV

How can the practice of evaluation be made viable?

As we have already seen, the problem faced by social policy is not only the scarcity of resources, although excessive emphasis is usually placed on that factor. There is also the problem of low efficiency in the use of resources and ignorance regarding the efficacy of the actions financed with those resources.

In order for social policy to be able to contribute to the achievement of the objectives of equity and economic development, it must be made more rational by changing the way it is executed and ensuring that its effects are truly positive. In order to achieve this, it is essential to evaluate what is being done and to establish permanent mechanisms for the follow-up and evaluation of programmes and projects.

There is no point in insisting on the provision of more resources if all that is intended is to repeat what has been done in the past, because as we have already seen, that will not help to overcome poverty or improve the quality of human capital. It is therefore necessary to modify institutions and financing mechanisms so as to incorporate evaluation activities.

Currently, there are a large number of important programmes under way in Latin America, many of them financed by international cooperation, where the logic of projects has been adopted. This logic differs considerably from the traditional way of implementing social policy. These experiences provide fertile ground for the institutionalization of the idea of incorporating evaluation activities and, in that way, generating a "virtuous circle" of demonstration and dissemination which will cause this logic of resource allocation and management to spread to the rest of the social area.

Appendix

MATRIX OPERATIONS INVOLVED IN COST-IMPACT EVALUATION

A. DEFINITIONS

TAC_i = Vector of the total annual costs of each of the systems i.

$$TAC_i = (TAC_1 , TAC_2 \ldots TAC)$$

OB_{ij} = Matrix representing the impact or degree of achievement of each of the objectives j of the systems i.

$$OB_{ij} = \begin{bmatrix} OB_{11} & OB_{12} & \cdots & OB_{1m} \\ OB_{21} & OB_{22} & \cdots & OB_{2m} \\ \vdots & \vdots & & \vdots \\ OB_{n1} & OB_{n2} & \cdots & OB_{nm} \end{bmatrix}$$

W_j = Vector of the weightings assigned to each of the objectives j.

$$W_j = (W_1, W_2 \ldots W_m)$$

B. OPERATIONS

1. *Cost/unit of impact ratios (CUI)*

These are obtained by dividing the total annual costs vector (TAC) by the achievement of objectives matrix (OB).

$$CUI_{ij} = \begin{bmatrix} CUI_{11} & \cdots & CUI_{1m} \\ CUI_{21} & \cdots & CUI_{2m} \\ CUI_{n1} & \cdots & CUI_{nm} \end{bmatrix} = 1/100 \begin{bmatrix} TAC_1 \\ TAC_2 \\ TAC_n \end{bmatrix} \begin{bmatrix} OB_{11} & \cdots & OB_{1m} \\ OB_{21} & \cdots & OB_{2m} \\ \vdots & & \vdots \\ OB_{n1} & \cdots & OB_{nm} \end{bmatrix}^{-1}$$

2. *Minimum cost/unit of impact ratios CUI (m)*

For each objetive (column) the minimum value of the CUIs must be selected

$$CUI_{ij}^{(m)} = \text{Min}_j \, CUI_{ij}$$

A matrix is then completed with the values thus obtained. This matrix has identical values in each column.

$$CUI_{ij}^{(m)} = \begin{bmatrix} CUI_{11}^{(m)} & \cdots & CUI_{1m}^{(m)} \\ CUI_{21}^{(m)} & \cdots & CUI_{2m}^{(m)} \\ \vdots & & \vdots \\ CUI_{n1}^{(m)} & \cdots & CUI_{nm}^{(m)} \end{bmatrix}$$

3. *Differences in absolute values (DA)*

These are obtained by subtracting from the matrix of the cost/unit of impact ratios (CUI) the minimum value obtained for each objective.

$$CUI_{ij}^{(DA)} = \begin{bmatrix} CUI_{11}^{(DA)} & \cdots & CUI_{1m}^{(DA)} \\ CUI_{21}^{(DA)} & \cdots & CUI_{2m}^{(DA)} \\ \vdots & & \vdots \\ CUI_{n1}^{(DA)} & \cdots & CUI_{nm}^{(DA)} \end{bmatrix} = \begin{bmatrix} CUI_{11} & \cdots & CUI_{1m} \\ CUI_{21} & \cdots & CUI_{2m} \\ \vdots & & \vdots \\ CUI_{n1} & \cdots & CUI_{nm} \end{bmatrix} + (-1) \begin{bmatrix} CUI_{11}^{(m)} & \cdots & CUI_{1m}^{(m)} \\ CUI_{21}^{(m)} & \cdots & CUI_{2m}^{(m)} \\ \vdots & & \vdots \\ CUI_{ni}^{(m)} & \cdots & CUI_{nm}^{(m)} \end{bmatrix}$$

4. *Differences in relative values (DR)*

These are obtained by dividing the matrix of the differences in cost per unit of impact in absolute values ($CUI_{ij}^{(DA)}$) by the matrix of minimum values of those ratios ($CUI_{ij}^{(m)}$).

$$CUI_{ij}^{(DR)} = \begin{bmatrix} CUI_{11}^{(DR)} & \dots & CUI_{1m}^{(DR)} \\ CUI_{21}^{(DR)} & \dots & CUI_{2m}^{(DR)} \\ \vdots & & \vdots \\ CUI_{n1}^{(DR)} & \dots & CUI_{nm}^{(DR)} \end{bmatrix} = 100 \begin{bmatrix} CUI_{11}^{(DA)} & \dots & CUI_{1m}^{(DA)} \\ CUI_{21}^{(DA)} & \dots & CUI_{2m}^{(DA)} \\ \vdots & & \vdots \\ CUI_{n1}^{(DA)} & \dots & CUI_{nm}^{(DA)} \end{bmatrix} \begin{bmatrix} CUI_{11}^{(m)} & \dots & CUI_{1m}^{(m)} \\ CUI_{21}^{(m)} & \dots & CUI_{2m}^{(m)} \\ \vdots & & \vdots \\ CUI_{n1}^{(m)} & \dots & CUI_{nm}^{(m)} \end{bmatrix} -1$$

5. *Differences in weighted relative values (DRW)*

These are obtained by multiplying the matrix of differences in relative values of the cost/unit of impact ratios ($CUI_{ij}^{(DR)}$) by the vector of the weightings of each of the objectives in question (W_j)

$$CUI_{ij}^{(DRW)} = \begin{bmatrix} CUI_{11}^{(DRW)} & \dots & CUI_{1m}^{(DRW)} \\ CUI_{21}^{(DRW)} & \dots & CUI_{2m}^{(DRW)} \\ \vdots & & \vdots \\ CUI_{n1}^{(DRW)} & \dots & CUI_{nm}^{(DRW)} \end{bmatrix} = \begin{bmatrix} CUI_{11}^{(DR)} & \dots & CUI_{1m}^{(DR)} \\ CUI_{21}^{(DR)} & \dots & CUI_{2m}^{(DR)} \\ \vdots & & \vdots \\ CUI_{n1}^{(DR)} & \dots & CUI_{nm}^{(DR)} \end{bmatrix} (W_1 \dots W_m)$$

6. *Vector of final results (RECES)*

This is obtained by multiplying the matrix of differences in weighted relative values $CUI_{ij}^{(DRW)}$ by a vector of value 1.

$$RECES_1^{(W)} = \begin{bmatrix} RECES_1^{(W)} \\ RECES_2^{(W)} \\ \vdots \\ RECES_n^{(W)} \end{bmatrix} = \begin{bmatrix} CUI_{11}^{(DRW)} & \dots & CUI_{1m}^{(DRW)} \\ CUI_{21}^{(DRW)} & \dots & CUI_{2m}^{(DRW)} \\ \vdots & & \vdots \\ CUI_{n1}^{(DRW)} & \dots & CUI_{nm}^{(DRW)} \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ \vdots \\ 1 \end{bmatrix}$$

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