SOFT MULTICRITERIA DECISION MODELS

FOR URBAN RENEWAL PLANS

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Abstract

The paper is dusted to an evaluation methodology for urban renewal plans. A central role is played by the concept of supply profiles of urban facilities. Urban renewal is considered to be a qualitative improvement of these profiles.

Many urban renewal plans are characterized by the availability of soft (ordinal or qualitative) information. Therefore, the paper gives an overview of soft multicriteria evaluation models. Next, special attention is paid to one particular kind of multicriteria analysis, viz. the frequency method. Complementary to the latter method, some attention is also devoted to multidimensional scaling techniques for nonmetric information. The usefulness of these two approaches for the evaluation of urban renewal plans is illustrated by means of a numerical example.

Contents

1. Introduction.

During the seventies there has been an increasing awareness of problems of urban decay and of bottlenecks in local policies. Municipal governments have been called upon to provide a wide variety of new amenities for urban inhabitants, whereas on the other hand the availability of present amenities was seriously affected.

Urban.systems appear to demonstrate an increasing divergence between supply and demand of urban functions. Two reasons can be mentioned for this phenomenon. First, there is the general decline in urban services (in terms of residential functions, job opportunities, cultural and medical facilities etc.). This is a typical supply phenomenon associated inter alia with the weak financial base of urban municipalities, the attainment of a tipping point in the housing market (see Thompson (1972)), the decreasing scale advantages of bigger agglomerations and segregational trends in urban communities (see Brown (1974), e.g.). The supply profile of urban functions (different categories of services and amenities) will be denoted by an (I x 1) vector $\underline{x}^s$.

In the second place, there is a shift in priorities of urban inhabitants regarding urban services and amenities. This shift in individual and collective urban preference structures is inter alia due to the improved welfare position of urban inhabitants, the influence of mass media and shifts in the demographic structure. As a consequence, problems of urban quality of life and of residential living conditions receive increasingly attention. This implies that the demand profile of urban functions is also affected. This demand profile will be represented by means of an (I x 1) vector $\underline{x}^d$.

Now it is clear that the general perception of the urban quality of life will show a decline from period t_0 to t_1, when the utility translation of the difference between $\underline{x}^s$ and $\underline{x}^d$ during this period is negative. In other words, the urban quality of life decreases, if:

$$(1.1) \quad u(\underline{x}^s - \underline{x}^d)_{t_1} < u(\underline{x}^s - \underline{x}^d)_{t_0} \ ,$$

where u is an aggregate utility index which transforms the supply and demand profiles into utility categories. This can be regarded as a special kind of a multi-attribute utility theory (see also Lancaster (1971)).

The problems of urban quality of life have placed an increasing demand on local governments in order to improve the urban functioning in general. So far, however, many urban developments and renewal efforts have not been quite succesful. This is due to several reasons: the limited rol and competence of local governments, the complex nature of municipal systems, lack of insight into impacts of urban policies, and the absence of an adequate evaluation framework for uncertain urban development plans (cf. Awerbuch and Wallace (1976)).

The present paper will be especially devoted to evaluation problems of urban development programs. Due to the qualitative and uncertain nature of these programs, there is a need for adjusted techniques that will help local governments to judge urban programs characterized by lack of accurate information on all impacts of these programs. The objective of the paper is to construct a tool that will help municipal policy-makers to judge alternative development and renewal plans on the basis of multiple decision criteria.

Therefore, the paper is organized as follows. In section 2 a brief introduction to urban renewal and development problems via a profile analysis will be given. The judgement of development alternatives is often hampered by inaccurate information, so that adjusted evaluation methods, viz. 'soft' multi-criteria evaluation methods, have to be devised. Section 3 presents a survey of such qualitative multicriteria methods. Next, in section 4 a certain specific method, viz. the frequency analysis, will be set out in more detail. The results of this qualitative analysis will be examined in quantitative (metric) terms by using recently developed multidimensional scaling methods. This will be the subject of section 5. The usefulness of the above mentioned qualitative approach for evaluating urban development and renewal plans will be illustrated by means of a numerical example in section 6. A brief evaluation will conclude this paper.

2. Urban Renewal Plans.

Urban renewal can be regarded as an urban (re)development process that aims at (1) restoring original functions of a city, (2) improving its present functions and (3) adding new functions to a city so as to accomodate better to the wishes of the urban community (see also Nijkamp and Soffer (1979)). In a formal sense, this implies that urban renewal attempts to meet the following condition related to (1.1):

$$(2.1.) \quad u_{t_1}(\underline{x}^S - \underline{x}^d) \geqslant u_{t_0}(\underline{x}^S - \underline{x}^d)$$

In order to comply with condition (2.1.), the local government has to improve the supply profile $\underline{x}^S$. This supply profile may contain inter alia the following elements pertaining to the urban quality of life:

$$(2.2.) \quad \underline{x}^S = \begin{bmatrix} \text{quantity of dwellings} \\ \text{quality of dwellings} \\ \text{general accessibility} \\ \text{cultural facilities} \\ \text{shopping facilities} \\ \text{medical facilities} \\ \text{educational facilities} \\ \text{employment facilities} \\ \cdot \\ \cdot \\ \cdot \end{bmatrix}$$

When the free market system does not guarantee to fulfilment of condition (2.1.), the local government may regard the urban quality of life as a merit good, so that it may aim at extending the supply profile $\underline{x}^S$ (cf. also Musgrave (1959)).

Therefore, urban renewal can formally be described via an improvement of x^s by means of public policies.

It is clear that such an integral profile improvement is not an unambiguous decision. The costs of adjusting a supply profile may be an important factor to be taken into account; the social distribution of the impacts of a new profile may be another factor (cf. Vipond (1974)). Consequently, there is not one supply profile, but there is a whole series of profiles each associated with a certain plan. Each profile has its own social, economic, environmental and physical impacts. Therefore, the evaluation of the various urban renewal profiles has to be based on a multiplicity of decision criteria.

The foregoing exposition implies that urban renewal policy attempts to identify the best profile from a series of feasible profiles $x_1^s, \ldots, x_N^s$. When these N successive profiles are integrated in a matrix system, the following profile matrix X of order I x N is obtained:

$$(2.3.) \qquad X = \begin{bmatrix} \underline{x}_1^s & \vdots & \cdots\cdots\cdots\cdots & \vdots & \underline{x}_N^s \\ & \vdots & & \vdots & \end{bmatrix}$$

In a sense, X can be regarded as an impact matrix for alternative urban renewal plans.

Normally these impacts are not purely monetary in nature and can neither be translated into monetary units. Therefore, instead of traditional evaluation techniques such as cost-benefit analysis, adjusted techniques have to be employed. In this respect, the recently developed multicriteria analyses appear to open a wide perspective (see for a survey among others Van Delft and Nijkamp (1977) and Nijkamp (1977)).

The practice of urban renewal plans, however, has demonstrated a lot of uncertainties in the impacts of these plans, so that quantitative (metric) information on these impacts is usually not available. Instead, the impacts are often represented by means of fuzzy or 'soft' qualifications such as 'good', 'better', 'best'. At best, these impacts are measured in ordinal numbers. Consequently, normal quantitative multicriteria analyses cannot be applied in the majority of urban renewal plans. This calls for adjusted qualitative or 'soft' multicriteria evaluation techniques. This is the subject of the next section.

3. A Survey of Soft Multicriteria Models.

Multicriteria analyses can be regarded as a general type of a multidimensional evaluation methodology which focuses on the heterogeneity and variety of the phenomena studied by treating all aspects of these phenomena in their own dimensions. In the case of ordinal, qualitative or fuzzy information these multicriteria analyses have to be adjusted so as to make them suitable for soft information. In general, the following qualitative or ordinal multicriteria analyses may be distinquished.

a. Expected value method.

This method is the simplest ordinal evaluation method by conceiving of ordinal preference scores as semi-probabilities ranked in descending order of importance (see Kahne (1975) and Schlager (1968)). In a similar way, the elements of a certain profile vector are ranked in descending rank order for each criterion. Next, for each alternative plan the ordinal preference scores are multiplied with the corresponding ordinal profile elements, so that one may directly obtain a rank order of all alternatives according to their 'expected values'. It is clear that this evaluation method is, however, a rather crude aggregation method based on non-permissable numerical operations.

b. Lexicographic method.

This method is based on a classification of evaluation criteria according to certain a priori defined importance classes (see Holmes (1971)). Next, the profile elements are also classified according to their degree of performance for each separate criterion. Hence, the alternatives may be ranked via a lexicographic ordering of the combined importance and performance classes. This method is a fairly simple method, although sometimes the identification of ordinal equivalence categories may be somewhat arbitrary (see also Lichfield et al (1975)).

c. Ordinal concordance method.

The ordinal concordance analysis can be regarded as an ordinal variant of the usual concordance technique (see Van Delft and Nijkamp (1977)). This analysis starts off with a pairwise comparison of alternatives. Next, one may calculate the concordance index as an aggregate preferencescore for those criteria in regard to which a certain plan has better outcomes than all other plans. Analogously, one may define a discordance index as an aggregate discrepancy index for those criteria in regard to which a certain plan has worse outcomes than all other plans. The only numerical problem is here the aggregation of the ordinal scores during the pairwise comparisons.

d. Permutation method.

This method employs the successive rank orders of alternatives (in terms of performances for each separate criterion) (see Jacquet-Lagrèze (1969) and Paelinck (1976)). Then a procedure is constructed which investigates the degree at which each plan supports the hypothesis that this plan dominates all others. This method is based on a simultaneous analysis of weights and performances via successive permutations, so that the most probable ranking of the alternatives can be identified. This is a more advanced method in which sometimes problems may emerge owing to conditional statements about probable rank orders of the alternatives.

e. Metagame analysis.

This analysis aims at reconstructing traditional game theory on a nonquantitative basis (see Hipel (1974) and Hipel et al (1976)). This method may be particularly suitable for conflicts among judges regarding the evaluation of alternatives. It is based on assigning zero-one values to particular options in order to denote whether or not an option is taken by the judge. Next a combination and comparison of the various options of the judges may lead to an identification of a compromise option which is marked by stability conditions via a qualitative min-max solution. A limitation of metagame analysis is that it only deals with zero-one values, so that no complete rankings are taken into account.

f. Eigenvalue method.

This method uses a matrix of pairwise comparisons of attributes such that the entries of this matrix reflect the dominance of one activity over another with respect to a specific comparison criterion (see Blair (1978)). Next, the preference analysis may be transformed into an eigenvalue problem by means of ratios of weights, so that a vector of relative weights of the attributes being compared may be assessed. This eigenvalue prioritization model is particularly appropriate to derive a cardinal judgment scale. It is not directly applicable as an evaluation technique as such; in that case a complementary analysis is needed.

g. Frequency method.

The frequency method is based on qualitative importance and performance classes (see Van Delft and Nijkamp (1977)). This method assigns the successive preference scores and the criterion outcomes to certain importance classes and performance classes, respectively. Next, one may count the number of times that a certain alternative falls into a combined importance-performance class. This method is rather simple and incorporates no unpermitted numerical operations, although it may sometimes be somewhat difficult to infer unambiguous conclusions. Because this method will be used in our urban renewal analysis, it will be set out in more detail in the next section.

h. Multidimensional scaling method.

The multidimensional scaling technique is also a recently developed qualitative evaluation method (see Nijkamp en Veenendaal (1978) and Nijkamp en Voogd (1979)). This method was especially developed to tackle problems of ordinal input data. This method will also be employed in the present study on urban renewal, so that it will be discussed at greater length in section 5.

4. A Frequency Analysis for Soft Decision Problems.

Suppose a profile matrix X with N alternative plans and I evaluation criteria (see (2.3.)). Next, one may distinguish (without loss of generality) 3 performance indices:

+ + +   very favourable impact
+ +   rather favourable impact
+   small favourable impact

The assumption is made that all criteria are measured as benefit criteria ('the higher, the better'). Consequently, all cost criteria have to be redefined as benefit criteria.

It is evident that such 'soft' information is not very accurate, but it is a usual circumstance in many evaluation problems (for example, in urban renewal policy). The fuzzy performance indices presuppose a certain frame of reference in order to assign the plan impacts to these performance classes.

In a similar way, qualitative preference scores can be incorporated in qualitative importance classes. Suppose (again without loss of generality) the following 2 importance classes:

x x   a very high priority
x   a normal priority

Clearly, the assignment of these importance indices has to be based on a frame of reference regarding all plan impacts.

Next, one may construct the following frequency tabel (Tabel 4.1.):

plan	x x			x		
	+ + +	+ +	+	+ + +	+ +	+
1						
·						
·						
·						
·						
·						
N						

Table 4.1. A frequency table of combined importance-performance indices.

Each element of this table represents the frequency that a certain plan outcome (+ + +, + + or +) occurs with a certain preference score (x x or x). In other words, the left upper entry of this matrix indicates the number of times that plan 1 has a very favourable outcome (+ + +) which is considered to be very important (x x).

Next, one may first attempt to eliminate dominated plans. All plans which have lower frequencies than a given plan may be eliminated. The following step is the selection of the optimal plan. This selection may be based on certain reasonable hypotheses concerning the relative dominance of plan impacts. The following hypotheses regarding the combined performance-importance indices are made:

$$(4.1.) \quad \{+ + +, x \, x\} \succ \{+ +, x \, x\} \approx \{+ + +, x\} \succ \{+, x \, x\} \approx \{+ +, x\} \succ \{+, x\}$$

where the symbols $\succ$ and $\approx$ mean 'preferred to' and 'approximately equivalent to', respectively. On the basis of these rules one may usually select the optimal plan (or at least the best plans) by comparing pairwise the rows of Table 4.1. The use of such a procedure for urban renewal plans will be illustrated in section 6.

5. Multidimensional Scaling Methods.

In the foregoing section the frequency method was described as an operational method to identify the best plan(s) in case of qualitative information. A basic problem was the fact that the relative difference between the successive plans could not be measured in metric terms. In order to cope with this problem, multidimensional scaling techniques may be useful.

These techniques have been developed during the last decades in the area of mathematical psychology; for instance, in order to infer metric conclusions from qualitative or ordinal individual features (see, for example, Carroll and Chang (1970), Coombs (1964), Kruskal (1964), Lingoes and Roskam (1971) and Torgerson (1954)). Recently these techniques have also found several applications in other disciplines such as geography, planning, marketing theory and regional-science (see for a survey among others Nijkamp and Van Veenendaal (1978), Nijkamp and Voogd (1979) and Voogd (1977)).

All multidimensional scaling methods are based on ordinal or qualitative rankings of similarities (or dissimilarities) among alternatives (such as objects, items, attributes, etc.) by various individuals or groups. These methods aim at generating a geometric representation of the positions of the alternatives and of the judges in an Euclidean (metric) space of a given dimensionality by employing a certain geometric scaling algorithm. By means of this operation metric conclusions can be inferred regarding the relative distances (discrepancies or differences) between the items, attributes or judges.

The essential background of multidimensional scaling is that a representation of ordinal data in a geometric space with fewer dimensions implies that more ordinal conditions are available than geometric coordinates are necessary. Hence, such abundant information involves many degrees of freedom which can be used by scaling algorithms to transfer ordinal inputs into metric outputs.

The positions of the items, attributes and judges can be represented via Euclidean coordinates. These coordinates are to be determined such that the interpoint distances between the points in a geometric space do not contradict the original conditions implied by the ordinal input data. In other words, this monotonicity condition should guarantee a maximum coorespondence between the orginal ordinal rankings (either similarities or dissimilarities) and the Euclidean distances in a geometric space with a lower dimensionality. The mathematics of this technique will not be exposed here, but can be found in the references quoted. In order to clarify intuitively the working of these methods, an illustrative exposition will be given below.

Assume, for instance, N alternative plans which are judged on the basis of I evaluation criteria by a decision-maker. The ordinal representation of the performances of these plans can be included in an $I \times N$ ordinal effectiveness table. Hence, for the N plans $I \times N$ ordinal statemens (or conditions) are specified.

Lut us now assume that we want to represent the N plans as points in a two-dimensional Euclidean space such that the $N(N-1)/2$ interpoint distances are in agreement with the ordinal effectiveness table. A representation of these N plans in a two-dimensional Euclidean space requires only $2N$ numbers, viz. the coordinates of these N points in a two-dimensional geometric space. Thus, the original $I \times N$ ordinal relations can be used to identify $2N$ cardinal numbers (cf. Fig. 5.1.).
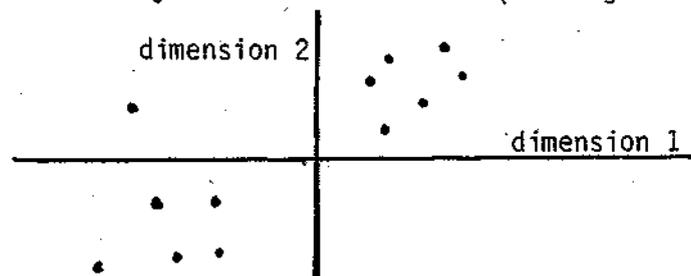

Fig. 5.1. An illustrative representation of N plans in a two-dimensional space by means of a multidimensional scaling method.

It is clear that, given the coordinates of the points in Fig. 5.1., quantitative statements can be inferred regarding the metric distances between the successive plans. On the basis of the characteristic features of the plans, the two dimensions (axes) can also be interpreted (see also Nijkamp and Van Veenendaal (1978)).

In case of more than one judge, the position of the judges (at least the relative importance assigned by the judges to the items) can also be represented in the same geometric space. Consequently, the relative differences in priorities of the judges can be assessed, so that the degree of mutual (dis)agreement can also be quantified. Similarly, one may gauge the degree of cognitive consistency among the judges.

When, in addition to an ordinal ranking of items, a judge also assigns ordinal preference scores to the various attributes, a double scaling problem emerges. Such a complex problem can be attacked by adjusted scaling algorithms (see Nijkamp (1979) and Nijkamp and Voogd (1979)). The same holds true for a set of policy scenario's which can be distinguished for the urban renewal strategies of a city. This will be illustrated in section 6.

6. A Numerical Illustration for Urban Renewal Plans.

Urban renewal policy is an attempt to improve the supply profile of all urban facilities. In general, there is a variety of different options or policy scenario's. The choice of a specific urban renewal plan will depend on the relative importance attached to the elements of the successive supply profiles. In other words, there are two stages in the analysis of urban renewal plans, viz. the valuation (the assessment of the performances or effectiveness scores of all plans for all policy criteria) and the evaluation (the assignment of priorities to the separate plan impacts by means of preference scores).

Let us now suppose the following illustrative example. A local government is confronted with the problem of a functional decay of the inner core of the city leading inter alia to a poor accessibility. Several solutions (i.e., alternative plans or scenario's) may be dis- tinguished in order to cope with the structural decline of the city. Clearly, each solution has certain advantages and disadvantages. After a thorough investigation of all plans it appears to be possible to represent the performances (effectiveness scores) of all plans by means of a qualitative impact table (cf. (2.3.)).

The following 6 feasible plans (i.e., N = 6) may be distinguished for the urban renewal problem at hand:
1) a small-scale improvement of the residential quality, without a substantial change in the urban infrastructure.
2) a partial rehabilitation and a partial demolition followed by constructing new residential buildings without substantial changes in the urban infrastructure.
3) a complete demolition and the construction of new dwellings without affecting the original spatial lay-out of the city, followed by a return of the original population.
4) a complete demolition and a construction of new residential buildings, on the basis of lower densities, but with a maintenance of the original urban lay-out.

5) a complete demolition and a construction of new residential buildings characterized by lower densities without maintaining the original urban infrastructure.

6) a complete demolition followed by the provision of both new dwellings and new urban amenities after a total reconstruction of the urban infrastructure.

Next, the assumption may be made that the local government wants to judge these alternative plans on the basis of the following 7 criteria (i.e., I=7):

1) the improvement of the urban and residential quality of life
2) the socio-economic distribution of the impacts of the new plans
3) the costs of the alternative plans
4) the impact on the urban employment
5) the urban population density
6) the accessibility of the city centre
7) the supply of urban amenities

It is clear that the cost criteria 3) and 5) have to be translated as benefit criteria, so that a high amount of costs will be represented by an effectiveness score +.

For the urban renewal plans the following qualitative impact table may be assumed:

plans criteria	1	2	3	4	5	6
1	+	++	++	+++	+++	++
2	++	+++	+++	++	++	+
3	+++	++	+	+	+	++
4	+	++	++	++	+	+++
5	+	++	++	+++	+++	++
6	+	+	++	++	+++	+++
7	+	++	++	++	++	+++

Table 6.1. Qualitative impact table of urban renewal plans.

The local government has to decide on the urban renewal plans on the basis of the 'soft' impact table 6.1., given its own priorities regarding the evaluation criteria.

The following preference scores will be assumed for the 7 policy criteria:

1	2	3	4	5	6	7
(xx	x	xx	xx	x	x	x)

Table 6.2. A vector of preference scores for urban renewal plans.

Thus, the assumption is made that there is one preference score for each criterion (i.e., a linear qualitative weighing system). In case of a nonlinear weighing system a whole matrix of preference scores has to be constructed.

On the basis of Table 6.1. and 6.2. the following frequency table of combined performance-preference scores can be constructed (see Table 4.1.):

plan	xx			x		
	+++	++	+	+++	++	+
1	1	0	2	0	1	3
2	0	3	0	1	2	1
3	0	2	1	1	3	0
4	1	1	1	1	3	0
5	1	0	2	2	2	0
6	1	2	0	2	2	1

Table 6.3. A combined performance-preference table
for urban renewal plans.

This table gives rise to rather straightforward conclusions. First, several plans may be eliminated, because it is easily seen that plan 6 dominates absolutely plans 1, 3, 4 and 5 (as can be checked by applying the conditions represented in (4.1.)). After the elimination of plans 1, 3, 4 and 5, the only choice remains between plan 2 and 6. But it can also easily be checked that plan 6 is slightly better than plan 2, so that plan 6 may be selected as the best renewal plan.

Next, it may be interesting to examine the degree at which the alternative plans differ mutually. As exposed in section 5, this can be performed by means of multidimensional scaling techniques. Therefore, the qualitative impact table 6.1. has to be transformed via the numbers 1,2 and 3 into an ordinal table (see Table 6.4.):

plans criteria	1	2	3	4	5	6
1	1	2	2	3	3	2
2	2	3	3	2	2	1
3	3	2	1	1	1	2
4	1	2	2	2	1	3
5	1	2	2	3	3	2
6	1	1	2	2	3	3
7	1	2	2	2	2	3

Table 6.4. A tranformed ordinal impact table
for urban renewal plans

A multidimensional scaling technique[1] applied to Table 6.4. led to the geometric results presented in the two-dimensional Euclidean space of Fig. 6.1. The goodness-of-fit of this two-dimensional confi guration appeared to be extremely good.

1) The procedure used here was the Minirsa program developed by Roskam (1975
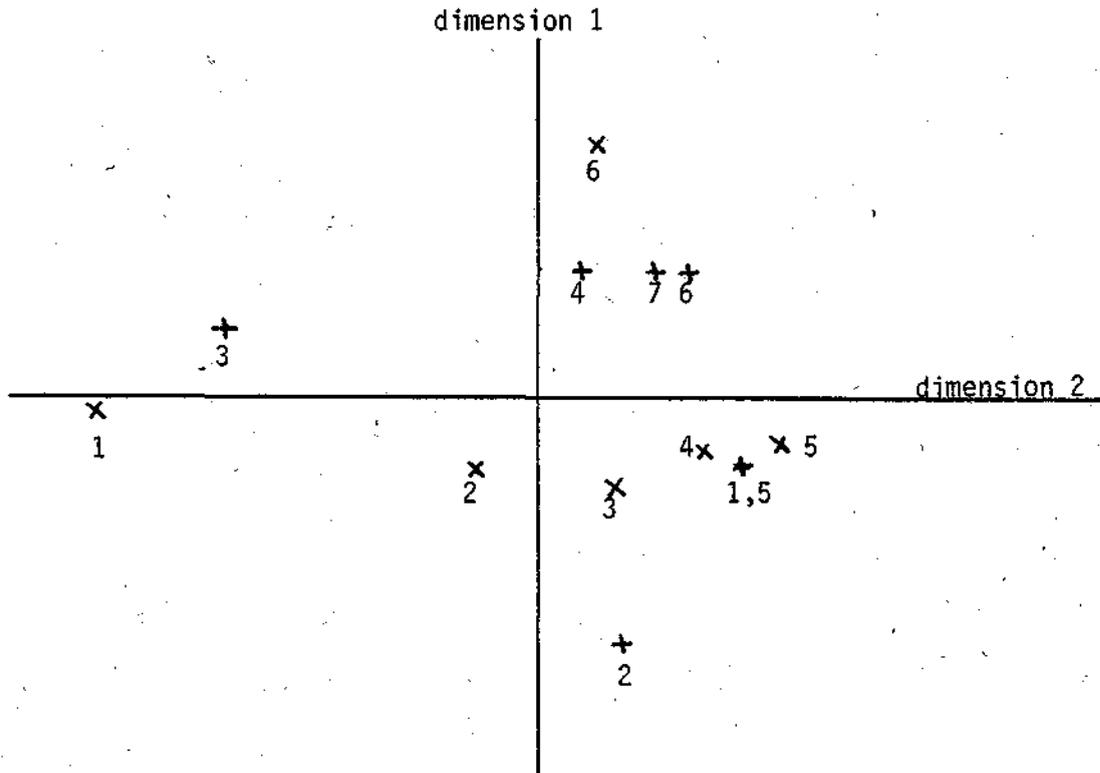
Fig. 6.1. A joint geometric representation of the urban renewal
plans and impacts after multidimensional scaling.

The results of Fig. 6.1. give rise to the following conclusions.
The metric configuration of the plans is denoted by the symbol 'x'.
It turns out that plans 3, 4 and 5 and to a lesser degree plan 2 are
rather closely located together. Plan 1 and plan 6 are clearly distinguishec
from the remaining ones. Of course, this metric configuration of the
plans is based on unweighted criterion outcomes, so that the relative
attractiveness of each plan cannot be judged; only the discrepances among
the plans can be identified.

The criteria positions measured in a metric sense are denoted by the
symbol '+'. It turns out that the criteria 4, 6 and 7 bear much
resemblance. This indicates that the impacts on the urban employment,
the accessibility to the city centre and the supply of urban amenities
are linked together. The same holds true for criteria 1 and 5; this
shows that quality-of-life and population density are mutually correlated.
Criterion 3 (the financial aspect) is clearly distinguished from criterion
2 (the distributional aspect) and from the two remaining sets of
criteria.

The results indicate that the horizontal axis may be interpreted in terms of economic and financial returns of the urban renewal plans, whereas the vertical axis reflects the environmental and social aspects of these plans. The left-hand axis is associated with traditional economic categories (such as efficiency and distributional equity), whereas the right-hand axis is more oriented to the new scarcity (environment, labour etc.)

7. Conclusion.

The main objective of this paper was to develop decision-making tools that may improve urban planning by providing appropriate evaluation techniques through which municipal officials can better choose among alternative urban development and renewal plans. Both the frequency analysis and the multidimensional scaling method appeared to be useful tools for dealing with 'soft' evaluation problems.

It should be emphasized, however, that such evaluation techniques do not take over the role of the policy-making process. The ultimate selection and implementation of an urban renewal plan is a matter of political responsibility of local officials and the local government. The value of the evaluation technique is that is makes the decision problem more transparant, so that the policy-makers are able to take account of all performances and consequences of urban renewal strategies. In this sense, soft multicriteria models may play an extremely important role in an integrated and multidimensional evaluation of alternative plans.

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