The sustainability of urban renewal projects: a model for economic multi-criteria analysis

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1. Abstract

Local governments are increasingly called upon to ensure the optimal allocation of scarce resources at their disposal, relevant for proper territorial transformation and development.

This assumes particular interest with regards to investments made in urban areas, which are essential to the government policies of such a complex system as that of the contemporary city. (Chan E.H. and Yung E.H.K., 2004; Yi-Kai J., Ropper K.O., Castro-Lacouture D., Ha Kim J., 2010).

Today the decisions taken relating to urban renewal interventions, that is for the recovery of a valid qualitative and functional dimension in urbanistic and/or building structures (Borri D., 1985), are rarely supported by logical and operational methodologies capable of effectively rationalising selection processes. For this purpose, it is necessary to propose and implement analysis models with the aim of promoting the sustainable development of the territory (Fusco Girard L., Nijkamp P., 1997; Mayer I.S., Van Bueren Ellen M, Bots P. W G, Van der Vart H., 2005; Morano P., Nesticò A., 2007; Chan E., Lee G.K.L., 2008; Hunt D.V., Lombardi D.R., Rogers C.D. and Jafferson I., 2008; De Mare G., Manganelli B., Nesticò A., 2013).

With the present paper a model of economic evaluation, that introduces original elements correlated to its processing algorithms, specifically defined for enabling the optimal selection of urban development projects, is written and tested by means of Operational Research.

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2. Integrated evaluation models and urban renewal processes

The development of plans and projects requires not only technical and design analysis, but also economic evaluations capable of integrating aspects of sustainability into the decision-making process with a view to achieving inter-generational equity. These aspects are not adequately taken into consideration if traditional income and economic growth indicators are used as a means to express a judgment on territorial policies (Larson E.W. e Gobelli D.H., 1989; Gray C.F. and Larson E.W., 2003). Instead, multi-criteria methodologies are imposed, by means of which it is possible to rationalise choices driven by complex and often conflicting multiple objectives (Ghasemzadeh F. and Archer N.P., 2000; Song B., Sun Q., Li Y., Que C., 2016).

In fact, there are many levels of complexity that characterize the processes of urban transformation. According to Kähkönen K. (2008) these include:

- *function complexity*, resulting from the simultaneous presence of both public and private functions*;*
- *complexity of the parties involved*, as each one of them has its own personal objectives*;*
- *resources complexity*, due to the scarcity of financial resources available.

In particular, the co-existence of public and private interests (Guarini M.R., Battisti F., Buccarini C., 2014a) has a strong impact on the re-capitalisation process of a consolidated urban territory and this refers precisely to the difficulty encountered when having to optimally allocate scarce resources in order to ensure sustainable development (Bryson J.M. and Roaring W.D., 1987). This is reinforced by a frequently uncertain and confused decision-making system, oriented towards favouring techno-practical territorial planning and instead of encouraging a social-practical form of government resulting from integrated evaluation (Farragher E.J. and Kleiman R.T., 1996; Florio M., 1999; Ingemar E., 2002).

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The reasons given explain the necessity to resort to *General Integrated Models* (*G.I.M.*) so as to favour the concrete feasibility of programmes of investment within an urban context, which not only bears financial criteria in mind, but also those of a social, cultural and environmental nature (Calabrò F., Della Spina L., 2014; Guarini M.R., Battisti F., 2014b; De Mare G., Granata M.F., Nesticò A., 2015; Nesticò A., Macchiaroli M., Pipolo O., 2015; Amato F., Maimone B.A., Martellozzo F., Nolè G., Murgante B., 2016).

This means simultaneously maximising the objectives of the biological system (biodiversity, resilience, bio-productivity), the objectives of the economic system (the fulfilment of basic needs, the strengthening of equity and the increase of goods and services) as well as the objectives relating to the social system (cultural difference, institutional sustainability, social justice, participation) (Barbier E.B., 1987) through decision support systems for urban renewal and rational and sustainable use of the territory (Cooper et al., 2001; Bentivegna V., 2009; Nesticò A., Pipolo O., 2015; Tajani F., Morano P., 2015).

A brief overview regarding the methodologies which are considered able to resolve *Projects Portfolio Selection Problems* according to the specific Operations Research logics is given below. It emerges that Discrete Linear Programming (DLP) can be an effective tool for selecting investments aimed at achieving financial, social, cultural and environmental sustainability. Therefore, a model for the optimal allocation of scarce resources is proposed. The model, written with A Mathematical Programming Language (AMPL) using DLP logics, is tested so as to define an investment programme finalized to urban renewal of a vast area.

3. Operational Research to support decision-making systems

The decision-making theory includes a series of studies aimed at analysing what a decision is, what a decision problem is and how it can

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be resolved. This theory represents a branch of Operational Research, developed on the basis of a renewed attention regarding topics of bounded rationality and the regime of the uncertainty within which the collective decision-making processes develop (Falcone D., De Felice F. and Saaty T. L., 2009, page 34).

The decision-making system is uncertain and complex due to its multiplicity of objectives and constraints. “The term *complexity* is an increasingly important point of reference when we are trying to understand the managerial demands of modern projects in general, and of the various situations encountered in projects” (Kähköen K., 2008).

The intrinsic complexity of the decisions to make with regard urban renewal imposes the development the economic evaluation of the impact that interventions have on the territory (Munda G., 2006).

It is the relationship between decision-making, real estate and investment that defines the analysis model (John W. & Sons, 2001). With specific respect to the interventions carried out on the city itself, development models are proposed because they take into account both financial aspects and those of extra-monetary nature (Graaskempo J.A., 1972, page 515). In fact, the multi-criteria logic fits with the multi-dimensional nature of territorial planning (Lee J.W. and Kim S.H., 2001).

The evaluation actually goes through the following stages:

1) the identification of the numerous objectives the project has (of a financial, social, cultural and environmental nature);
2) the definition of the criteria able to measure the capability of the intervention to achieve each of the different objectives. The criterion is “a principle or standard by which anything can be judged” (Lim C.S. & Mohamed M.Z., 1999, page 243). According to Ika L.A. (2009, page 7), the criteria are “the lens through which it can be determined whether a project is a success or a failure”;
3) the attribution of a performance indicator to every criterion.

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Essentially, the evaluation requires the subject of the analysis – the project – to be broken down into simple factors to every one of which a *performance indicator* must be attributed on the basis of certain and consolidated information.

Where the problem refers to the selection of a projects portfolio, optimisation algorithms are extremely useful because they are capable of simultaneously taking into account several criteria by means of the writing of an algebraic expression known as a *function objective* (Kaiser M.G., Arbi F. El., Ahlemann F., 2015). This *modus operandi* provides the opportunity to take into consideration other types of restriction that may condition the decision-making process.

In the case in question, the Operations Research makes several types of alphanumeric tools available, among which it is possible to choose depending on the problem to be solved. These are models which, above all, can easily be adapted to concrete situations.

With reference to urban and territorial sustainability, different dimensions of reality can be reconciled within one, unique frame, using an approach capable of taking into consideration the entire network of relationships as well as the parts of which urban reality consists.

4. Optimisation algorithms for multi-criterial evaluation

Operational Research, also known as the Decision-making Theory, models complex systems in order to make them evolve towards the desired objectives. It provides tools to support the decision-making activities in which it is required to manage limited resources with the aim of maximising (or minimising) an objective function.

In this way, most of the selection processes can be faced as an optimisation model, referable to a mathematical programming model such as the one seen below:

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$$\begin{cases} \max\ (\text{o}\min)\ C(x_1, \dots, x_n) \\ \varphi_m\ (x_1, \dots, x_n)\ \leq\ b_m \\ x\ \in\ X \end{cases}$$

in which the objective function C(x), the system of constraints (φ_m) to which the calculation of the optimal value must adhere as well as the set of variables (x) relating to problem all appear (Korte B., Fonlupt J. Vygen J., 2010).

In the construction of the model itself, the decision-making problem is formalised by using a mathematical language aimed at expressing the correspondence between relationships in the real world and mathematical expressions in a two-way correspondence relationship.

Mathematical programming problems are classified as follows:

1. *linear programming problems*, if the objective function as well as the functions that define the constraints are linear;
2. *non-linear programming problems*, if at least one of the functions that define the problem is not linear.

Although the assumption of linearity in the phenomena that distinguish the model may appear restrictive when compared to the complexity of the real phenomenon, this category of problems provides strong practical feedback. In fact, many real cases can be expressed with an adequate degree of certainty in the proposed terms relating specifically to linear programming. In particular, this occurs with respects to selection problems among urban renewal projects.

In turn, linear programming problems may be categorised as follows:

a. *continuous optimisation,* if the vector x assumes values in $\mathbb{R}^n$;
b. *whole-program* (or *discrete*) *optimisation,* when the considered variables assume values in Z^n;
c. *mixed,* when the variables assume both whole and continuous values.

In all cases, the choice of the problem-solving algorithm is of utmost importance. In fact, the same algorithm is linked to efficiency expressed in terms of cost (or complexity), that is as a measurement of the

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resources that are required in order to find the solution to the instance *p* of the problem.

The usable resources can be divided into:

- memory occupied;
- calculation time, or algorithm runtime.

Depending on the calculation time, a generic algorithm is said to have polynomial complexity or exponential complexity, and every single one of them resolves linear programming problems respectively called *treatable* (P) and *untreatable* (NP) problems. While the first type of problems is simpler to solve, the NP problems require the use of an exponential complexity algorithm, the problem-solving time of which, depending on the number of variables considered, may vary between 10^{-3} seconds to 17.9 minutes (Garey and Johnson, 1979).

Within the linear whole-program programming context, the main decision-making algorithms are:

- *dynamic programming algorithms*, based on the Bellman's principle of optimality;
- *implicit enumeration algorithms*, such as the Branch & Bound (B&B) algorithm, that are based on the recursive subdivision of the solution space;
- *cutting-plane algorithms*, such as the Gomory cutting-plane algorithm (Vercellis C., 2008).

With the aim of pursuing multiple urban renewal objectives (are m, with m>1), which demand – as it is told – a multi-criterial approach, the selection problem among n projects is considered, not all of them are feasible due to budget constraints.

One such problem could be modelling by resorting to linear programming tools. In fact, both the objective function and the constraint relationships can be translated into a linear form. More specifically, since the single project cannot be subdivided (Thusen G.J. and Fabrycky W.J., 1994), Discrete Linear Programming algorithms (DLP) can be implemented.

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In the next paragraph, it is selected the algorithm – the Branch & Bound – that seems the best to solve the selection problem with multi-criterial logic. In relation to the selected algorithm and with AMPL syntax, a rational model, which is easy to implement, is defined in order to guarantee the optimal allocation of the resources at disposal.

5. A model for sustainable urban renewal

Among the resolution algorithms that the Operations Research makes available, the B&B algorithm is preferred for the selection problem among *n* projects of urban renewal. This is due to the fact that it makes it possible to foresee the complexity of the problem to be treated in advance with the consequent reduction of the calculation time, both when compared to the dynamic programming algorithms as well as the cutting-plane algorithms. The B&B is based on a procedure called *divide et impera*, that turns the solution of a "difficult" problem into the solution of two or more simpler sub-problems.

Starting from a whole-program optimisation problem:

$$\begin{cases} z_I^* = \max c'x \\ \text{s.a } Ax = b \\ x \in Z_+^n \end{cases}$$

identified by S its admissible region, a whole collection of sub-regions S_1, $S_2 \ldots S_r$ of S is defined so that the following relationship is satisfied:

$$\bigcup_{k=1}^{r} S_k = S$$

Once the space regions of the admissible solutions have been identified, the corresponding linear optimisation sub-problems are taken into consideration:

$$\begin{cases} z^*_{I_k} = \max c'x \\ \text{s.a. } x \in S_k \end{cases}$$

This is the *Branch* operation, that consists in the construction of the tree of admissible solutions.

The algorithm tries to find the optimal value of the objective function among the *r* solutions of the previously identified sub-problems and it chooses the maximum value:

$$z^*_I = \max_{k=1,2,\ldots,r} z^*_{I_k}$$

To sum up, the solution of the original problem *I* is referred back to the solution of the *r* sub-problems defined on smaller and simpler regions to be solved.

Sub-problems which do not contain an optimal solution to the problem are rejected (*Bound* operation).

Different kinds of software can be used with the aim to implement the B&B algorithm that has been chosen, among of which there is the AMPL algebraic generator of models. It allows of connecting the algebraic model of the problem with the solver in charge of developing the algorithm (Bruglieri M., Cordone R., Liberti L., Iuliano C., 2010).

The model in Tab. 1 is just written with AMPL.

SELECTION PROBLEM

SETS

```
set PROJECTS ;
set SUSTAINABLE  INDICATORS;
```

PARAMETERS

```
param BUDGET;
param  INDICATORS_unit {PROJECTS, SUSTAINABLE INDICATORS} ;
param  COST {PROJECTS} ;
```

VARIABLES

```
var x{i in PROJECTS} binary ;
```

OBJECTIVE FUNCTION

```
maximise (or minimise) objective: sum {i in PROJECTS, j in INDICATORS} INDICATORS_unit[i, j]*x[i];
```

CONSTRAINTS

```
s.t. (subject to) constraints_0: sum {i in PROJECTS} COST [i]*x[i] <= BUDGET;
```

Tab. 1 - *Model for the selection of urban renewal projects (written with AMPL)*

The *n* urban renewal projects (set PROJECTS) are assesses according to *m* sustainability indicators (set SUSTAINABLE INDICATORS).

The numerical values that define the problem to be solved in detail are explained in the division PARAMETRES. They are:

- the available budget (param BUDGET);
- the multi-criterial matrix (param INDICATORS_unit {PROJECTS, SUSTAINABLE INDICATORS}) and
- the vector that represents the investment cost of each project (param COST {PROJECTS}).

After the unknown values of the problem (var x {i in PROJECTS} binary) have been defined, it proceeds to write the objective function:

MAXIMIZE (or MINIMIZE) objective: sum {i in PROJECTS, j in INDICATORS} INDICATORS_unit[i, j]*x[i].

At last, the costraint about the available budget is remarkable:

```
s.t. vinc_0: sum {i in PROJECTS} COSTO[i]*x[i] <= BUDGET.
```

It is clear that:

- AMPL makes it possible to build a parametric model. The *.mod* file is written without specifying the data used which are written in an appropriate *.dat* file;
- the elements of the problem (projects and performance indicators) are treated as *sets*;
- the unknown values – the projects – assume a binary value (*var* x *binary*);
- the objective function is a linear expression that maximises the investments' capacity for pursuing various objectives relating to the sustainable urban renewal of a vast area.

In the AMPL programming environment different solvers are used for solving continuous, discrete and mixed linear mathematical programming problems. Among those that can be implemented for the model in Tab. 1, it is possible to cite:

- CPLEX, which is used for linear, non-linear and quadratic programming problems;
- GUROBI, that implements linear programming problems with continuous and integer variables;
- LPSOLVE which is used for moderately-sized continuous and entire linear programming problems.

Note that the model's indicators in Tab. 1 are important equally for the decision maker. Different weights can be considered simply multiplying the values of the projects estimated according to the j-*th* criterion with coefficients p_j. Moreover, this points out the extreme versatility of the analytical scheme.

6. Case study

A set of 30 projects is taken into consideration for public funding and for the urban renewal and recovery of property of historical and architectural value.

Considering the limited budget at the disposal of the promoting authority, the objective is to finance those projects which are able to determine the best financial, social, cultural and environmental benefits for the territory.

The specificities of the vast area of interest, situated in the province of Salerno (Italy), and the availability of information on the interventions, lead to the evaluation of each project according to the following factors:

a) financial benefits;
b) effects on employment;
c) soil consumption levels;
d) degree of environmental impact;
e) capacity to recover property of historical and architectural value.

Which corresponding performance indicators are used:

a) the Internal Rate of Return (IRR);
b) the number of permanent employees intended as the number of new employees with a permanent work contract;
c) soil consumption levels, expressed in m^2, defined as "the phenomenon associated with the loss of an environmentally fundamental resource, due to the occupation of soil which was originally used for agricultural, natural or semi-natural purposes" (www.isprambiente.gov.it);
d) CO_2 emissions into the atmosphere, in terms of thousands of tons per year. The numerical values are positive (which are detrimental to the selection purposes) in case of CO_2 emissions, while they are negative (therefore the choice of these is preferred) where the project determines the destruction of CO_2, as in cases of the energy re-qualification of existing buildings or interventions relating to the planting of new tree species;

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e) the recovery of property of historical and architectural value must be intended as the series of interventions in which the transformation and the preservation of structures must integrate at best with the existing ones, also bearing the users’ demands and the available resources in mind. A qualitative scale from 1 to 5 is used, with increasing values relating to the increase of the positive effects following the recovery intervention.

The values of each parameter recorded for the 30 projects are specified in Tab. 2.

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	PROJECTS	COST (thousands of €)	IRR (%)	N° of permanent workers	LAND USE (thousands of m^2)	CO$_2$ (thousands of t/anno)	REC. (Scale 1 ÷ 5)
1	RECOVERY OF 19^{TH} - CENTURY BUILDING	1.120	7.80	9	0	- 4	3
2	DEVELOPMENT OF OLD SEWAGE TREATMENT PLANT	1.500	4.64	5	100	4	2
3	RESIDENTIAL AREA RENEWAL	9.350	8.72	13	85	- 3	5
4	PERIPHERAL URBAN AREA RE-GENERATION	6.380	4.85	8	-80	-5	5
5	POWER STATION RE-FUNCTIONALISATION	8.900	6.12	10	0	2	5
6	RIVER COURSE DEVELOPMENT	9.780	5.02	6	150	6	3
7	RESTORATION BUILDING INTENDED FOR USE AS A PLACE OF WORSHIP	1.500	9.18	0	0	-5	5
8	NEW MUNICIPAL PARK	1.850	10.90	10	10	-4	2
9	NEW SPORTS CENTRE	9.230	11.60	15	170	4	0
10	AIRPORT TERMINAL RE-QUALIFICATION	6.100	10.80	13	50	2	5
11	REPAIR OF PAVEMENTS AND STREET LIGHTING	1.012	8.90	0	0	-2	1
12	ECO-FRIENDLY STREET FURNITURE	200	10.64	0	0	0	3
13	MONASTERY RE-FUNCTIONALISATION	8.800	4.37	4	0	8	2
14	NORMAN CASTLE RECOVERY	7.000	4.98	3	0	-3	5
15	UNIVERSITY CAMPUS EXPANSION	10.140	7.18	11	189	2	0
16	RECOVERY OF ABANDONED FACTORY	1.300	10.89	16	70	4	5
17	BANCA ETICA PROJECT	1.405	10.99	11	3	0	4
18	NEW ECO-SUSTAINABLE SCHOOL BUILDING	4.200	11.62	18	151	-9	0
19	INDUSTRIAL ESTATE RE-FUNCTIONALISATION	10.405	8.01	9	180	7	3
20	OFFICE BLOCK CONSTRUCTION	7.154	9.78	13	190	8	0
21	RECOVERY OF DISUSED RAILWAY	1.250	7.22	0	-87	-6	5
22	RECOVERY OF FORMER SHIPYARD	12.000	4.34	0	250	1	4
23	NEW TOWN LIBRARY	1.000	8.07	9	0	5	3
24	EXPANSION OF RESIDENTIAL AREA	2.700	6.72	6	80	3	0
25	MEDIEVAL VILLAGE RE-FUNCTIONALISATION	3.800	10.02	12	0	-7	5
26	FORMER CUSTOMS OFFICE RENEWAL	6.180	5.60	11	200	1	2
27	NEW FULLY-EQUIPPED GREEN AREA	5.210	8.62	9	0	-8	0
28	RECOVERY OF DISUSED AREA	3.215	10.91	15	20	8	2
29	FORMER SALTWORKS RENEWAL	2.897	5.77	2	10	9	3
30	PORT RECOVERY	8.900	9.88	13	30	2	5

Tab. 2 - *Multi-criteria analysis matrix*

As for the comparison of projects, the normalisation of every attribute is carried out. This takes place by means of the following equation:

$$z_{ij} = \frac{x_{ij} - \mu_j}{\sigma_j}$$

where x_{ij} identifies the value taken on by the i-*th* project valued according to the j-*th* indicator, μ_j states the arithmetic average of the values assumed by the assessed n projects according to the same j-*th* indicator, σ_j represents the standard deviation of the values x_{ij} corresponding to the j indicator.

On normalised data (cfr. Tab. 3), the mathematical model proposed in the preceding paragraph is implemented.

The problem is faced by considering the projects to be selected how binary variables {0,1}, according to whether the i-*th* project is included (value 1) or not (value 0) in the investment programme.

In algebraic notation, the mathematical model of the problem in question is expressed as follows:

$$\begin{cases} \mathbf{max} \sum_{i} (\text{ IRR}_i + \text{N° OF PERMANENT WORKERS}_i + (\text{- SOIL CONSUMPTION})_i + \text{ EMISSIONS}_i + \text{RECOVERY }_i)^* x_i \\ \sum_{i} C_i * x_i \leq \text{ BUDGET} \\ x_i \in \{ 0,1 \} \ (i=1,\dots,n) \end{cases}$$

in which the objective function and the constraint regarding the available capital allocation appear.

In the AMPL programming environment, the *.dat* file (Tab. 3), that reports the multi-criteria analysis data performed for each of the 30 projects in Tab. 2, is associated the *.mod* file in Tab. 1.

.DAT FILE

```
set PROJECTS: = 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30;
set INDICATORS: = TIR NOOC LANDUSE CO2 REC.;
param INDICATORS_unit: =                                                param COST: =

      IRR    N° PERM. WORKERS   SOIL CONS.   CO2     REC.

  1   0.780        0.05           -0.94      -0.92   -0.46                    1   1120
  2   0.464        0.24            0.21       0.65   -1.15                    2   1500
  3   0.872        0.82            0.04      -0.72    0.92                    3   9350
  4   0.485        0.92           -0.98      -7.50    1.36                    4   6380
  5   0.612        0.24           -0.94       0.26    0.92                    5   8900
  6   0.502        0.05            0.79       1.05   -0.46                    6   9780
  7   0.918       -1.69           -0.94      -1.11    0.92                    7   1500
  8   1.090        0.24           -0.13      -0.92   -1.15                    8   1850
  9   1.160        1.21            1.02       0.65    0.23                    9   9230
 10   1.080        0.82            0.44       0.26    0.92                   10   6100
 11   0.890       -1.69           -0.94      -0.52   -1.85                   11   1012
 12   1.064       -1.69            0.21      -0.13   -0.46                   12   2000
 13   0.437       -0.91           -0.02       1.44   -1.15                   13   8800
 14   0.498       -1.11           -0.94      -0.72    0.92                   14   7000
 15   0.718        0.44            1.24       0.26    0.23                   15   10140
 16   1.089        1.40           -0.13       0.65    0.92                   16   1300
 17   1.099        0.44           -0.91      -0.13    0.23                   17   1405
 18   1.162        1.79            0.80      -1.90    0.92                   18   4200
 19   0.801        0.05            1.13       1.24   -0.46                   19   10405
 20   0.978        0.82            1.25       1.44    0.92                   20   7154
 21   0.722       -1.69           -1.94      -1.31    0.92                   21   1250
 22   0.434       -1.69            1.94       0.07   -1.85                   22   12000
 23   0.807        0.05           -0.94       0.85   -0.46                   23   1000
 24   0.672        0.05           -0.02       0.46    0.92                   24   2700
 25   1.020        0.63            1.02      -1.50    0.92                   25   2800
 26   0.560        0.44            1.36       0.07   -1.15                   26   6180
 27   0.862        0.05           -0.48      -1.70    0.92                   27   5210
 28   1.091        1.21           -0.71       1.44   -1.15                   28   3215
 29   0.577       -1.30           -0.83       1.64   -1.85                   29   3897
 30   0.988        0.82            1.24       0.26    0.92;                  30   8900 ;
param  BUDGET:= 33500 ;
```

Tab. 3 - *.dat file written in AMPL*

At this point the *.mod* and *.dat* files are entered into the AMPL command line, specifying the solver that implements the Branch & Bound algorithm:

```
ampl: reset;
ampl:.mod model FILE;
ampl: .dat data FILE;
ampl: option solver cplex/gurobi/lpsolve;
ampl: solve.
```

The optimal combination is made up of the projects:

1 - 2 - 7 - 8 - 11 - 12 - 16 - 17 - 18 - 20 - 21 - 23 - 24 - 26 - 28 - 29

The corresponding objective function value is 45.95 and the total cost of investment is 33.329 thousands of Euro. The available budget of 33.500 thousands of Euro is almost entirely used.

Having chosen a pre-conceived approach to solve multi-objective problems, in which the decision-maker has the possibility to choose the nearest solution to its decision-making policies, with an ε-*constrained* type algorithm, a further constraint can be imposed to the problem:

$$\text{objective}_{i} <= \text{objective}_{(i-1)} - \varepsilon$$

so as to extrapolate, with ε = 1‰, the list of the best combinations of projects. The Tab. 4 shows the first ten combinations, each of which has the objective function value and the investment cost.

	PROJECTS COMBINATION	OBJECTIVE FUNCTION	COSTS (in thousands of €)
1	1-2-7-8-11-12-16-17-18-21-23-24-26-28-29	45.95	33.329
2	1-2-7-8-11-12-16-17-20-21-24-28-29	45.80	33.053
3	1-2-7-8-11-12-13-16-17-18-21-23-28-29	45.73	33.249
4	1-2-7-8-10-11-12-16-17-18-21-23-24-28-29	45.65	33.249
5	1-2-7-8-11-12-16-17-18-21-23-25-26-28-29	45.43	33.429
6	1-2-7-11-12-16-17-18-20-21-23-24-28-29	45.38	32.453
7	1-2-7-8-11-12-16-17-18-20-23-25-28-29	45.28	33.153
8	1-2-7-11-12-13-16-17-18-23-24-28-29	45.20	32.849
9	1-2-7-8-10-11-12-16-17-18-21-23-25-28-29	45.13	33.349
10	1-2-7-8-11-12-16-17-18-23-24-26-28-29	44.96	32.079

Tab. 4 - *Results of the model. List of the best combinations of projects according to multi-criterial valuation*

It is possible to note that the objective function value doesn't change interrogating the different solvers in AMPL (CPLEX, GUROBI, LPSOLVE).

The analysis so far conducted assumes that all evaluation criteria have same importance. It is also possible to assign different weight to various indicators. If $p_1, \dots, p_5$ are the coefficients able to "weigh" the five indicators among them, therefore the objective function becomes:

$$\max \sum_{i} (p1{*}IRRi + p2{*}N° \text{ PERM. WORKERS } i + p3{*}(- \text{SOIL CONS.})i + p4{*} \text{ EMISSIONS } i + p5{*}RECOVERYi) {*}xi$$

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7. Conclusions

The proposed econometric model makes it possible to obtain the optimal combination of projects for urban renewal with a view to achieving the sustainable development of the territory.

The model lends itself to the construction of investment plans on behalf of both types of decision-makers, of both a public and a private nature, without the two situations undergoing significant changes in both the structure and as regards the implementation methods of the mathematical system. All projects are evaluated according to multi-criteria logics, so that it is possible to find compromise solutions, in accordance with the stakeholders different preferences.

The AMPL mathematical programming environment makes it possible to write the evaluation model in a simple form which is easy to understand, to which data deriving from multi-criteria analysis must then be associated. The objective function and the constraint conditions are expressed in terms of Discrete Linear Programming.

The case study that concerns the selection of investment projects for the sustainable urban renewal of a vast area in the province of Salerno (Italy), shows the effectiveness and the simplicity of the implementation of the analysis scheme necessary for the definition of the optimal combination of initiatives able to maximise the value of the objective function, while complying with the available budget. In fact, the inclusion of data is rapid and the interpretation of the logic of processing is immediate by virtue of the maximisation algorithm that is implemented.

Not only strictly financial indicators (Internal Rate of Return of the project) are taken into account, but also social (number of employees NO. OC), environmental (soil consumption and CO_2 emissions into the atmosphere) and cultural (the capacity of the investment to determine the recovery of property of historical and architectural value) factors.

If a political decision had to determine different combinations of projects, the calculation model would notice the “distance” measured as a difference among the values of the return function for every combination and the optimal solution. Indeed, the results of the economic analysis provide important elements for the decisions. But these elements are not intended to replace political considerations which have to lead the resources allocation processes.

The introduction of p_j coefficients in the function to be maximized is in response to the decision-making demand for one or more evaluation criteria to be given more importance.

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