Integrating Financial Analysis and Decision Theory for the Evaluation of Alternative Reuse Scenarios of Historical Buildings

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Abstract. The expected utility theory assumes that the advantage of an agent under conditions of uncertainty can be calculated as a weighted average of the utilities in each state as possible, by using as weights the likelihood of the occurrence of individual states.

The expected utility is thus an expected value (according to the terminology of the theory of probability). In order to determine the utility according to this method, it is supposed that the decision maker is be able to order their preferences with regard to the consequences of different decisions.

The experiment described in the paper shows that different actors of a decision process tend "to move" the Centre of gravity of the decision to their preference. Arrow's theorem taught that there is no unanimity.

The starting point of the case of study is an analysis of the probability for different way of use of a Heritage property, related to tourism and leisure activities: Catering, Conferences and hosteling. The different actors have different preferences on each one of the three activities. Their vision partially contrasts with the likelihood of generating income through the activities. Each activity can create income as a function of use of the Fabric (for one use or for the other). The coexistence of the three forces of the combined use has a limitation, so some use combinations generate more income than others, according to a probability curve.

Each actor will attempt to shift the business mix toward equilibrium that appreciates most. Whereas, as an element of interpretation of the behavior of multi-actor, Kannehman's approach consider that each subject will see the advantage linked to a different combination from that with most likely utility; the different combination is affected by the expectations of actors, and described by the "perspective theory".

Keywords: Expected utility · Perspective theory · Reuse of buildings · Business plan · AHP

1 Introduction

The expected utility theory states that the convenience of a given event depends on its probability of occurrence, under the assumptions of completeness, transitivity, independence and continuity [1, 2].

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The expected utility is thus an expected value according to the terminology of the probability theory. In order to determine the utility according to this method, the decision maker must be able to order his preferences with regard to the impacts of different decisions.

However, in a multi-actor decision-making context the perceived utility of a given event and its realistic chance of occurrence are not always related since different actors can show different expectations and visions about the event itself.

In such decision context, [3, 4] rationality suggest that the perceived utility of all the actors playing a role in the decision process should be assessed. The prospect theory [5] describes different behaviors when social actors choose between probabilistic alternatives that involve a risk under uncertain conditions. The prospect theory states that people make decisions on the basis of individual losses and gains, rather than on the probabilistic outcome. Since each social actor has different expectations and values, his own perceived utility differs from those of other actors.

In this sense, each actor assumes a specific reference point when defining the value function of a set of events. This differs from expected utility theory, in which a hypothetical completely rational agent is indifferent to the reference point. The application of the prospect theory returns a correction of the expected value through subjective valuations of the relative importance of alternative events. When dealing with evaluation of possible reuse scenarios for cultural heritage and historical buildings [6–8], a number of actors can show different expectations with regard to reuse alternatives [9]. In this paper we propose an integrated approach, combining financial analysis and multi-criteria with Analytic Hierarchy process [10, 11] and a multi-group analysis based on coalition formation as decision tools in order to compare the Net Present Value (NPV) deriving from an activity of refurbishment and reuse of an historic building, when the NPV is firstly, calculated by the use of a probabilistic approach, and secondly by the reference of the expected utility of the outcomes for the individual decision makers.

2 Case of Study

2.1 The Context

We apply the methodology to the analysis of reuse scenario for an historic monastery in a village in Southern Italy.

Instead of associating to each variable of the NPV the probability that it will occur in maximum, medium or minimum extent, we will join the significant weight of the acceptability assigned by each decision maker to them. This phase represents the shift from the likelihood of utility to the perspective of utility.

At the end we will represent the Decision framework showing the “distances” among the different expectation of the actors.

Serino is a village about 10 km from Avellino and 30 km from the Salerno in Campania Region, Southern Italy. The St. Francis Monastery in Serino is a monument with significant architectural and artistic value: its cloister is decorated with frescoes by Ricciardi in 1700. Today the monastery is in a state of abandonment. In Serino other architectural and cultural assets are existing: the seventeenth-century Hermitage of San Gaetano, the Medieval Castle, the sixteenth-century Monastery of St. Lucia and some Roman archaeological sites. The monastery should host new functions and activities:

- hosteling for visitors of the area of Mount Terminio, pilgrims of the Montevergine Shrine and person belonging to the staff of the University of Fisciano, as well as casual visitors;
- rent for religious ceremonies and conferences with banquet opportunity (Fig. 1).

Fig. 1. The convent of san francis in serino

2.2 Calculation of Likelihood Function of NPV

The most significant uncertainties relate to the occupancy forecasts of the building facilities and the likelihood to find funding for the restoration work.

After the phase of fund raising a Cost-Revenue Analysis has been carried out.

The financial analysis of the reuse alternatives for the St. Francis Monastery is needed in order to verify the economic sustainability of the restoration.

The framework of these uncertainties is made more evident through the financial analysis that describes the variability of the Net Present Value (NPV) of the monastery after the restoration as a function of some key variables, namely:

- the amount of public funding for the restoration work, in order to reduce restoration costs (variable X1);
- the average annual occupancy rate of accommodation facilities (Y1), the number of conferences per year (Y2) and the number of religious ceremonies (Y3).

The NPV is calculated as the sum of each yearly difference between revenues and costs actualized at the present time:

$$NPV = \sum_{i=1}^{10} \frac{\mathrm{R}_i(\mathrm{Y1}, \mathrm{Y2}, \mathrm{Y3}) - \mathrm{C}}{(1+r)^i}$$

The average occupancy of accommodation facilities in the area varies between 50 % and 65 % of the total annual number of beds per night offered.

For the monastery, it is that the average level of occupancy is achieved in the next 10 years from the restoration.

Therefore in the formula of Fig. 2, the difference R-C is depending by Y1, Y2, Y3 (if the cofounding is considered also X1 becomes constant).

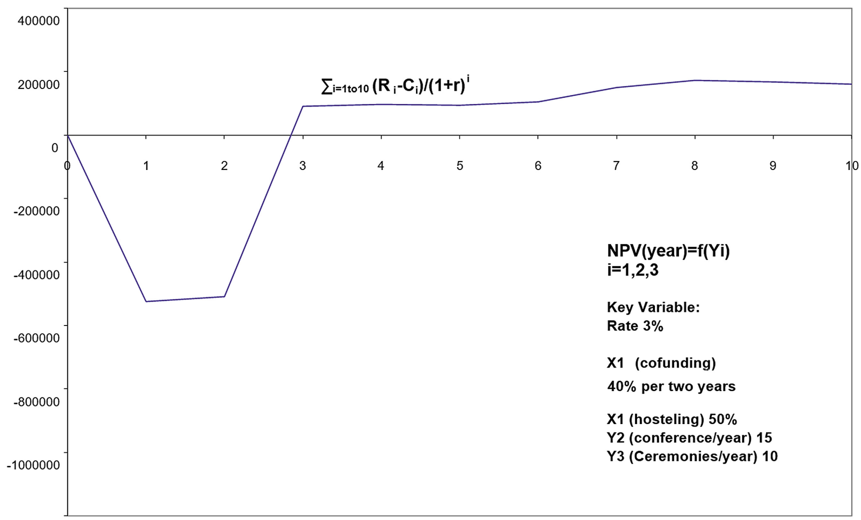

Fig. 2. The average condition of convenience for reusing the Monastery, represented by the rule of variation of the Net Present value in the first ten Year.

The financial analysis shows that the economic sustainability of the restoration is based on a public funding equal to 40 % of the total costs, it is achievable in 10 years (considering an Rate r of 3 %) of activity of the newly introduced facilities and it is based on some fixed values of the variables Y1, Y2, Y3, namely 50 %, 15 and 10. The cost of renewal is assumed as constant.

3 Probabilistic Analysis of the Re-Use Revenue for Determining the Expected Value

The expected value of a prediction is the probability that an event will occur in the mode identified by the same prediction.

In order to determine the probability that an event will occur, it must be known or built a law of frequency distribution (discrete or continuous).

The probability will result from the frequency data related to variable values. If the NPV of the example is then treated according to the key variables X1,Y1,Y2,Y3,, identified the chances PX1*,PY1*,PY2*, PY3* that the variables assume the values X1*, Y1*,Y2*, Y3*, the consequent expected NPV is function of PX1*,PY1*,PY2*, PY3*.

They can then build a set of discontinuous distributions based on permutation, such as those in the Table 1, relative to NPV obtainable in the different hypotheses of reuse, by varying between 50 % and 62 % the intensity of hosteling (variable Y1), between 10 and 20 the number of annual congresses (variable Y2), and between 6 and 14 the number of annual ceremony events (variable Y3).

Permutations generally refer to the three values (intermediate and the two extremes lower or higher). Having the ability to determine the frequency of minimum usage situations, maximum and intermediate structures for the activities (reception, events, ceremonies) in the reference group, they consider the discrete probability distribution corresponding to the detected frequency.

Table 1. The relationship between probability of extremes and average conditions of variables generating the occurrence of profitable activities after the refurbishment

	Hypothesis 1		Hypothesis 2		Hypothesis	
Constant	X1=40% Y2=15, Y3=10		X1=40% Y1=50%, Y3=10		X1=40%, Y1=50%, Y2=15	
Variable	Y1	$\partial \frac{VAN}{\partial Y_1} Y_1$	Y2	$\partial \frac{VAN}{\partial Y_2} Y_2$	Y3	$\partial \frac{VAN}{\partial Y_3} Y_3$
MAX	62,5%	VAN>0	20 conference	VAN>0	15 ceremonies	VAN>0
MED	57,5%	VAN>0	15 conference	VAN>0	10 ceremonies	VAN>0
MIN	50%	VAN>0	10 conference	VAN<0	6 ceremonies	VAN<0

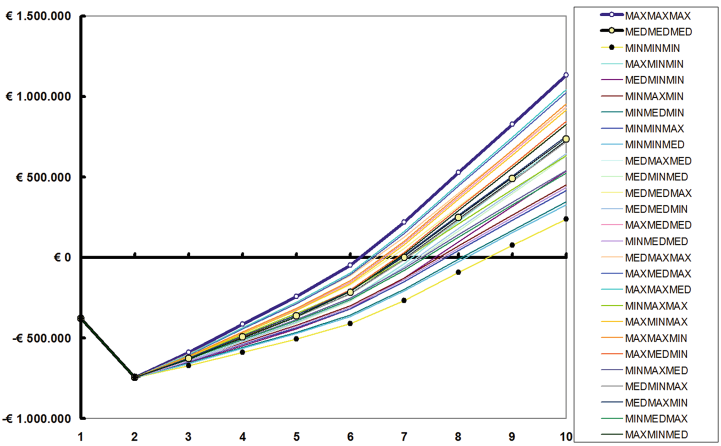

Fig. 3. The range of variation of the NPV in the time interval of 10 years according to the permutations of the revenue (Min Med Max) of each activity (Y1, Y2, Y3) (Color figure online)

In order to improve the financial analysis, we select three different values for each of the variables Y1, Y2, Y3, in order to consider an optimistic (MAX), a pessimistic (MIN) and an intermediate (MED) alternative (see Table 1). We then calculate the NPV for all permutations of the set values of Y1, Y2, Y3, as shown in Fig. 3.

If we associate the composed likelihood of each permutation of the vector (Y1, Y2, Y3) we can calculate the probability function of NPV (Fig. 4).

The graph below shows how the construction of the cumulative probability corresponds to an approximation of the points representing each combination (probability of NPV) due to the permutations of singular probability (represented in the discrete

Permutation of Y_1, Y_2, Y_3	NPV (rate 3%)	Composed probability $P(Y_1) \times P(Y_2) \times P(Y_3)$	$P(Y_1)$	$P(Y_2)$	$P(Y_3)$
MAX-MAX-MAX	1132608	2,37%	28,2%	28,7	29,3%
MAX-MAX-AVER	1043282	3,72%	28,2%	28,7	46,0%
MAX-AVER-MAX	1025417	3,72%	28,2%	45,0%	29,3%
MAX-MAX-MIN	953956	2,00%	28,2%	28,7	24,7%
MAX-AVER-AVER	936091	5,84%	28,2%	45,0%	46,0%
AVER-MAX-MAX	932312	4,08%	48,5%	28,7	29,3%
MAX-MIN-MAX	918226	2,17%	28,2%	26,3%	29,3%
MAX-AVER-MIN	846765	3,64%	48,5%	45,0%	24,7%
MAX-MIN-AVER	828900	3,41%	28,2%	26,3%	46,0%
MED-AVER-MAX	825121	6,39%	48,5%	45,0%	29,3%
AVER-MAX-MIN	753660	3,44%	48,5%	28,7	24,7%
	NPV > 750000	**Prob.=40,78%**			
MAX-MIN-MIN	739574	1,83%	28,2%	26,3%	24,7%
AVER-AVER-AVER	735795	10,04%	48,5%	45,0%	46,0%
AVER-MAX-AVER	735795	6,40%	48,5%	28,7	46,0%
AVER-MIN-MAX	717930	5,87%	48,5%	26,3%	29,3%
MED-AVER-MIN	646469	6,26%	48,5%	45,0%	24,7%
MIN-MAX-MAX	631868	1,96%	23,3%	28,7	29,3%
MED-MIN-AVER	628604	5,87%	48,5%	26,3%	46,0%
MIN-MAX-AVER	542543	3,08%	23,3%	28,7	46,0%
AVER-MIN-MIN	539278	3,15%	48,5%	26,3%	24,7%
MIN-AVER-MAX	524677	3,07%	23,3%	45,0%	29,3%
MIN-MAX-MIN	453217	1,65%	23,3%	28,7	24,7%
MIN-MED-AVER	435351	4,82%	23,3%	45,0%	46,0%
MIN-MIN-MAX	417486	1,80%	23,3%	26,3%	29,3%
MIN-AVER-MIN	346026	2,59%	23,3%	45,0%	24,7%
MIN-MIN-AVER	328160	2,82%	23,3%	26,3%	46,0%
MIN-MIN-MIN	238835	1,51%	23,3%	26,3%	24,7%
	NPV < 750000	**Prob.=59,22%**			

Fig. 4. The likelihood of variation of the NPV according to the permutations of the revenue (Min Aver Max) of each activity (Y1, Y2, Y3)

probability distribution in the chart above) to an area under a limit function (represented in the graph below).

The cumulate probability is more less equal to 40 %, to overpass the average NPV and equal to the 60 % to stay under the average NPV.

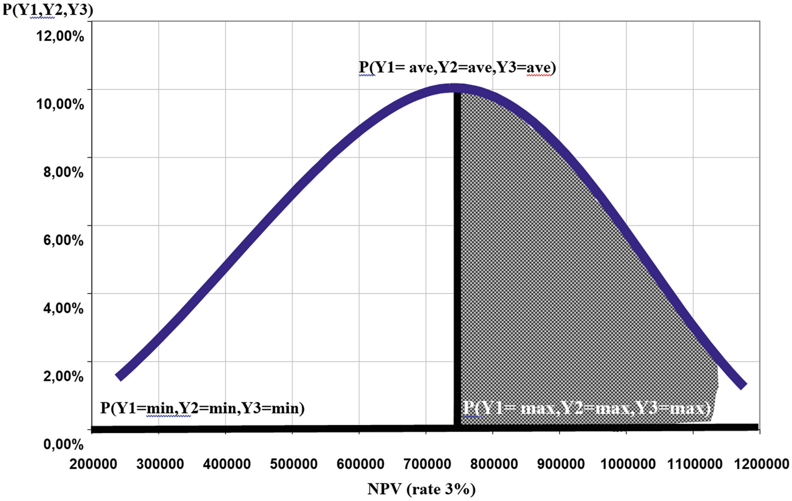

Fig. 5. The composite cumulate likelihood of the average NPV according to the permutations of the revenue (Min Aver Max) of each activity (Y1, Y2, Y3)

4 The Gaming Among DM

When we look at a future event, we can assume that: the probability of manifestation of a given same event is due by a combination of constrains that we can assume "external" respect to the decision problem and respect to the behavior of the actors involved in the decision process.

We will call these actors Decision Makers (DM).

The following DM are involved in the decision process, discriminating their point of view on the reuse of the Convent on the size of the different activities envisaged:

- the Friars, that is the Owners of the Convent,
- the Municipality,
- the County,
- he Ministry's local Delegate for Architectural Heritage and Landscape.

The constrain are the element conditioning the probability of occurring of a given event. Outside the decision problem, constrains will encounter the favor of one or another decision maker in a different way.

The most the constrain occurs in favor of one decision maker, the most this decision maker will see profitable the event. Despite to the expectation of actors, the relationship between constrains and probability is independent by their expectation.

Arrows' Theorem of Impossibility [12] states that there is no unanimous decision in multi actor decision processes. We intend to measure the degree of conflict between the different DM, as a potential cost/obstacle to reach the agreement [13].

It is not true, for example, that all the DM tend to prefer the maximization of net present value, per se, through the maximization of all key variables size. According to the different expectations and different targets some DM may find desirable to strike a balance between economic functions represented by the key variables not pushed to the extreme use of the building [14–16]. In our case the expectation of each actor is described as follows.

The Friars intend to maximize returns (an extreme expectancy for all three key variables).

The Municipal government (assuming a co-management of assets) expresses a greater preference for more stable assets (the key variable to be maximized is then Y1: hosteling business).

The provincial government believes prioritize the activities linked to congresses and cultural events, according to a local promotion policy that aims to reach potential users, mainly from the cultural and academic world. (the key variables to maximize Y2 are: conferences and events).

The Ministry Delegate intends to limit the massive use of the Convent, preferring activities diluted over time that does not involve excessive pressure, favoring the hosteling (the key variable to be maximized is Y1: hosteling business).

For three key variables (business accommodation, activities for conferences and ceremonies), and four decision makers, they will have design assumptions with respect to the minimum, average, and maximum of activities twelve sets of weights. We could consider the relationship between the expectation of DM and the probability of occurring a NPV as a measure of the "distortion" of the expected value given by the study of probability respect to the "desiderata" of DM.

The use of Analytic Hierarchy Process is useful to define the expected value for each actor, but giving a weight to the importance that each dimension of the three activities (hosteling, conferences, ceremonies) assumes for each DM (see example in Fig. 6).

With the use of the Saaty' Method, each decision matrix expresses a qualitative preference defined a combination of the Degree of Acceptability of Option (DAO) referring to a given event compared to another, translated into weights.

You then will have a distribution of weights generating the DAO of each DM for each key variable. For the ieth decision maker (DM) you will have the following Set of Option (SO):

$$\text{SOi} \quad \begin{array}{ccc} \text{UiA (Y1max)} & \text{UiA (Y1med)} & \text{UiA (Y1min)} \\ \text{UiA (Y2max)} & \text{UiA (Y2med)} & \text{UiA (Y2min)} \\ \text{UiA (Y3max)} & \text{UiA (Y3med)} & \text{UiA (Y3min)} \end{array} \qquad (1)$$

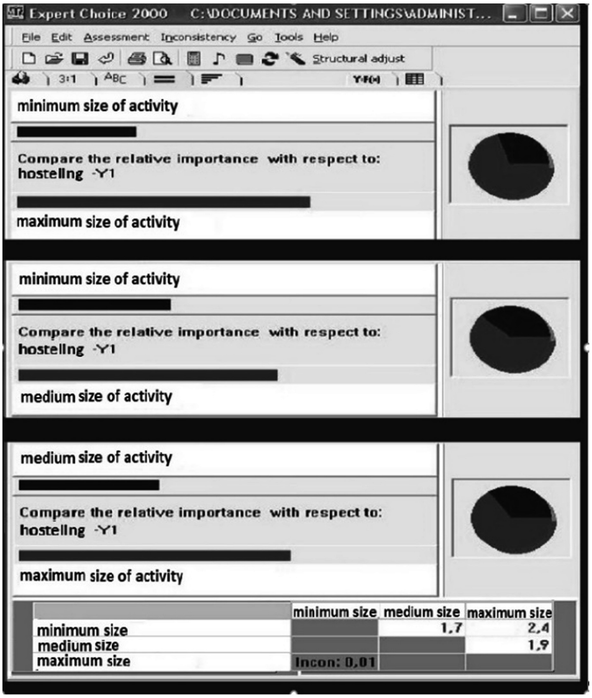

Fig. 6. An example of the application of AHP to identify the ratio among the expectation of Friars in case of maximum, average, and minimum intensity of Hosteling.

The results of the identification, which gives a short description hereinafter, are reported in the expectations as follows in Table 2.

The similitude between the point of view of DM4 (the County) and DM1 (the Friars) in the table, is evident where the high Expected Utility is in the same tern (the first) for both Decision Makers.

As already reminded, it is visible in Table 2 that the DM “Friars” want to maximize each function related to intensity of use. Therefore, the more profitable combination according to the care of Friars is the permutation corresponding to the NPV obtained by the tern (max EU1-maxY2-maxY3), as expressed in the first three row of the Table 2. As already done, is possible to represent the cumulative curve of Expected Utility for Friars, in the same way of the cumulative likelihood. As in Fig. 7 is represented the variation of Expected Utility od DM1 (Friars), and in Fig. 8 the EU function of Friars and in Fig. 9 a comparison between probability and expected utility for the Friars.

Note that we can observe only one table of variation of Probable NPV (such as shown in Fig. 4), while the Expected NPV can be represented for each DM.

Table 2. The DAO (EU) for the SO of each DMi (i = 1,2,34)

Friars (DM_1)	**$EU_1(Y_1max) = 51$ %**	$EU_1(Y_1med) = 30$ %	$EU_1(Y_1min) = 19$ %
	$EU_1(Y_2max) = 49$ %	$EU_1(Y_2med) = 29$ %	$EU_1(Y_2min) = 22$ %
	$EU_1(Y_3max) = 46$ %	$EU_1(Y_3med) = 29$ %	$EU_1(Y_3min) = 24$ %
County (DM_2)	**$EU_2(Y_1max) = 42$ %**	$EU_2(Y_1med) = 30$ %	$EU_2Y_1min) = 28$ %
	$EU_2(Y_2max) = 52$ %	$EU_2(Y_2med) = 30$ %	$EU\ _2Y_2min) = 18$ %
	$EU_2(Y_3max) = 28$ %	$EU_2(Y_3med) = 29$ %	**$EU_2(Y_3min) = 43$ %**
Ministry Delegate (DM_3)	**$EU_3(Y_1max) = 58$ %**	$EU_3(Y_1med) = 25$ %	$EU_3(Y_1min) = 17$ %
	$EU_3(Y_2max) = 21$ %	**$EU_3(Y_2med) = 30$ %**	**$EU_3(Y_2min) = 49$ %**
	$EU_3(Y_3max) = 20$ %	$EU_3(Y_3med) = 29$ %	$EU_3(Y_3min) = 51$ %
County (DM_4)	**$EU_4(Y_1max) = 53$ %**	$EU_4(Y_1med) = 29$ %	$EU_4(Y_1min) = 18$ %
	$EU_4(Y_2max) = 40$ %	$EU_4(Y_2med) = 31$ %	$EU_4(Y_2min) = 29$ %
	$EU_4(Y_3max) = 42$ %	$EU_4(Y_3med) = 31$ %	$EU_4(Y_3min) = 27$ %

5 The Coalition Among DM

5.1 The Intersection Between Expected Utility and Likelihood

Then is the time to create a coalition diagram. A diagram of coalition needs to assess the similarity of points of view, and the probability of solving conflicts among decision makers.

In the case of study the construction of the coalition diagram starts from the following considerations:

- respect to the same financial revenue (represented by a given NPV) each subject feeds a different expectation;
- the average Expected Utility of each DM (corresponding to a wait of 50 % utility) corresponds to different financial advantages (and therefore in net present values) for each DM.

The procedure at this point considers the following steps:

(a) the identification of the "average acceptable NPV", corresponding to the expected 50 % (degree of expectation) on a given decision maker (in our case the promoter of the intervention, that is, DM1 "Friars").
(b) the identification of the "average acceptable" NPV, corresponding to an expected utility of 50 % of the other decision makers
(c) identification of expected utilities by the other DMs corresponding the "average acceptable" NPV by the DM1.
(d) Comparison of the results with the construction of a "coalition diagram", in which the determinations of NPV shows

The coalition diagram represented in a Cartesian Plane, the distance between the point of view of different DM; on the vertical axes is represented the EU of each DM, and on the Horizontal axis is represented the NPV having the average of EU.

Value of partial EU Y_1, Y_2, Y_3	rate 3%	Expected Utility $U_A(Y_1)$ x $U_A(Y_2)$ x $U_A(Y_3)$	EU_1 (Y_1,)	EU_1 (Y_2)	EU_1 (Y_3)
MAXMAXMAX	1132608	11,50%	51%	49%	46%
MAXMAXMED	1043282	7,32%	51%	49%	29,3%
MAXMEDMAX	1025417	6,80%	51%	29%	46%
MAXMAXMIN	953956	6,17%	51%	49%	24,7%
MAXMEDMED	936091	4,33%	51%	29%	29,3%
MEDMAXMAX	932312	6,76%	30%	49%	46%
MAXMINMAX	918226	5,16%	51%	22%	46%
MAXMEDMIN	846765	7,25%	30%	29%	24,7%
MAXMINMED	828900	3,29%	51%	22%	29,3%
MEDMEDMAX	825121	4,00%	30%	29%	46%
MEDMAXMIN	753660	3,63%	30%	49%	24,7%
	VAN > 750000	**EU=66,21%**			
MAXMINMIN	739574	2,77%	51%	22%	24,7%
MEDMEDMED	735795	2,55%	30%	29%	29,3%
MEDMAXMED	735795	4,31%	30%	49%	29,3%
MEDMINMAX	717930	1,93%	30%	22%	46%
MEDMEDMIN	646469	4,26%	30%	29%	24,7%
MINMAXMAX	631868	4,28%	19%	49%	46%
MEDMINMED	628604	1,93%	30%	22%	29,3%
MINMAXMED	542543	2,73%	19%	49%	29,3%
MEDMINMIN	539278	1,63%	30%	22%	24,7%
MINMEDMAX	524677	2,53%	19%	29%	46%
MINMAXMIN	453217	2,30%	19%	49%	24,7%
MINMEDMED	435351	1,61%	19%	29%	29,3%
MINMINMAX	417486	1,92%	19%	22%	46%
MINMEDMIN	346026	1,36%	19%	29%	24,7%
MINMINMED	328160	1,22%	19%	22%	29,3%
MINMINMIN	238835	1,03%	19%	22%	24,7%
	VAN < 750000	**EU=33,78%**			

Fig. 7. The likelihood of the expected utility for Friars due to NPV according to the permutations of the expected revenue (Min Med Max) of each activity (Y1, Y2, Y3)

In the diagram in this example (Fig. 10), the points corresponding to the positions of the Ministry Delegate (DM3) and of the County (DM4) are very close, as well as the points corresponding to the positions of the Friars (DM1) and the Municipal Administration (DM2). At a first glance it is visually evident that the diagram shows the presence of two coalitions (DM3 and DM4; DM1 and DM2).

A first rough interpretation could attribute a more similarity to local actors on one hand, and super-territorial actors on the other side.

It is clear that in the presence of a greater number of actors this representation can be even more significant in presence of an effective “cloud” of point.

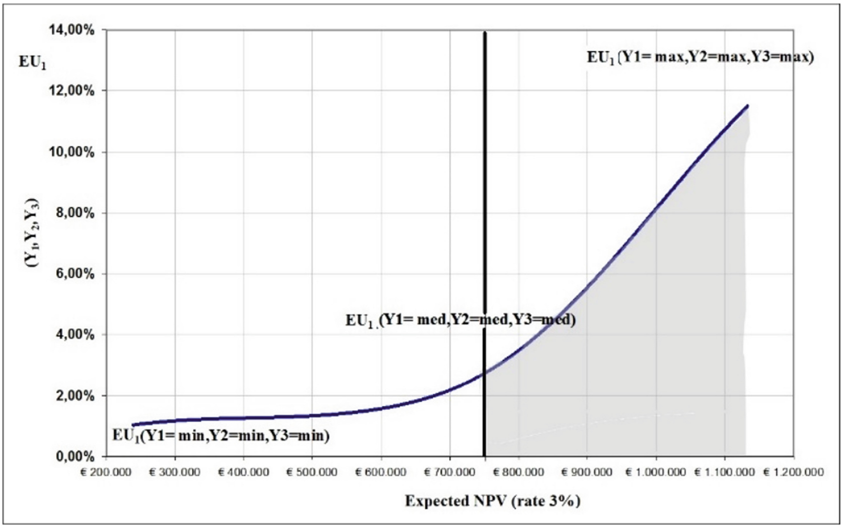

Fig. 8. The composite cumulate Expected utility according to the permutations of the expected revenue (Min Aver Max) of each activity (Y1, Y2, Y3) for DM1 Friars.

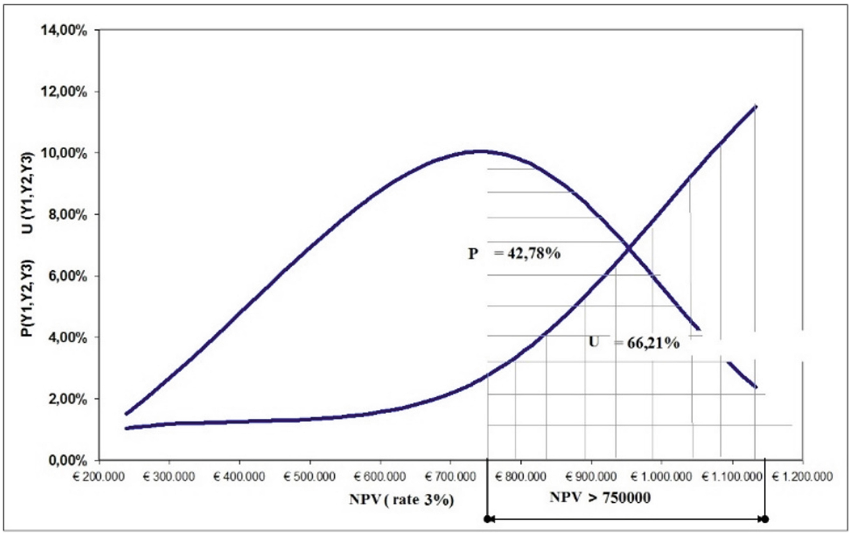

Fig. 9. The intersecton of the composite cumulate Expected Utility for DM1 Friars (in Fig. 8), according to the permutations of the expected revenue for DM1 Friars and the Likelihood curve of NPV (in Fig. 5)

On the one hand it is obvious that the expectations of each subject described here, through the use of the Saaty method, are determined by elements of a different nature, in an index that synthesizes, but implicitly, various elements themselves, such as objectives, conveniences, ethical positions, etc. [16, 17].

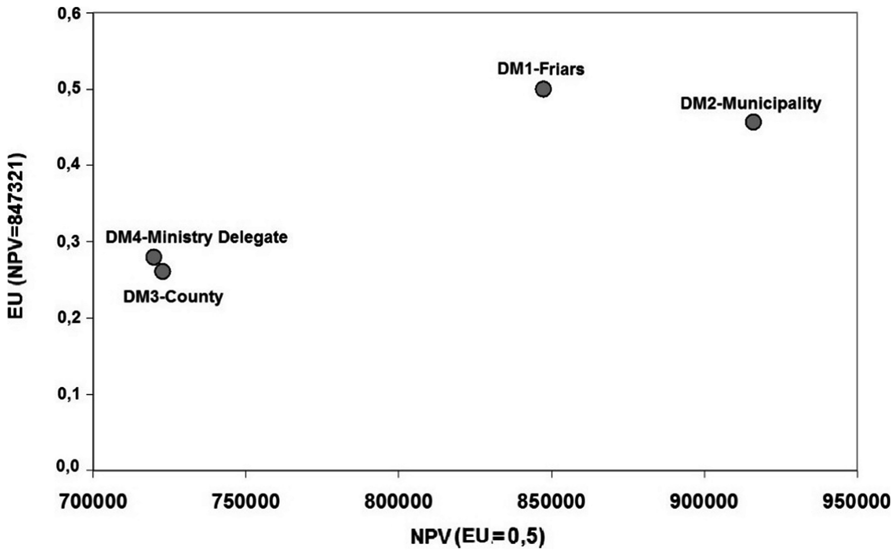

Fig. 10. The Coalition diagram shows a couple of possible alliance among DM1 and DM2 on one side, and among DM3 and DM4 on the other side

It appears that local actors (DM1 and DM2) have a more ambitious point of view, in terms of expected NPV, and in terms of expected utility of the reuse. This is evident when looking at their position on the more far corner of the Diagram

6 Conclusion

The integration of the two indicators, Likelihood and Expected Utility, considered as magnifying glass of NPV analysis in a multiactor process, allows a step forward a strictly financial analysis, by providing a social key of interpretation; furthermore, show the need for which it will be useful to argue with new methodological research and future experiments [14–16].

The expanded financial analysis thus becomes a supporting element to the negotiation stage, passing through a process of integrate assessments, taking into account the exercised influence on the final decision by different actors and the fragmentary nature of positions of DM, showing possible convergences or conflicts of interest on a same result.

The experiment can be ascribed in the family of Decision Making test and Theory, starting from seminal and basic assessment of perception and expectation.

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