APPLICATION OF A FUZZY ROUGHNESS INDEX TO THE ROAD ECONOMIC DECISION MODEL FOR LOW AADT ROADS IN DEVELOPING COUNTRIES.

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ABSTRACT

The Road Economic Decision Model (RED) is an assessment tool created by the World Bank for the analysis of investments on roads subject to low levels of traffic in developing countries. Of the variables used in this model, roughness is among those showing the highest incidence in the determination of a project`s Net Present Value (NPV). The difficulty in defining roughness, a rather qualitative attribute in this type of roads in terms of a precise figure may lead to biased NPV estimates. This paper introduces the application of a fuzzy roughness index based on simple fuzzy math, which enables the translation of a qualitative, first-hand appraisal of a road´s roughness into a quantitative expression, a triangular fuzzy number, increasing thus the amount of information in the model. As a result, the estimation of net present value is also interpreted in terms of fuzzy math. Investment alternatives for a road may be then compared on the basis of the "representation" of each "fuzzy" NPV obtained for the investment alternatives. An analysis conducted on the basis of fuzzy roughness and fuzzy net present values can lead to select an alternative that is discarded with a standard approach.

INTRODUCTION

The Road Economic Decision Model (RED) has been developed by the World Bank for the economic assessment of investment projects on roads handling low volumes of traffic (<200 AADT) (*1*). This program has been developed as a set of excel spreadsheets, and it takes into account the particular features of such roads, i.e. variability of surface conditions over the seasons of the year, uncertainty regarding traffic counts or about the future condition of the road due to the availability of funding for maintenance (*2*). The use of other models, such as the Highway Design and Maintenance Standard (HDM III) or the Highway Development and Management Model (HDM-4), is extremely difficult in a context of scarce information, and above all on unpaved roads whose condition may be highly variable from stretch to stretch.

RED provides an estimation of the net benefits of the different alternatives and presents a set of economic indicators that contribute to the choice of an alternative by the analyst. The spreadsheet conducting the economic evaluation is the most important module of the model, and it is capable of comparing up to three alternatives against the "no project" situation. While HDM uses road deterioration models, RED works on the basis of a level of service that remains constant over the evaluation period, which is adopted by the analyst for each investment alternative. This simplification is justified due to the following reasons:

- Scarce or unreliable information on traffic using a road.
- Difficulty in measuring roughness on unpaved roads.
- Uncertainty on the regularity of maintenance works being carried out.
- Seasonal variability on the condition of the road, mostly related to rainfall seasonality in tropical and subtropical climates.

INACCURACY AND INCREASED INCIDENCE OF ROUGHNESS

As a simplified version of HDM, RED uses many less variables, which brings along the increase sensitivity of results to each of the variables used. Testing for several projects what value should the different variables take to obtain a zero NPV, roughness emerges among the most relevant inputs to RED (*3*).

Simultaneously, information regarding the condition of a road is uncertain, given the difficulty of measurement or lack thereof. By other hand, low traffic roads are in general unpaved roads, which *per se* tend to register higher roughness and small operation speeds.

Road roughness is one of the most important variables of vehicle operating costs. In addition, it is one of the most important elements regarding safety in unpaved roads, along with geometry and suitable sign posting (*4*).

Roughness is usually measured through the International Roughness Index (IRI), defined as the summation of vertical displacements divided by distance (*5*). However, on a low traffic network that is likely to present a considerable high IRI, this indicator is usually not measured but introduced as a qualitative and subjective variable, given the unavailability of funding to perform field surveys and the appropriateness of the application of an instrument to provide a systematic and reliable measurement of this variable (6). Nevertheless, subjective IRI surveys may be conducted (class 4 measurements, *5; 7*), and in this cases IRI depends entirely on the experience and professionalism of the field surveyor as a function of vehicle speed and the defects on the superficial layer of the road. But even for the professional surveyor, an error margin of up to 30% is expectable (2 and 6 m/km) (*5*). Additionally, the subjectivity of users should also be considered, since they are the most frequent evaluators of a road´s condition (*8*).

This paper will therefore propose a mathematical treatment to reduce these problems, considering the inaccuracy related to roughness determination in the NPV estimation.

FUZZY MATH AND FUZZY SETS

Roughness is clearly an attribute variable in a scale with defined extremes according to the International Road Roughness Experiment (*5*). However, in everyday language, references to undefined measures of degree are frequent, among which reference to a road segment being rougher than others should be included. To systematize this scale, Sayers et al introduce two scales for subjective roughness measurements, one for paved and one for unpaved roads.

The nature of Roughness is intrinsically inaccurate, in the same manner the creator of the fuzzy sets explained the basis of his theory:

Clearly, the "class of all real numbers which are much greater than 1", or "the class of beautiful women", or "the class of tall men", do not constitute classes or sets in the usual mathematical sense of these terms. Yet, the fact remains that such imprecisely defined "classes" play an important role in human thinking, particularly in the domains of pattern recognition, communication of information, and abstraction.

The purpose of [fuzzy sets] is to explore in a preliminary way some of the basic properties and implications of a concept which may be of use in dealing with "classes" of the type cited above. ... Essentially, such a framework provides a natural way of dealing with problems in which the source of imprecision is the absence of sharply defined criteria of class membership rather than presence of random variables. […]" (*9*)

The theory of fuzzy mathematics may be applied to the figures obtained from subjective roughness ratings, making it possible to take full-advantage of all the information, without requiring sensitivity analysis. A fuzzy number is a subset of real numbers as it is defined by a membership function (μ), which reflects the degree of "truth" selected by the analyst (*9*) for a certain situation. For example, a fuzzy number for the real number "2" may be defined as (fig. 1):

$$\mu_2(x) = \begin{cases} 0 & \text{if } x < 1 \\ x - 1 & \text{if } 1 \leq x \leq 2 \\ -x + 3 & \text{if } 2 \leq x \leq 3 \\ 0 & \text{if } x > 3 \end{cases} \qquad (1)$$

The theoretical development of the quantitative techniques to manipulate this type of numbers with absolute generality may be found in (*10*).

In our case, and in many practical applications, the use of triangular fuzzy numbers remarkably simplifies the manipulation of data without losing interest in terms of the conclusions for practical purposes. Triangular Fuzzy Numbers have a triangular membership function that includes a real number with membership equal to 1 (fig. 1).

The unitary value for μ is related to the central value of the fuzzy number which is, despite the inaccurate nature if the variable, the most plausible value given by the user. Generalizing, a Triangular Fuzzy Number (TFN) is uniquely determined by three real numbers, such that a1 ≤ a2 ≤ a3, and is represented as A = (a1, a2, a3) (fig. 2).

$$\mu_A(x) = \begin{cases} 0 & \text{if } x < a_1 \\ (x - a_1) / (a_2 - a_1) & \text{if } a_1 \le x \le a_2 \\ (-x + {}_3) / (a_3 - a_2) & \text{if } a_2 \le x \le a_3 \\ 0 & \text{if } x > a_3 \end{cases} \quad (2)$$

Table 1 summarizes the four basic operations with TFNs. Both product and division operations gives as a result a fuzzy number that in practice can be considered as TFN even if it is not. This assumption is based on the fact that vertexes are the same and the central value is practically identical.

DEFINITION OF IRI AS A FUZZY VARIABLE

The advantage of transforming IRI as a TFN lies on the one hand in the simplicity to define its value, closer to the categories of degree used in everyday language. On the other hand, the mathematical fuzzy treatment incorporates a larger amount of information than an accurate figure would (*9*).

To define IRI as a TFN, the scale for class 4 measurements was used (*5*). In this scale the different degrees of roughness correspond to classes around central values with no defined boundaries.

With the assistance of pavement specialists and based on the scale for class 4 measurements, the colloquial language expressions related to the road roughness condition, were associated with the characteristics of the road and with a fuzzy roughness defined as a triangular fuzzy number.

The objectives of this approach were to build a methodology compatible with the criteria already in use and to minimize the so-called issue of "subjectivity" of membership functions of fuzzy numbers.

Table 2 presents the adaptation of the standard roughness scale to a fuzzy treatment. Figure 3 pictures the TFN scale thus built.

NET PRESENT VALUE AS A "FUZZY" NUMBER

The basis for investment choice in economic analysis, and in particular in the application of the RED model, is the NPV estimate. This indicator is particularly applicable for the decision criteria between alternatives such as those mentioned at the beginning, of the same technological nature. A number of criteria for the systematic comparison of NPV values have been formulated, such as Wald`s pessimistic criteria, Hurwickz`s optimistic criteria, Laplace`s rational criteria or Savage`s criteria. All are aimed at reducing uncertainty, defined as the impossibility to anticipate if a number of conditions will take place. For example, it may be uncertain if maintenance routines will be effectively carried out. A clear definition of uncertainty is presented to enhance once more the particularity of the issue dealt with in this article: the intrinsic inaccurate nature of a variable. Leaving the question of uncertainty aside, this section addresses the implications of the adoption of a fuzzy IRI on NPV estimates.

As a result of the application of a fuzzy IRI, a "fuzzy" NPV is obtained as a range of possible values. Note that this it is not a TFN, since it comes from a set of figures obtained dividing fuzzy numbers. However, taking into account the previous assumption regarding product and division operations with fuzzy numbers (Table 1), the fuzzy NPV   may be taken as a TFN.

In order to calculate the fuzzy VPN of the different alternatives the standard VPN formula is needed.

$$VPN = -A + \sum_{j=1}^{n} \frac{Q_j}{(1+i)^j} \qquad (3)$$

A = Initial Investment
n = Evaluation Period (years)
Q = Economic Benefits per year
i = Discount Rate

As in this case the cash flow is a TFN the operations mentioned in Table 1 should be used.

If “fuzzy” NPVs are considered, the “associated value” or “representation” of the corresponding TFNs may be compared in order to select the best alternative. Figure 4 shows two “triangular” NPVs. B`s vertexes are displaced to the right of A`s vertexes, so choice for B requires no further analysis.

Figure 5 pictures the case where the respective “representation” of both “fuzzy” NPVs must be obtained to make a choice.

Given a TFN A= (a_1 , a_2 , a_3) , its representation is equal to:

$$a = \frac{a_1 + 2a_2 + a_3}{4} \qquad (4)$$

Using the values in Figure 5:

$$\overline{a} = \frac{(-1) + 2 \text{ x } 1 + 7}{4} = 2{,}667 \qquad (5)$$

$$\overline{b} = \frac{(-2) + 2 \text{ x } 2 + 5}{4} = 1{,}75 \qquad (6)$$

So, comparing TFN A`s representation (5) with TFN B`s (6) it is concluded that A>B, so investment alternative A is chosen. (5) and (6) are not NPV values but figures that allow for a comparison.

INCORPORATION OF FUZZY MATH INTO THE RED MODEL

The use of fuzzy math improves decision-making in project selection, adequately internalizing the defining features of the variables playing in the analysis (*9*). With this purpose, RED was downloaded from the World Bank`s website (*1*) and thoroughly searched to identify the links between roughness and each investment alternative´s NPV. The model was reprogrammed to introduce the fuzzy definition of IRI and estimate “fuzzy” NPVs.

Two new spreadsheets were added to the model to avoid making any changes in the original version. The first, labeled “roughness setting”, allows to define in fuzzy terms a road´s current roughness and that corresponding to the evaluated alternatives (fig. 6). The second additional spreadsheet presents a summary of the fuzzy assessment, identifying the alternative yielding the highest “fuzzy” NPV (fig. 7).

To apply the fuzzy version of RED the following steps must be followed:

1) Define the variables considered as inputs to the model in the respective spreadsheets, as in the original version of the model.

2) Open “roughness setting” spreadsheet (fig. 6).
3) Introduce roughness in fuzzy terms for each of the investment alternatives and the “no project” situation.
4) Click on the “PROCESS DATA” key.
5) Click on “RESULTS”, which gives access to a summary sheet (fig. 7). The fuzzy NPVs for each alternative are shown and plotted as TFNs. The highest NPV alternative is shown in a separate box.
6) Click on “BACK TO ROUGHNESS SETTING” to go back, or click on “SAVE AND EXIT” to finish.

It is important to mention that based on the information analyzed, this is the first paper which tries to apply fuzzy logic to the RED. That´s why it doesn´t include any references of previous papers about this subject.

CASE STUDIES

Once developed the fuzzy approach this new methodology was applied to ten case studies in order to compare the results with those obtained by standard analysis.

These case studies correspond to ten low-AADT roads in the province of Formosa, Argentina (Table 3). For each road three different alternatives of investment were analyzed (pavement, gravel or only basic works), plus the situation without project.

According to both methodologies the roughness associated with each surface was defined (Table 4). In the standard analysis estimate values of IRI were used to define the roughness, while with the fuzzy approach colloquial expressions were used.

Once it was defined the roughness and all the features of each of the ten roads, results were obtained. Table 5 shows the alternative selected with each analysis in each case.

The results shows that in 30% of the cases analyzed, the alternative selected with the fuzzy approach was different to the one selected with the standard analysis. This proves that a fuzzy analysis can lead to select a different alternative that the one selected based on the original model. This change on the decision is a consequence of defining roughness as a fuzzy variable because it provides much more information into the analysis.

CONCLUSION

An adjusted version of IRI was applied to the RED economic decision model. Simple fuzzy math enables a better quantitative treatment of an intrinsically inaccurate variable. This, in turn, implies an approach of quantitative analysis to common language used by officials conducting field surveys and designing investments and maintenance procedures on low AADT roads.

A test with ten case studies proved that in the selection of an investment alternative the fuzzy approach may lead to different and more informed conclusions than those that can be reached through the standard RED model. However, the great value of this approach lies on the fact that it is possible to increase the information considered in the analysis of alternatives with less information and effort compared with the standard model.

Overall, IRI as a fuzzy variable is easier to obtain, and implies an increase of the information introduced in the analysis of alternatives.

FUTURE RESEARCH

After having shared the fuzzy RED model with experts on the subject appeared some changes that could be performed in order to improve it.

The most important of these improvements would be to redefine the membership functions associated with the colloquial language expressions, used to define the road roughness in a fuzzy way. In this regard one possibility would be to use a trapezoidal fuzzy number instead of triangular fuzzy number. This could be done relatively easily but then a fuzzy calculator should be incorporated in the RED model to operate with those new fuzzy numbers.

REFERENCES

1. World Bank. Sub-Saharan Africa Transport Policy Program. Road Economic Decision Model main webpage. http://www4.worldbank.org/afr/ssatp/Resources/HTML/Models/RED_3.2/red32_en.htm accessed 10/26/2007.
2. Archondo Callao, R. *The Roads Economic Decision Model (RED) for the economic evaluation of low volume roads. Software user guide and case studies*. World Bank Technical Paper SSATP No. 78, The World Bank, Washington DC, 2004.
3. Roca, M. *Aplicación de la matemática borrosa a la evaluación de proyectos: el caso del modelo RED*. Thesis, Pontificia Universidad Católica Argentina. Buenos Aires. 2008.
4. Caldwell, R. and E. Wilson. Starting a Safety Improvement Program for Rural Unpaved Roads. *Transportation Research Record: Journal of the Transportation Research Board*, No. 1652, 1999, pp. 126-130
5. Sayers, M.W., T. D Gillespie, and W.D Paterson. *Guidelines for the Conduct and Calibration of Road Roughness Measurements*. World Bank Technical Paper No. 46, The World Bank, Washington DC, 1986.
6. Archondo Callao, R. *Unpaved road´s roughness estimation by subjective evaluation*. World Bank Infrastructure notes Transport No. RT-2, The World Bank, Washington DC, 1999.
7. Namur, E. and Hernán de Solminihac. *Estimation of roughness in unpaved roads and use of this measurement as intervention threshold*. Proceedings of the 88th Annual Meeting of the Transportation Research Board of the National Academy of Science. Washington DC. CD-ROM
8. Loizos, A. A simplified application of fuzzy set theory for the evaluation of pavement roughness. *Road and Transport Research*, Vol. 10, No. 4, 2001, pp. 21-32.
9. Zadeh, L. Fuzzy sets. *Information and control*, Vol. 8, 1965, pp. 338-353.
10. Buckley, J.J. The fuzzy mathematics of finance. *Fuzzy Sets and Systems* Vol. 21, 1987, pp. 257-273.

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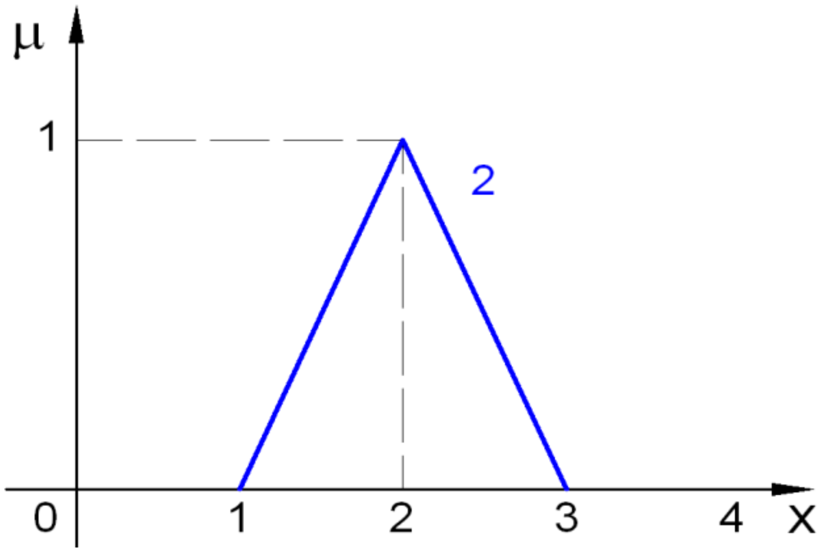

FIGURE 1 Membership function of a triangular fuzzy number (TFN).

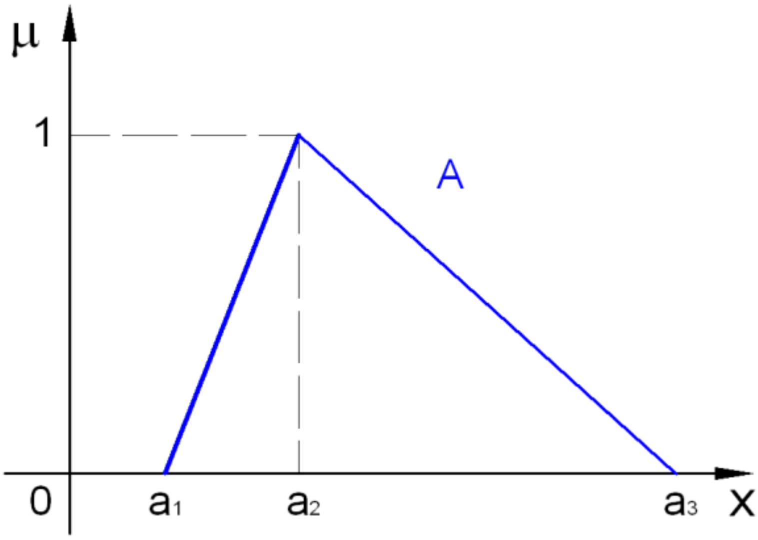

FIGURE 2 Generic membership number of a triangular fuzzy number (TFN).

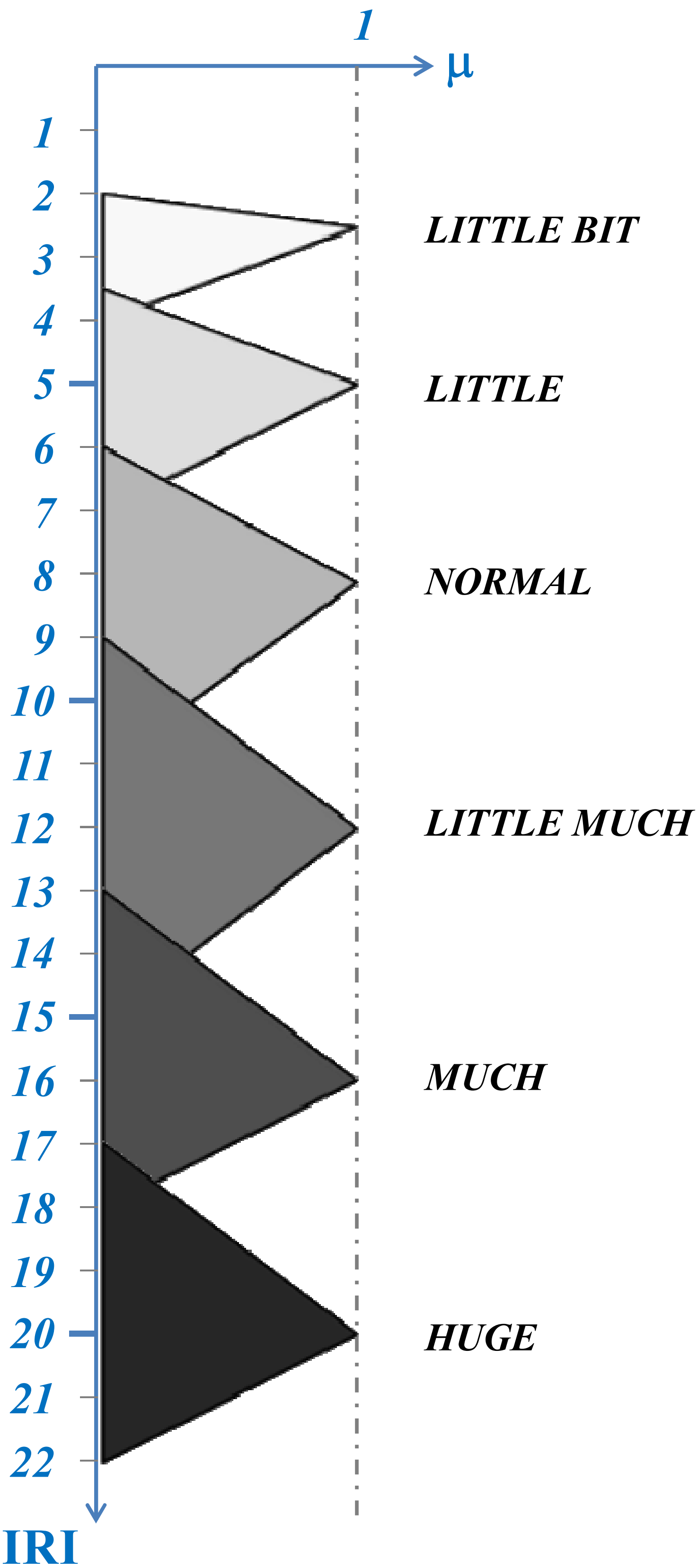

FIGURE 3 Overlapped membership functions for the six roughness levels.

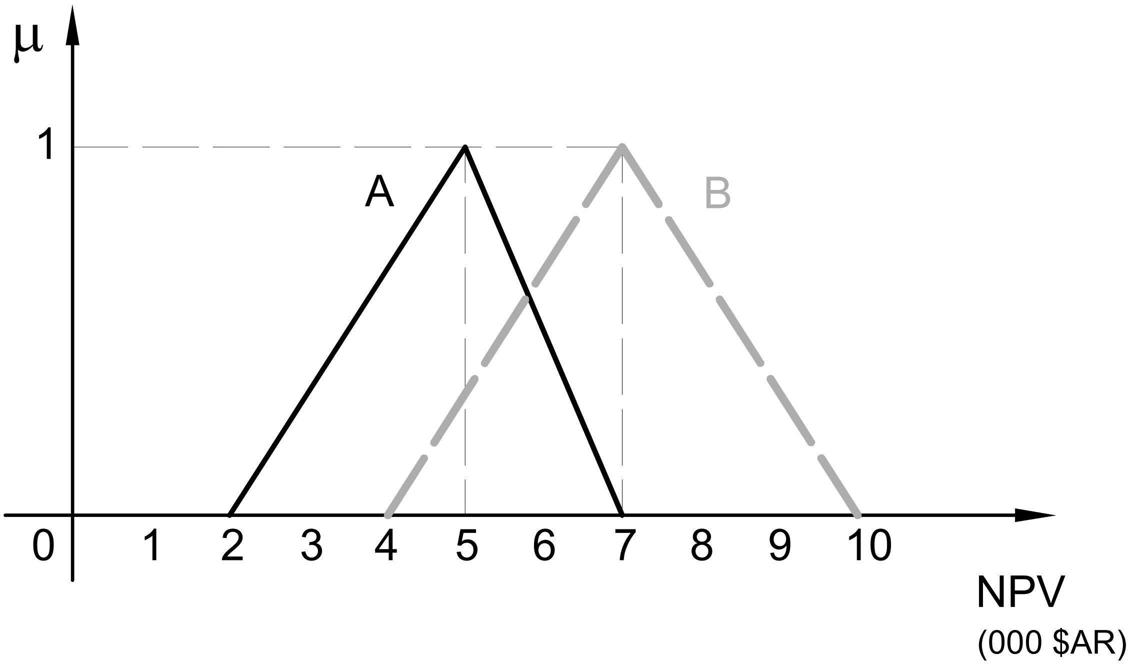

FIGURE 4 Two evidently differing "fuzzy" NPVs.

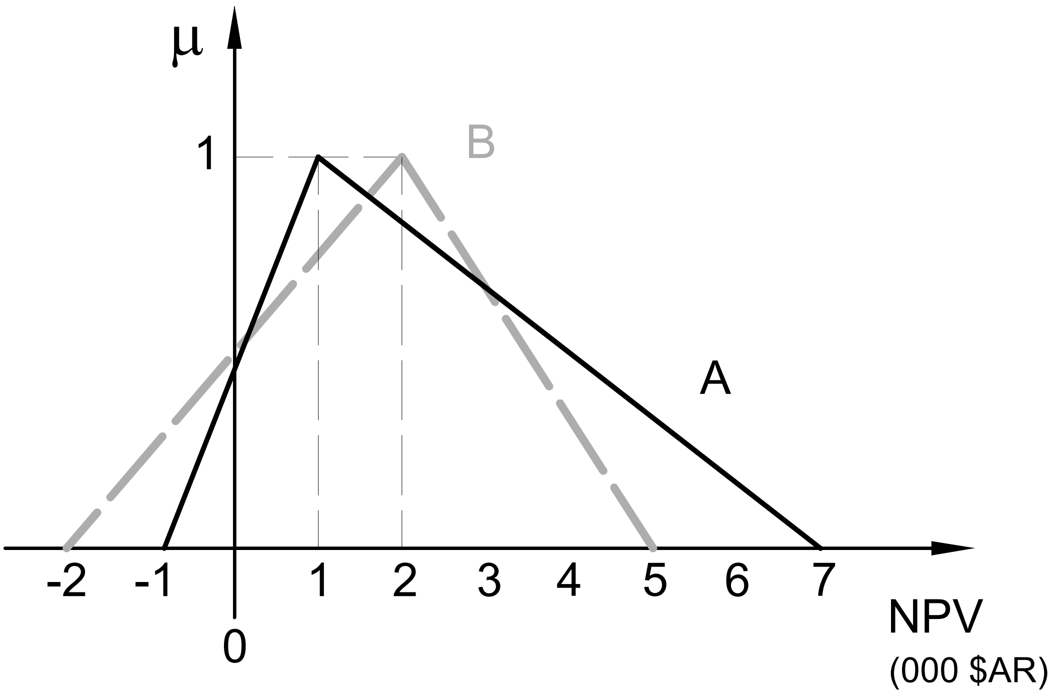

FIGURE 5 Overlapped "fuzzy" NPVs.

Roughness Setting

ROUGHNESS	ALTERNATIVE 0	1	2	3	CHARACTERISTICS OF THE ROAD
LITTLE BIT	○	◉	○	○	Recently bladed surface of fine gravel, or soil surface with excellent longitudinal and transverse profile (usually found only in short lenghts).
LITTLE	○	○	○	○	Ride comfortable up to 80-100 Kph aware of gentle undulations or swaying. Negligible depressions (e.g. < 5mm/3m) and no potholes.
NORMAL	○	○	◉	○	Ride comfortable up to 70-80 Kph but aware of sharp movements and some wheel bounce. Frequent shallow moderate depressions or shallow potholes (e.g. 6-30mm/3m with frequency 5-10 per 50m). Moderate corrugations (e.g. 6-20mm/0,7-1,5m).
LITTLE MUCH	○	○	○	◉	Ride comfortable at 50 Kph (or 40-70 Kph on specific sections). Frequent moderate transverse depressions (e.g. 20-40mm/3,5m at frequency 10-20 per 50m) or occasional deep depressions or potholes (e.g. 40-80mm/3m with frequency less than 5 per 50m). Strong corrugations (e.g. > 20mm/0,7-1,5m).
MUCH	○	○	○	○	Ride comfortable at 30-40 Kph. Frequent deep transverse depressions and/or potholes (e.g. 40-80mm/1-5m at frequency 5-10 per 50m); or occasional very deep depressions (e.g. 80mm/1-5m with frequency less than 5 per 50m) with other shallow depressions. Not possible to avoid all the depressions except the worst.
HUGE	◉	○	○	○	Ride comfortable at 20-30 Kph. Speeds higher than 40-50 Kph would cause extreme discomfort, and possible damage to the car. On a good general profile: frequent deep depressions and/or potholes (e.g. 40-80mm/1-5m at frequency 10-15 per 50m) and occasional very deep depressions (e.g. > 80mm/0,6-2m). On a poor general profile: frequent moderate defects and depressions (e.g. poor earth surface).
UNDEFINED ALTERNATIVE	○	○	○	○	

PROCESS DATA

FIGURE 6 Spreadsheet to enter roughness values.

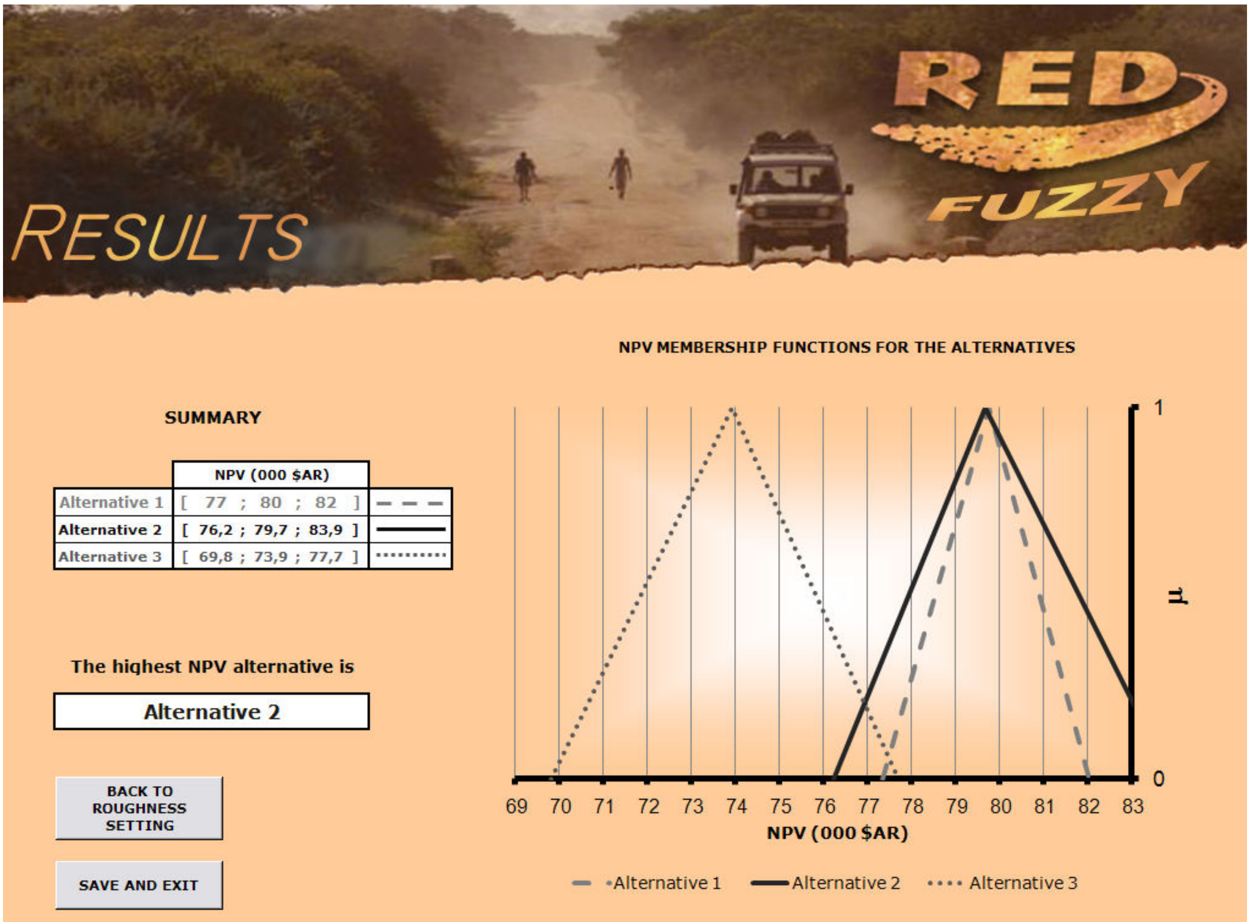

FIGURE 7 Fuzzy results spreadsheet.

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TABLE 1 Operations with TFNs

A		[a_1 ; a_2 ; a_3]
B		[b_1 ; b_2 ; b_3]
SUM	C = A + B	[c_1 ; c_2 ; c_3] = [$a_1 + b_1$; $a_2 + b_2$; $a_3 + b_3$]
SUBSTRACTION	C = A - B	[c_1 ; c_2 ; c_3] = [$a_1 - b_3$; $a_2 - b_2$; $a_3 - b_1$]
PRODUCT	C = A x B	[c_1 ; c_2 ; c_3] = [MIN ($a_1 x b_1$, $a_1 x b_3$, $a_3 x b_1$ y $a_3 x b_3$) ; $a_2 x b_2$; MAX ($a_1 x b_1$, $a_1 x b_3$, $a_3 x b_1$ y $a_3 x b_3$)]
DIVISION	C = A / B	[c_1 ; c_2 ; c_3] = [MIN (a_1/b_1, a_1/b_3, a_3/b_1 y a_3/b_3) ; a_2/b_2 ; MAX (a_1/b_1, a_1/b_3, a_3/b_1 y a_3/b_3)]

TABLE 2 Definition of the roughness as a TFN

ROUGHNESS	DESCRIPTION OF THE ROAD	FUZZY IRI (TFN)
LITTLE BIT	Recently bladed surface of fine gravel or soil surface with excellent longitudinal and transverse profile (usually found only in short lengths).	[2 ; 2,5 ; 4]
LITTLE	Ride comfortable up to 80-100 km/h. aware of gentle undulations or swaying. Negligible depressions (e.g. < 5mm/3m) and no potholes.	[3,5 ; 5 ; 7]
NORMAL	Ride comfortable up to 70-80 km/h but aware of sharp movements and some wheel bounce. Frequent shallow-moderate depressions or shallow potholes (e.g. 6-30mm/3m with frequency 5-10 per 50m). Moderate corrugations (e.g. 6-20mm/0.7-1.5m).	[6 ; 8 ; 11]
LITTLE MUCH	Ride comfortable at 50km/h (or 40-70 km/h on specific sections). Frequent moderate transverse depressions (e.g. 20-40mm/3-5m at frequency 10-20 per 50m) or occasional deep depressions or potholes (e.g. 40-80mm/3m with frequency less than 5 per 50m). Strong corrugations (e.g. > 20mm/0.7-1 Sm).	[9 ; 12 ; 15]
MUCH	Ride comfortable at 30-40 km/h. Frequent deep transverse depressions and/or potholes (e.g. 40-80mm/l-5m at freq. 5-10 per 50m); or occasional very deep depressions (e.g. 80mm/l-5m with frequency less than 5 per 50m) with other shallow depressions. Not possible to avoid all the depressions except the worst.	[13 ; 16 ; 18]
HUGE	Ride comfortable at 20-30 km/h. Speeds higher than 40-50 km/h would cause extreme discomfort and possible damage to the car. On a good general profile: frequent deep depressions and/or potholes (e.g. 40-80mm/ I-5m at frequency 10-1 5 per 50m) and occasional very deep depressions (e.g. > 80mm/0.6-2m). On a poor general profile: frequent moderate defects and depressions (e.g, poor earth surface).	[17 ; 20 ; 22]
Measurement Conversions: (1in = 25,4mm) - (1ft = 0,305m) - (1yd = 0,914m) - (1mi = 1,61km)		

TABLE 3 Characteristics of the projects analyzed

Nº	ROAD Nº	SECTION	LENGTH (KM)	TERRAIN TYPE	SURFACE	STATUS	AADT
1	9	Bañaderos - Las Maravillas	145	FLAT	EARTH	POOR	138
2	28	Km. 642 - Las Lomitas	40	FLAT	EARTH	POOR	105
3	6	Timbo Pora - Tres Lagunas	102	FLAT	EARTH	POOR	161
4	14	R.P. Nº 2 - L. Monte Lindo	50	FLAT	EARTH	POOR	106
5	16	La Esperanza – L. Monte Lindo	72	FLAT	EARTH	POOR	105
6	39	La Florencia - Ing. Juárez	41	FLAT	EARTH	POOR	101
7	23	Bañaderos - Palo Santo	56	FLAT	EARTH	POOR	123
8	23	Gral. Belgrano - Puerto San Carlos	41	FLAT	EARTH	POOR	123
9	39	Ing. Juárez - Pescado Negro	65	FLAT	EARTH	POOR	161
10	39	Pescado Negro – Gral. Mosconi	60	FLAT	EARTH	POOR	161

TABLE 4 Example of the definition of the roughness: Case study 1

ALTERNATIVES		STANDARD ANALYSIS (IRI)	FUZZY APPROACH
Alt. 0	Without Project	22	HUGE
Alt. 1	Pavement	2	LITTLE BIT
Alt. 2	Gravel	7	NORMAL
Alt. 3	Basic Works	10	LITTLE MUCH

TABLE 5 Comparison of RED results: Standard Analysis vs. Fuzzy Approach

PROJECT Nº	ROAD Nº	SECTION LENGTH (KM)	AADT	ALTERNATIVE SELECTED		
				STANDARD ANALYSIS	FUZZY APPROACH	¿CHANGE THE DECISION?
1	9	145	138	EARTH	GRAVEL	**YES**
2	28	40	105	EARTH	EARTH	NO
3	6	102	161	EARTH	GRAVEL	**YES**
4	14	50	106	EARTH	EARTH	NO
5	16	72	105	EARTH	EARTH	NO
6	39	41	101	EARTH	GRAVEL	**YES**
7	23	56	123	GRAVEL	GRAVEL	NO
8	23	41	123	GRAVEL	GRAVEL	NO
9	39	65	161	GRAVEL	GRAVEL	NO
10	39	60	161	GRAVEL	GRAVEL	NO