

### FUZZY MODELING OF RISK IN INVESTMENT ANALYSIS

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With the introduction of Modern Portfolio Theory (MPT) by H. Markowitz [5], risk analysis became a subject of primary importance in investment analysis. Traditionally, MPT seeks asset allocations on an efficient frontier, consisting of portfolios which maximize return for a given degree of risk. Risk in this case is identified with standard deviation of return on the portfolio.

This theoretical approach drew considerable criticism from the circles of practical investors, as identification of standard deviation with risk seems to defy common sense investors. Recent developments in risk analysis in industrial safety and in actuarial sciences seem to converge towards analyzing risk in terms of its simple, elementary factors (such as likelihood, exposure, and consequences in industrial safety [3] and C-1, C-2, C-3 risks in actuarial sciences [1]).

It has been pointed out by Biller and Feagans [2] that risk is in many situations better described as a fuzzy concept, as there may not exist a unique risk that a hazardous event will occur in a given period of time. Furthermore, both technical and fundamental analysis have produced numerous rules of investing which seem to describe risk in a fuzzy, rather than quantitative, way. For example, investors following the low P/E ratio rule consider the P/E ratio of 9 to be low, 12 to be more or less low, 15 - medium, and 20 - high, with the boundaries between low and medium, and medium and high not clearly defined.

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Karwowski and Mital [4] proposed that the likelihood L, exposure E, and consequences C in industrial safety risk analysis be treated as linguistic variables. Derivation of risk scores S, treated also as linguistic variables, was then done through the process of approximate reasoning (in that case Zadeh's maximin rule [6] was followed).

This novel approach was an inspiration in proposing to view investment risk in terms of its elementary factors: L - liquidity risk, E - interest rate risk, and I - inflation risk, all of them viewed as linguistic variables, with primary terms for each of the factors being LOW, MEDIUM, and HIGH (with possible use of linguistic hedges such as VERY, MORE OR LESS, etc).

Following simple technical and fundamental rules of investing (the choice of appropriate rules is flexible, depending on the person designing the expert system, but such flexibility is an essential factor in fuzzy set expert systems design) we assign linguistic values to L, E, and I depending on comparison of current value of a stock index to its moving averages, changes in the discount and prime rates, and comparison of current value of the price of gold to its moving average, respectively.

Explicit approximate reasoning shows then how a change in the interest rate environment from E = MEDIUM to E = HIGH impacts the change from S = MORE OR LESS HIGH to S = HIGH, a warning signal to investors. Similarly, a drop of the current stock price index below its moving average, such as in early October 1987, may produce a change in the risk environment.

It is a common knowledge that human experts in the field of investment analysis are in agreement that rules of investment have an approximate meaning, with time span and price ranges not clearly defined. In view of that, our fuzzy modeling approach seems to offer hope of significant insight into the functioning of the markets.

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