All Sciences Proceedings

1st International Conference on Pioneer and Innovative Studies

June 5-7, 2023 : Konya, Turkey

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Development of A Fuzzy Logic-Based Cost Modeling System for Sugar Industry

Ameer Hamza Khan*, Dr. Muhammad Sajid [2], Rohail Ahmed [3]

[1]Department of Industrial Engineering, University of Engineering and Technology, Taxila, Pakistan
[2]Department of Industrial Engineering, University of Engineering and Technology, Taxila, Pakistan
[2]Department of Industrial Engineering, University of Engineering and Technology, Taxila, Pakistan

*(Ameer.Hamza@students.uettaxila.edu.pk)
[2](sajid.malik@uettaxila.edu.pk)
[3](Rohail.Ahmad@students.uettaxila.edu.pk)

Abstract **–**The objective of the study was to create a fuzzy logic-based cost modelling system for the sugar industry in order to comprehend the impacts of sugar cost determinants on total cost. The designed system takes into account variables such as fluctuating cane prices, cane weight, distribution distances, and crushing cessation. The data is collected from the cost statements of various Pakistani sugar refineries. The primary research objective was to determine the effects of the unpredictability of various cost variables on the ultimate price of sugar. The cost determinants were deemed input variables, while the cost of sugar production was considered an output variable. The cost variables were categorised as follows: cost of basic materials, cost of distribution, cost of labour, cost of operations, factory overheads, and crushing cessation (losses). The Mamdani Fuzzy Inference system was used to analyse the data. To develop the system, 729 fuzzy rules and three levels of fuzzy sets were created. The developed fuzzy logic-based system is able to evaluate the sugar cost structure and take uncertainty factors into account. Consequently, a significant contribution of the developed system is the provision of heuristic principles that facilitate the selection of cost-effective outcomes.

Keywords – Fuzzy Logic, Cost Modeling System, Uncertainties, Fuzzy İnference System (FIS), Heuristic Rules.

I. INTRODUCTION

Considering the modern terrain, characterized by numerous uncertainties, it is essential for both individuals and businesses to make decisions in circumstances marked by uncertainty. In the current rapidly changing environment, businesses can only endure by making reliable and precise decisions. In the current era of intense rivalry, the sugar industry is seeking a cost model that is flexible and can effectively optimize its manufacturing expenses while accounting for potential losses to remain viable in a highly competitive market. This enables the sugar industry to enhance their decision-making process regarding manufacturing expenses and to accurately project their profitability. Improving the performance of physical operations can prove to be a challenging task without a thorough analysis of the manufacturing report generated by our own mill. [1]. To improve profit and optimize manufacturing costs, sugar millers should consider all uncertain costs and ambiguous losses. Manufacturing cost and profit are co-related and interdependent. If the manufacturing costs are high, profits will be low as producing goods will be relatively more expensive and if manufacturing costs are low, profits will be higher as producing goods will be relatively cheaper [2]. Insufficient attention has been given to the methodical cost modelling of incomplete or conflicting information, constraints, and consequences in the context of engineering design and costing within the manufacturing sector. The significance of cost modelling is paramount across various manufacturing sectors. The sugar industry also necessitates the implementation of efficient cost modelling techniques to reduce the expenses associated with the manufacturing process. It is

essential to exercise cost control measures rather than implementing unscientific cost reduction strategies as the latter may compromise the quality of the product. This is achieved through an analysis of the cost drivers that contribute significantly to the expenses encountered during the manufacturing process, as well as an evaluation of the factors that lead to profit reduction and resource wastage. The sugar industry's manufacturing process is characterized by various cost drivers that are essential for plant operation and maintenance. Moreover, it is noteworthy that the incidence of indeterminate losses is considerably elevated within the sugar industry. The sugar factory faces challenges in developing an effective cost control model due to inadequate availability of appropriate applications for managing unpredictable expenses and losses, as noted in reference [3]. The utilization of a fuzzy logic cost model is imperative for businesses to account for uncertainties in costs and losses [4]. Fuzzy logic is regarded as a contemporary paradigm shift in computer logic, which enables computers to emulate logical reasoning like human behavior. The application of fuzzy logic within the manufacturing sector has yielded numerous benefits. Several benefits can be derived from implementing effective manufacturing processes, including time and cost reductions, as well as improved precision in estimating profits and expenses. Fuzzy logic has been devised to address situations with inherent uncertainty that occur often in everyday life, in contrast to classical logic [5]. Simultaneously, fuzzy logic incorporates multiple logics by opposing binary logic on the basis that classical Aristotelian logic is no longer sufficient in contemporary times [6].

A. *Background*

The manufacturing cost of sugar is varying every year. The uncertainty in sugar production is high due to variation in fuel prices, variation in expenses on BMRE (Balancing, Modernization, Rehabilitation and Expansion), variation in sugar cane prices due to competition among sugar mills and uncertain crushing stoppage. It may lead to underestimate or overestimate of product cost. To overcome this limitation, this study presents a fuzzy logic-based cost modeling system for sugar industry. It would assist the industry to estimate the accurate cost under uncertain circumstances.

B. *Objective*

This study includes the following objectives:

- To conduct literature review in the field of cost estimation, cost estimation techniques and cost modeling for sugar industries.
- To conduct industrial field study for data extraction and analysis for cost modeling.
- To develop cost modeling system framework for sugar industry.
- To validate and refine the developed cost modeling system and application.

II. Literature Review

With today's fast technological advancement, the importance of energy was emphasised in studies that used the fuzzy logic technique to the energy industry. The purpose of this study was to use intuitive fuzzy logic and a multi-criteria decision-making approach to the financial performance of eight energy businesses traded on the Borsa Istanbul stock exchange. Eight actual energy providers' data from 2013-2017 were utilised in the study. Companies operating in the energy industry had their results compared [7]. The significance of the idea of internal controls was originally brought up in another study that employs a fuzzy logic approach to the risk assessment process within the context of internal controls. The benefits of using fuzzy logic for dealing with ambiguity were outlined. It was also emphasised that risk assessment makes use of fuzzy logic in many different industries, from engineering to banking. The research looked at how well a fuzzy logic approach works for assessing risks within the framework of internal controls. An overview of the relevant literature is provided first. After that, a sample was compared using both the conventional approach and the fuzzy logic approach. The study used the Mamdani fuzzy logic approach (system) [8]. The need of making money for a company's survival was highlighted in a research on fuzzy logic, as was the need for enterprises to have a strategy for reaching that profit goal. It was clarified that target costing is required for this to work. Concurrently, the importance of using fuzzy logic for estimate inside the target costing process in an unpredictable context was highlighted [9]. Accounting information may be made more trustworthy by adhering to the IFAC (International Federation of Accountants) standards of electronic accounting (e-accounting), as noted in

a research that use fuzzy logic to evaluate the quality of e-accounting principles. Differences between paper-based accounting and its digital counterpart, e-accounting, were the subject of this research. Also highlighted [10] was the need of fuzzy logic instruments in evaluating the state of e-accounting practises in Iraq. Demand for civil aviation, which acquired significance worldwide, has expanded throughout the globe, and the industry has improved in recent years, according to a research that assesses and compares the financial risk levels of airline businesses using the fuzzy logic approach. In addition, the civil aviation industry's competitive framework was outlined. The aforementioned competitive framework necessitates the formation of alliances and partnerships among airlines. Since the 1990s, when low-cost airline firms entered the market, competition in the civil aviation industry has only risen. However, the cost of doing business for airlines has gone up due to the need to fulfil basic safety standards. In light of these findings, it is clear that it is more challenging for airlines to manage financial risks. Fuzzy logic was used to compare the financial risk levels recorded across the financial ratios of the low-cost airlines to those of the three most well-known global airline alliances (Star Alliance, Oneworld, and SkyTeam) [11]. Classical logic, according to a research that used the fuzzy logic approach to analyse a dairy company, did not provide objective conclusions. Fuzzy logic, it was suggested, was also resulting in quicker and more adaptable answers. Therefore, data from a dairy industry was used to inform a fuzzy logic linear programming model. The research followed Werner's methodology [12]. To ensure efficiency in transport operations, it is essential to both reduce costs and improve the financial condition, as indicated in a research that evaluates the impact of transport cost management using the fuzzy logic approach on financial performance. Later, it was clarified that fuzzy logic was only one of several tools used to guarantee the efficiency of transportation operations. The study's major objective was to demonstrate that using fuzzy logic improved transportation efficiency and cut expenses for businesses. Fuzzy logic was shown in the research to allow the same amount of work to be done in less time and at a lower cost, given the same number of transportations and load capabilities of a company [13]. The limitations of conventional approaches were highlighted in a scientific research illustrating the use of fuzzy logic in cost-volume-profit analysis. Current practises provide little value, according to the study, since they do not account for risk and uncertainty. However, a cutting-edge approach is required to evaluate the expertise of profit planning specialists and so enhance the decision-making process. At that stage, fuzzy logic becomes crucial [14]. A research done in Spain looked at whether or not firms that have strong ties to their constituents also have better social and financial outcomes. 52 Spanish firms with shares on the Spanish stock market were studied for this article. Fuzzy logic was used as a research strategy. Consistent with other research, this study discovered a favourable but statistically insignificant link between a company's degree of strategic connectedness to business stakeholders and its social and financial success [15].

III. METHODOLOGY

Research is defined as a way of knowing or understanding [16]. It includes the creation of knowledge, testing of knowledge, and investigation of a problem for decision making. From the literature [17], it has been investigated that research method consists of five components that are considered for conducting the research. It includes the (i) research purpose, (ii) research context, (iii) research questions, (iv) research approaches for data collection and (v) research validation. Figure 1 shows a summary of the chosen research methods adopted by the researcher for the accomplishment of this research work. Research purpose mainly consists of three types, namely (i) explanatory, (ii) exploratory and (iii) descriptive. After analysis of the research aim, objectives, and background, explanatory and exploratory are considered the most suitable types for this study as this study aims to develop the cost modeling system at the initial design stage of product development for the metal casting process. It has not been researched enough or little information exists about it, so exploratory is considered the most critical research purpose at an early stage of research, while in later stages of this study, explanatory research approach becomes applicable. From the point of view of inquiry mode, research approaches are divided into qualitative research and quantitative research [18].

Qualitative research considers an inductive reasoning approach. In this approach, based on an exploratory approach, data is gathered through

interviews, surveys, and observations [19]. Based on data gained, research questions can be modified in qualitative research, so researchers [19] also called it a flexible research design. The main advantages of qualitative research include: (i) it encounters direct with the world, (ii) it allows unique experiences to be considered, and (iii) it studies objects thoroughly. In the qualitative approach, the primary focus is on the collection of knowledge from experimentation or measurements in a deductive way. In this approach, significant data collected is of numerical form, and quantification is the major theme of it. Replication, hypothesis testing, operational definition, and control are the main characteristics of the quantitative approach. The significant advantages of quantitative approach include: (i) it offers power and precision, and (ii) results are replicable and verifiable.

In this study, qualitative research approach has been used. The main reason behind the selection of this research approach is that it can tackle higher number of elements that arise in the data. These elements then can be used as evidence during interpretation of observed changes [20]. Using qualitative research approach, extracted data from observations, interview and field documents are ironic and they yield rich information about the said objects [21]. As this research work includes the understanding of current practices in the cost estimation area, cost modelling system development iteratively and validation through industrial case study and experts' opinion, so qualitative research is considered the most suitable technique for this study.

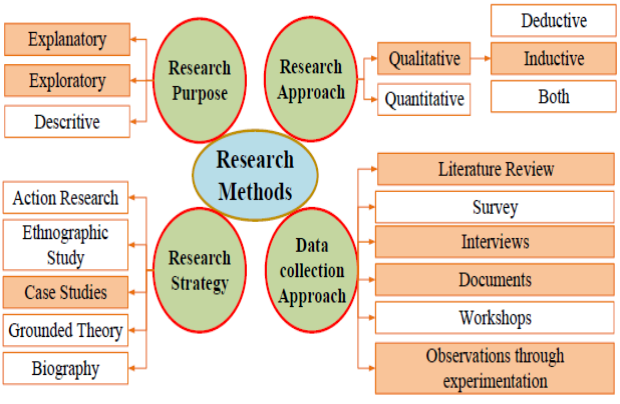

Fig. 1 Methodology

According to [22], five research strategies can be applied in qualitative research family namely, (i) ethnography, (ii) case study, (iii) phenomenology, (iv) grounded theory and (v) biography.

In this research work, the case study research strategy has been considered as the scheme for performing the research. It is selected because it includes an empirical examination of a specific current phenomena within its actual life perspective using numerous bases of evidence [23]. Also, case study is the most suitable strategy for the types of problems where research and theory are at their initial design stage [24].

IV. Results

The "intermediate" cost is estimated using Mamdani's fuzzy inference method, which is an embedded method in MATLAB. Following this phase is a defuzzification procedure that converts the ambiguous values into numeric values representing the total cost. The total number of fuzzy rules required is contingent on the number of inputs for each fuzzy set. The developed model utilises multiple cost drivers that are dependent on user input parameters; therefore, information loss may occur when combining two or more cost drivers to estimate manufacturing costs. To avoid a high degree of inaccuracy in the results, more linguistic indicators were applied to each input category. If the inference engine has n inputs and each has k linguistic values, such as very low, low, medium, high, and very high, then the given inference engine will have kn fuzzy rules. Figure 2 depicts the Mamdani Infernce Engine for sugar manufacturing cost estimation. Raw material cost, distribution cost, operational cost, labour cost, factory overheads, and compression stoppages result in a total of 729 distinct ambiguous rules. The system permits users to select the cost variables and modify the imprecise criteria for estimating the total cost of sugar manufacturing.

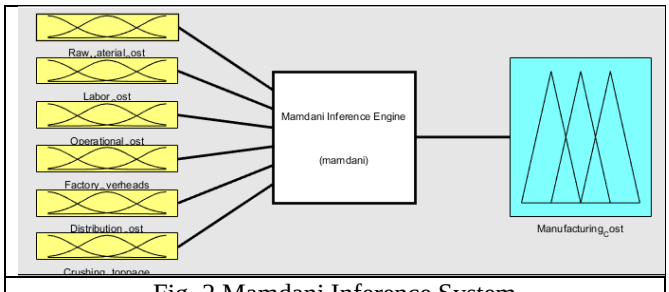

Fig. 2 Mamdani Inference System

Figure 3 illustrates the effect of labour and material costs on output cost. Labour and raw material costs have an effect on output cost, but overlapping ranges of two input parameters result in extreme

cost levels (figure 3, yellow and dark blue). To reduce the output cost of sugar production, initial capital inputs and basic material costs must be minimised. Not surprisingly, the extrema of low and high output cost are only attained when the ranges of raw material cost and labour cost coincide, i.e., output cost only reaches its lowest range when both parameters are at their lowest ranges. The system may use the same charts with different inputs to calculate output cost at various input levels, as well as operational and capital costs for other inference engines. This model's primary objective is to leverage uncertainty factors and determine output cost.

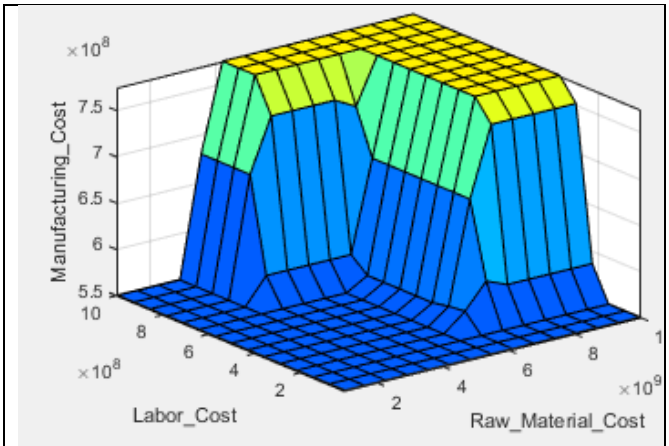

Fig. 3 Output cost level related to Labor Cost and Raw Material Cost

V. Discussion

The proposed framework offers a comprehensive and systematic approach to accurately measuring the costs of sugar manufacturing, while considering the inherent unpredictability of the process. These uncertainty factors associated with the manufacturing process are used as input parameters to a multistage fuzzy inference process. These factors are based on manufacturing cost drivers and operational losses. This model estimates the cost of the manufacturing process based on selected parameters. The input parameters in the developed system are divided into two categories. The first category of input parameters consists of data regarding uncertain costs like Raw Material cost, Distribution cost, and Crushing Stoppages. The second category of input parameters consists of Labor cost, Operational cost, and Factory overheads. These parameters are converted to fuzzy sets and are processed in fuzzy inference engine represented in Figure 1. It is important to note that the inference system is multistage: first-stage inputs for intermediate inference engines are 1) Raw Material cost, 2) Distribution cost, 3) Crushing Stoppage. Whereas 4) Operational cost, 5) Labor Cost and 6) Factory Overheads are defined as inputs directly passing to the main fuzzy inference system. The second-stage inputs consist of two types. First the outputs from Raw Material cost FIS, Distribution cost FIS and Crushing Stoppage FIS are inputs to the main output cost Fuzzy Inference System, Second the free input parameters like Labor cost, Operational cost, and Factory Overheads passing directly to output cost FIS. These various input parameters are passed through fuzzy inference engine. After applying fuzzy rule base in multistage fuzzy inference systems for each input, the final output cost will be a crisp value.

VI. Conclusion

This study aimed to develop a fuzzy logic-based system to develop a cost modelling system for the sugar industry, taking into account all pertinent uncertainties and imprecisions. The system for cost estimation uses heuristic principles in the form of an IF–THEN rule. The ranges for imprecise cost factors of manufacturing processes were constructed using fuzzy theory, and Mamdani's fuzzy inference system was implemented in MATLAB. The developed ranges are unique for each cost variable. The fuzzy sets were constructed using the entire manufacturing cost structure, which included the costs of basic materials, labour, operations, distribution, compression, and factory overheads. It has been determined that the unpredictability of capital costs, projected annual capacity, and operational costs can result in significant variations in the manufacturing output cost. Distribution costs and labour costs may have an equal impact on the ultimate cost of manufacturing output. The proposed methodology can help cost predictors evaluate the effects of uncertain elements in the sugar manufacturing cost structure and make informed decisions. The study addresses the research void in cost modelling of the sugar manufacturing process by analysing key cost drivers and quantifying the effects of manufacturing process uncertainties. The illustrative case scenarios and user-friendly interface enable managers to respond quickly to what-if scenarios without requiring a profound understanding of mathematics. Future research could examine this topic by

investigating the economic viability of potential applications in specific industries.

VII. Challenges and Limitations

Fuzzy logic-based sugar industry cost models have certain drawbacks: Fuzzy logic uses language rules, which need subjective judgements and interpretations. Membership functions and expert-based norms add subjectivity that may differ across persons. Subjectivity may cause cost modelling findings to vary. Fuzzy logic models need correct and trustworthy data to generate membership functions and rules. However, collecting high-quality sugar industry statistics may be difficult. Inaccurate or inadequate data might impair the model's accuracy and cost projections. Many input variables and rules may make fuzzy logic-based models difficult. Complexity reduces model interpretability, making input-output linkages difficult to grasp. This interpretability may impair decision-making and reduce the model's practicality. Once rules and membership functions are specified, fuzzy logic models are static. Changing market circumstances, technology, and industry dynamics might make model adaptation difficult. This constraint limits the model's response to changing situations and may lead to erroneous cost forecasts. Fuzzy logic models must be validated and calibrated for accuracy and dependability. Due to the absence of sugar industry norms or standards, verifying such models is problematic. The model's results may be questionable without adequate validation techniques. Sugar industry fuzzy logic cost estimating methods may need to be coupled with supply chain management or financial forecasting technologies. Integration is difficult and requires technological skills. While beneficial in collecting and expressing imprecise or uncertain information, fuzzy logic has its own limits. It may struggle with sophisticated nonlinear interactions or cost driver subtleties. Machine learning or optimization may be better for certain difficulties. Fuzzy logic-based cost models in the sugar sector must account for these constraints. Fuzzy logic may be useful when combined with other modelling methods and updated often to reflect industry changes and data availability.

References

[1] Dilip S. Patil, Cost reduction in sugar mill: a case study (2017), Proceedings of 75th Annual Convention of STAI: 759 – 768

[2] C. Shan and L. Dong, Production Cost Management in Chinese Sugar Industry. Vol. 6 (4): 291 - 295 (2004)

[3] B. Vijay, S. K. Shetkar, Cost management techniques used in sugar industry. Vol. 7 (5) (2015).

[4] F. C. Yuan, The use of a fuzzy logic-based system in cost volume - profit analysis under uncertainty, Expert Syst Appl 36 (2009), 1155–1163.

[5 new] Kiyak, E., & Kahvecioglu, A. (2003). Fuzzy logic and its application to flight control problems. Journal of Aviation and Space Technologies, 1(2), 63–72.

[5] T. Aslan, G. Baral, C. Mucedidi, Target costing using fuzzy logic. Vol. 7 (1) (2017).

[6] A. P. Chansaad, S. Chaiprapat. Y. Pisal. Fuzzy inference method for material loss and cost estimation under uncertainty: A case study of wooden product manufacturing, Journal of Intelligent & Fuzzy Systems 27 (2014) 2379–2389

[7] Karcioglu, Yalcin, & Gultekin, (2020). Financial performance analysis using intuitionistic fuzzy logic and entropy based multi-criteria decision-making method: An application on energy companies traded in BIST. MANAS Journal of Social Studies, 9(1), 360–372.

[8] Umarusman, N., & Selduz, H. (2018) Using fuzzy inference systems for risk assessment within internal control: A case study. Journal of Social Research and Behavioral Sciences, 4(6), 85–116.

[9] Aslan, T., Baral, G., & Mucedidi, C. (2017). Target costing using fuzzy logic. Emerging Markets Journal, 7(1), 40–46.

[10] Thabit, T. H., & Abbas, N. H. (2017). A proposed fuzzy logic-based framework for e-accounting evaluation in Iraq. Qalaai Zanist Scientific Journal, 2(6), 731–751.

[11] Tunahan, H., Esen, S., & Takil, D. (2016) The comparative analysis of financial risk level of airlines companies by using fuzzy logic method. Journal of Accounting, Finance and Auditing Studies (JAFAS), 2(2), 239–264.

[12] Cevik, O., & Yildirim, Y. (2010) An application in milk products factory with fuzzy linear programming. KMU Journal of Social and Economic Research, 12(18), 15–26.

[13] Ergulen, A., & Deran, A. (2009). The management of transportation costs with fuzzy logic approach and its effects on financial performance. Journal of Accounting and Finance (MUFAD), 43, 227–236.

[14] Yuan, F.-C. (2009). The use of a fuzzy logic-based system in cost-volume-profit analysis under uncertainty. Expert Systems with Applications Journal, 36(2, Part 1), 1155–1163.

[15] Munoz, M. J., Rivera, J. M., & Moneva, J. M. (2008). Evaluating sustainability in organisations with a fuzzy logic approach. Industrial Management & Data Systems, 108(6), 829–841.

[16] Eleren, A. (2007). Evaluation of the financial statements of cement enterprises registered to the ISE with fuzzy logic

approach. Afyon Kocatepe University Journal of Economics and Administrative Sciences, 9(1), 141–153.

[17] Baldwin, A. A., Brown, C. E., & Trinkle, B. S. (2007). Opportunities for artificial intelligence development in the accounting domain: The case for auditing, intelligent systems in accounting. Finance and Management, 14(3), 77–86.

[18] Roztocki, N., & Weistroffer, H. R. (2005). Evaluating information technology investments: A fuzzy activity-based costing approach. Journal of Information Science and Technology, 2(4), 30–43.

[19] Pathak, J., Vidyarthi, N., & Summers, S. L. (2005). A fuzzy-based algorithm for auditors to detect elements of fraud in settled insurance claims. Managerial Auditing Journal, 20(6), 632–644.

[20] Kiyak, E., & Kahvecioglu, A. (2003). Fuzzy logic and its application to flight control problems. Journal of Aviation and Space Technologies, 1(2), 63–72.

[21] Lin, J. W., Hwang, M. I., & Becker, J. D. (2003). A fuzzy neural network for assessing the risk of fraudulent financial reporting. Managerial Auditing Journal, 18(8), 657–665.

[22] Friedlob, G., & Schleifer, L. (1999). Fuzzy logic: Application for audit risk and uncertainty. Managerial Auditing Journal, 14(3), 127–137.

[23] Castillo, O., & Melin, P. (1996). Automated mathematical modeling for financial time series prediction using fuzzy logic, dynamical systems and fractal theory. Paper presented at the IEEE/IAFE 1996 Conference on Computational Intelligence for Financial Engineering (CIFEr), 120–126.

[24] Chiu, Yu; Park, Chan S., (1994), Capital Budgeting Decisions with Fuzzy Projects. Engineering. Economist. 43(2), p125-126