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***Research Article***

# Building a Cost Modeling System using Fuzzy Logic for Sugar Industry

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***Abstract –*** To understand the effects of cost factors on the overall production cost, the study's goal was to develop a fuzzy logic-based cost modelling system for the sugar sector. The information is gathered from sugar factories in Pakistan. Utilising a multistage fuzzy inference approach, the model is created. To analyse the cost of producing sugar, the model is verified using cost factors including the cost of raw materials, the cost of labour, and the cost of distribution. The main goal of the study was to ascertain how these uncontrollable cost factors affected the price of producing sugar. The sub-cost components were used to analyse the cost variables independently. For each cost variable, a different fuzzy inference technique was used to interpret their response. Then a complete Mamdani inference system for manufacturing cost was created. The final inference system's input was derived from the results of the sub inference systems. In order to design the system to assess the effects of specified cost drivers on the production cost, a total of three input variables, one output variable, and twenty-seven if-then rules were established. The created fuzzy logic-based system can assess the cost of producing sugar while taking uncertainty into consideration. As a result, the created system's offer of a cost estimating model that makes it easier to choose outcomes that are cost-effective is a major contribution.

*Keywords – Fuzzy Logic, Cost Estimation, Fuzzy Inference System, Sugar Industry, Cost Estimation Model*

## I. INTRODUCTION

In today's world of competition, the sugar industry is looking for a flexible cost model to optimize its manufacturing cost and consider uncertain losses to survive in a competitive environment. This allows the sugar industry to make more informed decisions about their manufacturing cost and more accurately estimate their profitability. It is not easy to enhance the physical process performance without analyzing the final manufacturing report of our own mill [1]. To improve profit and optimize manufacturing costs, sugar millers should consider all uncertain costs. 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]. The cost should be controlled, not reduced unscientifically because that lowers the quality of the product. This is done by considering various cost drivers that incurred huge cost consumption during the manufacturing process. In the sugar industry the dynamics of manufacturing process includes several types of cost drivers to hold and run the plant. But also, the rate of uncertain losses is very high in the sugar industry. Due to the lack of supplies of appropriate software applied to control these uncertain costs and

losses, there is difficulty in establishing the effective cost controlling model in the sugar factory [3]. It is only possible for businesses to consider uncertainties in cost using fuzzy logic cost model [4]. Fuzzy logic is a modern computer logic revolution that enables computers to mimic human behaviour through logical applications. The utilisation of fuzzy logic in manufacturing processes and industries has yielded numerous benefits. Some of the benefits include time and money savings, increased production efficiency, and improved accuracy in cost and profit estimates. Fuzzy logic is specifically designed to handle the uncertainty often faced in everyday situations, in contrast to classical logic. Fuzzy logic, in contrast to binary logic, embraces multi logic by asserting that classical Aristotelian logic is insufficient in the present context. [5] The objective of this study is to forecast the manufacturing cost of sugar. MATLAB software is commonly utilised for cost analysis. The research holds relevance and significance due to the utilisation of fuzzy logic, an advanced technique for analysing costs, profits, and making decisions in the face of risk and uncertainty. The fuzzy logic technique is highly effective in predicting profits or losses in developing countries and economies. It is important to acknowledge that emerging countries generally have a higher prevalence of uncertainties and risks compared to developed countries [6]. The purpose of this paper is to develop a cost modelling system for the sugar industry. This system will address the uncertain cost drivers and losses by utilising fuzzy logic. Fuzzy logic is a highly effective problem-solving approach for a wide range of audit and information processes [7]. It considers fuzzy information in uncertain situations and allows for accurate results with ease. In order to establish a strategic plan, it is crucial to have accurate knowledge of the production cost values [8].

### 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

The manufacturing industry has not sufficiently addressed the systematic cost estimation of incomplete or conflicting cost factors, constraints, and consequences during engineering design and costing. Parametric techniques commonly used in cases of incomplete information have limited assessment capabilities [9]. Probabilistic evaluations have significantly enhanced the management of cost uncertainties and have found recent applications in industries for addressing uncertain losses. However, the use of this method is restricted to situations where there is a sufficient historical foundation available to apply probabilistic analyses [10]. An effective assessment of advanced technologies, along with the associated uncertainty, requires the development of a new methodology. The utilization of fuzzy logic attributes in cost models and affordability applications tackles the challenges associated with (1) insufficient data in cases where materials have limited characterization data, (2) processes with limited empirical data, and (3) manufacturing processes that have a minimal or nonexistent manufacturing base [11]. This chapter provides a review of the literature that is relevant to the study's objective.

## III. MATERIALS AND METHOD

The research approach has been divided into five main phases.

### A. *Phase 1*

Phase 1 of research methodology is about literature review. This phase has completed in the following four steps. The detailed work of cost modeling and fuzzy logic methods has been done to understand the application of fuzzy logic in cost modeling of sugar industry. Phase 1 follows the following steps.

- Cost Estimation
- Cost Estimation Techniques
- Fuzzy Logic-Based Cost Estimation Techniques
- Research Gap

### B. *Phase 2*

*In phase 2, research methodology includes data collection regarding major cost factors. Data is collected via experts' opinions, sugar mills annual cost reports. Phase 2 is based on the following parts.*

- Sugar mill's experts' opinions
- Sugar mills annual cost reports

### C. *Phase 3*

*Phase 3 of research methodology starts with the development phase. In this phase fuzzy logic-based cost modeling system develops, major cost variables are observed through sugar mills annual cost reports.*

- Development of Fuzzy Logic-Based Cost Model

### D. *Phase 4*

In phase 4, an industrial case study will be employed to assess the fidelity of the developed model. The input variables are tested in the developed model for analysis on MATLAB software built-in simulation tool for Mamdani Inference system.

- Case Study data analysis
- MATLAB based Mamdani Fuzzy Inference System
- Results

### E. *Phase 5*

In phase 5, the results of costs will be assessed to validate the cost model. After validation, conclusions, discussions, and future recommendations will be made for more refinement of the developed model if necessary.

- Developed Cost Model Verification and Validation
- Conclusions
- Discussions
- Future Recommendations

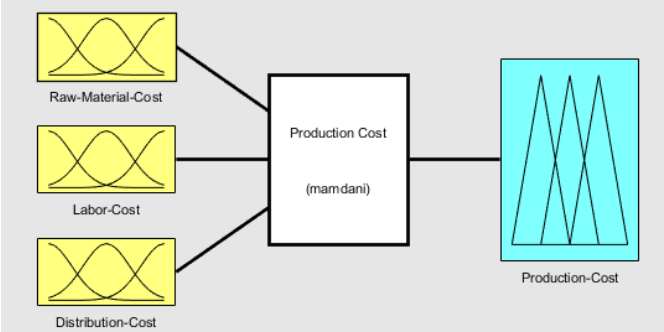


Fig 1 Fuzzy Inference System for Sugar Production Cost

## IV. RESULTS

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, and labour cost, result in a total of 27 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.

Mamdani inference system IF-THEN rule base, a cost estimation system is developed as shown in fig below. It is a prototype of cost estimation system develops on Microsoft Visual Studio. It shows the impact of each cost driver on the total production cost.

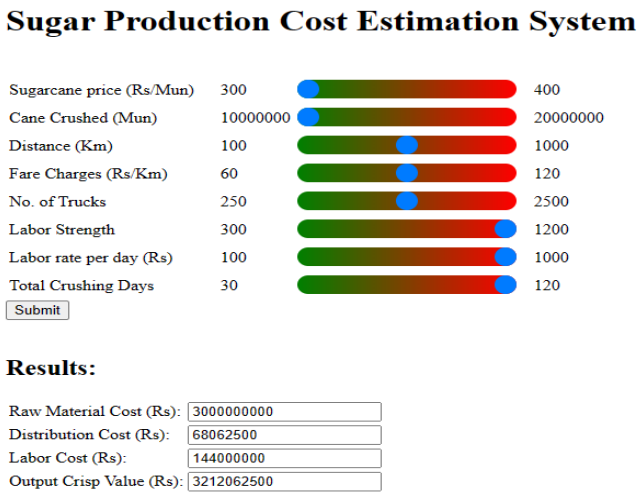


Fig 2 Developed System for Sugar Production Cost

## V. DISCUSSION

Instead of assessing the impact of various cost drivers on the total production cost, the output cost of three cost drivers were examined. Since the ranges for cost drivers are pre-defined based on reported value from the literature, the primary objective of this research was to incorporate the uncertainty which is inherited in sugar manufacturing cost. IF-THEN rules are constructed in a way that if both cost drivers are low, production cost will be very low. Similarly, if both cost drivers are high, the output cost will be very high.

As the primary purpose of this model is to leverage the uncertainty factors and determine the sugar production cost. The final form of inputs and their ranges are presented in chapter 4. To assess the developed fuzzy logic cost model with its rules, different case scenarios were tested for its sensitivity to simultaneous variations of inputs. All the input variables were tested for different results. The ranges for inputs are defined and the chosen values for testing are random values with in the chose range. For example, the MEDIUM raw material cost and HIGH labor cost and LOW distribution cost values MEDIUM production cost.

Please note that the values considered in this study may not accurately represent the exact costs of sugar production. The limitations of the study are inherent in the nature of fuzzy logic, which relies on expert knowledge and the inputs provided. The cases presented are purely hypothetical, and the input values used were obtained from existing literature. However, it is evident from this study that single-point estimates are inadequate in accurately representing the diverse manufacturing process costs associated with various cost drivers. The study's methodology demonstrates the effectiveness of utilising fuzzy logic to address uncertainties.

## VI. CONCLUSION

The aim of this study was to develop a fuzzy logic-based cost model to estimate the cost of sugar production taking into consideration all relevant uncertainties and in accuracies. The cost estimation system has employed IF-THEN rules. By applying the fuzzy theory, the ranges were constructed for imprecise cost drivers for sugar production, and the Mamdani's fuzzy inference system was implemented in MATLAB. The ranges for each input cost drivers are developed. The fuzzy sets were constructed for the whole cost estimation system. It is found that the uncertainty in raw material cost and labor cost may result in considerable deviations of the final production cost. Moving towards the practical application of this cost estimation model, it may be considered useful where cost drivers have ambiguity and uncertainty. The study addresses the research gap amongst the various studies on cost modeling techniques.

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