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Application of Fuzzy Mamdani Model for Cost Optimization in LPG Transshipment System

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Abstract
A novel approach to product transshipment is presented in this paper. A heuristic fuzzy network is developed for modelling complex systems by describing the global behaviour of the structure. Managers on a daily basis are confronted with optimization problems which arise in manufacturing systems, oil, and gas sectors, bottling companies etc. Thus, there is need for efficient and robust computational algorithms which can solve these problems arising in different fields. Unfortunately, managers rely on classical methods while making allocation decision which does not guarantee optimal solution. In this study, fuzzy logic is applied by effectively designing and simulating an outbound system and creating membership functions and rules. The effectiveness of the proposed method is demonstrated using data from an LPG plant in Delta State. The company spent approximately 41,500NGN to supply products from source to two transshipment points using classical perception. The cost of distribution was quite high compared to result obtained by using fuzzy inference system (FIS). FIS gave a better solution of 32,790NGN. A total sum of 8,710NGN would have been saved using the Fuzzy inference system model developed. This method provides much faster response and accurate solution to cost optimization in transshipment operations.

Keywords: **Fuzzy, Transshipment, Algorithm, Optimization**

1. Introduction
The major challenge manufacturers face in industries today is how to consistently meet with customers' requirements and demands at an optimal cost with the ability to effectively compete in the market. These require the optimization of production process and the distribution operations. Optimization problems arise in various disciplines such as engineering design, manufacturing system, oil and gas sector, bottling company etc. Thus, in view of the practical effectiveness of optimization problems there is a need for efficient and robust computational algorithms which can unravel these problems arising in different fields. Transshipment problems and inventory management, etc can be solved using heuristics (Azmi and Harold, 2013).

In addition to these, demand of products at various locations is always higher than the availability at the source. It is, therefore, necessary that for any company to survive or remain competitive, it must provide the required demand of products at the right time they are needed and at the lowest possible cost. The paramount way to make an industry have global competence is to provide products of higher quality, reduce operation cost, and raise the fulfilment of customers (Yang-Hua et al., 2008).

Determining optimal delivery schedules turns out to be a very difficult. Problem specific heuristics are common for solving this kind of problems (Nahmias, 2001; Anyaeche, 2007).

Artificial Intelligence (AI) techniques have been proven to be the best approach for addressing complex task. AI has been used efficiently in transportation engineering for design and solving of complex problems to enable computers to exhibit intelligent behavior (Simoes et al., 2010).

Transshipment model is applicable in a single and multiple product system (Okwu et al 2012).

Mohammed et al. (2013) developed a transshipment model that determines the optimal replenishment quantities necessary to minimize the inventory cost function. The objectives of their research include: to propose a transshipment policy that takes into account the fuzziness of parameters and to derive the approximate replenishment quantities. Amma (2011) presented research with focus on transshipment problems in supply chain system using Juaben oil mill company limited as a case study to reduce the transportation problems at inbound and outbound level. The techniques employed in determining an optimal solution to transshipment problem is the same employed under direct transportation model.

Rajendran and Pandian (2012), used a new methodology called splitting method for finding an optimal solution to a transshipment problem in which all parameters are real integers. They considered a transshipment problem having *m* origins and *n* destinations. A good number of research are of the view that fuzzy logic is better applied to uncertainty and stochastic issues. Traditional methods are commonly used for addressing transshipment model as shown in literature. This research exposed the expressive power and global strength of artificial intelligent technique, fuzzy logic in handling transshipment problem.

The objective of the study is to develop a methodology that involves Mamdani fuzzy models for effective facility design and determination of optimal flow path to minimize cost of products to various locations. The model was applied using well-known liquefied petroleum gas (LPG) firms in Warri, to ascertain their utilities in two TPs.

1.1 Review of Fuzzy Logic Applications

Tu-Changchun and Rangnathvarma (2012) researched on fuzzy multi agent system which was developed to depict the relationship among parent criteria and their sub-criteria and criteria and the weight of all criteria. Amit and Zhiling (2012) demonstrated that the fuzzy logic approach provides a robust analysis for vendor selection. Balendra et al. (2013) and Nwachukwu (2018) looked at fuzzy logic decision Making approach for three stage selection transportation process, internal selection problem with multiple objectives. The criteria attributes used were qualitative as well as quantitative factors. These factors and their interdependencies made the problem a highly complex one. This fuzzy based scheduling model was developed by using the Fuzzy Logic TOOLBOX of MATLAB. The procedure they adopted for modeling the fuzzy based scheduling are as follows: The route selection which depends on three fuzzy factors; the number of parts already waiting in each machine buffer in terms of sum of processing time, how long it will take to complete the requested operation and the travelling time through the route. They choose fuzzy variables and name them as Work-In-Raw material (coal), demand of sector as input variables and the Route selection purpose which is chosen as the output variable. They used Mamdani method and maximin method for fuzzification and method of centroid for Defuzzification method to construct a fuzzy inference system (FIS). Their final result was clearly shown using the variation obtained from the Mat Lab surface Viewer, which is 3D graph of two input to one output. Where production process and dispatch are input to one output. Okwu et al. (2021) applied Fuzzy Mamdani Model for prediction of biogas yield. Sayed (2015) carried out research onscheduling of handling/storage equipment in container terminals using Fuzzy logic controller (FLC) and Genetic algorithm (G.A). In his research, a fuzzy logic controller (FLC) was designed to improve the performance of a G.A in optimization of integrated scheduling of handling/storage equipment in automated container terminals.

2. Methodology

The study applies Fuzzy set to Transshipment Model using data from three LPG plants. By using the Mamdani model the input and output parameters was defined and membership function created with well-defined rules which was simulated in the fuzzy logic system.

2.1 Fuzzy Set Applied in Transshipment Model

The research first applies a standard membership function in the fuzzy set to describe the factors in the overall transshipment, including the demand at the transshipment point, the anticipated products filled and available at the three plants and the unit cost of distribution from plants to TP.

3. Experiments and Discussion

An example used is that of three sources (LPG plants) located in Warri, Nigeria. In other to expand the system, it became necessary to create two transshipment points (TP) within the state to make the product available to customers at strategic locations. Products can flow from any of the three sources to the two TP. Fuzzy logic rule is suggested for effective facility design, Table 3.1 gives a clearer illustration of product availability and demand at source(s) and TP.

3.1 Parameters

Production facility: 3

Total TP= 2

Demand at TP1: 1710 items per week.

Demand at TP2: 1290 items per week

Periodic availability of item at Plant 1 = 1290

Periodic availability of item at Plant 2 = 780

Periodic availability of item at Plant 3 = 930

The unit cost of distributing items from Plant to TP 1 and 2 is shown in Table 2.

Table 1: Product Availability and Demand at Source and TP

Product Availability at Source		
S/No	**Source/Sink**	**Availability**
1	Source 1	1290
2	Source 2	780
3	Source 3	930
Product Demand at Transshipment Points		
4	TP1	1710
5	TP2	1290

Table 2: Product Availability and Demand at Source and TP

S/No	Source	Sink	Unit Cost from Source to Sink
1	S1	TP1	12
2	S1	TP2	10
3	S2	TP1	10
4	S2	TP2	13
5	S3	TP1	13
6	S3	TP2	18

Procedure for Using Fuzzy Logic to Address Transshipment Problem

To effectively design and simulate a fuzzy logic system, the basics steps below are necessary:

i. First define the input and output

ii. Create membership function

iii. Create rules

iv. Simulate results in Fuzzy Logic System.

The architecture of the input output system was developed as shown in Figure1.

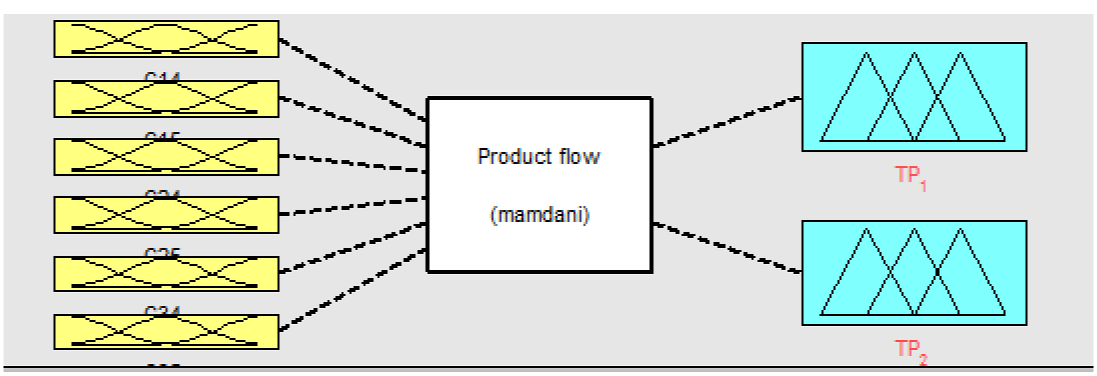


Figure 1Mamdani Architecture Showing Product Flow from Source to TP

Rules were Perfectly Created and Defined Using the Rule Editor. With the graphical user interface as Simulink input, an initial fuzzy model was derived to trigger the modelling process, The model is required to select the appropriate input variable, input space partitioning and choosing the number and type of membership function (MF). The membership function used is the Gaussian MF. Let the unit cost of distributing products to each depot and the demand at different depots be the input signal to the Sources. The solution was mapped out into FIS model explained in linguistic term of "WHAT IF" rule. Fuzzy Inference System have the Mamdani model. The architecture of the Mamdani model is suitable for effective facility design using FIS as demonstrated in Figure1.

Membership function associated with the fuzzy inference system and variables are stated clearly in Figure 2.

a. (b)

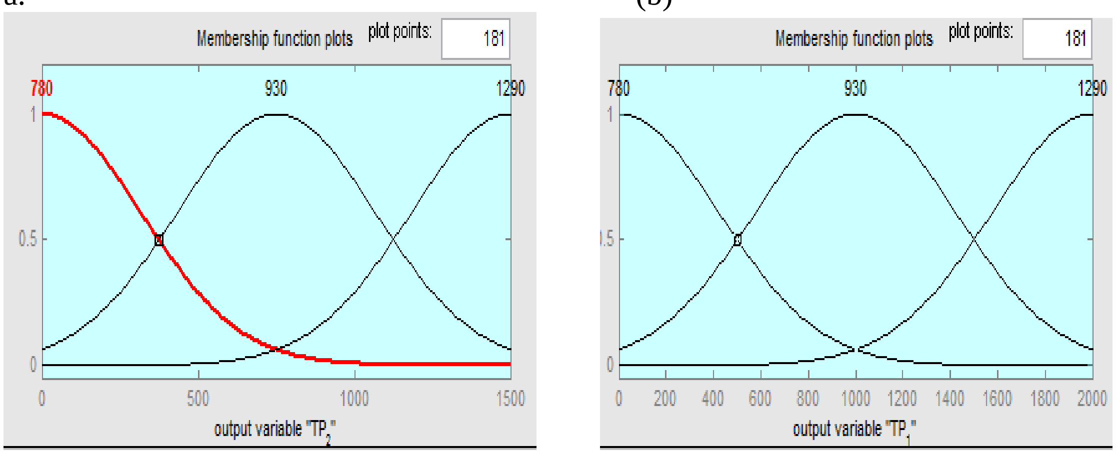
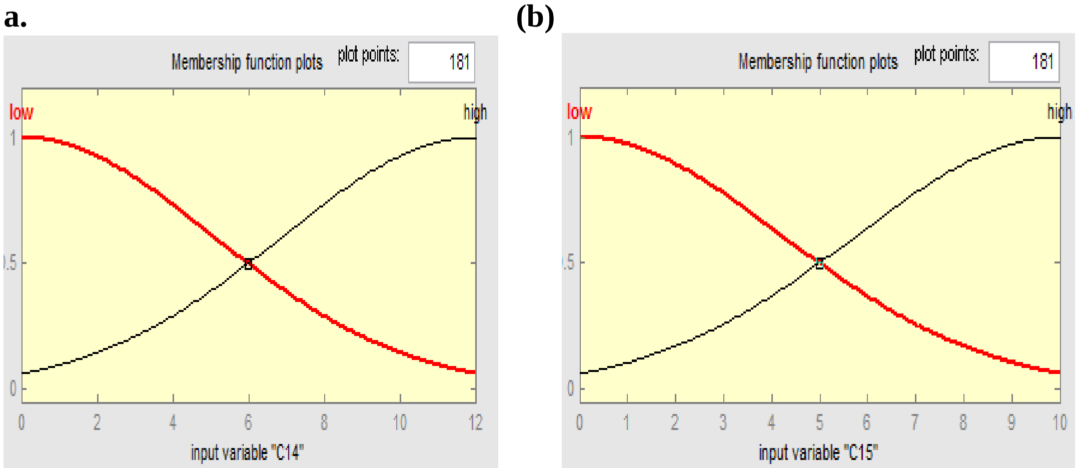


Figure 2: Membership Function Plot for Output Variables (a,b)

a. **(b)**



(c) **(d)**

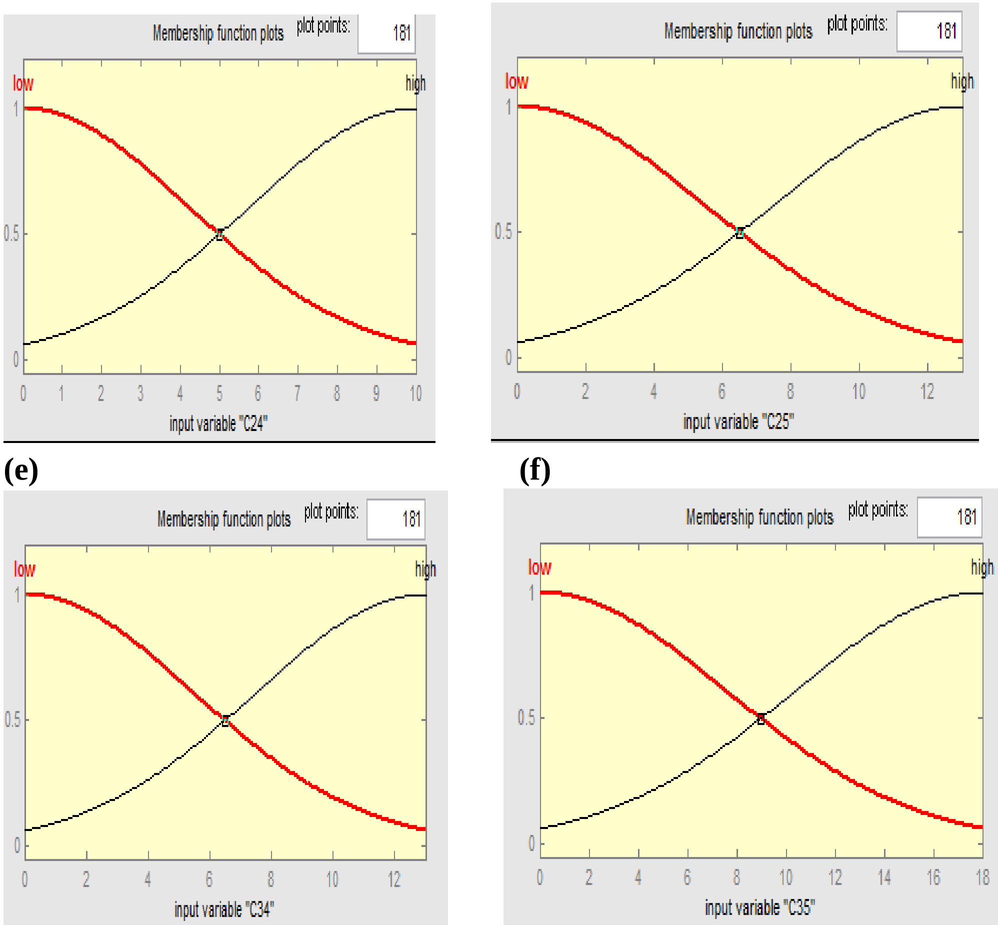


Figure 3: Membership Function Plot for Input Variables

With the membership function properly defined in Figure 3, it is necessary to create fuzzy rules.

Key

Very high product (VHP) = 1290

High product (HP) = 930

Low product (LP) = 780

Fuzzy Inference System Linguistic Rules

1. If C14 is high and C15 is low, then supply VHP to TP2
2. If C14 is low and C15 is high, then supply VHP to TP1
3. If C24 is high and C25 is low, then supply VLP to TP2
4. If C24 is low and C25 is low, then supply VLP to TP1
5. If C34 is high and C35 is low, then supply HP to TP1
6. If C34 is high and C35 is low, then supply HP to TP2

Rules Created and Defined Using Rule Editor and Sensitivity Analysis

Simulation of results in Fuzzy Logic System with rule viewer for input output signal is demonstrated in figure 4.

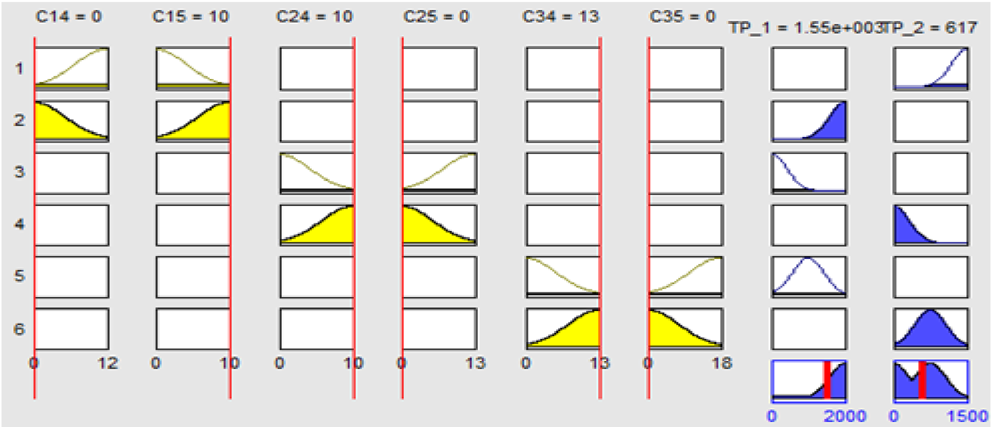
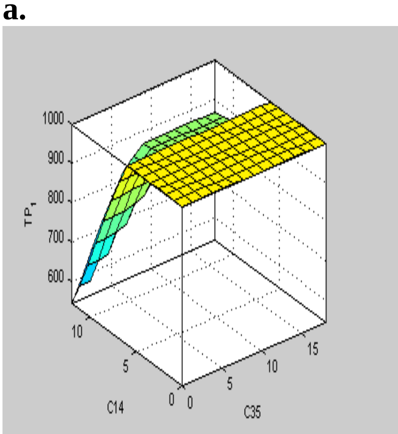
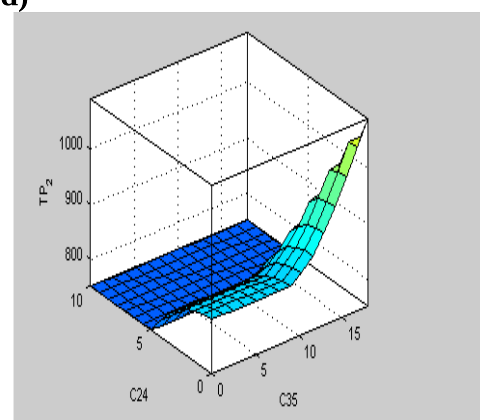


Figure 4.Rule Viewer for Input and Output Signal

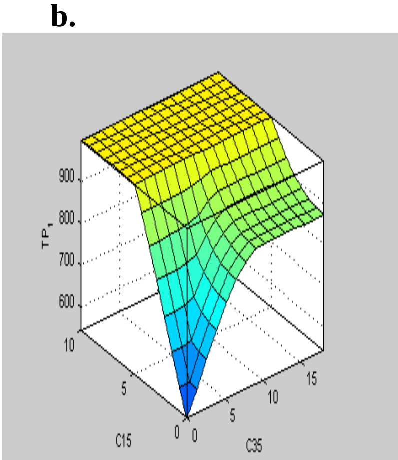
a.



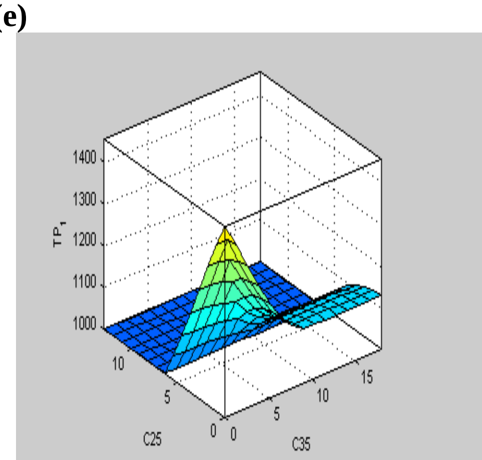
(d)



b.



(e)



c.

(f)

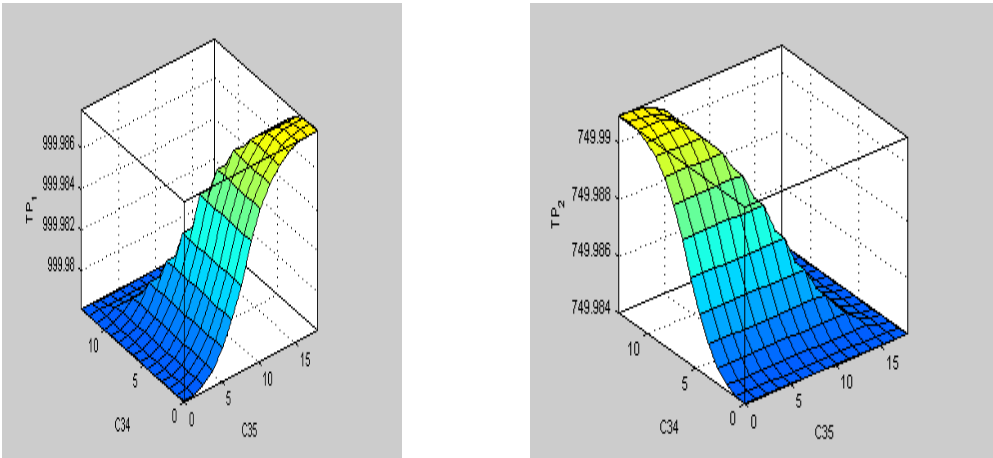


Fig. 5. 3D Input-Output Control Surface Plot Fuzzy Inference System (a,b,c,d,e,f)

The control surface in figure 5, graphically represent all possible inputs and outputs in terms of cost, demand, and supply. It is a three-dimensional case scenario since we have two input (cost and demand) and one output (supply). For example, graph (a) shows that when C14 is low and C35 is low, then TP1 is high. For graph (b), when C15 is high and C35 is high then TP1 is high. For graph (c), at very low C34 and high C35, TP1 is low. For graph (f), at high C34 and very low C35, TP2 is very high.

Table 3. Predetermined Fuzzy Logic Rule Viewer of ANFIS

Supply Point (SP)	Transshipment Point 1	Transshipment Point 2	Cost from SP to TP1	Cost from SP toTP2	Optimal Cost of Supply toTP1	Optimal Cost ofSupply toTP2
S1	0	1290	12	10	0	12900
S2	780	0	10	13	7800	0
S3	930	0	13	18	12090	0
Total cost of Supply from SP to TP1 and 2					19890	12900
Total cost of supply from source to transshipment points					N32,790	

Conclusion

This study is focused on fuzzy set-intransshipment system by taking into consideration availability, demand and unit cost of LPG products from source to TP. Fuzzy Mamdani model was applied to predict the right quantity of product that could flow from each source to the two TPs. The company spent approximately N41,500 supplying product from source to TPs using strategic perception. The cost of distribution is quite high compared to result obtained by using the Simulink fuzzy inference system. Using global approach gave a better solution of N32,790. A total sum of N8,710 representing 21% of the total amount would have been saved using the Fuzzy inference system developed. Mamdani fuzzy logic has demonstrated a global optimal solution in a transshipment system, The model is also capable of predicting accurate location of facilities.

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