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Fuzzy Rule-based System for Corruption Control in Nigerian Police Force

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Authors' contributions

This work was carried out in collaboration among all authors. Author ABS designed the study, wrote the protocol, manages the literature searches and wrote the first draft of the manuscript. Author IM performed the analysis using fuzzy logic tools of Matlab and affected the reviewer's corrections/observations. Author JMG managed the analysis of the study and discussed the results. All authors read and approved the final manuscript.

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ABSTRACT

This paper has attempted to develop an artificial intelligence model based on fuzzy logic for the control of corruption in Nigerian Police Force. The researcher employed fuzzy rule-base inference system methodology using four inputs variables; funding, logistics and operational equipment (FLOE) condition of service, remuneration and motivation (CSRM), recruitment, training and promotion (RTP), confidence and support by the community (CSC) were used to determine the corruption severity level. An output variable; corruption severity level (CSL) was adopted for the model development. The simulation was carried out using MATLAB 2015 for Windows. The results revealed that it is very obvious for Nigeria as a country to have a Police Force whose corruption severity level is low. Thus (i) Condition of service, remunerations and motivation has to be excellent; (ii) Funding, logistics and operational equipment has to be adequate; (iii) Recruitment, training and promotion has to be excellent, and finally (iv) Confidence and support by the community has to be very high.

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Keywords: Nigerian police force; fuzzy logic; corruption severity level.

1. INTRODUCTION

Global concerns about corruption have intensified in recent years. There is increasing evidence that corruption undermines development. Based on expert opinion from around the world, the Corruption Perceptions Index measures the perceived levels of public sector corruption worldwide. The findings are less than encouraging. Not a single country comes close to top marks, while over 120 countries score below 50 on the scale of 0 (highly corrupt) to 100 (very clean). This means less than a third of countries are even above the midpoint. Corruption hurts all countries [1].

The challenges of corruption remain a major devastating issue facing a developing country like Nigeria since the colonial period. Ogbu [2] defined corruption as "an abuse of position or inducement of an abuse of position for an undeserved benefit, advantage or relief". Thus, corrupt practices includes: bribery, extortion, fraud, embezzlement, nepotism, cronyism, appropriation of public institutions assets and properties for private use, and influence peddling.

In Nigeria, corruption has become the order of the day happening among the young and the old, the politician and the non-politician as well as military and the non-military [3]. It has been estimated that close to $400 billion was stolen from Nigeria's public accounts from 1960 to 1999, and that between 2005 and 2014 some $182 billion was lost through illicit financial flows from the country (United Nations Office on Drugs and Crime [4]. The menace of corruption in Nigeria is endemic and on the increase despite several attempts even by successive governments to ameliorate the blight. President Muhammadu Buhari has shown some level seriousness in his commitment to lead anticorruption efforts in Nigeria, through strengthening whistleblowing incentives and protections, high-profile investigations of prominent individuals for large-scale theft of public funds, and the recovery of billions of naira by Nigeria's anti-corruption agencies.

The forces, which deter corruption, are often weak as some, if not most, of the law enforcement agencies are themselves corrupt. In addition, rulers, politicians and civil servants are highly corrupt, and professional organizations may be incapable of sanctioning their members [3]. The principal agency charged with the responsibility of internal peace and security of nations all over the world is the police. Nigerian Constitution [5] provides for the establishment of the Nigerian Police Force under section 214.

The growing concern that corruption within the Nigeria police force in Nigeria remains difficult to manage, despite numerous anti-corruption strategies that have been devised to curb police corruption, it remains difficult to reduce corruption within the force. The present system, which involves the anti-grafts agencies such as Economic and Financial Crime Commission (EFCC), Independent Corrupt Practices Commission (ICPC) going after corrupt persons is hindered by weak government institutions, poor pay incentives/motivation, lack of openness and transparency among others.

Nowadays, research in the field of Artificial Intelligence (AI) has made it possible for computer scientists to develop intelligent programs that incorporate knowledge of many experts in a particular area to assist in solving sophisticated problems that are difficult for human's brain to handle alone. For example [6] employed the use of Fuzzy Logic Control (FLC) methodology to design a system for the determination of severity level of Osteomyelitis in adults and children. Fuzzy models have the capability of recognizing, representing, manipulating, interpreting, and utilizing data and information that are vague and lack certainty.

Thus, this research work attempts to control corruption in Nigeria Police Force by developing a fuzzy rule-based system.

2. RELATED STUDIES

Mathematical modelling for measuring and removing corruption from the society was by Waykar [7]. They observed and concluded that the real world problem is "corruption". They converted this problem into mathematics problem then developed some models such as "Mathematical Corruption Model, Mathematical Corruption Control Model, Mathematical Corruption-Development Model, Mathematical Development Model and Mathematical E-virus Constant Model". These models were used for measuring as well as removing the corruption from the society of any country of the world.

Administrative corruption by Providing a fuzzy inference system of good governance to combat corruption was studied by Morteza et al. [8]. They proposed a comprehensive model to measure the administrative corruption through a widespread study in the review of literature of previous studies. The output of the model was compared with the experts' opinion and it shows that model was effective.

Epidemic diffusion model as designed by Hathroubi [9] was used by Kermack and McKendrick [10] to studied corruption as an epidemic phenomenon. The framework of the model has allowed the study of corruption dynamics and the statement of a threshold epidemiological theorem of corruption. The study revealed that an epidemic corruption occurs when the number of corruptible surpasses the threshold.

Mathematical model of corruption was developed by Abdulrahman [11] and used for studying the stability analysis of the transmission dynamics of corruption in a population with a constant recruitment rate, standard incidence rate and effort rate against corruption. The study revealed that the corruption free equilibrium is globally asymptotically stable if the reproduction number (R_0) R≤1, and globally asymptotically stable endemic if $R_0 \geq 1$.

The institutional and cultural factors that account for police corruption in various countries were examined by Williams [12]. The results showed that the police corruption primarily arises from our deficiencies in four major areas (i) recruitment, training and promotion; (ii) resources such as pay and equipment; (iii) system of accountability, court and law; (iv) cultural traditions. The researcher recommended that laws must be passed with zero tolerance for corruption, Corrupt practices among the police and the overall effects of corruption on how the outfit carries out its mandatory responsibility in the society with particular concern on the impact of corruption on maintenance of law and order; the factors responsible for corrupt practices among the Nigerian police personnel; and the extent of corruption within the Nigerian police were examined [13].

The solution to curb police corruption, proposes incorporating in policing certain virtues embedded in the Afrocentric ethic of *Omoluabi*, such as good character, respect, diligence and communalism were provided for by Akpunonu-Ogu [14]. This approach according to him could provide insights to complement the existing anti-corruption mechanisms that aim to reduce police corruption.

3. SYSTEM OVERVIEW

Fuzzy logic may be regarded as an attempt at formalization of two important human capabilities, first the capability to think and make rational decision in an environment with incomplete information. Second the capability to carryout wide variety of physical and mental task without any dimension or computation. Fuzzy logic is a superset of conventional logic that has been expanded to handle the concept of partial truth values between the Boolean dichotomy of true and false [15].

3.1 Fuzzy Inference System

A fuzzy inference system (FIS) is a system that uses fuzzy set theory to map inputs to outputs. The process of fuzzy inference involves all of these pieces: Membership Functions, Logical Operations, and If-Then Rules. General diagram of a FIS includes three main parts: A fuzzifier, a rule base and a defuzzifier. There are two main types of FIS: Mamdani and Sugeno FIS with the own advantages. Mamdani FIS is computationally efficient. It can be used to model any inference system in which the output membership functions are either linear or constant. It works well with linear, optimization and adaptive techniques. It has guaranteed continuity of the output surface and well suited to mathematical analysis. Sugeno FIS has the strength in the intuition, widespread acceptance and well suited to human input [16].

According to Vaishali and Supriya [17], Fuzzy Inference System provides a way of mapping input space to output space. Mapping provides a basis for decision making. The primary task of fuzzy inference system is decision making based on *IF-THEN* rules. Along with *IF-THEN* rules FIS uses “AND” or “OR” connectors for making necessary decisions. FIS is the key unit of a fuzzy logic system. Input to FIS need not be always fuzzy; it may be crisp or fuzzy, but the output is always a fuzzy set from the FIS. The process of fuzzification and defuzzification is of great importance in FIS. Fuzzy Inference System is also known as fuzzy expert system, fuzzy model and fuzzy rule-based system. FIS consists of five functional blocks. They are:

i) Fuzzification unit converts the crisp values into fuzzy values.
ii) Rule Base contains a number of fuzzy IF-THEN rules.

iii) Database defines the various membership functions of fuzzy sets used in fuzzy rules.
iv) Decision-making unit performs the required operations on the rules.
v) Defuzzification unit converts the fuzzy sets into crisp set as a result

3.2 The Design of Fuzzy Expert System (FES)

An expert system is a computer program that helps in solving problems demanding substantial human expertness by using explicitly exhibited domain knowledge and computational decision procedures. These are designed to make available some of the skills of an expert to non-experts, as they attempt to imitate the thinking patterns and logical decisions of an expert. The FES makes use of the theory of fuzzy reasoning [18]. Fuzzy inference is the process of developing the mapping from a given input to an output using fuzzy logic which then offers a base from which decisions can be made or patterns perceived. The classical logic has only two truth values, true or false, and so the process of inference is simplified as compared to fuzzy logic, where we have to be concerned not only with propositions but also with their truth values. Every FES has a fuzzy inference system that reasons using fuzzy logic membership functions, which refers to the degree to which the value of a particular attribute belongs to a set. The FES designed and employed in this research can be generalized by means of a simple structure as shown in Fig. 1.

3.3 Model Development

The FES developed in this research employs the Mamdani type fuzzy inference technique. This technique is performed in four steps:

i) Fuzzification of the input variables is done by the fuzzification module, which translates crisp inputs into fuzzy ones; that is, classical measurements are converted to fuzzy values through the use of linguistic variables;
ii) Application of the Fuzzy operator and formation of rules for evaluation: done by a set of if-then fuzzy rule bases or knowledge bases, consisting of a set of conditioned fuzzy propositions;
iii) Aggregation of the rule outputs: done by the fuzzy inference engine which has a specific inference method here the Mamdani type. It applies fuzzy reasoning mechanisms to obtain outputs and carries out the computation using fuzzy rules;
iv) Defuzzification is done by a defuzzification module which transforms fuzzy outputs back to crisp values.

3.3.1 Fuzzification

The fuzzifier converts the crisp inputs which are supplied to the system to fuzzy inputs and also determine the degree to which these inputs belong to each of the appropriate fuzzy sets. These fuzzy inputs are then used in the inference engine to generate fuzzy outputs. For developing control tool for corruption in NPF, data is required that is capable of representing the menace as well as the severity of the corruption. Basically the data consists of opinion of the experts, corruption reports, journals, and other secondary sources. By consulting the experts and by analysing the data from the other sources mentioned four attributes were considered and used as the inputs variables for determining the corruption severity levels. Fuzzy values were assigned for each of these input variables to get different fuzzy sets based on the expertise of the specialists and knowledge from the standard textbooks and journals. Triangular membership function was adopted for both inputs and output variables to simplify computation. The membership function parameters for the input variables and the membership function plots for the input variables and the output variable is given below:

i) Condition of Service, Remunerations and Motivation (CSRM) having linguistic variables and parameters as follows: Poor [0 2 4], Moderate [2 4 6], Good [4 6 8] and Excellent [6 8 10].
ii) Funding, Logistics and Operational Equipment (FLOE), having linguistic variables and parameters as follows: Inadequate [0 2.5 5], Relatively adequate [2.5 5 7.5], and Adequate [5 7.5 10]
iii) Recruitment, Training and Promotion (RTP), having linguistic variables and parameters as follows: Poor [0 2 4], Fair [2 4 6], Good [4 6 8] and Excellent [6 8 10].
iv) Confidence and Support from Community (CSC), having linguistic variables and parameters as follows: Low [0 2 4], Moderate [2 4 6], High [4 6 8] and Very High [6 8 10].
v) The output variable Corruption Severity Level (CSL) parameters are defined based on the linguistic variables which are High [15 22.5 30] corruption level, Low (7.5 15 22.5) corruption level and Very low (0 7.5 15) corruption level.

3.3.2 Rule determination and evaluation

The basic requirement of rule-based systems is that the expert's knowledge and thinking patterns should be specified in an explicit manner. The set of rules in an FES is known as the rule base or knowledge base. Fuzzy rule-based systems, in addition to handling of uncertainties, also have several additional capabilities. Here approximate numerical values can be specified as fuzzy numbers. The performance of an FES mainly depends on its rule base so the optimization of the membership function distributions stored in the database is the most important process. The rules in a Fuzzy Expert System are in the form: If *x* is low and *y* is medium, then *z* is high, where *x* and *y* are input variables, *z* is an output variable, low is a membership function (fuzzy subset) defined on *x*, medium is a membership function defined on *y*, and high is a membership function defined on *z*. The antecedent or the preceding part (the rule's premise) describes the degree to which the rule applies, while the conclusion part (the rule's consequent) assigns a membership function to each of the output variables. If a fuzzy rule has more than one antecedent, the fuzzy operator AND or OR is used to obtain a single value that represents the result of the antecedent evaluation. Based on the descriptions of the input and output variables, 56 rules were constructed by selecting an item in each input and output variable box and one connection (AND). None was chosen as one of the variable qualities to exclude any of the variables from a given rule. The weight was specified to unity.

3.3.3 Aggregation of rule outputs

It is the process of the unification of the rules. The membership functions of all the rule consequents previously clipped during rule evaluation are taken and combined into a single fuzzy set. In this process a number of clipped consequent membership functions are changed into one fuzzy set for each output variable. The inference methodology used is the Mamdani inference method. In Mamdani inference method rules are of the following form:

> *R_i: if x_1 is A_{i1} and ⋯ and x_r is A_{ir} then y is C_i for i=1,2,…., where L is the number of rules, x_j (j=1,2,…,r) are the input variables, y is the output variable, and A_{ij} and C_i are fuzzy sets that are characterized by membership functions $A_{ij}(x_j)$ and $C_i(y)$, respectively. The consequence of each rule is characterized by a fuzzy set C_i. The final output of a Mamdani system is one or more arbitrarily complex fuzzy sets which usually need to be defuzzified.*

3.3.4 Defuzzification of the output

The aggregate of a fuzzy set constitutes a range of output values, and so it must be defuzzified in order to resolve a single output value from the set. The defuzzification method used here was the centroid calculation, which returns the center of area under the curve. The defuzzified value was calculated based on the following equation:

$$d_{CA}(C) = \frac{\int_{-c}^{c} C(z) z dz}{\int_{-c}^{c} C(z) dz} \quad (1)$$

where $d_{CA}(C)$ is the defuzzified value and *C* is the membership function. Every rule was examined for a given set of input values using the AND operation and the rule which satisfied the operational logic was used to generate the output for the inference system. The output given by each rule was aggregated and then defuzzified using centroid calculation to generate a single output which was a single number representing the Corruption Severity Level (CSL) as depicted in Fig. 8.

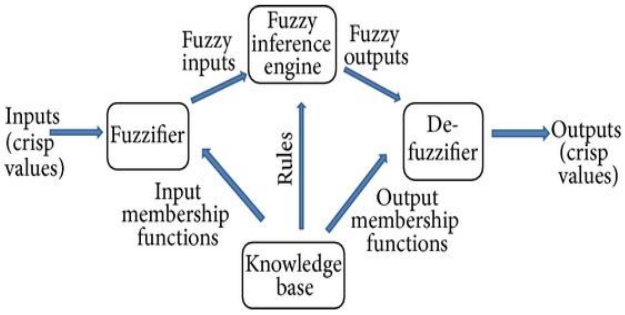

Fig. 1. Components of fuzzy based system
Source: [19]

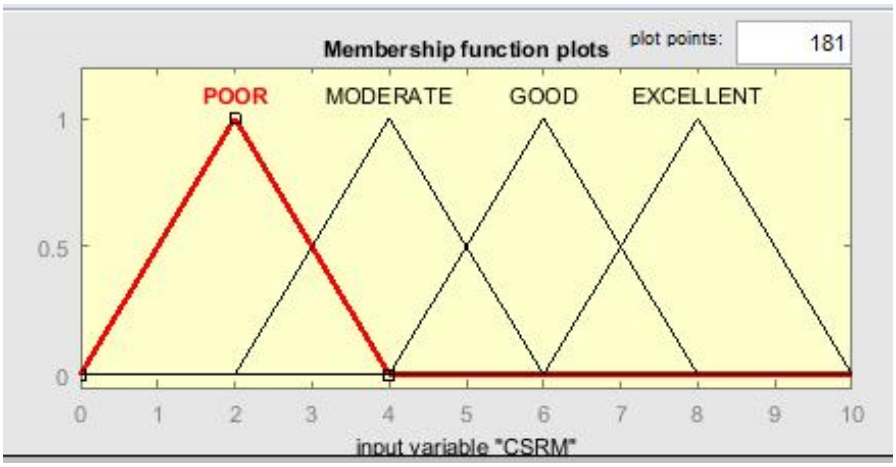

Fig. 2. Membership function for Condition of Service, Remunerations and Motivation (CSRM)

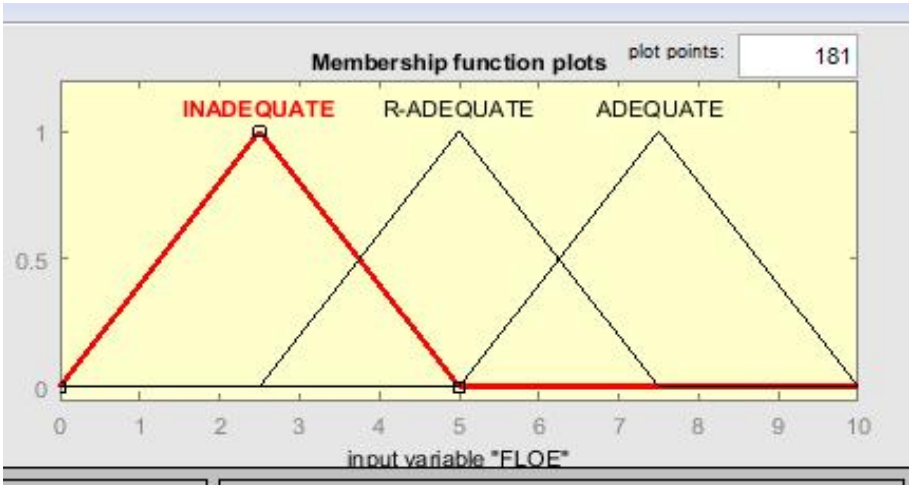

Fig. 3. Membership function for funding, logistics and operational equipment (FLOE)

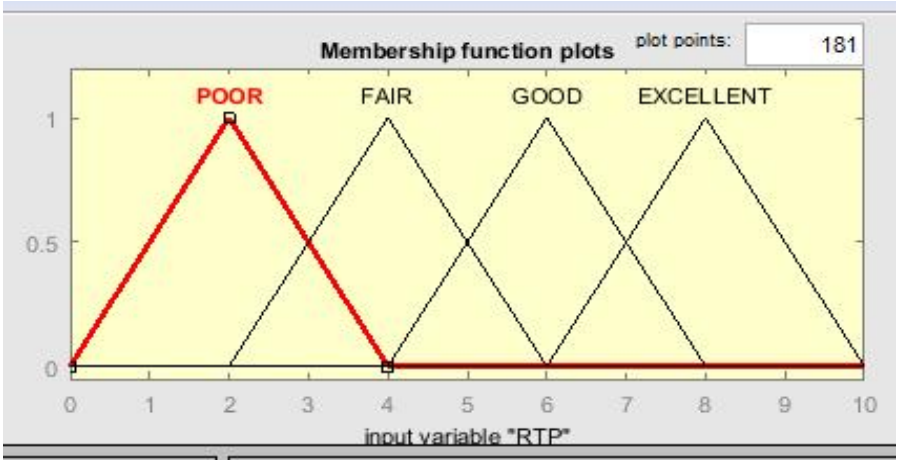

Fig. 4. Membership function for recruitment and training promotion (RTP)

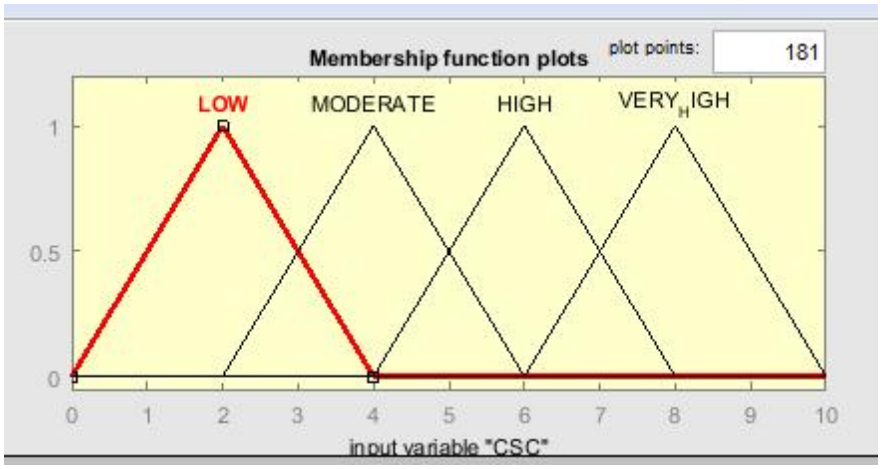

Fig. 5. Membership function for confidence and support by the community (CSC)

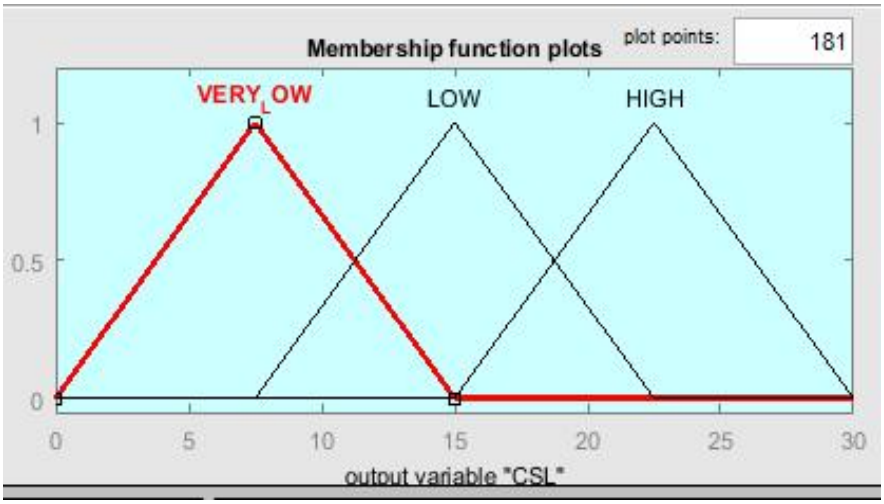

Fig. 6. Output membership function showing severity levels of corruption

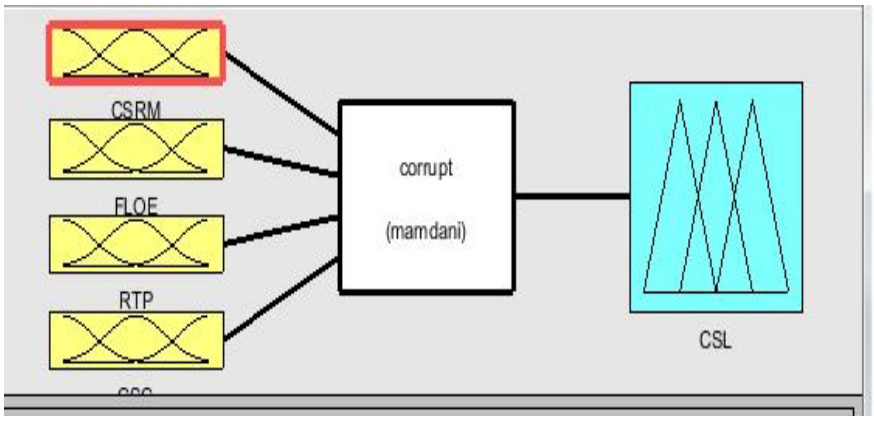

Fig. 7. Multi-input single output corruption control model

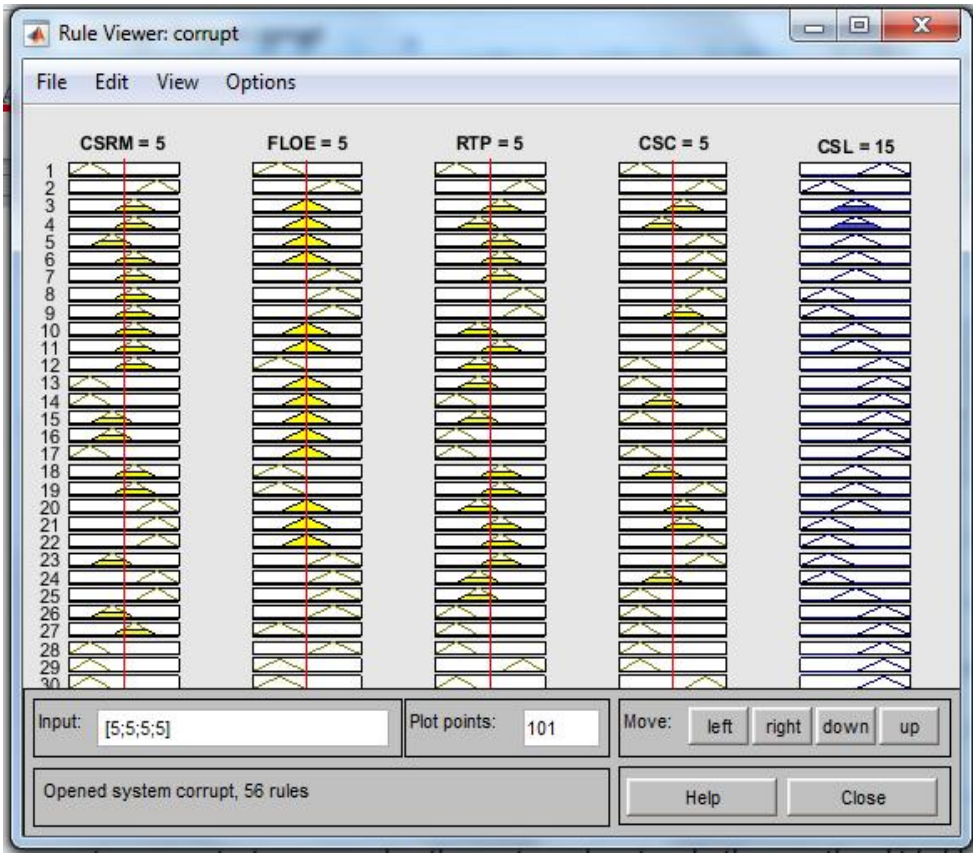

Fig. 8. Rules viewer of the model

4. RESULTS

4.1 Model Simulation

Modeling the fuzzy-based system for the determination of corruption severity levels four distinct input variables are chosen based on the experts' recommendation that corruption in NPF can be determined using CRMS and any three other corruption determining factors above. These input variables are *CSRM*, *FLOE*, *RT, CSC*.

The fuzzification of the inputs provides the degree to which each part of the antecedent has been satisfied for each rule – "belongingness". Since the antecedent of the rules used in the determination of severity level using fuzzy logic is more than one part, the fuzzy operator "AND" is applied to obtain one number that represents the result of the antecedents for that rule. This number will then be applied to the output function. The input to the fuzzy operator is four membership values from fuzzified input variables. The output is a single truth value.

In fuzzy system, every rule has a weight (a number between 0 and 1) which is applied to the number given by the antecedent. However, in the research work, a weight of 1 is assigned to each rule.

After assigning the weights to each rule, the implication method is then implemented. A consequent is a fuzzy set represented by a membership function, which weighs appropriately the linguistic characteristics that are attributed to it. The consequent is reshaped using a function associated with the antecedent. The input for the implication process is a single number given by the antecedent, and the output is a fuzzy set. Thereafter, implication is implemented for each rule.

Defuzzification process can be achieved via various methods. There are five built-in methods currently supported: Centroid, bisector, middle of maximum (the average of maximum value of the output set), largest of maximum, and smallest of maximum. However, the most popular fuzzification method is the centroid function

calculation which returns the center of area under the curve.

Decision making is made possible via the combinatorial effect of the database and the rule base that both constitute the knowledge base. This is sequel to the fact that decision are based on the testing of all the rules in an FIS, the rules are combined in the best manner with the assistance of experts in order to make decision.

Rules were generated for this research represented by 4 linguistically designed input with the CSRM, CSC, RTP having four (4) membership functions each , and the input variables FLOE is having three (3) membership functions. Rules generation in fuzzy system follows human reasoning pattern which make it more flexible in composition. It is just like a dialogue taking into cognizance the pros and cons on a circumstance. In the rule viewer provided by the Fuzzy inference System (FIS) in figure below, sliding the red lines changes the input values and, and generate a new output response, also, the inputs can be set explicitly using the edit field.

4.2 Simulation

The simulation was carried out with MATLAB 2015 for windows. The researcher's interest was observed how the different input variables were related towards determining the severity level of corruption in the Nigerian Police Force. The Variables SCRM, RTP and CSC were compared against FLOE to determine the trend of corruption levels in NPF. The surface viewer plot in the following (Figs. 9, 10, 11, 12 and 13) renders a 3D surface from two input variables and the output of a FIS. It displays the dependency of the output on any two of the inputs variables (that is, it generates and plots an output surface map for the system).

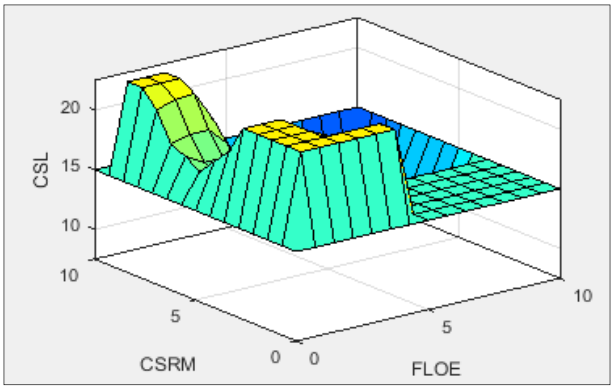

Fig. 9. Surface viewer plot of severity of CSL between FLOE and CSRM

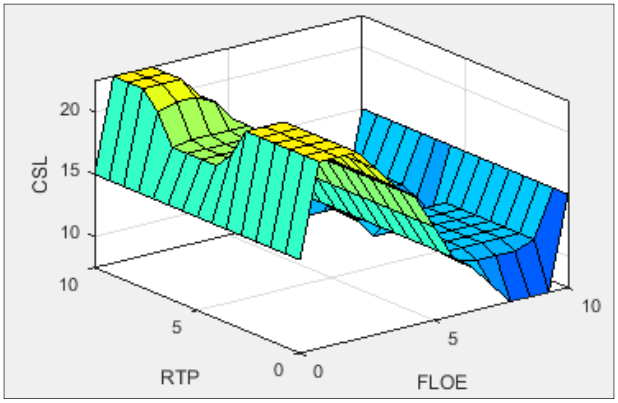

Fig. 10. Surface viewer plot of severity of CSL between FLOE and RTP

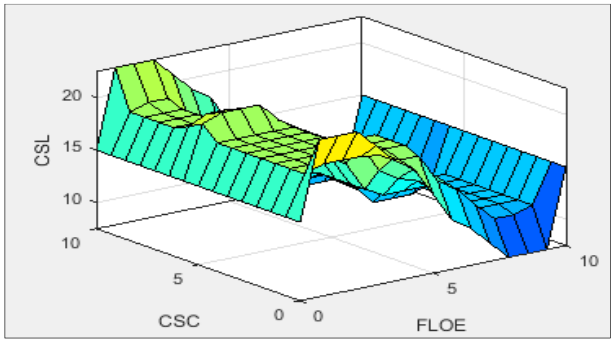

Fig. 11. Surface viewer plot of severity of CSL between FLOE and CSC

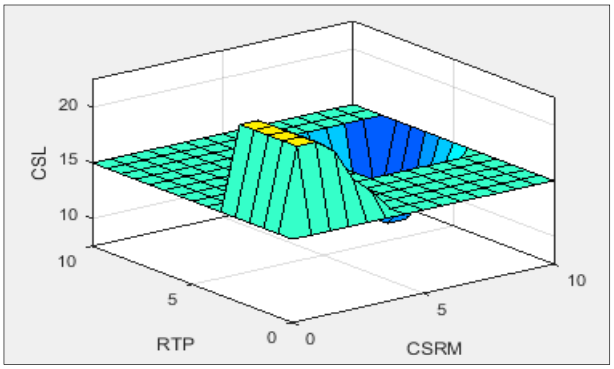

Fig. 12. Surface viewer plot of severity of CSL between CSRM and RTP

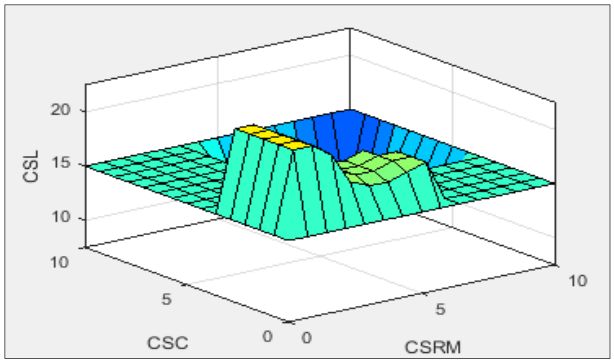

Fig. 13. Surface viewer plot of severity of CSL between CSRM and CSC

5. DISCUSSION

Recall the output parameter Corruption Severity Level (CSL) is defined on the basis of the linguistic variables Very high (15 – 30) level corruption, High level corruption (7.5 – 22.5) and Low level corruption (0 – 15). On the other hand, we have four input parameters defined as follows:

i. CSRM with linguistic variables Poor (0 - 4), Moderate (2 – 6), Good (4 – 8) and Excellent (6 – 10).
ii. FLOE with linguistic variables Inadequate (0 – 5), Relatively adequate (2.5 - 7.5), and Adequate 5 – 10).
iii. RTP with linguistic variables Poor (0 – 4), Fair (2–6), Good (4–8) and Excellent (6–10).

iv. CSC with linguistic variables Low (0–4), Moderate (2–6), High (4–8) and Very high (6–10).

It is clear from Fig. 9 that when the condition of service, remuneration and motivation poor (0-4) and funding, logistics and operational equipment (FLOE) is inadequate (0-5), then the corruption severity level (CSL) becomes very high (15-30). Also, if CSRM is good (4-8) and FLOE is relatively adequate (2.5-7.5), then obviously the corruption severity level will be low (0-15). In the situation where the CSRM is excellent (6-10) and FLOE is adequate (5-10), then the corruption severity level will also be low.

In Fig. 10 if the recruitment, training and promotion (RTP) is poor (0-4) and funding, logistics and operational equipment (FLOE) is inadequate (0-5), then the corruption severity level (CSL) will be very high (15-30). If the RTP is fair (2-6) and FLOE is relatively adequate (2.5-7.5), then the corruption severity level will be low (0-15). The CSL will also be low if the RTP is excellent (6-10) and FLOE is adequate (5-10).

In Fig. 11 If the confidence and support by the community (CSC) is low (0-4) and funding, logistics and operational equipment (FLOE) is inadequate (0-5), then the corruption severity level (CSL) will be very high (15-30). If the CSC is high (4-8), but FLOE is relatively adequate (2.5 – 7.5), the CSL will be low. The CSL will also be low if CSC is very high (6-10) and FLOE is adequate (5-10).

In Fig. 12 if recruitment, training and promotion (RTP) is poor (0-4) and condition of service, remuneration and motivation (CSRM) is also poor (0-4), then the corruption severity level (CSL) will be very high (15-30). If RTP is fair (2-6) and CSRM is good (4-8), the CSL will be low. CSL will also be low if both RTP and CSRM are excellent.

In Fig. 13 if confidence and support by the community (CSC) is low and condition of service, remuneration and motivation (CSRM) is also poor (0-4), then the corruption severity level (CSL) will be very high (15-30). If CSC is high (4-8) and CSRM is good (4-8), then the CSL will be low. Also if CSC is very high (6-10) and CSRM is excellent (6-10), then CSL will also be low.

6. CONCLUSION

This research work has attempted to develop an artificial intelligence model based on fuzzy logic for the control of corruption in Nigerian Police Force. The researcher employed fuzzy rule-base inference system methodology using four inputs variables; funding, logistics and operational equipment (FLOE) condition of service, remuneration and motivation (CSRM), recruitment, training and promotion (RTP), confidence and support by the community (CSC) were used to determine the corruption severity level. An output variable; corruption severity level (CSL) was adopted for the model development. The simulation was carried out using MATLAB 2015 for windows. The Variables SCRM, RTP and CSC were compared against FLOE as depicted in (Figs. 9, 10, 11, 12 and 13) and discussed in section 4.3. The results revealed that it is very obvious for Nigeria as a country to have a Police Force whose corruption severity level is low. Thus (i) Condition of service, remunerations and motivation has to be excellent; (ii) Funding, logistics and operational equipment has to be adequate; (iii) Recruitment, training and promotion has to be excellent, and finally (iv) Confidence and support by the community has to be very high.

The researcher further recommends the Nigerian federal government should use the findings of this research in order to have corrupt free nation of our dreams.

Hence, the need for more complex approaches to fighting corruption in the world and Nigeria Police in particular.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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