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Optimization of Governance Factors for Smart City Through Hierarchical Mamdani Type-1 Fuzzy Expert System Empowered with Intelligent Data Ingestion Techniques

Areej Fatima[1,2], Sagheer Abbas[1], Muhammad Asif [1], Muhammad Adnan Khan [1,*], Muhammad Saleem Khan[1]

[1]Department of Computer Science, National College of Business Administration and Economics, Lahore, Pakistan.
[2]Department of Computer Science, Lahore Garrison University, Lahore, Pakistan.

Abstract

A Smart City is an urban area that uses the Internet of things (IoT) sensors to collect data and information to enhance the operational aptitude, in a way to manage assets and resources efficiently. Smart governance is a factor of a smart city for intelligent utilization of ICT to enhance the basic leadership. The smart government may be considered as a reason for creating smart governance, through the application of rising information and communication technology for administering. Smart Governance is totally dependent on the information that is being recorderded. Smart consists of multiple factors that an essential role in smart city activities, which require complex collaborations between governments, citizens and different partners. In this article, a new computational method is proposed for the evaluation of the Governance factors of the smart city using Hierarchical Mamdani Type-1 Fuzzy Expert System and empowered with fuzzy based data ingestion techniques.

Keywords: Product Inference Engine, Information and Communication Technology, Ubiquitous Sensor Networks, Internet of Things, Internet of Services, Internet of Energy, Internet of People

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1. Introduction

The Smart city communities are an enthusiastic and developing examination topic. As of late, a few logical investigations regarding the matter have been composed, exhibited and examined. A far-reaching outline of the cutting edge in this examination field is accessible (Schaffers, 2012). While some examination works centre around an abnormal state view of citizens setting and let us go into consideration how the smart future city might appear on the urban eyes. Others presented a modern model or administration for the city. Throughout the year, a smart definition of the smart city has been offered. Nam and Pardo, analyzing some of these definitions in two firmly related works (Nam, 2011) notice that most works can be classified into various categories. They talk to the next smart cities, either a masonry, social or basic structure or a combination of three. In any case, from the freely chosen perspective, every commitment goes to urban innovation: in the first case attempting to structure the outside and substantial part (engineering, biology, etc.). In the second, the social part (governance, policy and citizen cooperation). While concentrating on the framework, the third is technical and internet-based, which is related to the city's intelligent system. Depending on how to use, it is acceptable to every work appreciation that is in the best contextual context. Another topic, the key to Smart City's idea and reverts it in recognition. This association, from a passive topic, transforms citizens into a live actor, an essential part of the framework, which becomes a real, live ecosystem, in turn, is now known as a living laboratory. (Schaffers, 2012). In ICT, the idea of a smart city expands intelligent and integrated networks, for example, USN. Actually, a smart city receives and integrate knowledge from the IoT, the IoS, the IoE and the IoP (Jos´e M Hern´andez-Mu˜noz, 2011) (Union, 2005). For example, information about traffic sensor intelligent integration, weather stations, and surveillance cameras can be used to spread around the city, (for example, citizens, ambulances, taxes) Current state of the urban route network with time traffic data and choice of paths.

Smart city minimises the human effort. In fact, shared conversations in smart cities are the enterprise's infrastructure

*Corresponding author. Email: madnankhan@ncbae.edu.pk

from the common city. For example, the city electric grid can be continuously checked to automatically warn the industrial control framework of the potential in electricity supply. The definition of mass deployment of large-scale sensors and citizens and re-accessible services for the administration. In this research work, a citizen environment is also held an open innovation platform to perform widely used in (Union, 2005). In (Schaffers, 2012) Explain a cloud computing model to offer different types of IT services for the citizens. Cloud management and monitoring are performed using mobile Android OS clients. The idea of this theory is to control the administration of every city of artists (citizens, companies, officials) to review the impact of government implemented in the context of Smart City and presenting novel-related promises presented by the author, Focus on fetching.
Several research topics and case studies are offered to understand the challenges introduced by the massive use of government in modern cities.

2. Literature Review

IoT is a recent communication paradigm which has concepts in the future, all the things that are utilized in day by day schedule of life must be embedded with microcontrollers, sensors, and transceivers for digital transmission and communication, and appropriate protocol nodes. That kind of protocol can be utilized to make them ready to generate extraordinary chance to communicate with each other and with the clients, turning into a crucial piece of the Internet (Luigi Atzori, 2010).
The IoT is actually to build up and influence the Internet considerably more to dedicate and widespread. Additionally, by simplifying the IoT enables things for simple procedures and associations, for example, home machines, test cameras, viewing and sensor, electric gadgets, actuators, showcases, vehicles etc. The application will confirm the improvement. These are widely used by the amount and rating of the collected information. That information utilizes for produced by such protests offer new administrations to natives, people groups, organizations, and open administrations. This worldview of IoT positively discovers application in various fields and territories, for example, vehicle robotization, modern and home mechanization, therapeutic sciences, versatile social insurance, shrewd atmospheres and ecological, intelligent vitality utilization the board and brilliant networks, car, activity the board, and numerous others (Paolo Bellavista, 2013).
However, such a diverse field of application of IoT for the smart city makes the recognition of best solutions make satisfying the requirements of all related application scenarios alarming challenge. Such kind of difficulty has led to the propagation of different and, occasionally, discordant proposals for the practical and applied the realisation of IoT systems. Henceforth, Machine-to-machine (M2M) communications are adding tremendous and marvellous interest from mobile network operators, device manufacturers, equipment vendors, as well as research and calibration bodies. The most important thing, is IoT platform designing and development, requires a perfect solution that is called middleware-level solution to enable the seamless interoperability between Machine-to-Machine based application and existing internet-based service (Luca Foschini, 2011).
The smart city project is most popular nowadays. The forecast for the latest estimation and research estimates that in the future, the global health organization living in more than a world population in the municipal areas claimed that by 2050, 70% of the world's population would remain in cities. (Melinda Moore, 2003). Fuzzy logic can smaller with data rising from computational observation and awareness, unclear, off base, obscure, incompletely evident, or without boisterous limits. Fuzzy logic allows for the enclosure of vague human assessments in computing problems. Additionally, it gives a compelling way to compromise of various criteria and better evaluation of choices. Current computing strategies dependent on fuzzy logic can be utilized in the improvement of smart frameworks for essential leadership, distinguishing proof, design acknowledgement, streamlining, and control (A & Zadeh, 2013).
Fuzzy inference rules will be the shelter for giving round all variables in smart urban areas. The plan is relied upon to encourage wellbeing, economic framework, environment, and Energy and Water utilization other guardians to make choices wisely. Subsequently, the IoT based framework can be utilized all the more proficiently without bargaining with the nature of the administration of the framework (Bhunia, 2014).
Additionally, more than half the world's population is living in cities. In this situation, one of the most advanced percentages can be used in developing countries, those who are the lion of natural resources consumption. Many studies have highlighted the importance of environmental protection strategy in urban areas because the environmental impact of these areas is to make it deeper than the big, deep and the world's citizens (William Rees, 1996)
Therefore, for this, to ensure stability and efficiency of scholars and researchers, to encourage the stability and effectiveness of such complex ecological system to find out the best way to encourage, strategically and to the city's organisers.
The smartness project is used for creating luxury in life. The smart city is a project which use the latest technology to enhance the quality of urban life. Smart City also improves environmental standards and provides better services to citizens (Hall, 2000). Transmission and Information Technology is important to support and change urban city to smart city (Dameri, 2012). The digital city is used alike a synonymous and identical of a smart city. Also, other translators are used, but the digital city is most frequent.
However, there might create an ambiguity when we use similar meaning words for specific one thing. So, smart and digital want to say the same thing or if they define different cities, technologies, and strategies. This is not just an educational or ideological matter but an operational one because we appreciate the type of city to adequately define what we intend to make economic, social, political and technical choices useful and profitable projects. Set up to apply tasks for our ideal city. IoT paradigm's application and

architecture in Smart City are mainly attracted to the local and regional administration that can be the initial adjusters of such technologies. Thus, a wide range of IT paragraphs can be adopted. (Prasad, 2017).

Urbanization is a file of change from customary country economies to present day mechanical one. It is a whole deal process through which the extent of masses among common and urban gets changed for urban settlement. Frequently urbanization has been considered as over urbanization because of its fast development of urban populace particularly in vast urban communities. It has been seen that high rate of populace development in urban regions, especially in expansive urban areas, is the result of high characteristic development and neediness driven rustic to urban relocation in short and long run (Sureshchandra, 2016).

Computational Intelligence approaches like Fuzzy system (Areej, et al, 2019) (Hussain et al, 2019), Neural Network (Ayesha, et al, 2019), Swarm Intelligence (Khan, et al, 2019) & Evolutionary Computing (Khan, et al, 2015) like Genetic Algorithm (Khan, et al, 2013) (Ali, et al, 2016) , DE, Island GA (Umair, et al, 2015), Island DE (Khan, et al, 2015) are strong candidate solution in the field of smart city (Wang et.al, 2019) (Kashif, et al, 2018), wireless communication (Asad, et al 2018) etc.

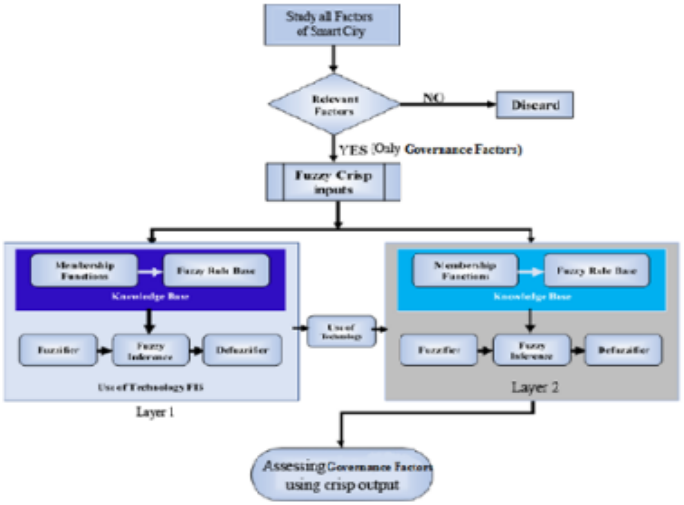


Figure 1: Proposed OGF-SCT-HMT-1-FES Methodology

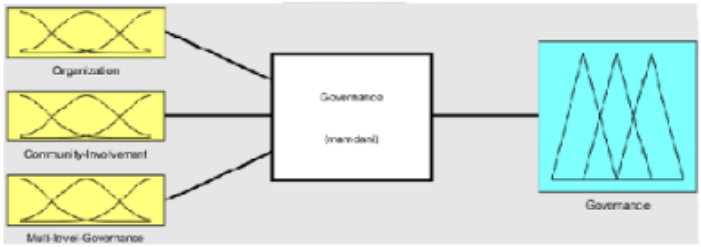


Figure 3: Final Layer of proposed OGF-SCT-HMT-1-FES

3. Proposed Methodology

The proposed approach based on fuzzy logic and describes a model that allows us to evaluate and estimate the actual weight of each factor only for Governance of Smart City. The proposed model present in more advanced and give us an accurate figure to measurement, estimation, and evaluation. Thus, by using this system help us to make any policy for business perspective and decision making.

Intelligent techniques are versatile in governance factors classification and estimation. Prominent techniques like fuzzy logic play a significant role in governance factors classification and help develop various continuous control schemes. This thesis presents the effectiveness of fuzzy logic concept in classifying the governance factors. Following is Flow chart representing proposal methodology of Governance Factors Smart City graphically. Figure 1 is a representation of the proposed methodology on how the flow of work is performing. This is showing the study of all factors relevant to Smart city is categories. They have discarded all irrelevant factors except the governance. Only governance factors will be processed and will use for evaluation of weight through

$$\text{FIS}.\mu_{A\cap B\cap C\cap D\cap E\cap F}(a,b,c,d,e,f) = \min[\mu_A(a),\mu_B(b),\mu_C(c),\mu_D(d),\mu_E(e),\mu_F(f)] \quad (1)$$

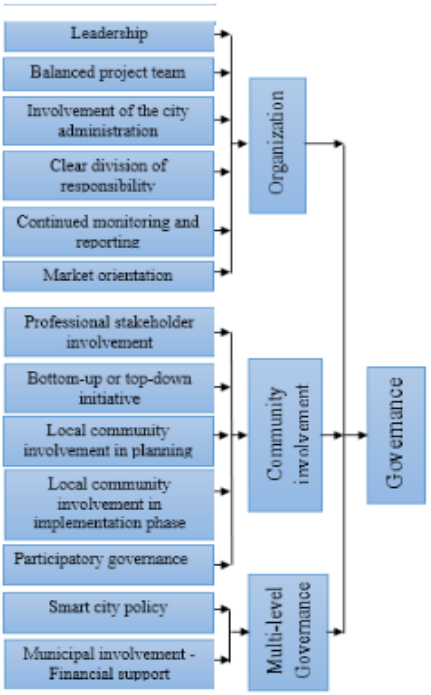


Figure 2: Proposed OGF-SCT-HMT-1-FES Expert System

3.1 Input Fuzzy Sets

Figuring input variable data prices are used to assess the quality of the governance to diagnose. For intelligent data ingestion, digested values are divided into three categories, which are Low, Normal and High after the interaction with the specialist. All input inputs are displayed in Table 1 with their numerical values.

Table 1. Input variable of proposed OGF-SCT-HMT-1-FES

Organization			
Properties/Parameter	**Low**	**Normal/Avg**	**High**
Leadership	≤ 19	11 ≤A≤ 39	≥31
Continued monitoring and reporting	≤ 14	6 ≤B≤ 29	≥ 21
		Low	**High**
Involvement of the city administration		≤ 19	≥ 11
Balance project team		≤ 14	≥ 6
Clear division of responsibility		≤ 14	≥ 6
Market orientation		≤ 19	≥ 11
Community Involvement			
Properties/Parameter	**Low**	**Normal/Avg**	**High**
Professional stack-holder involvement	≤ 19	11≤ G ≤ 39	≥ 31
		Low	**High**
Bottom-up or top-down initiative		≤ 19	≥ 11
Local community involvement in the planning phase		≤ 24	≥ 16
Local community involvement in the implementation phase		≤ 19	≥ 11
Participatory governance		≤ 13	≥ 7
Multi-level Governance			
Properties/Parameter		**Low**	**High**
Smart city policy		≤ 19	≥ 11
Municipal involvement Financial support		≤ 19	≥ 11

3.2 Fuzzy Output Variable

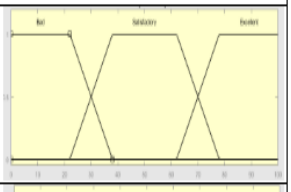
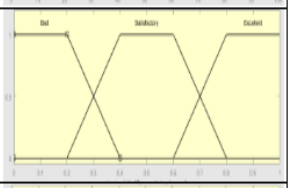
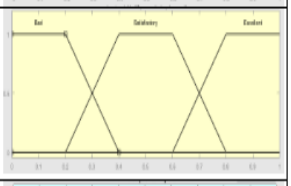
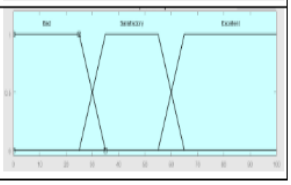
In this research, multi-layered architecture is offered to assess the assessment of governance factors. The production of all levels -1 layer and the final layer is shown in variable table 2.

Table 2. output variable of proposed OGF-SSCT-HMT-1-FES

Sr #	Layers	Output Variables	Semantic Sign
1	Level-1 Layers	The organization, Community involvement and Multi-level Governance	Bad
			Satisfaction
			Excellent
2	Final Layer	Governance	Bad
			Satisfaction
			Excellent

3.3 Membership Functions

Table 3. FIS Input/output Variables of Organization with Graphical & Mathematical representation of Proposed Methodology OGF-SCT-HMT-1-FES.

	Input	Membership Function	Graphical Representation of MF
1	N= $\mu_N(n)$	$\mu_{N,BA}(n) = \{\max(\min(1, \frac{38-n}{16}), 0)\}$ $\mu_{N,SA}(n) = \{\max(\min(\frac{n-22}{16}, 1, \frac{78-n}{16}), 0)\}$ $\mu_{N,EX}(n) = \{\max(\min(\frac{n-62}{16}, 1), 0)\}$	
2	P= $\mu_P(p)$	$\mu_{P,B}(P) = \{\max(\min(1, \frac{0.4-m}{0.2}), 0)\}$ $\mu_{P,NA}(P) = \{\max(\min(\frac{m-0.2}{0.2}, 1, \frac{0.8-m}{0.2}), 0)\}$ $\mu_{P,EX}(P) = \{\max(\min(\frac{m-0.6}{0.2}, 1), 0)\}$	
3	Q= $\mu_Q(q)$	$\mu_{Q,B}(Q) = \{\max(\min(1, \frac{0.4-c}{0.2}), 0)\}$ $\mu_{Q,NA}(Q) = \{\max(\min(\frac{c-0.2}{0.2}, 1, \frac{0.8-c}{0.2}), 0)\}$ $\mu_{Q,EX}(Q) = \{\max(\min(\frac{c-0.6}{0.2}, 1), 0)\}$	
6	Output=O $\mu_O(o)$	$\mu_{O,B}(O) = \{\max(\min(1, \frac{35-O}{10}), 0)\}$ $\mu_{O,NA}(O) = \{\max(\min(\frac{O-25}{10}, 1, \frac{65-O}{10}), 0)\}$ $\mu_{O,EX}(O) = \{\max(\min(\frac{O-55}{10}, 1), 0)\}$	

3.4 Fuzzy Prepositions

A fuzzy compound is a form of fuzzy atomic proposition using "or," "," and "not" based on the proposal, which represents the fuzzy union, intersections and complement respectively. Here, n, p, & q variables represent Leadership, continued monitoring and reporting, Involvement of the city administration, Balance project team, Clear division of responsibility and Market orientation. Then the following fuzzy propositions hold:

$$s: n \times p \times q \rightarrow O_1 \qquad (2)$$

All input and output variable values are made about the possibility of the real range because the FIS specialist system works on the opportunities (range 0-1).

Here the function t- norm for final layer in equation (2) is defined as:

$$s: [0,1] \times [0,1] \times [0,1] \rightarrow [0,1] \qquad (3)$$

Equation (3) transforms the membership functions of fuzzy sets of Leadership, continued monitoring and reporting, Involvement of the city administration, Balance project team, Clear division for a Final layer of proposed fuzzy inference system among membership function of the intersection of Leadership, continued monitoring and reporting, Involvement of the city administration, Balance project team, Clear division that is:

$s[\mu_N(n), \mu_P(p), \mu_Q(q)]$
$= \min[\mu_N(n), \mu_P(p), \mu_Q(q)]$ (4)

In Equation. (3), for the function t; getting qualified as an intersection, following axioms must be satisfied and will be called as t-norm:

Axiom w1: Bounded Condition
$s(0,0) = 0; s(\gamma,1) = s(1,\gamma) = \gamma$

Axiom w2: Commutativity
$s(\alpha,\beta) = s(\beta,\alpha)$

Axiom w3: Nondecreasing
If $\alpha \leq \alpha'$ and $\beta \leq \beta'$, then $s(\alpha,\beta) \leq s(\alpha',\beta')$

Axiom t4: Associativity
$s[s(\alpha,\beta),\gamma] = s[\alpha, s(\beta,\gamma)]$

Eq. (4) can be written regardings-norm as:
$\mu_{N\cap P\cap Q}(n,p,q) = s[\mu_N(n), \mu_P(p), \mu_Q(q)]$ (5)

From Eq. (4) & (5)
$\mu_{N\cap P\cap Q}(n,p,q) = \min[\mu_N(n), \mu_P(p), \mu_Q(q)]$ (6)

3.4 Lookup Table

The lookup table for the proposed OGF-SCT-HMT-1-F Expert System contains 12 input-output rules from 144 as shown in table 3.

Table 5. Lookup table for proposed OGF-SCT-HMT-1-F Expert Systems

Rules	Organization	Community Involvement	Multi-level Governance	Governance
1	B	B	B	B
2	B	B	S	B
3	B	S	E	E
4	B	S	B	S
5	S	E	S	E
6	S	E	E	E
7	S	B	B	B
8	S	B	S	S
9	E	S	E	E
10	E	S	B	S
11	E	E	S	E
12	E	E	E	E

Fuzzy IF-THEN rules apply to the terms described on the member-function. These rules are elements of the Fuzzy rule. Other components such as rules of the surface, rule viewers, etc., are based based on the fuzzy, so the foundation of Fuzzy rules is a major factor in the FIS. Fuzzy rule base of our expert system has 144 rules at the final layer. Rules are denoted by $Rs^n, where\ 1 \leq n \leq 144$.

Rs^1= **IF** Organization is bad AND Community Involvement is bad AND Multi-level Governance is bad, **THEN** Governance is Bad

Rs^2= IF Organization is bad AND Community Involvement is excellent AND Multi-level Governance is satisfactory, THEN Governance is Satisfactory

Rs^3= IF Organization is excellent AND Community Involvement is excellent, AND Multi-level Governance is satisfactory, THEN Governance is Excellent.

.
.
.

Rs^{144}= IF Organization is excellent AND Community Involvement is excellent, AND Multi-level Governance is excellent, THEN Governance is Excellent.

3.5 Fuzzy Interface Engine

The process of combining the fuzzy IF-THEN rules from the fuzzy rule base into a mapping from a fuzzy input set to fuzzy output based fuzzy logic principle is called the fuzzy inference engine. The fundamental part of Fuzzy Inference is membership functions, fuzzy logic operators, and if-then rules. All guidelines in the fuzzy rule base are consolidated into a single fuzzy relation that lies under the internal item on info universes of discourse, which is then seen as a single fuzzy IF-THEN rule. A reasonable operator for joining the rules is union.

Let Rs^n represents a fuzzy relationship that represents the final layer of proposed OGF-SCT-HMT-1-FES fuzzy IF-THEN. which one is

$$Rs^n = N^n \times P^n \times Q^n \rightarrow {S_w}^n \quad (7)$$

Equation (7) can be written as

$\mu_{N\cap P\cap Q}(n,p,q) = \mu_N(n) \cap \mu_P(p) \cap \mu_Q(q)]$ (8)

The principles of the final layer are translated as a single fuzzy connection characterized by

$$R_{144} = \bigcup_{n=1}^{144} Rs^n \quad (9)$$

This combination of rules is called a Mamdani combination. Assume i and Ψ be any two fuzzy sets and also input and output of fuzzy inference engine respectively. To view R_{144} as a single fuzzy IF-THEN rule by using the generalized modus ponens (Hellendoorn, February 1992), we obtain the output of the fuzzy inference engine as

$\mu_{Execellent\cap Satisfactory\cap Bad}(\Psi)$
$= sup_{i\in(N,P,Q)}\ t[\mu_i(n,p,q), \mu_{R_{144}}(n,p,q,S_w)]$ (10)

The PIE of proposed OGF-SCT-HMT-1-FES can be written as

$\mu_{\Psi}(Governance)$
$$= \max_{1\leq n\leq 144}\left[sup_{i\in(N,P,Q)}\left(\prod_{j=1}^{81}\left(\mu_{N_j,P_j,Q_j}(n,p,q), \mu_{H_{1_i}H_{2_i}H_{3_i}}(h_1,h_2,h_3)\right)\right)\right] \quad (11)$$

3.6 De-Fuzzifier

The important component of the expert system is Defuzzifier. Center of gravity (COG) is the best process of Defuzzifier. In proposed OGF-SCT-HMT-1-FES COG is

used. As the center of the area covered by the membership function of CoG Ψ *, λ, it is that,
The CoG determines the Ψ * as the focal point of the territory secured by the enrolment capacity of λ, that is,

$$\Psi^* = \frac{\int \lambda \, \mu_\lambda(\lambda) d\lambda}{\int \mu_\lambda(\lambda) d\lambda} \qquad (12)$$

The graphical representation of defuzzifier of proposed OGF-SCT-HMT-1-F expert system is shown in figure 4a-4c.
Figure 4a shows governance quality concerning components (Multi-level-governance and organization). That observed governance is Excellent (Yellowish shade). And governance is satisfactory (Greenish Shade). Another wise water quality is bad (Bluish Shade).

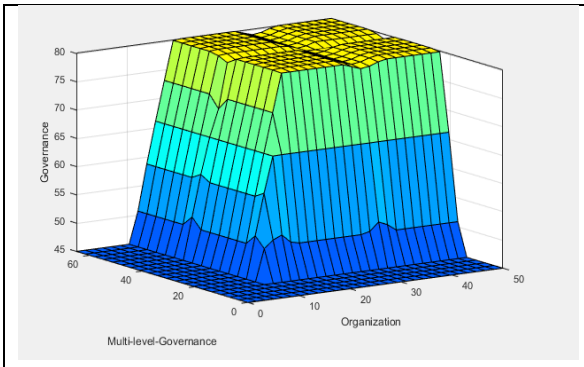


Figure 4a. Rules Surface of governance quality based upon: Multi-level Governance and Organization

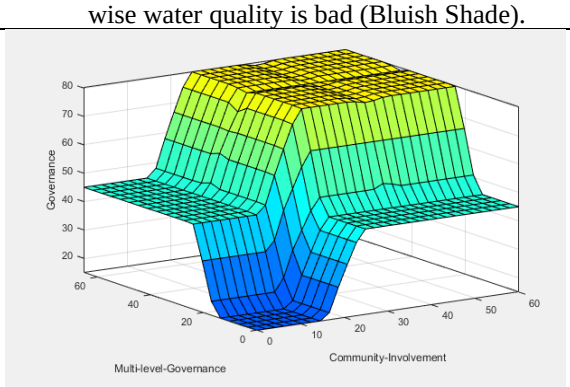


Figure 4b. Rules Surface of governance quality based upon: Multi-level Governance and Community-Involvement

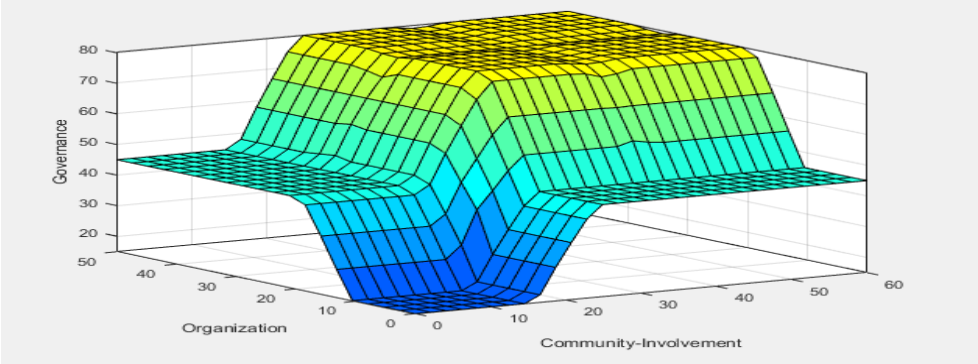


Figure 4c. Rules Surface of governance quality based upon: Organization and Community-Involvement

3.7 Simulation Results

Figure5a describes if the Organization is bad AND Community Involvement is bad AND Multi-level Governance is bad then Governance is Bad

Figure 5a: Final Layer, Lookup diagram of Bad Governance for proposed OGF-SCT-HMT-1-F Expert System.

Figure5b describes if the Organization is satisfactory AND Community Involvement is satisfactory AND Multi-level Governance is bad then Governance is Satisfactory.

Figure5c describes if the Organization is excellent AND Community Involvement is excellent, AND Multi-level Governance is excellent then Governance is Excellent.

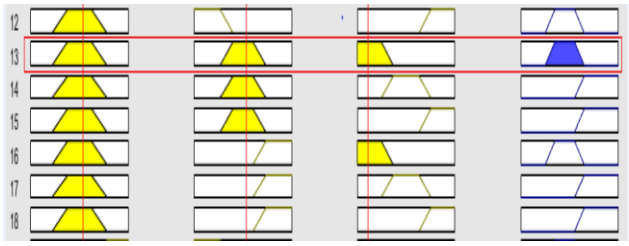


Figure 5b. Final Layer, Lookup diagram of satisfactory Governance for proposed OGF-SCT-HMT-1-F Expert System

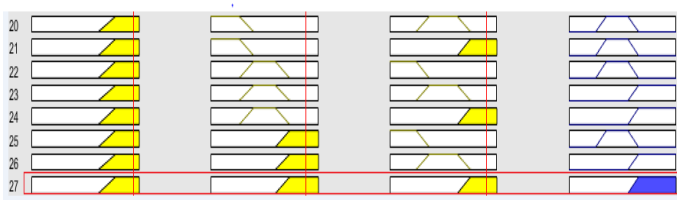


Figure 5c. Final Layer, Lookup diagram of Excellent Governance for proposed OGF-SCT-HMT-1-F Expert System

4. Conclusion

This paper has focused on the rule of governance in a smart city based on intelligent data ingestion techniques. The study of an emerging area that fascinates scientific and policy attention. More specifically, this paper provides further vision in descriptions of, the association among smart governance and idea such as smart and electronic government, an idea of smart cities. This paper demonstrates that smart government can be considered as a reason for creating smart governance, through the application of rising information and communication technology (ICT) for administering. Smart governance as intelligent utilization of ICT to enhance basic leadership through a better joint effort among various stakeholders, including government and residents, can be certainly identified with government approaches. For this situation, ICT-based instruments, for example, web-based life, social media and transparency can be factors that enhance national commitment and bolster the improvement of new administration models for the brilliant government. Smart governance may likewise have an essential role in smart city activities, which require complex collaborations between governments, citizens and different partners. Base on the research, this paper coins a meaning of 'smart city governance' based on fuzzy inspired data ingestion and contributes to developing a system for building new, smart governance models tending to the difficulties of the digital society, cooperative governance, information sharing, native commitment, openness and transparency.

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