Hindawi
Advances in Fuzzy Systems
Volume 2022, Article ID 3375567, 9 pages
https://doi.org/10.1155/2022/3375567

Research Article

Mitigation of Corruption by Implementing e-Government Using Soft Computing

Shareef M. Shareef

Software and Informatics Engineering Department, College of Engineering, Salahaddin University, Erbil, Iraq

Correspondence should be addressed to Shareef M. Shareef; shareef.shareef@su.edu.krd

Received 3 August 2022; Revised 14 September 2022; Accepted 27 September 2022; Published 6 October 2022

Academic Editor: Jose A. Sanz

Electronic government (e-government) allows citizens to contact government authorities directly through computers, smartphones, and the Internet. In the return reducing face-to-face interaction with government employees decreases their permissive role and the potential for corruption, hence enabling the government to be more effective and trustworthy and provide transparency and accountability. However, e-government is not the only aspect of the larger battle against corruption; it is not the only way to reduce corruption. e-government is successful in the fight against trivial and administrative corruption. In spite of that, broad governmental actions, including both preventative and perhaps disciplinary anticorruption measures are required to combat corruption. This research aims to identify the factors that affect success in reducing the level of corruption in e-government, and then evaluate these factors by developing a model that determines the effective factors that impact the mitigation of corruption. We believe that a soft computing-fuzzy logic algorithm is an appropriate method for evaluating and determining the effective factors, and hence might lead to a feasible way to the success of e-government. The findings revealed that the model is adaptable and may be used in e-government performance applications for government authorities and experts.

1. Introduction

Government authorities may enhance the frequency of interactions between citizens and government, as well as the quality of government services and trust in government, to enhance the efficiency and transparency of government services. This is done by implanting e-government system. e-government is the use of ICT as a tool to provide services to the citizens, businesses, and government institutions effectively and efficiently. Thus, enable government to be more effective and trustworthy and sharply increase the possibilities of establishing and mitigating corruption [1–4]. Many countries across the globe are experiencing high levels of corruption, particularly in developing countries. Corruption can be defined as the abuse of public power for personal or private gain [5]. In other words, corruption is the exploitation of public authority for private gains. Transparency International [6], a trustworthy worldwide body, mentioned that over 2/3 of the180 nations and regions studied scored less than 50, on a scale of (0–100) highly corrupt to very clean, demonstrating the tremendous inescapability of corruption around the world. The area and nature of government corruption differ in political, financial, and social settings, but the drivers of corruption, monopoly of power, discretion, and the lack of accountability and transparency may be all-inclusive [7]. e-government applications have the ability to establish more consistent, efficient, and accurate procedures that will certainly reduce the level of corruption.

In addition, corruption has attracted increased attention among e-government researchers in the recent decade, determined by the desire to combat it and has become a hotly disputed topic in the field of Computer Science. However, the most prevalent discussion has been on the capacity of e-government programs to combat corruption [8, 9]. Some research studies verifying how corruption obstructs economic development offer a convincing argument that affordsto challenge corruption are especially important in developing countries [10, 11]. Particularly, e-government tools and applications have some control over corruption in the public sector by resolving the issues of improper information dissemination, lack of transparency, lack of accountability, improper law implementation, political corruption, monopoly of power, abuse of authority, lack of e-participation and improper ICT infrastructure, lack of public service bargains, and misuse of public power for private gain [5, 12, 13].

Although e-government is not the only factor in mitigating corruption, yet it is one of the parts of the general battle against corruption. Connection shows that e-government is powerful in the battle with petty and administrative corruption. In any case, grand corruption, in which the political elites exploit their position of power to create economic policies that, maximizes their own personal gains. To battle against it, far-reaching state measures are required, including both preventive and perhaps abusive enemy of corruption measures [14]. This paper uses the Kurdistan Region of Iraq (KRG) as a case study, that uses a fuzzy logic algorithm to examine the success factors influencing the e-government in developing countries in the context of various factors that drive corruption, such as increase of accountability and transparency (AT), e-participation (EP), and computer literacy (CL) [15–18].

The rest of the paper is organized as follows: the second section reviews the related literature, and section three illustrates the characteristics of the fuzzy inference system (FIS). Developing a model that determines and evaluates the effective factors that impact the mitigation of corruption in a way to achieve the success of e-government is presented in section four. In section five the collected data will be added to the model using MATLAB simulation and discusses the results. Some conclusions reached in this paper will be presented in section six.

2. Literature Review

Citizens are realizing the importance and benefits of electronic government such as accountability, transparency, law implementation, dissemination of information, the convenience of e-service availability, friendly use of the website, and others. The active nature of e-government suggests e-services to make changes in their related processes and decisions made to satisfy citizens' needs. e-services are adopting ICT tools and systems with the collaboration of fuzzy logic systems to predict the future of the government. With the help of ICT, the government have more possibilities to choose types and structures of the required information to serve citizens.

Many researchers, Bhatnagar and Apikul [19], Andersen [20], Elbahnasawy [21], Lupu and Lazar [22], and Park CH and Kim K. [18] believe that e-government has the potential to mitigate corruption. According to Bhatnagar and Apikul [19], the use of ICT has revolutionized public services substantially. Bertot et al. [23] arrive at a broad theoretical conclusion on the potential of e-government to increase openness and boost anticorruption efforts. Mensah and Mi [24] and Kizabekova and Chernyshenko [25] consider the effect of e-government and electronic communications in general on the advancement of propaganda, transparency, and accountability in the society.

In this research, the fuzzy inference system, an area under the umbrella of the soft computing model for factor evaluation to mitigate corruption will be used. In this regard, Fei et al. [26], used the fuzzy analytic hierarchy process to assess the success of e-government, the weights of criteria and subcriteria of evaluation in e-government performance management were determined using a fuzzy multicriteria decision making (MCDM) technique. This technique has the benefit of being able to be utilized for both qualitative and quantitative criteria. The findings suggested that the model is adaptable and may be used in e-government performance applications. Roy, et al. [27], described the classification of call centre customers and service advisors and then used a fuzzy expert system framework to allocate each customer call and customer service advisor (CSA) to a predefined type from the classifications. The least quantity of information necessary by the adviser to service the client may be generated and presented on the screen once the writers define the kind of consumer and advisor. The study proposes a loyalty index that assesses customer satisfaction declines based on complaints within the call centre and forecasts turnover time periods using customer profiles. Once the profile has been defined, a long-term estimate of how long the client will stay with the firm may be calculated.

In spite of the fact that ICT is commonly inspected as an anticorruption weapon, it can also lead to the inverse impact when such instruments are utilized for rather than against corruption. Rising innovations can give new corruption openings through cryptocurrencies, the dark web, or the abuse of well-intended advances such as computerized open administrations and central databases (World Bank, 2014). Some researchers consider points to the unfavourable utilization of ICT for corruption. In another word, some people or institutions use ICT in the wrong way, for example, €2 million vanish each year from Croatian tollbooths due to authorities entering wrong information into the modern computerized data framework [28]. So, investing in ICTs can be corrupted due to a major negative effect [29]. Such cases underline the reality that ICT is not per se a nostrum against corruption, and it can play into the hands of corrupt authorities. In addition, some studies [11, 18] have argued that e-government cannot eliminate public sector corruption. However, numerous studies [3, 5, 13, 30] have suggested that e-government technologies and apps can reduce corruption in the public sector by addressing problems such as lack of accountability, ineffective governance, information inequalities, and service delays between others. On the other hand, some studies contend that e-government may not be sufficient to address corrupt behaviours that have remained even after the digitization of public services [31].

Furthermore, there were some research studies examining the impact of corruption on e-government, in contrast to the majority of the studies under evaluation that postulated the possible impact of e-government on corruption and examined this one-way relationship. Elbahnasawy [21] examined board data from 160 countries and determined that, amongst the few studies to investigate this inverse relationship, the relationship was directed from e-government to corruption but not the other way around. A clean public administration may be the primary force behind the spread of business-oriented e-services, according to an econometric analysis of 24 European countries that found corruption to have a detrimental influence on the provision of e-government services to enterprises [32]. In conclusion, this matter is clearly understudied and is lacking both theoretical justification and empirical evidence. Nevertheless, it is still not clear based on the accessible writing beneath the conditions that e-government encourages instead of controlling corruption. How can e-government elude being captured by corrupt elites strengthening the very societal partitions they were implied to decrease?

The literature has been found lacking in the area of identifying and evaluating factors that affect corruption using a fuzzy system. All these papers do not focus on criteria related to mitigation of corruption by implementing e-government. This research seeks to address gaps by providing some critical factors that enable performance evaluation of effective and efficient e-government by developing a model using a fuzzy inference system that will assist in evaluating important factors, hence it might lead to reducing the level of corruption.

3. The Fuzzy Inference System

However, there is widespread literature that tackles the factors that impact the success of e-government, particularly in developing countries where the identification of the factors that affect the corruption of e-government using a fuzzy inference system are none or few. This research uses a fuzzy inference system by using MATLAB fuzzy logic toolbox to accomplish its objectives. Fuzzy logic is an essential component for the soft computing as it is a mathematical language to express something. The idea of choosing the fuzzy inference system is to help decision-makers to identify the effective factor that impacts the success of e-government which is based on human decision-making. Fuzzy logic advocated by Zadeh [33] gives us a language, with sentence structure and local semantics, through which we can translate our qualitative knowledge about the problem to be solved. Fuzzy units are described against crisp units. For crisp units, the element (ч) belongs to a set (S) or does not belong to it totally. By contrast, the fuzzy set concept allows the step-by-step evaluation of the membership of elements in a set. This is defined with the help of a membership function valued in the actual unit interval (0 and 1).

Fuzzy logic may be a capable problem-solving technique with a multitude of applications in implanted control and data processing. It gives an extremely easy way to draw clear conclusions from unclear or ambiguous data. In other words, fuzzy logic likens human decision-making to its ability to work from estimated data and find exact solutions. In spite of the fact that numerous variables impact the decision process of corruption reduction, the recognition of an impacting factor is more vital than the real level of the factor itself. For instance, in case the level of accountability and transparency is higher than its real execution, at that point it will contribute to the success of e-government. There may be cases where the reverse is genuine as well, but in those cases, a higher level of influence will be required to change the perception level [34].

In this section, we will propose a model and execute to visualise the design and execution of a fuzzy inference system by considering the success of e-government. The following factors are considered to identify the reduction of corruption and lead to the success of e-government according to the three factors. Therefore, our model consists of three factors (increased accountability and transparency (AT), e-participation (EP), and computer literacy (CL) inputs) and a single output that is the success of e-government. Data was collected from the result of interviews carried out by experts of the ministries in the KRG, rules are determined from their practical and past experiences.

The scope and the range of input are as follows:

Range of the linguistic variable (low) differs from 1 to 40

Range of the linguistic variable (high) differs from 40 to 70

Range of the linguistic variable (very high) differs from 70 to 100

For the scope and the range of the output as follows:

Range of the linguistic variable of the output (corrupt) differs from 1 to 30

Range of the linguistic variable (marginally success) differs from 30 to 60

Range of the linguistic variable (success) differs from 60 to 80

Range of the linguistic variable (Great success) differs from 80–100

The values for each input are computed in MATLAB using a fuzzy inference system. The fuzzy inference system (FIS) utilizes the following stages, and the architecture of FIS is shown in Figure 1.

3.1. Fuzzy Rule Base. This section covers the fuzzy logic system's rules and membership functions for regulating and controlling decision-making. It is a collection of knowledge in the IF-THEN rule from the experts. In which defines the relationship between input factors and output. It also utilized to illustrate how the output is subject to anybody or two of the inputs.

Here, IF refers to the conditions that are satisfied and THEN refers to the consequences that are deduced.

3.2. Fuzzification. The process of changing the success of e-government scores into fuzzy inputs with the assistance of membership functions that characterizes how each point within the input space is mapped to a membership value between 0 and 1. Fuzzy output: the inference engine at that point applies a reason to compute fuzzy output done by utilizing IF-THEN rules which relate numerous input and

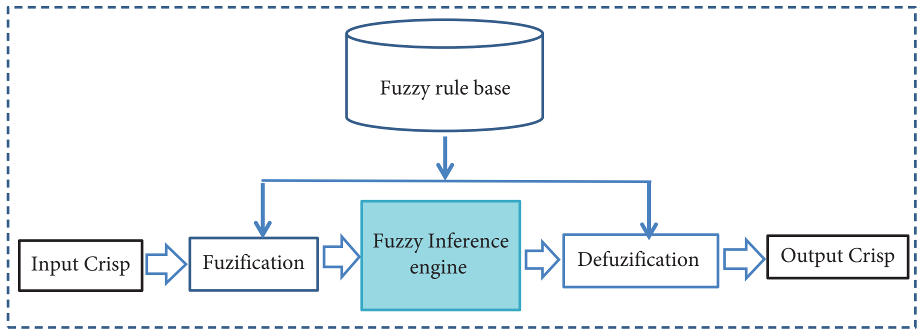

Figure 1: Architecture of the fuzzy logic system.

output factors. In other words, raw inputs are transformed into fuzzy sets via the Fuzzifier component. The fuzzy sets are sent to the control system, where they are processed further.

3.3. Inference Engine. This is a tool that determines the best rules for a given set of data. The input data is subsequently subjected to these rules, resulting in a fuzzy output.

3.4. Defuzzification. The internal fuzzy output factors are changed over into crisp values that can really be utilized. The crisp output denotes the by and large achievement of the government. The centre of gravity (COG) or the centroid calculation approach is utilized for defuzzification. The COG finds the point where the vertical line would slice the aggregate set into two equal masses.

4. Propose a Model Using the Triangular Membership Function

In this section, the researcher aims to develop a model, since this model is more suitable for this kind of problem. Different components for assessing success will be considered. We will consider the most important three of the factors selected and will be fuzzified as input fuzzy factors, and then it will be fuzzified with reasonable fuzzy linguistic factors, and eventually, a fuzzy inference system will be created. The primary step within the plan of our model is to determine fuzzy sets to characterize the input and output. For simplicity, each factor will be characterised by three fuzzy sets, as shown in Tables 1 and 2.

4.1. Fuzzification. In this stage, for each input factor, we consider membership functions so that the clear inputs get to be fuzzy and are within the fuzzy inference system. The membership function is utilized to represent a grade for each linguistic variable. There are distinctive kinds of membership functions, such as triangular, trapezoidal, and Gaussian. In this study, the researcher uses a triangular membership function, which is illustrated in Figure 2.

Figure 2 shows that we select the three parameters and one output of the e-government status and apply them to the FIS and arrange the rules, then we evaluate the e-government success.

Table 1: Input factor with its linguistic variables.

Input factors	Linguistic variables		
AT	Low	High	Very high
Range	1–40	40–70	70–100
EP	Low	High	Very high
Range	1–40	40–70	70–100
CL	Low	High	Very high
Range	1–40	40–70	70–100

Fuzzification of the input parameter AT with their membership function and its corresponding range as illustrated in Table 1, the membership functions are touching each other as shown in Figure 3.

Figure 4 shows fuzzification of output parameter EP with their membership function and its corresponding range as illustrated in Table 1, the membership functions are touching each other for achieving better results.

Figure 5 illustrates fuzzification of input parameters CL with their membership function and its corresponding range as illustrated in Table 1.

4.2. Rule Based. The rule base is known as the fuzzy IF-THEN set that shapes the heart of the FIS. There are two primary methods for deciding fuzzy rules: one is the utilization of expert knowledge and the other is the utilization of self-organized training, such as neural systems. In this study, the first method will be utilized to decide on fuzzy rules. As per the input and output factors fuzzified as a depicted rule base is produced by applying experts reasoning to observe or make the choice to assess the success level of e-government. The IF-THEN rule is defined as; if X is Ai and Y is Bi then Z is Ci, where X and Y are inputs and Z is the output (conclusion); Ai, Bi, and Ci are linguistic variables, low, high, and very high. To compute the output, Mamdani's model will be used. There are 27 number of rules produced utilizing the 'AND' and 'OR' operators. The overall rules are shown in Figure 9.

Rule 1: if TA is low, EP is low, and CL is low, then the level of e-government will be corrupt (need improvement).

Rule 2: if TA is low, EP is low, and CL is high, then the level of e-government will be corrupt (need improvement).

Rule 3: if TA is low, EP is low, and CL is very high, then the level of e-government will be corrupt (need improvement).

Table 2: Output with its linguistic variable.

Output	Linguistic variables			
Success of e-government	Corrupt (need improvement)	Marginally success	Success	Very success
Range	1–30	30–60	60–80	80–100

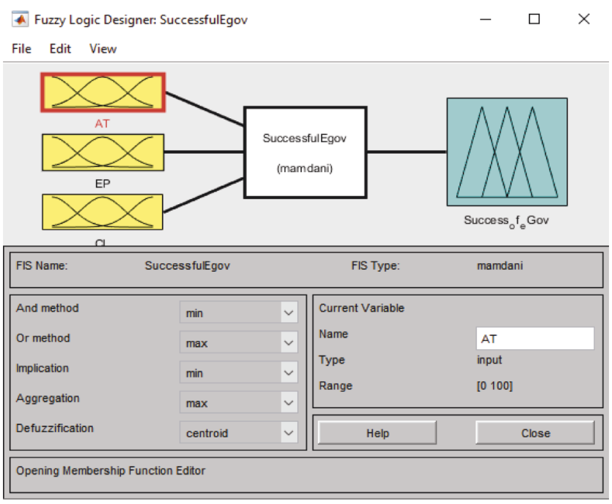

Figure 2: Design of three inputs and one output of fuzzy inference system triangular.

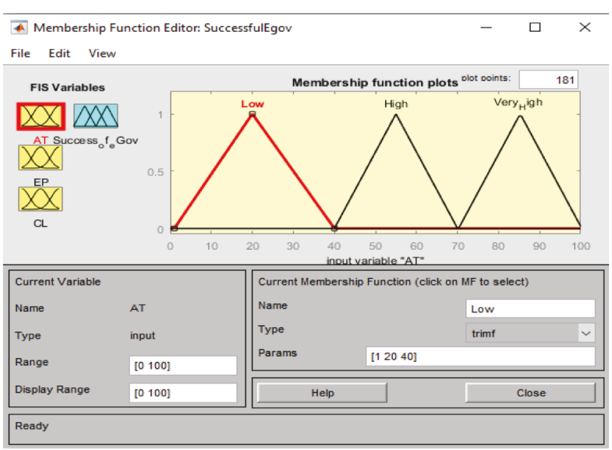

Figure 3: Fuzzification for IAT.

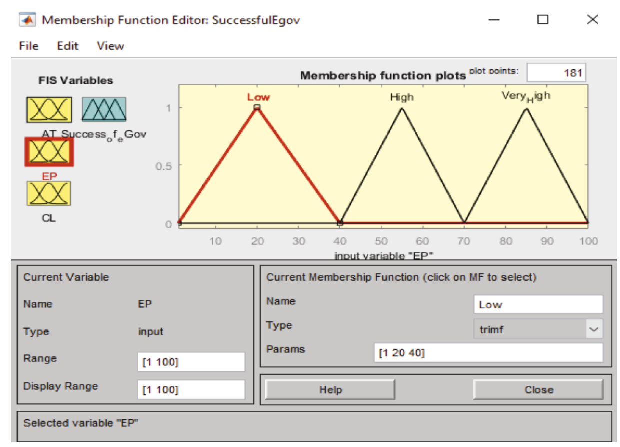

Figure 4: Fuzzification for EP.

Rule 4: if TA is low, EP is high, and CL is low, then the level of e-government will be corrupt (need improvement).

Rule 26: if TA is very high, EP is very high, and CL is high, then the level of e-government will be very successful.

Rule 27: if TA is very high, EP is very high, and CL is very high, then the level of e-government will be very successful.

4.3. Defuzzification. Defuzzification means the conversion of the fuzzy output values into a crisp value. In other words, it is a method of turning a fuzzy set into a definite number. Hence, the input of the diffuse method could be a fuzzy set (the sum of the output fuzzy sets) and its result is a number. Fuzzy makes a difference with a midstage valuation is the ultimately wanted output for each variable which is only one number. In this study, we will use the commonly used method for the defuzzification of the outputs which is the centre of gravity (COG) method [35].

$$\mathrm{COG} = \frac{\int \mu i\ (x) x dx}{\int \mu i\ (x) dx}, \tag{1}$$

where μ is a membership degree and x is its value. In other words, all these values with their weights or membership function degrees are taken into account to find the centre of gravity or single output. A reasonable approximation can be gained by calculating it over a sample of point. The output of this is the input to the next fuzzy model that evaluates the level of success of e-government, corrupt, marginally success, success, and very success for identifying and evaluating the overall success of e-government.

5. Simulation and Discussion

In this study, the researcher used MATLAB toolbox software to identify and evaluate the effectiveness of the three factors impacts the success level of e-government. The three factors are given to the model as input to define which factor has had a remarkable effect on the level of the success of e-government. The extracted rules for inputs for estimating output are illustrated in Table 3.

The output of the fuzzy logic system can be seen in Figure 7. The simulation of this fuzzy inference in the three dimension can be represented in 27 rules; the factors that illustrate the most remarkable impact on the output in various formats are mentioned here.

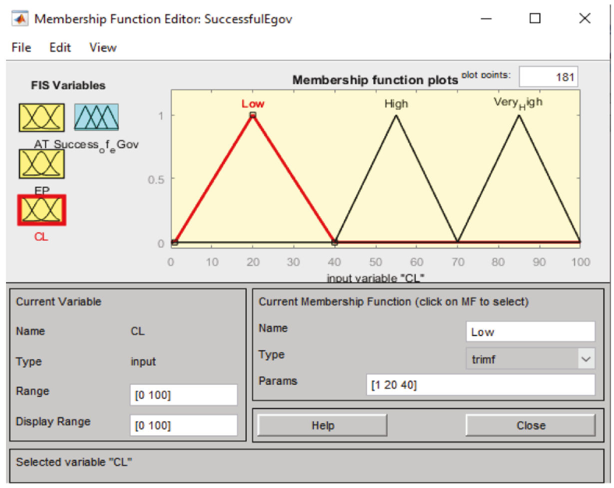

Figure 5: Fuzzification for CL.

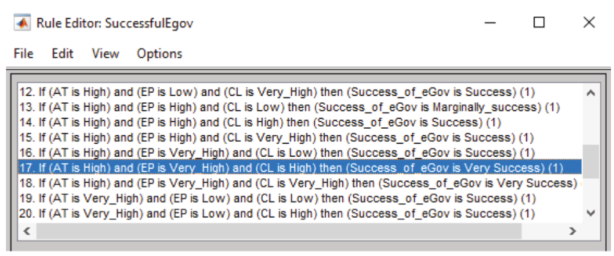

Figure 6: Rule base developments.

Table 3: Extracted rules.

Rule numbers	TA	EP	CL	Output
1	L	L	L	Corrupt
2	L	L	H	Corrupt
3	L	L	VH	Corrupt
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
24	VH	H	VH	Very successful
25	VH	VH	L	Very successful
26	VH	VH	H	Very successful
27	VH	VH	VH	Very successful

Figure 8 shows that the highest magnitude for the level of success is when accountability and transparency (AT) are "Very-High" and e-participation (EP) is "High." This suggests that when government agencies are accountable and transparent to their citizens to some degree and hence people have belief in their government.

Figure 9 illustrates that the highest scale for the level of very success is when accountability and transparency (AT) are "Very High" and computer literacy (CL) is "Very High." This suggests that when government agencies are accountable and transparent to their citizens to some degree and hence people have belief in their government. In the contrast, the government will be corrupt when the levels of accountability and transparency are low along with low of computer literacy.

Figure 10 illustrates that the highest degree for the level of very successful e-government is when e-participation is "Very High" and CL is "Very High." This suggests that when government provide opportunities for its citizen to use e-services and allow them to participate in decision making, hence the level of participation will increase. In addition, the advancement of computer literacy and the reduction of the digital divide extensively impact the reduction of corruption.

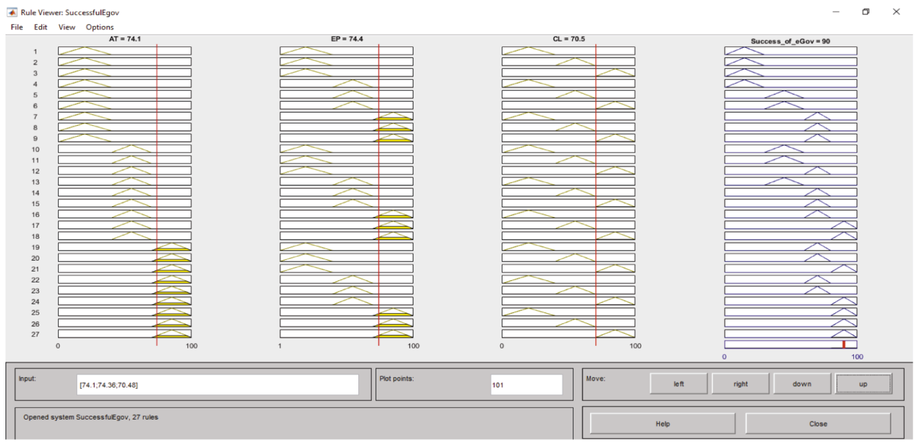

Figure 7: Rule base and output assessment values.

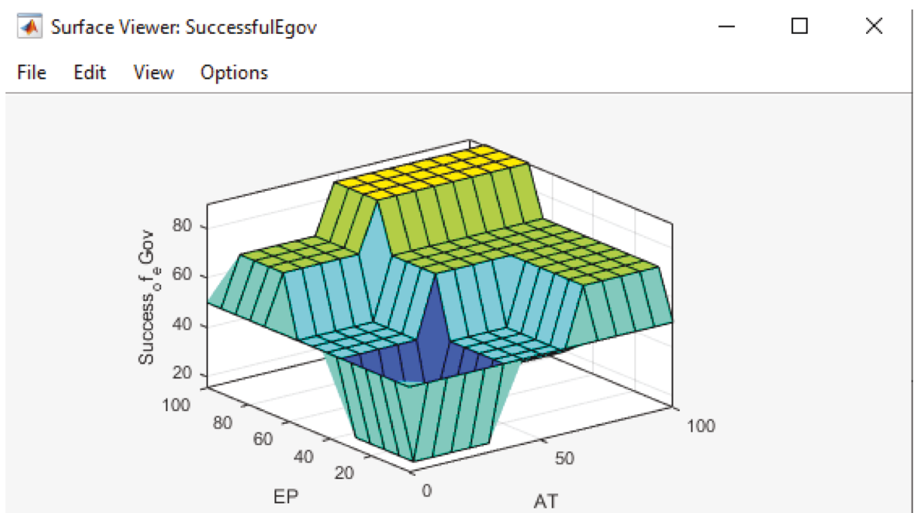

Figure 8: Three dimension of the EP and IAT with the success of e-government.

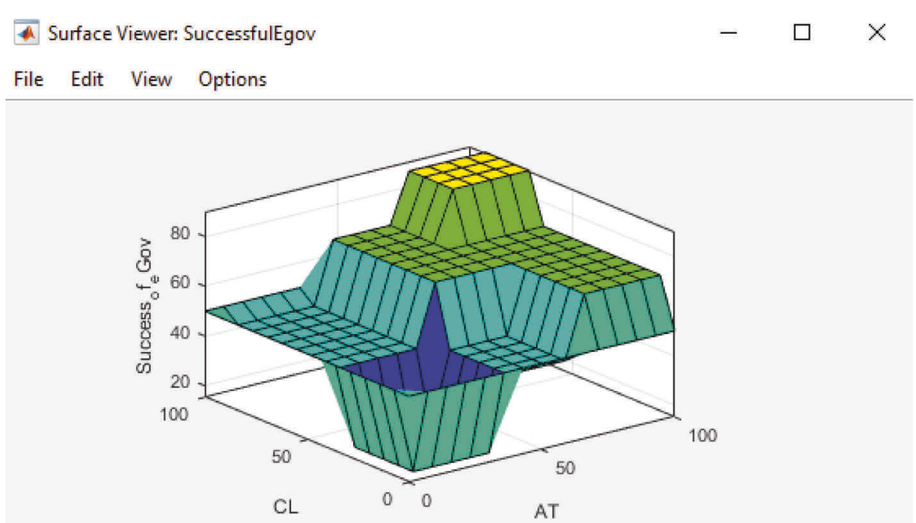

Figure 9: Three dimension of the IAT and CL with the success of e-government.

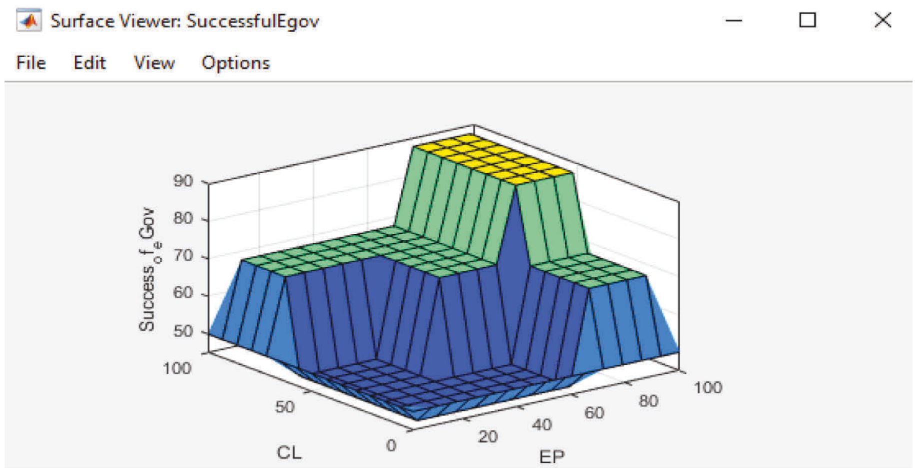

Figure 10: Three dimensional of the EP and CL with the success of e-government.

6. Conclusion

In this paper, a model has been proposed based on fuzzy logic to evaluate the factors that impact the mitigation of corruption. It attempted to identify factors that connect with a positive impact on decreasing corruption in KRG. The factors influencing the success of e-government in terms of three input variables were considered. The finding of this model illustrated that there is an important positive relationship between e-government implementation and reduction of corruption. The highest degree for the success is when ATs are very high and CL is very high. This implies that when government agencies are accountable and transparent to their citizens to some degree, people have trust in their government. Furthermore, the highest magnitude for the level of success is when EP is high. The development of computer proficiency and the reduction of the digital divide extensively impact the reduction of corruption. Among worldwide e-government investigations, there is an experimental proof for a clear quantitative relationship between the application of e-government and the decrease of corruption in developed and developing countries, which will lead and will boost the success of e-government in a significant way. For the concrete conclusions of the relationship between e-administrations and the reduction of genuine corruption, the time is required because according to the experts, it takes longer to evaluate the effect of the combat against corruption on developing countries in particular. Therefore, we believe that from the verifiable time viewpoint, with the advancement of measures taken by the e-government to increase the level of e-participation and increase the level of computer literacy along with the increase of transparency and accountability, these relationships will be more obvious and more special for future comparative ponders.

Data Availability

The data have been collected through interviews with the IT people in Kurdistan regional government's institution, along with some information taken from the government website: https://uk.gov.krd/.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] L. Chen and A. K. Aklikokou, "Relating e-government development to government effectiveness and control of corruption: a cluster analysis," *Journal of Chinese Governance*, vol. 6, no. 1, pp. 155–173, 2021.

[2] L. Chen and A. K. Aklikokou, "Relating e-government development to government effectiveness and control of corruption: a cluster analysis," *J. Chin. Gov*, vol. 119, 2019.

[3] T. Ahmad, R. Aljafari, and V. Venkatesh, "The Government of Jamaica's electronic procurement system: experiences and lessons learned," *Internet Research*, vol. 29, no. 6, p. 1571, 2019.

[4] X. Zhao and H. D. Xu, "E-government and corruption: a longitudinal analysis of countries," *International Journal of Public Administration*, vol. 38, no. 6, p. 410, 2015.

[5] S. C. Srivastava, T. S. H. Teo, and S. Devaraj, "You can't bribe a computer: dealing with the societal challenge of corruption through ICT," *MIS Quarterly*, vol. 40, no. 2, pp. 511–526, 2016.

[6] Transparency International, "Corruption Perceptions Index 2020," 2020, https://www.transparency.org/en/cpi/2020.

[7] C. Deane, "E-Government anti-corruption strategies," *Recommendations for implementation of an e-records management system*, https://ssrn.com/abstract=2782504, 2016.

[8] N. H. Hartani, V. Q. Cao, and A. Q. Nguyen, "Reducing corruption through egovernment adoption," *Journal of Security and Sustainability Issues*, vol. 9, no. M, pp. 202–213, 2020.

[9] E. B. Aduwo, E. O. Ibem, A. O. Afolabi et al., "Exploring anti-corruption capabilities of e-procurement in construction project delivery in Nigeria," *Construction Economics and Building*, vol. 20, no. 1, pp. 56–76, 2020.

[10] J. J. Mistry and A. Jalal, "An empirical analysis of the relationship between e-government and corruption," *International Journal of Digital Accounting Research*, vol. 12, pp. 145–176, 2012.

[11] D. K. Basyal, N. Poudyal, and J. W. Seo, "Does e-government reduce corruption?" Evidence from a heterogeneous panel data model Transform," *Transforming Government: People, Process and Policy*, vol. 12, no. 2, pp. 134–154, 2018.

[12] L. Silva and R. Hirschheim, "Fighting against windmills: strategic information systems and organizational deep structures," *MIS Quarterly*, vol. 31, no. 2, pp. 327–354, 2007.

[13] K. Vu and K. Hartley, "Promoting smart cities in developing countries: policy insights from Vietnam," *Telecommunications Policy*, vol. 42, no. 10, pp. 845–859, 2018.

[14] G. Sheryazdanova, R. Nurtazina, B. Byulegenova, and I. Rystina, "Correlation between E-government and corruption risks in Kazakhstan," *Utopía Y Praxis Latinoamericana*, vol. 25, no. 7, 2020, https://www.redalyc.org/journal/279/27964362004/27964362004.pdf.

[15] A. Corojan and J. Criado, "E-government for transparency, anti-corruption, and accountability: challenges and opportunities for Central American countries," *Handbook Of Research on E-Government in Emerging Economies: Adoption, E-Participation, and Legal Frameworks*, pp. 328–330, IGI Global, Hershey, PA, 2012.

[16] A. Addo, "Controlling Government Corruption through IT: An Opportunity Theory Perspective," in *Proceedings of the International Conference on Information Systems*, Barcelona, Spain, September 2018.

[17] A. Addo and P. K. Senyo, "Digitalization and government corruption in developing countries: towards a framework and research agenda, academy of management," 2020, https://journals.aom.org/doi/10.5465/AMBPP.2020.16765abstract.

[18] C. H. Park, K. Kim, and K. Kim, "E-government as an anti-corruption tool: panel data analysis across countries," *International Review of Administrative Sciences*, vol. 86, no. 4, pp. 691–707, 2020.

[19] S. Bhatnagar and C. Apikul, "Fighting corruption with e-government applications," *APDIPe-Note*, vol. 8, pp. 1–4, 2006.

[20] T. B. Andersen, "E-Government as an anti-corruption strategy," *Information Economics and Policy*, vol. 21, no. 3, pp. 201–210, 2009.

[21] N. Elbahnasawy, "E-government, internet adoption, and corruption: an empirical investigation," *World Development*, vol. 57, pp. 114–126, 2014.

[22] D. Lupu and C. G. Lazăr, "Influence of e-government on the level of corruption in some EU and non-EU states," *Procedia Economics and Finance*, vol. 20, pp. 365–371, 2015.

[23] C. J. Bertot, P. T. Jaeger, and J. M. Grimes, "Promoting transparency and accountability through ICTs, social media, and collaborative e-government," *Transforming Government: People, Process and Policy*, vol. 6, no. 1, pp. 78–91, 2012.

[24] K. Mensah, "Exploring the moderating effect of perceived usefulness on the adoption of E government services," *International Journal of Electronic Government research*, vol. 15, no. 1, pp. 17–35, 2019, https://www.irma-international.org/viewtitle/231561/?isxn=9781522564409.

[25] A. Kizabekova and V. Chernyshenko, "E-Government Avatar-Based Modeling and Development, Avatar-Based Control," *Estimation, Communications, and Development of Neu Multi Functional Technology Platforms*, pp. 19–34, 2020.

[26] J. Fei, R. Yao, and L. Yu, "Fuzzy analytic Hierarchy process application to E- government performance evaluation," in *Proceedings of the IEEE Fifth International Conference on Fuzzy Systems and Knowledge Discovery*, Jinan, China, October 2008.

[27] R. Roy, S. Shah, A. Tiwari, and J. Hadden, "Soft Computing in the Service Industry," in *Proceedings of the 6th Recent Advances In Soft Computing Conference.Canterbury*, pp. 1–9, United Kingdom: Springer-Verlag, July 2006.

[28] ReSPA, "Abuse of information technology (IT) for corruption," *Regional School of Public Administration*, Danilovgrad, 2013, https://www.respaweb.eu/download/doc/01+Abuse+of+IT+for+Corruption+ENG.pdf/3150c827ad9bae7b31ba4e04e69ad1af.pdf.

[29] P. Charoensukmongkol and M. Moqbel, "Does investment in ICT curb or create more corruption?" A cross-country analysis," *Public Organization Review*, vol. 14, no. 1, pp. 51–63, 2014.

[30] T. Nam, "Examining the anti-corruption effect of e-government and the moderating effect of national culture: a cross-country study," *Government Information Quarterly*, vol. 35, no. 2, pp. 273–282, 2018.

[31] S. Saxena, "Factors influencing perceptions on corruption in public service delivery via e-government platform," *Foresight*, vol. 19, no. 6, pp. 628–646, 2017.

[32] P. Seri, A. Bianchi, and N. Matteucci, "Diffusion and usage of public e-services in Europe: an assessment of country level indicators and drivers," *Telecommunications Policy*, vol. 38, no. 5-6, pp. 496–513, 2014.

[33] L. A. Zadeh, "Fuzzy sets," *Information and Control*, vol. 8, no. 3, pp. 338–353, 1965.

[34] F. Akhter, "Implement fuzzy logic to optimize electronic business success," *International Journal of Advanced Research in Artificial Intelligence*, vol. 5, no. 3, 2016.

[35] M. Gupta and J. Mago, "Fuzzy expert system to evaluate the quality of service provider in the implementation of E-government," *International Journal of Computer Application*, vol. 67, no. 18, pp. 16–22, 2013.