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Study of Illegal Wildlife Trade based on ARIMA and Linear Regression Modeling

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Abstract

Illegal wildlife trade has been on the rise in recent years, posing a threat to endangered species and ecosystems. In response to this problem, this study aims to identify the most suitable clients to implement anti-illegal trade projects and assess their capacity. Using a client assessment model, we identified the World Customs Organization as the most suitable to undertake a five-year project, predicted trade trends through an ARIMA model, and demonstrated project effectiveness. Intervention analysis showed that the project could reduce the number of illegal transactions. However, the project required more resources and authority. Linear regression modeling reveals that the client needs to be upgraded in many areas. This study provides important guidance for reducing illegal wildlife trade and calls for increased cooperation and resource allocation to protect wildlife ecosystems.

Keywords

AHP; ARIMA; Linear Regression.

1. Introduction

In recent years, the spreading illegal wildlife trade has posed a serious threat to endangered biological communities and ecosystems, triggering great concern about the issue on a global scale [1]. Governments and relevant organizations have taken measures in an attempt to curb this crisis [2]. However, in the face of the expanding and worsening scale of illegal trade, we urgently need more in-depth research and more effective interventions to protect wildlife and maintain ecological balance.

The purpose of this paper is to provide important guidance for reducing illegal wildlife trade by identifying clients best suited to implement anti-illegal trade programs and assessing their capacity. We use a client assessment model to identify the World Customs Organization (WCO) as the most suitable to undertake this five-year program, use an ARIMA model to predict trade trends and demonstrate program effectiveness. Our research not only explores the magnitude of the problem in theory, but also seeks solutions in practice, calling for greater global cooperation to protect precious biodiversity and ecosystems.

2. Client Evaluation Model

2.1. Determination of Indicators and Data Collection

To establish the client evaluation model, we select several indicators for determine the most appropriate client to choose. Among the indicators, the WCO indicator stands out for its superior ability of finance, human resources, information technology, legal force, public influence over the other indicators. Meanwhile, it exhibits more interest in reducing the amount of illegal wildlife trades. To compare the matching degree between different organizations and

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our illegal wildlife trade reduction project, we use the AHP framework to determine which client to choose [3].

Our framework is presented as follows:

Resources: the capabilities that a potential client can allocate to support and implement the project, including financial, human, and technology resources.

Authority: the institutional and legal power that a client or organization has to impose and carry out actions against the illegal wildlife trade.

Degree of interest: the degree of dedication and enthusiasm a potential client exhibits in tackling the problem of the illegal wildlife trafficking.

Following the identification of the indicators, we collect data offered by official organizations, including Kenya Wildlife Service (KWS), World Customs Organization (WCO), World Environment Organization (WEO), and Biodiversity Research Institute (BIR). The reduction of illegal wildlife trade requires abundant resources and mandatory, therefore, we choose large organizations such as international organizations, National government agency, non-governmental organization, scientific research institution as our main study object. After the first-level indicators are determined, we obtain 6 second-level indicators. As shown in Table. 1.

Table 1. The indicators of the AHP framework

Level 1	Level 2		Unit
Resource	Financial Resources	FR	US$
	Human Resources	HR	people
	Information and Technology Level	ITL	-
Authority	Legal Force	LF	-
	Public Influence	PI	-
Level of interest	N/A	LI	number

2.2. Determination of the Optimal Client

After deciding the first-level indicators and the following second-level indicators of the client evaluation model, the AHP framework is used to evaluate the overall capabilities.

Table 2. Summary result of judgement matrix

	Resource	Authority	LI	Feature Vector	Weight Value (%)
Resource	1	0.2	3	0.843	18.295
Authority	5	1	8	3.42	74.184
LI	0.333	0.125	1	0.347	7.52
	FR	HR	IT	Feature Vector	Weight Value (%)
FR	1	5	7	3.271	73.959
HR	0.2	1	2	0.737	16.659
ITL	0.143	0.5	1	0.415	9.381

To form a hierarchy of indicators, we use the judgement matrix in Table. 2 to calculate the weight value of every indicator to know the different importance of each indicator that contributes to an organization's overall capability. The feature vector, the system adopts root method for calculation by default, and the feature variable reflects the weight of the factor. The weight value, that is, the normalization result of the feature variable, maps the feature vector to the interval of 0~1.

Approximate weight value of the feature vector:

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$$W_i = \frac{(\Pi_{j=1}^{n} a_j^i)^{\frac{1}{n}}}{\sum_{i=1}^{n} \left(\Pi_{j=1}^{n} a_j^i\right)^{\frac{1}{n}}}, ij = 12kn \tag{1}$$

The weight value is obtained by normalizing the feature vector:

$$W = (W_1, W_2, \dots, W_n)^T \tag{2}$$

The results of weight calculation of analytic hierarchy process (based on root method) show that the weight of resources is 18.295%, the weight of authority is 74.184%, and the weight of level of interest degree is 7.52%. The weight of financial resources is 73.959%, the weight of human resources is 16.659%, and the weight of information is 9.381%. The maximum value of index weight is financial resources (73.959), and the minimum value is information (9.381).

In order to ensure the correctness and rationality of the obtained weights, a consistency test needs to be carried out. A CR value should be calculated to test whether there are logical errors exist in the judgement matrix.

To obtain the CR value, a concordance index (CI) should be calculated:

$$CI = \frac{\lambda_{max} - n}{n-1} \tag{3}$$

Among them,

$$\lambda_{max} = \sum \frac{(AW)_i}{nW_i} \tag{4}$$

Apparently, the larger CI, the greater the error. Therefore, the randomness consistency ratio is used to test CR:

$$CR = \frac{CI}{RI} \tag{5}$$

The Consistency test results require CR value to be less than 0.1, which is used to judge whether there are logical errors when people construct judgment matrix. For example, there are three indicators A, B, C, we judge that A is more important than B, B is more important than C, so logically A must be more important than C, but if C is more important than A when constructing judgment, A is more important than C, then you have made a logical error and cannot pass the consistency test.

Table 3. Summary result of the judgment matrix of the scheme layer

Node Items	KWS	WEO	BRI	WCO	CR Value	Consistency Test
FR	0.087	0.313	0.054	0.547	0.014	Pass
HR	0.118	0.305	0.051	0.527	0.018	Pass
ITL	0.118	0.305	0.051	0.527	0.018	Pass
LF	0.099	0.321	0.045	0.535	0.025	Pass
PI	0.11	0.301	0.063	0.526	0.008	Pass
LI	0.118	0.305	0.051	0.527	0.018	Pass

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Table. 3 shows that the CR value of all second-level indicators are less than 0.1. Therefore, there are no logical error in the construction of the judgement matrix.

After the weight of each indicator is determined, we use the data of each indicator collected from the four organization to calculate the value of each organization for every indicator. Since the score of the upper-level node can be calculated according to the score weight of its child nodes, only the leaf nodes are constructed when the scheme layer judgment matrix is constructed, that is, N leaf nodes are constructed to construct N judgment matrices, which are used to synthesize pair comparison and obtain the score of the scheme layer for a certain leaf node.

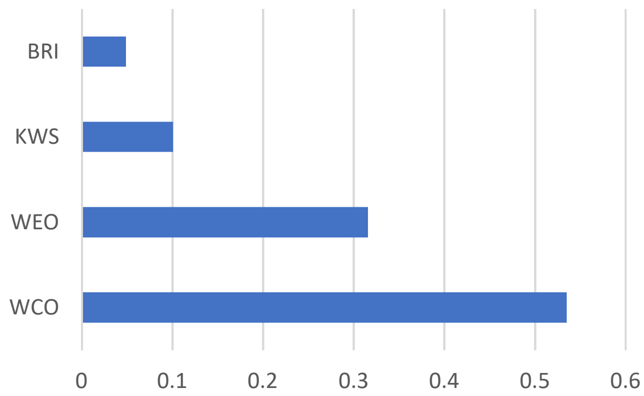

Figure 1. Scheme score for each organization

Based on single ranking of index hierarchy and total ranking of scheme hierarchy shown in Figure 1, the best scheme for the most suitable customers is WCO, and its quantitative score is 0.535.

3. Client Persuasion

3.1. The Importance of Reducing Illegal Wildlife Trade

The increasing number of illegal wildlife trade have threatened the ecosystems and mainly by reducing the amount of some species. Pangolin trade can be seen as the most popular illegal wildlife trade all over the world. Take pangolin trade as an example, a total of 1485 trading incidents were reported to CITES, and 809,723 whole pangolins were estimated to be involved in commerce for the full period between 1977 and 2014.

As shown in Figure 2, the United States is the most linked nation in the network (61 links out of 44 trading partners); it is followed by China (28/23), Japan (25/19), Italy (22/18), and Singapore (19 15). The top five trading nations account for 63% of import and export trade links. Only the United States, accounting for 78% of pangolin trafficking events, was a significant importer of pangolin items among the five nations.

This extensive pangolin trade exacts far-reaching ecological consequences, precipitating profound imbalances within ecosystems. Pangolins, as integral components of ecosystems, assume a pivotal role in pest regulation through their predation on ants and termites. The precipitous decline in pangolin populations disrupts this delicate ecological equilibrium, potentially resulting in the unchecked proliferation of insect populations with cascading repercussions on vegetation, soil dynamics, and the broader biotic milieu. Beyond ecological perturbations, the vulnerability of pangolins to exploitation underscores the broader ramifications of biodiversity loss. Illegal wildlife trade not only jeopardizes the viability of specific species but also undermines the overall robustness and resilience of ecosystems. This pertinence extends to socio-economic dimensions, given the reliance of local communities on intact ecosystems for sustenance and livelihoods.

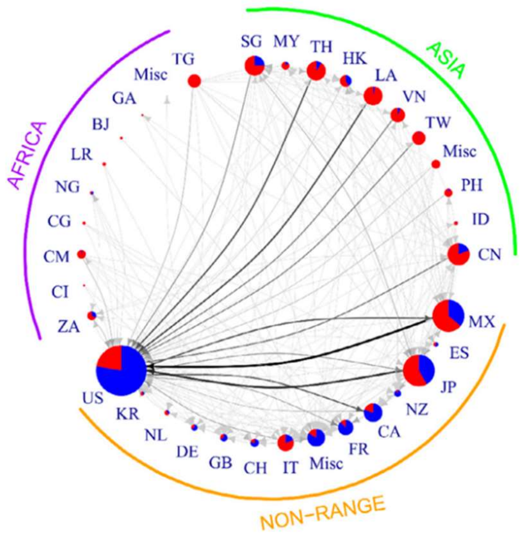

Figure 2. Global distribution of illegal wildlife trade by area source

3.2. Future Predict

The five-year project has several interventions on the process of illegal wildlife trafficking. To make a prediction of the amount of illegal wildlife trade after the implementation of the five-year project, we have collected statistics of relevant cases from CITES reports, as shown in Figure 3.

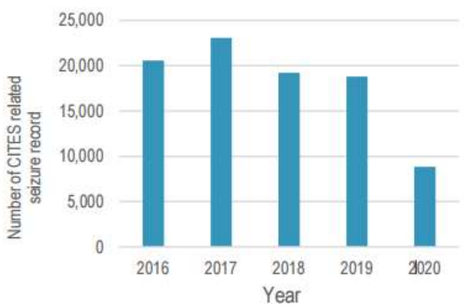

Figure 3. Annual impounded quantity of wild animals before intervention

We introduced the ARIMA method for forecasting the amount of global illegal wildlife trade in the future five years.

The ARIMA model is commonly applied when analyzing and modeling multiple time period data [4]. The underlying premise of the model is that a random process generates the time series that needs to be forecasted. It is possible to precisely characterize and define the random process's structure if the random process that creates the sequence remains constant across time. Future values of the sequence can be inferred from past data. The future value of the sequence is expressed in the model as a linear function of the lag term and the lag period of the random disturbance component [5]. The overall form of the ARIMA model is as follows:

$$Y_t = c + \alpha_1 Y_{t-1} + \cdots + \alpha_p Y_{t-p} + \epsilon_t + \beta_1 \epsilon_{t-1} + \cdots + \beta_q \epsilon_{t-q} \tag{6}$$

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Table 4. Annual impounded quantity of wild animals after intervention

Year	Number
2021	12000
2022	11345
2023	10293
2024	9594
2025	8840

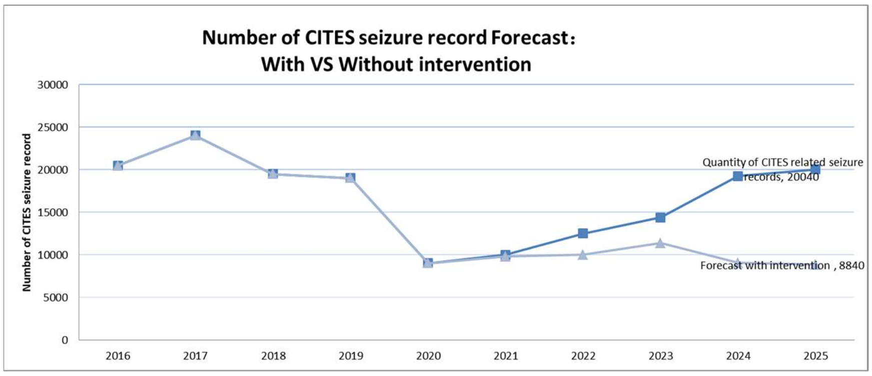

Figure 4. The trend of annual impounded quantity of wild animals after intervention

The compelling data presented in Table.4 and Figure 4 underscore the substantial efficacy and impact anticipated through the proposed intervention in the five-year project aimed at mitigating illegal wildlife trade. Prior to the intervention, the estimated magnitude of illegal wildlife trade, as reflected in the comprehensive dataset, stands at a concerning level of 20040 cases. However, with the meticulous implementation of measures aligned with the World Customs Organization's (WCO) involvement, a remarkable transformation is anticipated.

Post-intervention, the projected decline in the estimated number of illegal wildlife trade incidents to 8,840 signifies a monumental reduction from the baseline figures. This significant drop, indicative of the project's potential efficacy, attests to the tangible and transformative outcomes achievable through concerted efforts, collaboration, and strategic interventions facilitated by WCO's authoritative role. The stark contrast between the pre- and post-intervention scenarios serves as a persuasive testament to the efficacy of the proposed measures in curbing the illicit activities that imperil global biodiversity.

Such a considerable reduction not only quantifies the tangible success of the intervention but also underscores the potential preservation of countless endangered species. The implications extend beyond mere numerical representation, encapsulating the preservation of delicate ecosystems, safeguarding biodiversity, and upholding international commitments to combat wildlife trafficking.

3.3. Extra Resources and Authorities Required

To better carry out the project, our client may need extra resources and authority to minimize the amount of illegal wildlife trade. Therefore, we introduced a linear regression model to determine the optimal number of different factors our client need to allocate.

Linear regression is a statistical analysis method that uses regression analysis in mathematical statistics to identify the quantitative connection between two or more variables that is interdependent [6]. In the formula $y = w'x + e$,, where e is a normal distribution and the error has a mean of 0, it is represented. Regression analysis involves simply one independent variable, one dependent variable, and a straight line that roughly represents the connection between them. Unitary linear regression analysis is the name given to this type of study. Multiple linear regression analysis is used when there is a linear connection between the dependent and

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independent variables in a regression study including two or more independent variables. The least squares approach or gradient descent method may be used to solve linear regression and produce a straight line for $y = bx + a$. Use the least squares approach as an illustration. Generally speaking, y is impacted by several factors.

For example, the linear connection $x1, x2, \ldots, x_k, k$ factors, may often be understood as follows:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k + \varepsilon \tag{7}$$

In our study model of the amount of the extra authority and resources our client need, we define the dependent variable y as follow:

$$y = the\ reduced\ amount\ of\ illegal\ wildlife\ trade \tag{8}$$

The independent variables are defined as follows:

$$x_1 = the\ client's\ funding\ into\ the\ project \tag{9}$$

The funding variable includes how much capital the client invests into the conduct and control of the activities in the project.

$$x_2 = the\ client's\ human\ resources \tag{10}$$

This variable includes the number of members the client has, which contains technical experts, customs staff of various countries within the organization.

$$x_3 = the\ client's\ technical\ support \tag{11}$$

This variable includes the organization's data analysis tools, monitoring equipment, etc.

$$x_4 = the\ client's\ education\ strategy \tag{12}$$

This variable indicates the client's measure to educate people to fight against illegal wildlife trade.

$$x_5 = the\ client's\ law\ enforcement \tag{13}$$

This variable includes the legal measure the client makes to reduce illegal wildlife trade.

$$x_6 = the\ client's\ cooperation \tag{14}$$

This variable indicates the client's cooperation with other organizations or countries.

In order to get n sets of observations $(x_{t1}, x_{t2}, \ldots x_{tk})$, $t = 1,2, \ldots, n$ $(n > k\ 1)$, y and $x_1, x_2 \ldots x_k$ make n independent observations at the same time. They meet the relation: where, uncorrelated, are all random variables with the same distribution. To represent the aforementioned formula as a matrix, let:

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$$Y = X\beta + \varepsilon \tag{15}$$

Using the Least square method, we can get the value of β:

$$\beta = (X^T X)^{-1} X^T Y \tag{16}$$

Among them, $(X^T X)^{-1} X^T$ is called the pseudoinverse of X. Using this method, we can get the optimal value of different factor $x_1, x_2, x_3, x_4, x_5, x_6$, the values are shown in Table. 5.

Table 5. The value of each variable

Factor	Value
x_1	16.5
x_2	12.25
x_3	19.5
x_4	14.75
x_5	18.25
x_6	18.75

Figure 5. The extra resources the client needs

Based on the results of Figure 5, this model enables us to consider more external factors and internal mechanisms provides a comprehensive perspective to assess and predict the impact of a project.

4. Conclusion

Through this study, we provide insights into the serious threat to biodiversity and ecosystems posed by the illegal wildlife trade and the responses to this problem. We successfully identified and assessed the World Customs Organization as the most suitable client to implement the five-year project and predicted the trend of illegal trade through the ARIMA model, proving the necessity and effectiveness of the project. Our research underscores the importance of global cooperation and calls for increased cooperation among governments and organizations working together to reduce the scale of illegal wildlife trade and protect endangered species and the continued health of ecosystems. However, more resources and support are needed for project implementation, especially in terms of funding, technology and cooperation. We hope that this study will attract more attention and promote the implementation of sustainable

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conservation measures on a global scale, so that we can work together to safeguard our valuable natural heritage.

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