

# A Study on Illegal Wildlife Trade Based on Analytic Hierarchy Process and ARIMA Model

Yiyang Ma \*

School of statistics, University of International Business and Economics, Beijing, China

\*Corresponding Author: 1450778322@qq.com

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## ABSTRACT

This study delves into the pressing global issue of reducing illegal wildlife trade, with a specific emphasis on elephants, given their paramount ecological, economic, and ethical importance [1]. Through a methodical approach, we meticulously evaluate potential clients using the Analytic Hierarchy Process, aiming to discern their suitability based on factors such as power, resources, and interest. Additionally, we develop the Illegal Trade in Elephants Prediction Model, utilizing advanced ARIMA forecasting techniques and time series analysis to project future trade scales. Complementing this, a comprehensive resource allocation strategy is devised through a sophisticated linear regression and programming model, considering a myriad of factors including political and financial support, technical expertise, and conservation strategies. We meticulously analyze key indicators over time to gauge the efficacy of our intervention efforts, utilizing both ARIMA and linear regression models to demonstrate a decline in illicit activity and an enhancement in program success rates.

## KEYWORDS

Illegal wildlife trade; Elephants; Analytic Hierarchy Process; ARIMA model; Resource allocation; Project evaluation

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## 1. INTRODUCTION

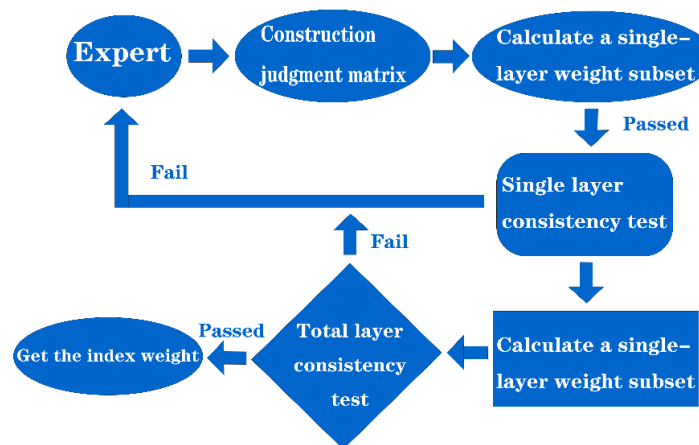
Trade, an ancient practice dating back to neolithic times, has evolved alongside shifts in geography and societal structures. Today's globalized economy, involving eight billion people, generates staggering annual revenue, notably USD 220 billion from legal wildlife trade. However, this trade also brings forth multifaceted social, economic, and conservation challenges, intersecting with the objectives outlined in the United Nations Sustainable Development Goals (SDGs). Of particular concern is the plight of elephants, symbolizing the broader crisis facing many species due to factors like poaching for ivory and habitat loss. In response, this study aims to develop a data-driven 5-year project targeting the reduction of illegal wildlife trade. The primary objective is to persuade a potential client to implement the proposed project, necessitating a comprehensive understanding of the client's capacities, interests, and the feasibility of the proposed interventions. By addressing key challenges such as client selection, project suitability, resource evaluation, impact assessment, and risk analysis, this research endeavors to provide a robust framework for mitigating the scourge of illegal wildlife trade.

## 2. CLIENT ASSESSMENT AND SUITABILITY

### 2.1. Identifying an Appropriate Client

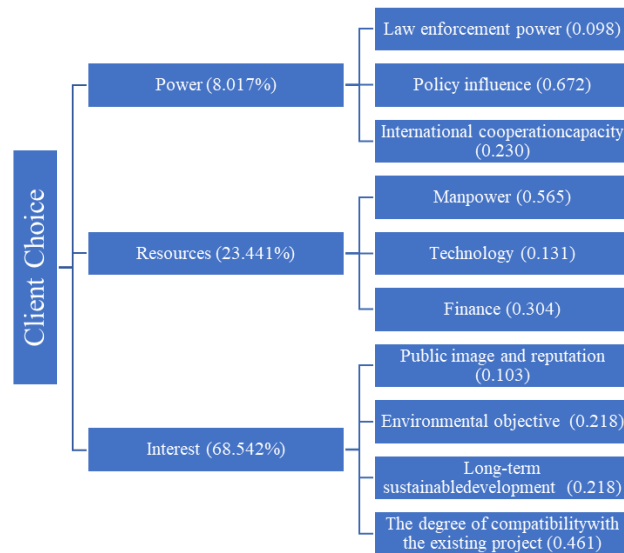
This study evaluates potential clients for its proposed project across two distinct categories: official actors, represented by governmental or quasi-governmental bodies, and unofficial actors, exemplified by Non-Governmental Organizations (NGOs). Specifically, the National Forestry and Grassland Administration (China) is assessed as a key official actor, while WWF serves as a prominent NGO counterpart. Through a comprehensive analysis encompassing dimensions of power, resources, and interest, the evaluation aims to discern the most suitable collaborator for the envisaged project. The ensuing evaluation reflects differential strengths and capacities between the evaluated entities, underscoring nuanced considerations such as enforcement capabilities, policy influence, financial and technical resources, and organizational motivations. Such evaluative insights provide a foundational framework for strategic decision-making processes and facilitate informed partnership selections geared towards addressing the challenge of illegal wildlife trade.

The Analytic Hierarchy Process (AHP) was put forward by T.L. Schaty, a professor at the University of Pittsburgh, in the mid-1970s [2]. It decomposes complex problems into multiple component factors, and further decomposes these factors according to the domination relationship, divides them into the target layer, criterion layer and index layer and compose them, forming a multi-objective and multi-level model and forming an orderly hierarchical structure. The relative importance of the factors in the hierarchy is determined by pairwise comparison, and then the overall order of the relative importance of the factors is determined by the judgment of the evaluation subject. The basic idea of analytic hierarchy process (AHP) is to transform the overall judgment of the weight of multiple elements in complex problems into a "pairwise comparison" of these elements, and then turn to the overall weight of these elements to sort the judgment, and finally establish the weight of each element. The specific process is shown in Figure 1.



**Figure 1.** AHP Model Technological Process

This study employs a systematic methodological approach to evaluate potential clients for the proposed project. Firstly, a hierarchical structure is established to categorize relevant factors systematically. This structure encompasses an overarching goal of customer strength, intermediate criteria such as power, resources, and interests, and specific evaluation indicators. Such an organization facilitates a structured assessment of potential clients (Figure 2).



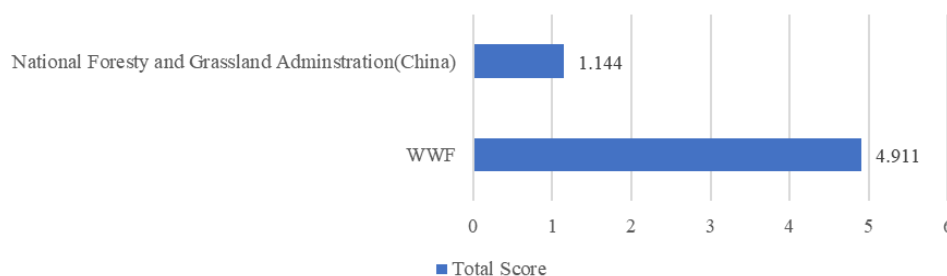
**Figure 2.** Performance Evaluation Index System

Subsequently, matrix analysis is conducted across different layers of the hierarchical structure to derive comprehensive insights. These analyses yield judgment matrices that summarize the relationships and relative importance of various evaluation factors. Specifically, tables delineating specific dimensions of power, interest, and resources provide detailed assessments of key evaluation criteria.

To ensure the robustness of the evaluation process, a consistency test is performed. The consistency ratio (CR) is calculated to validate the absence of logical errors in the judgment matrices, thereby enhancing the reliability of the evaluation outcomes [3].

Finally, the scheme-level evaluation offers a holistic overview of assessment outcomes for each potential client. Through a comparison between WWF and the China Forestry and Grassland Administration, relative strengths and weaknesses across various evaluation criteria are elucidated. This rigorous methodological approach facilitates informed decision-making, aiding in the selection of the most suitable client for the proposed project.

The output result is shown in Figure 3 below.



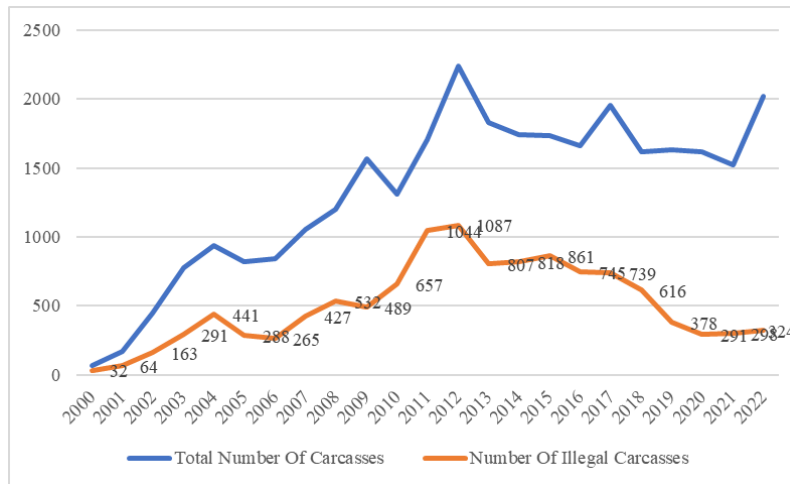
**Figure 3.** Total Score of two actors

Based on single ranking of indicators and total ranking of scheme hierarchy, the best scheme for Customer Choice is WWF, whose quantization score is 4.911.

## 2.2. Illegal Trade in the Elephants Prediction Model

Our project relies on real elephant trade and seizure data sourced from reputable organizations like CITES, WWF, MIKES, and TRAFICC. Through meticulous data preprocessing, we ensure reliability and consistency. Exploratory analysis reveals Africa's predominant role in illegal elephant hunting, with over 60% of global incidents concentrated in this region. Focusing on the top ten countries for illegal hunting, Africa emerges as a central player, with nations like Kenya, Congo, and Tanzania

prominently contributing to illegal carcasses. Overall, our data-driven approach underscores the urgency of addressing illegal elephant trade and emphasizes Africa's pivotal role in conservation efforts (Figure 4).



**Figure 4.** The Number of total and illegal Carcasses

The ARIMA model, standing for Auto Regressive Integrated Moving Average Model, is a commonly used model in time series analysis. It combines Auto Regression (AR) and Moving Average (MA) methods, along with an Integration step to make non-stationary time series data stationary. The ARIMA model is particularly suitable for time series data with long-term trends or seasonal patterns and is widely applied in fields such as economics, finance, and meteorology [4].

The illegal carcasses data is typically time series and non-stationary data, which is suitable for ARIMA model to predict the future illegal carcasses.

After confirming the model applied, we take the following steps to predict the illegal carcasses in 2023 and 2024.

#### Step 1: Stationarity Test-ADF Unit Root Test

Performing a unit root test on the original time series data, the p-value is 0.2902, greater than 0.05 was obtained, indicating the presence of a unit root, and suggesting that the original time series is unstable.

To judge the non-stationary original time series, several differences are needed to transform it into stationary series, and the results show that first-order difference. The unit root test shows that the P-value is 0.1, which is less than 0.05. The null hypothesis is rejected and the time series after first-order difference is considered stable.

#### Step 2: White noise test

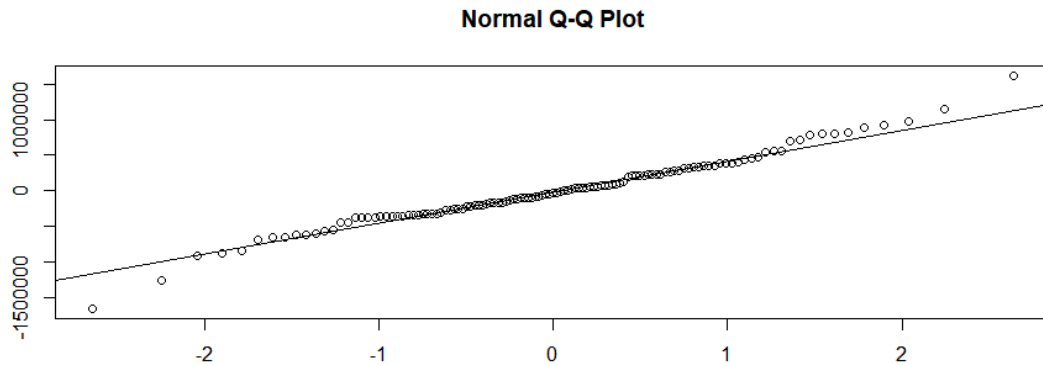
This test determines whether the time series after difference has white noise, or whether the numerical randomness in the time series is high and does not have regularity. After testing, the P-value of the sequence after difference is less than 0.05, which is not white noise, and the next ARIMA model fitting can be conducted.

#### Step 3: Determine the values of p and q.

There are two methods to fit ARIMA model, one is to judge the values of p and q by ACF function graph and PACF function graph, and the other is to predict automatically by software algorithm. We chose the second method to determine the optimal value of p and q, and the output result of the optimal model is ARIMA (0,1,1) (2,0,0) [12].

#### Step 4: Model Test

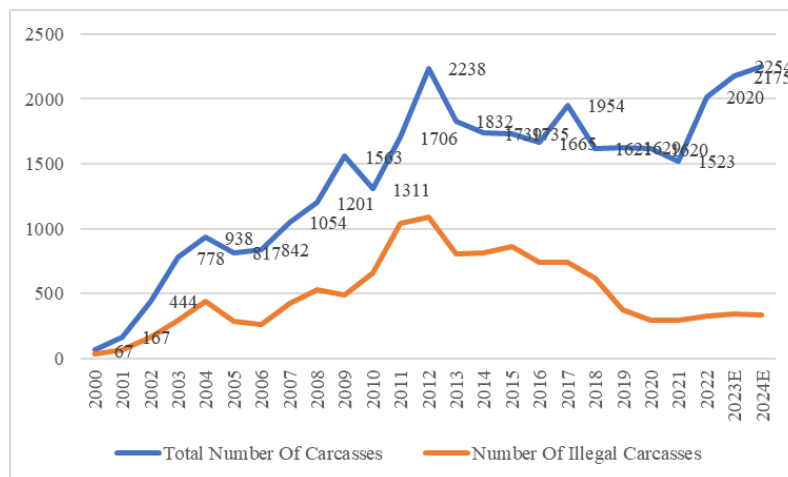
We can judge whether the residuals obey normal distribution by drawing the fit degree of QQ graph and its additional line, and then further judge whether the residuals are correlated by evaluating the white noise of the residuals of the fitted model. It can be seen from the output results that the residuals follow normal distribution, and the P-value is greater than 0.05, which proves that the residuals are not correlated, and the model prediction can be conducted in the next step (Figure 5).



**Figure 5.** QQ graph with Additional line

#### Step 5: Model Prediction

For the original sequence, the values of the second two periods are predicted as 341 and 335, which represents a smaller increase in number (Figure 6).



**Figure 6.** The Number of total and illegal Carcasses(E)

This is the model designed to predict the scale of illegal trade in elephants in 2023 and 2024 to reflect the necessity of this project. As mentioned in the last part, the prediction is 341 and 335, demonstrating that the protection of wild elephants is not enough even though there have been several initiatives and projects.

Considering the actual situation, the relevant legislation in Africa is not perfect, the enforcement intensity is insufficient, and the local people depend on the ivory trade to survive, which makes it more necessary for our project to promote the positive change of local people's ideas, promote legal progress, and promote the development of alternative industries in relevant countries.

### 3. RESOURCE EVALUATION AND FEASIBILITY

#### 3.1. Model Theory

Multiple linear regression model formula:

$$Y = C_0 + C_1X_1 + C_2X_2 + \dots + C_nX_n + \varepsilon \quad (1)$$

Where Y is the reduced wildlife trade,  $X_1, X_2, \dots, X_n$  are predictors, which are the strategies that can be taken or resources spent that can be allocated,  $C_0, C_1, \dots, C_n$  are the model parameters, which are the extent of influence of each predictor on the value of the objective function Y,  $\varepsilon$  is error term.

Linear programming operations research models:

$$\text{Min } Y = \sum_{i=0}^n c_i X_i \quad (2)$$

$$\sum_{i=0}^n c_i X_i \leq B_{total}, \forall i \quad (3)$$

$C_i$  is the intensity of the impact of the strategy that can be adopted or the resources that can be allocated,  $B_{total}$  is the total budget.

In the assessment of required authority and resources using a Linear Programming Operation Research Model, decision variables are defined to gauge various forms of support, including political, financial, technical, environmental, international, and public opinion. Through weighted analysis via the analytic hierarchy process (AHP), precise model parameters are calculated, ensuring their sum approximates 100%.

Leveraging data from WWF 2023, where contributions total \$216,777,707 and the project's estimated cost is \$16.77 million, estimated costs for each decision variable are allocated to optimize the model within budget constraints. These estimates allow for strategic allocation of resources:

- (1) Political support (X1) approximately \$420.877 million
- (2) Financial support (X2) approximately \$119.201 million
- (3) Technical and scientific support (X3) approximately \$252.153 million
- (4) Degree of environmental protection (X4) approximately \$416.634 million
- (5) International cooperation (X5) approximately \$350.745 million
- (6) Public opinion and social support (X6) approximately \$118.195 million

#### 3.2. Coping Strategy

- (1) Legislative strategy:

Based on the results of data analysis, policy recommendations are made to the government and relevant departments to promote the formulation of stricter laws and regulations to combat illegal wildlife trade.

Revision of data protection laws: ensure that the collection and processing of data on wildlife in relevant systems complies with national data protection laws.

- (2) Law enforcement strategy

strengthen cross-border cooperation, improve law enforcement technology and capabilities, and set up special crackdown operations. At the same time, a coordination mechanism composed of environmental protection, technology, finance, and other departments is established to jointly promote project operation.

(3) Publicity and education strategies

Raise public awareness through social media, public platforms, school education, community activities and other means.

(4) Sustainable economic development strategies:

Provide vocational skills training, develop alternative livelihoods, support local ecotourism, etc.

(5) Technology innovation strategy

Research and development of new technical means, such as the use of AI, blockchain and other technologies, to improve regulatory efficiency, real-time tracking of illegal wildlife trade dynamics.

(6) Cooperation strategy

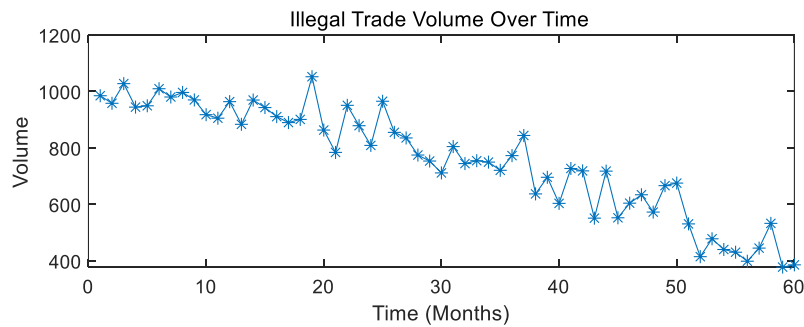
Apply for project financing support from international development agencies and environmental protection funds.

## 4. IMPACT ASSESSMENT AND RISK ANALYSIS

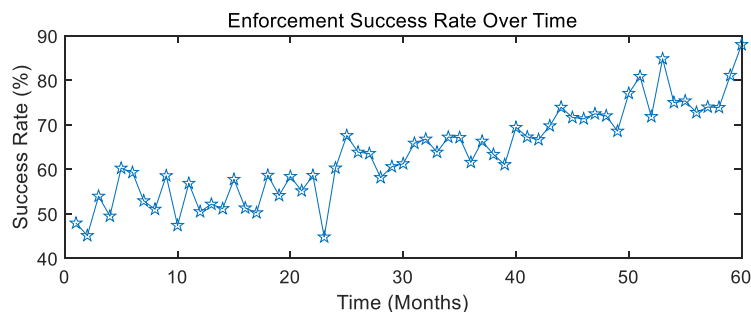
### 4.1. Estimating Comprehensive Impacts

The efficiency of a project was influenced by many elements. As for our own project's action, we focus on the relation between legislation and the law enforcement and illegal trade volume.

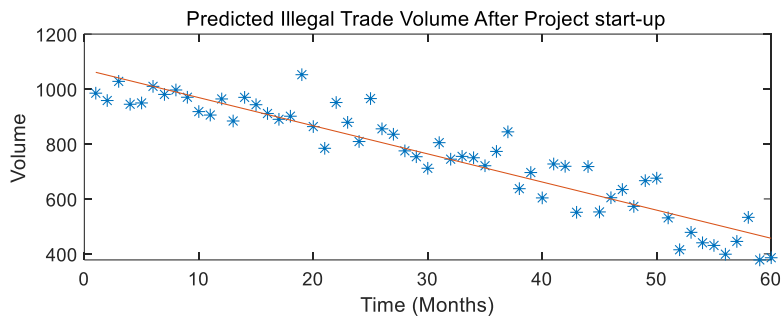
Based on the features of data, we used ARIMA model and linear regression model to follow the changes of key indicators over time and evaluate the effectiveness if project is set up (Figure 7 to 10) [5].



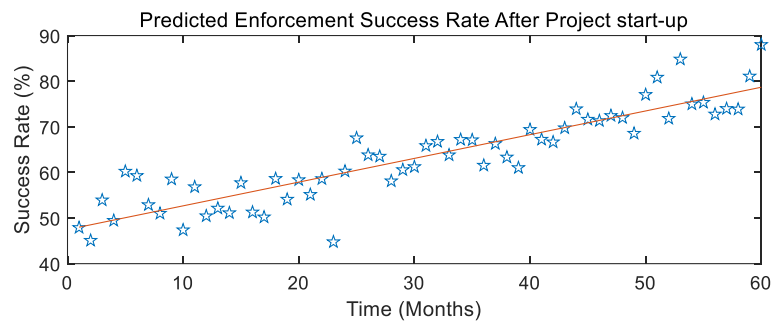
**Figure 7.** The Illegal Trade Volume Over Time



**Figure 8.** The Enforcement Success Rate Over Time



**Figure 9.** The Predicted Illegal Trade Volume After Projects start-up



**Figure 10.** Predicted Enforcement Success Rate After Project start-up.

This chart reflects the year-over-year decline in illegal behavior and the improved success rate of our programs with increased enforcement.

The second chart shows that if our program is implemented, as the success rate of our program increases, the number of wild elephants illegally killed also decreases.

In terms of economic benefits, according to the Customs Annual Report, the average price of an elephant in the illegal trade is between 20,000 and 30,000 US dollars, which is a huge number of transactions, and from the perspective of fighting crime, this has a significant effect on cutting the profits of poaching programs and fighting crime from the perspective of economic benefits.

From the perspective of environmental protection, elephants are not only a rare species, but also play an indispensable role in the whole biological chain. In terms of plant transmission, Blake et al. 's research shows that elephants have a significant positive impact on tree species spread only by elephants, helping these tree species overcome the Janzen-Connell effect [6]. It also shows an increased aggregation on the spatial scale. At the broader landscape scale, species spread by elephants alone are randomly distributed, while species similarity in other modes of transmission decay with space, showing the key role of elephants in maintaining species diversity and facilitating species spread by large animals.

## 5. CONCLUSIONS

In conclusion, our model demonstrates strengths in its scientific and comprehensive selection of indicators, drawn from data spanning over 180 countries, enhancing the reliability of our study. Furthermore, the adaptability of data processing methods to various analytical approaches and topic requirements adds robustness to our model. However, limitations exist, notably in the model's lack of fitting accuracy, due to the team's limited breadth of data processing techniques. Additionally, some questions remain unconfirmed through multiple methodologies, representing another drawback. Future research directions should focus on exploring more complex models and algorithms to address intricate issues in animal protection. Moreover, incorporating multidimensional data collection

strategies, as suggested by Q4, can enhance prediction accuracy and overall model efficacy. These advancements will contribute to improving the predictive capabilities and adaptability of the model, thereby facilitating advancements in animal conservation efforts.

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