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Illegal wildlife trade measuring based on data-driven analyses

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Abstract. Illegal wildlife trade (IWT) stands as a silent yet devastating force. In this paper a 5-year project is proposed to have a measurable impact on reducing the illicit trade based on data-driven analyses. First, we develop the Client Performance Evaluation Model to identify the ideal client. Secondly, the AI-Powered Wildlife Guardian Project (AWGP) is designed to monitor and manage the IWT chain, from supply to demand. Additional powers and resources for the project's success are identified. The C4ADS Air Seizure Database highlights China's need for the authority for cross-border monitoring and enforcement. The Impact Prediction Model (IPM) is crafted using time-series analysis to predict the effects of the project on illegal wildlife trade. Initially, there were 41 seizures in 2023, with an expected rise to 104 by 2028 without intervention. A probability analysis is conducted to determine the likelihood of achieving the goal of reducing illegal wildlife trade by 50%. Finally, a probability analysis is conducted to determine the likelihood of achieving the goal of reducing illegal wildlife trade by 50%.

Keywords: Illegal Wildlife Trade; Client Performance Evaluation Model; Impact Prediction Model; TOPSIS.

1. Introduction

1.1. Background

Illegal wildlife trade is a global scourge that poses a severe threat to biodiversity, with an estimated annual value of up to 26.5 billion US dollars, as reported by the Wildlife Conservation Society [1]. There is a pressing need for a strategic, data-driven approach to develop a project that is not only feasible but also capable of achieving substantial reductions in illegal wildlife trade.

1.2. The related work

The illicit trade of wildlife has far-reaching consequences that extend beyond the animal kingdom. According to Mozer and Prost [2], the trade contributes to the decline of endangered species and the spread of zoonotic diseases, which have a significant impact on global health [3]. Besides, it might threaten the livelihoods and lead to the exploitation of vulnerable populations through "forced labor" [4]. This trade also intersects with other criminal networks including drug and human trafficking (Keskin et al., 2023). In their study, the trade is described as one of "the most lucrative illegal industries" [5]. It undermines legal economies while increasing corruption and violence in regions where enforcement is weak.

Reducing illegal wildlife trade is a complex challenge as the demand for wildlife products persists due to various drivers. These include the perceived medicinal value [5], social status [6], exotic pets [4], as well as spiritual and religious practices [7] (Keskin et al., 2023; Lee et al., 2020; Mozer & Prost, 2023; Everard et al., 2019). In addition, the absence of cooperation between law enforcement agencies across countries results in fragmented efforts. In their study, Mozer and Prost (2023) take the European Union as an example, and find that the trafficker can shift to "smaller airports or other countries"for transit". According to Fukushima et al. [8], the trade facilitated by the internet could be more difficult to monitor and enforce laws across jurisdictions. Therefore, reducing illegal wildlife trade requires a multifaceted approach with demand reduction efforts and international cooperation.

1.3. Our work

We firstly set up the Client Performance Evaluation Model with two indicators: status quo of wildlife protection and execution capabilities through EWM and TOPSIS. With the use of machine learning and big data analyze, an AI-Powered Wildlife Guardian Project is established based on Digital Innovation and Virtual Reality. Finally, we give a comprehensive analysis of the model, which the success probability is 0.6858.

2. Preliminary

2.1. Assumptions

1. The indicators we selected and possessed can accurately reflect the status quo of wildlife protection and execution capabilities in each country.

2. The status quo of wildlife protection and execution capabilities of the selected countries are representative of the global situation.

3. The development of the virtual pet market will stimulate a substitute demand for illegal wildlife and products.

2.2. Notations

The symbols used in the following paper are listed in Table 1. Notes: all data from the paper comes from the World Official Environment Institution websites.

Table 1. Symbols notation

Notations	Description
x_{ij}^*	normalized value of x_{ij}
p_{ij}	proportion of the i-th country under the j-th index
E_j	information entropy of the *j*-th index
w_j	weight of the *j*-th index
S_i	overall country score
X_j^+	best solution
X_j^-	worst solution
D_i^+	positive ideal solution distance
D_i^-	negative ideal solution distance
Y_t	number of seizures at time point *t*
α_i	autoregressive parameter
β_i	moving average parameter
c	white noise term
γ_t	intervention weight
I_t	intervention variable
x_{ij}	value corresponding to the *i*-th country under index *j*

3. Models' construction

3.1. The establishment of simulation model

Faced with numerous national governments and non-governmental organizations that are related to wildlife trade, our primary focus is on various national governments as they often possess more powers, resources and interest in reducing illegal wildlife trade than non-governmental organizations [9]. With the aim of selecting a suitable government which is willing and capable to enact our proposed project, we need to assess not only the status quo of wildlife protection in each country but also their execution capabilities. Therefore, we have established a Client Performance Evaluation Model, mainly employing the Entropy Weight Method (EWM) and the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) for comprehensive evaluation. It is shown in Figure 1.

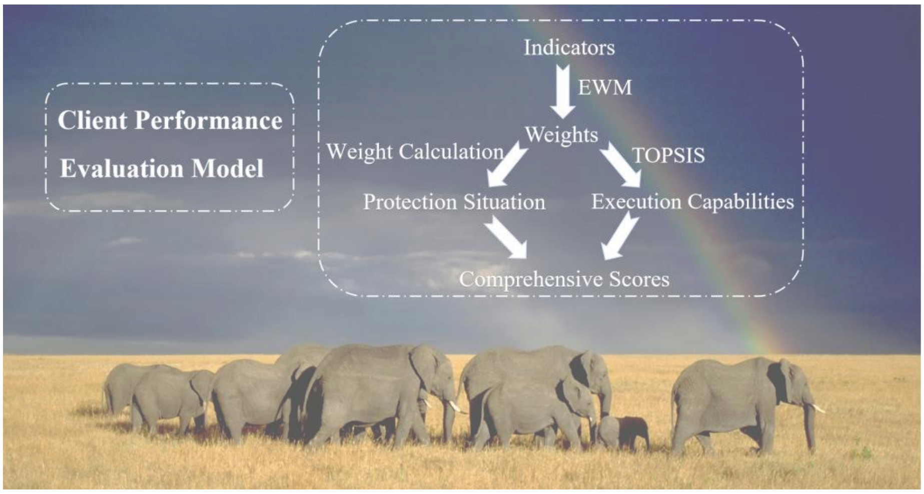

Figure 1. Schematic Diagram of the Model

3.2. Criteria of Client Performance Evaluation Model

We have divided our indicators into two dimensions: the status quo of wildlife protection in each country and their execution capabilities.

A lower score corresponds to a poorer conservation status, indicating a more severe level of wildlife loss. We have primarily selected three main indicators to measure the status quo of wildlife protection: the diversity of wildlife species, the nature reserves coverage ratio, and the number of wildlife seizures. It is shown in Table 2.

Table 2. Indicators for Examining the Status Quo of Wildlife Protection

Symbol	Description
NRCR	Nature Reserves Coverage Ratio
NWS	Number of Wildlife Seizures
DWS	Diversity of Wildlife Species

The diversity of wildlife species refers to the variety and richness of different plant and animal species within a specific ecosystem or geographical area. A higher diversity of wildlife species indicates a healthier and more resilient environment, fostering sustainability and contributing to the overall health of the planet. The nature reserves coverage ratio quantifies the proportion of land allocated as nature reserves, emphasizing a country or region’s commitment to biodiversity conservation. A higher coverage ratio indicates a greater dedication to preserving natural habitats and protecting diverse ecosystems. The number of wildlife seizures measures instances of illegal wildlife trafficking, highlighting the threats to biodiversity. Monitoring this metric helps assess the effectiveness of conservation efforts and enforcement.

3.3. Calculation of Weights and Comprehensive Scores

We integrate the Entropy Weight Method (EWM) and the EWM-TOPSIS method [10], aiming to bolster the precision and rigor of the model. This combination ensures the objectivity of the evaluation results, rendering it superior to alternative methodologies.

For both dimensions, we employ the EWM method to calculate the weights. The following outlines the calculation of weights for the dimensions. Considering n sub-indicators and k countries.

$$p_{ij}=\frac{x_{ij}^{*}}{\sum_{i=1}^{k}x_{ij}^{*}} \tag{1}$$

For the *j*-th indicator, calculate its information entropy.

$$E_j=-\frac{\sum_{i=1}^{k}p_{ij}\cdot ln\ p_{ij}}{ln\ k} \tag{2}$$

For the *j*-th indicator, calculate its weight.

$$w_j=\frac{1-E_j}{\sum_{j=1}^{n}1-E_j} \tag{3}$$

3.4. Application results

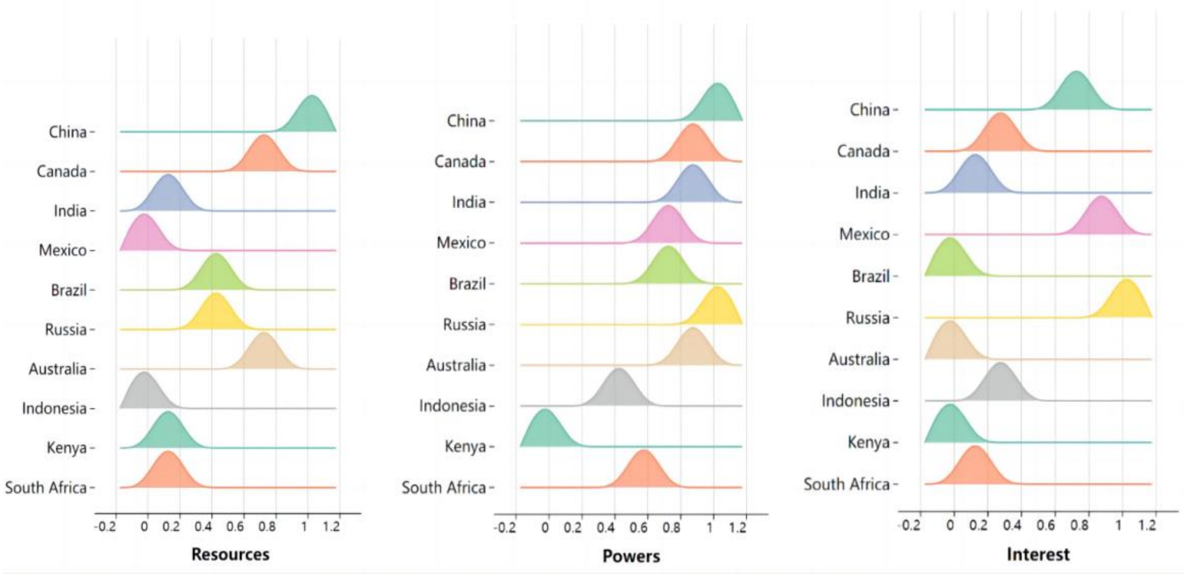

Figure 2. Application Results

From Figure 2, we visualize three key factors: resources, powers, and interest. On the same numerical axis, the higher peaks positioned towards the right indicate higher scores. In terms of resources, China, Canada, and Australia exhibit relatively high scores, indicating robust resource support. China also achieves the highest score in terms of powers, indicating that it has considerable decision-making power and control when implementing legislative frameworks. Kenya, on the other hand, scores relatively lower, suggesting potential limitations in those fields. Mexico and Russia score higher regarding interest, indicating a high level of enthusiasm and commitment in reducing illegal wildlife trade.

Generally, greater execution capabilities lead to increased efficiency in implementing policy projects. In countries with low scores in terms of the status quo of wildlife protection, there might be a stronger motivation to implement projects to reduce illegal wildlife trade. From the scatter plot above, it is evident that Australia performs well in the protection of wildlife, while China still faces prevalent issues in illegal wildlife trade, indicating that it might have a strong motivation to undertake policy projects to further reduce illegal wildlife trade activities. Based on the analysis above, we decide to select the Chinese government as our client, as it possesses the necessary powers, resources, and interest to implement a project aimed at reducing illegal wildlife trade. In other words, the Chinese government might not only be capable but also willing to achieve the the expected goal of a proposed project.

4. AI-Powered Wildlife Guardian Project

In 2023, China's "Operation Net Shield" campaign, a joint effort by eight government agencies, drew attention to the extent of illegal online wildlife trade. As part of this operation, a total of 484,863 internet and courier companies and 350,179 commercial (and private) users were inspected, resulting in the confiscation of 705, 571 wild animals and plants and 28,496 wildlife products, and the recovery of over 11 million yuan in illegal profits [11].

In response to the growing challenge of illegal traffickers evading traditional monitoring and prevention methods, we aim to develop an AI-Powered Wildlife Guardian Project (AWGP) to reduce illegal wildlife trade and address the shortcomings of current strategies. The project is structured into three strategic stages, each building upon the successes and insights of the previous phase.

4.1. Project and Client Alignment

The project's alignment with the Chinese government is evident in three critical aspects: powers, resources, and interest.

1. Powers. The Chinese government boasts a comprehensive legislative framework and a massive law enforcement team, evidenced by the successful seizure of 1,337 significant wildlife trade cases between 2013 and 2023, with an impressive CEI of nearly 100%. The robust legal foundation and effective enforcement capabilities offer the essential powers to execute and supervise the project's objectives.

2. Resources. China's advancements in artificial intelligence, big data, and the Internet of Things have been remarkable. In 2022, the country invested over 400 billion US dollars in research and development. This substantial investment can provide with advanced technological foundations and ample financial support. Through leveraging technologies such as infrared monitoring, real-time alert systems, blockchain, big-data analytics, machine learning algorithms, and virtual reality, our project can help the government significantly reduce illegal wildlife trade.

3. Interest. The Chinese government's unwavering commitment to combat illegal wildlife trade is not only evident in its proven track record in addressing wildlife trade cases but is also emphasized through its proactive involvement in international agreements. In 2020, China hosted the 15th meeting of Conference of the Parties to the Convention on Biological Diversity in Kunming, where the "Kunming Declaration" was adopted. In addition, the government has conducted public awareness campaigns and educational programs to promote the protection of wildlife and the importance of biodiversity conservation. Furthermore, China's strong interest in digital innovation, including digital payments and e-commerce, aligns with our project's emphasis on technology.

4.2. Impact Prediction Model

We plan to apply an optimized model based on time-series analysis to conduct an in-depth study of illegal wildlife trade over the past 20 years and predict trends for the next five years. This model will enable us to quantify trends and patterns in illegal transactions, providing insights into future developments. Before the project's implementation, we will use the model derived from historical data to forecast wildlife trade, establishing a baseline for pre-project assessment.

After project implementation, we will continue to monitor the development of illegal wildlife trade, updating the model and refining predictions. By comparing the actual post-project data with the baseline forecasts, we can directly evaluate the project's impact on illegal transactions. A decrease in actual data would reasonably be attributed to the project's positive effects. This analytical approach not only quantifies the project's impact but also provides clients with a data-driven framework for assessing its effectiveness.

1. We applied the Augmented Dickey-Fuller (ADF) test for stationarity. At a zero-order difference, the significance level p-value was 0.091, not statistically significant, thus failing to reject the null hypothesis. At a first-order difference, the p-value was 0.003, statistically significant, allowing us to

reject the null hypothesis and successfully transform the non-stationary time series into a stationary one.

2. After determining the model order as 1, we then calculated the Autocorrelation (AC) and Partial Autocorrelation (PAC) coefficients and used criteria such as the Akaike Information Criterion (AIC) to identify the optimal ARIMA model (0,1,1).

3. To validate the ARIMA (0,1,1) model, we conducted a white noise residual test.

4. We then used the tested ARIMA (0,1,1) model to make predictions.

Upon examining the data, it's evident that there was a sudden drop in the number of seizures in 2017, which we discovered was due to China's strict ban on the trade of ivory and ivory products [9]. However, there was a sharp increase in 2018. Without the implementation of our proposed project, based on the trends we have fitted, the number of seizures for illegal wildlife trade would continue to rise, posing greater threats to biodiversity.

Conversely, if China adopts and executes our project, as seen in 2017, the initial sharp decrease in seizures due to intensified policy enforcement or other subjective factors would be followed by a gradual reduction over the next four years, eventually stabilizing. This trend change suggests that our project has a deterrent effect in the initial stage, creating an effect that prevents the spread of illegal trade activities. As the project progresses, the number of seizures would start from a high value and gradually decrease, eventually stabilizing. This implies that societal awareness of illegal wildlife trade has improved, effectively curbing trade activities. Additionally, China's efficiency in handling illegal wildlife trade cases has significantly increased, making it difficult for those activities to evade law enforcement.

This positive change not only reflects the project's initial success but also its profound long-term impact on societal awareness. The project not only effectively curbs the spread of illegal wildlife trade but also contributes substantially to global biodiversity conservation and sustainable development goals. To sum up, our project is not only practical and actionable but also has the potential to bring about profound and positive changes to Chinese society in the long term. It is a powerful strike against illegal trade and a positive contribution to global ecological balance and sustainable development objectives.

4.3. Model analysis

The primary considerations are the inevitable issues of equipment aging and insufficient technological investment after project implementation. For instance, aging equipment may lead to inaccurate monitoring results. Besides, we are not capable to equip all wildlife with monitoring chips. Assuming the negative impact is continuous, we can quantify these as random variables with a normal distribution to describe their distribution. By reviewing feedback from past related projects, we can estimate the probability of achieving the desired outcomes given these factors.

$$P_1 = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \quad (4)$$

Insufficient human resources and weak big data detection capabilities are significant factors to consider. A lack of human resources may reduce the effectiveness of monitoring and reducing illegal transactions, while weak big data detection may prevent the system from fully mining and analyzing transaction data. We can model the effects of human resources and big data detection using an exponential distribution, which helps quantify their impact on the project and provides comprehensive information for its design and execution.

We particularly focus on the adoption of VR technology and virtual pet platforms and their impact on the project's effect. The extent of adoption may be influenced by factors such as user acceptance. We can model the adoption as a binomial distribution, describing the probability of its widespread use in practice. By reviewing user acceptance based on related research data, we can better predict their actual application within the project.

$$P_3 = C_n^k p^k \cdot (1-p)^{n-k} \quad (5)$$

Next, we gather data on these three aspects from relevant literature and empirical studies. We then input these data into the corresponding probability distribution formulas to obtain probabilities related to these factors $\{0.9815, 0.8294, 0.8425\}$. Since these aspects do not have clear causal relationships, we treat them as independent. Multiplying these probabilities yields a final probability, denoted as P_{total}, which is 0.6858. This process helps quantify the contribution of each factor to project success and provides more accurate information for project design.

It is evident that after implementing our project, China has a high likelihood of achieving the expected outcomes, and it has relatively good coping mechanisms for the challenges in these three aspects. Through detailed data analysis and probability calculations, we provide a scientific basis for project implementation.

5. Conclusion

Based on Client Performance Evaluation Model (CPEM), we have meticulously selected the most suitable client for our project. Through assessing the status quo of wildlife protection and execution capabilities with a total of 12 sub-indicators, we ensure a tailored approach that lays a strong foundation for the project’s success. The project’s rationale is clearly articulated, demonstrating the Chinese government’s readiness in terms of power, resources, and interest. This strategic alignment is essential for the project’s effectiveness and long-term sustainability. However, the project’s effectiveness relies heavily on the availability and accuracy of statistical data. The complexity of the model and the challenge of data collection mean that the outcomes are highly dependent on the quality of the data available. Next, we tend to study how to resolve the complex computational process and the lack of Consideration for Cyclical Changes.

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