Research on Monitoring Illegal Wildlife Trade Based on Data-Driven Models

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Abstract. This paper aims to evaluate client selection and project alignment in wildlife conservation projects using the Analytic Hierarchy Process (AHP) and TOPSIS models. The World Wide Fund for Nature (WWF), China Wildlife Conservation Association (CWCA), and the National Forestry and Grassland Administration are selected as candidate clients. Quantitative analysis uses three indicators: resources, power, and interest. The results indicate that WWF is the most suitable client regarding comprehensive resources, power, and interest. Additionally, the paper analyzes the cost-benefit and organizational development contributions of WWF implementing the "Electronic ID" project, highlighting its potential to enhance WWF's international influence and reputation. The study demonstrates that leveraging technology to track and protect wildlife can curb illegal wildlife trade and promote biodiversity conservation.

Keywords: Wildlife conservation, Client selection, Analytic Hierarchy Process, TOPSIS.

1. Introduction

The sharp decline in global biodiversity and the increase in illegal wildlife trade has become serious environmental and social issues[1, 2]. These problems not only threaten the survival of wildlife but also disrupt the balance of ecosystems, consequently affecting human health and well-being[3]. To address this challenge, governments and environmental organizations worldwide are seeking effective methods to protect endangered species and combat illegal wildlife trade[4].

Despite numerous measures, such as legislation, law enforcement, and public education, illegal wildlife trade remains rampant[5]. This indicates that current measures are insufficient to solve the problem. Therefore, new technological means, such as electronic ID systems, need to be introduced to enhance the monitoring and management capabilities of wildlife[6].

This study, based on currently published literature conducted a quantitative analysis using various indicators to evaluate three potential clients. Utilizing the AHP-TOPSIS method, this study identified the most optimal client. This study then performed a cost-benefit analysis on five representative data-driven cases. Based on the results of wildlife conservation efforts and potential benefits, this study proposed a benefit function, demonstrating that WWF should undertake the electronic ID project. Through these steps and processes, our research provides comprehensive technical support and a scientific basis for the implementation of the Wildlife Electronic ID project. This study aims to enhance wildlife protection and combat illegal trade effectively.

2. Selection Criteria and Client Analysis

To ensure a strong correlation between the selected clients and the project, this study uses "wildlife conservation" as a keyword and follows the classification of government organizations, non-governmental organizations, and international organizations. This study conducts a global search within the scope of world organizations. Considering the representativity of the organizations and their alignment with the project, this study ultimately selects Client A as the World Wide Fund for Nature (WWF), Client B as the China Wildlife Conservation Association (CWCA), and Client C as the National Forestry and Grassland Administration.

Taking into account the working methods and domains of the three clients, this study selects resources, power, and interest as evaluation indicators. Considering the abstract nature of these indicators, quantification should be based on specific data.

Resources: The total expenditure in the 2022 financial budget reports indirectly reflects the resource capabilities of these three clients.

Power: Quantification of power is based on the number of policies and legal documents issued by the three clients in 2023. This study searched for literature using the keywords "WWF" and "policy" in CNKI and found 7 documents; for the China Wildlife Conservation Association, this study found 3 documents; and for the National Forestry and Grassland Administration, this study found 11 documents.

Interest: Interest is reflected by the degree of participation in wildlife conservation activities. This study scores clients based on the information and experience, with scores ranging from 0 to 1.

The final determined evaluation indicators are shown in Table 1.

Table 1. Performance Indicators for Clients

	Expenditure/million$	Documents/ piece	Interest/score
Client A	462.07	7	0.7
Client B	206.19	3	0.8
Client C	18.2336	11	0.5

Setting Client Selection as the goal layer, Resources, Powers, and Interest as the criteria layer, and Client A, B, and C as the alternative layer, a hierarchical evaluation indicator system is constructed, as shown in Figure 1.

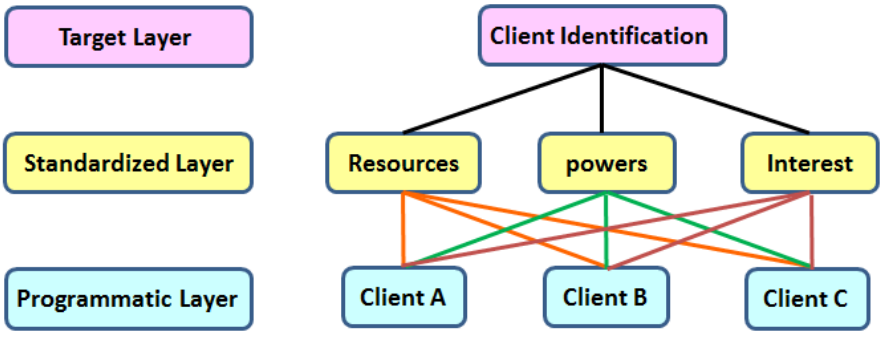

Figure 1. Hierarchical Evaluation Indicator System

According to Santy's 1-9 scale, expert ratings are given for the three following indicators: Resources, Power, and Interest, as shown in Table 2. Corresponding judgment matrices (1) are then constructed.

Table 2. Judgment Matrices for Resources, Power, and Interest

	Resources	Powers	Interest
Resources	1	2	4
Powers	1/2	1	2
Interest	1/4	1/2	1

$$W = \begin{bmatrix} 1 & 2 & 4 \\ 0.5 & 1 & 2 \\ 0.25 & 0.5 & 1 \end{bmatrix} \quad (1)$$

The consistency check is conducted on the judgment matrices and the calculated consistency indicator CI (consistency indicator) $<10^{-6}$. Therefore, the judgment matrices pass the consistency

check. Subsequently, the normalization operation is performed on the judgment matrices to obtain the weights for the three indicators: Resources, Power, and Interest. This is represented by the diagonal matrix (2).

$$w = \begin{bmatrix} 0.571 & 0 & 0 \\ 0 & 0.286 & 0 \\ 0 & 0 & 0.143 \end{bmatrix} \tag{2}$$

In Table 3, since Expenditure, Documents, and Interest are all performance indicators, it is only necessary to perform dimensionless processing on the data in Table 3. as shown in Table 3. The normalized benefit indicators in Table 3 can be expressed as a 3×3 matrix B, as shown in formula (3). Multiplying the matrix B by the weight vector w yields a new matrix C.

Table 3. Normalized Performance Indicators for Clients

	Expenditure	Documents	Interest
Client A	1.000	0.636	0.875
Client B	0.446	0.273	1.000
Client C	0.039	1.000	0.625

$$B = \begin{bmatrix} 1.000 & 0.636 & 0.875 \\ 0.446 & 0.273 & 1.000 \\ 0.039 & 1.000 & 0.625 \end{bmatrix} \tag{3}$$

$$C = Bw = \begin{bmatrix} 0.571 & 0.182 & 0.125 \\ 0.255 & 0.078 & 0.143 \\ 0.022 & 0.286 & 0.089 \end{bmatrix} \tag{4}$$

The maximum and minimum values of each column in the matrix C are extracted to form the row vectors representing the ideal solution C_j^* and the anti-ideal solution C_j^0, as shown in formulas (5) and (6), respectively. Next, the Euclidean distances are based on matrix C form S^* and S^0 column vectors, as shown in formulas (7) and (8), and calculated f_i^* by formula (9).

$$C_j^* = \max_{i=1}^{3}(C_{ij}) = (0.571 \quad 0.286 \quad 0.143) \tag{5}$$

$$C_j^0 = \min_{i=1}^{3}(C_{ij}) = (0.022 \quad 0.078 \quad 0.089) \tag{6}$$

$$S^* = \sqrt{\sum_{j=1}^{3}\left(C_{ij} - C_j^*\right)^2} = (0.106 \quad 0.379 \quad 0.551)^{\mathrm{T}} \tag{7}$$

$$S^0 = \sqrt{\sum_{j=1}^{3}\left(C_{ij} - C_j^0\right)^2} = (0.560 \quad 0.239 \quad 0.208)^{\mathrm{T}} \tag{8}$$

$$f_i^* = \frac{S_i^0}{S_i^0 + S_i^*} \ (i=1,3) \tag{9}$$

Finally, the row vector $f^* = (0.841 \quad 0.387 \quad 0.274)$ is obtained. As f_i^* represents the distance to the least favorable value, and f_1^*=0.841 is the maximum, this study can conclude that the World

Wide Fund for Nature (WWF) is the client most aligned with our proposal in terms of comprehensive resources, power, and interest.

3. Case Studies in Wildlife Conservation

Established in 1961, WWF is one of the world's largest independent non-governmental environmental conservation organizations[7]. The organization's functional positioning revolves around the protection of wildlife and global environmental conservation[8]. With 2,500 full-time employees, over 5 million supporters, and volunteers, WWF works globally to reduce human intervention in nature, striving to protect biodiversity and the habitats of living organisms. WWF's responsibilities are clearly defined, and it has invested in over 13,000 wildlife conservation projects, involving funds totaling around 10 billion US dollars[9].

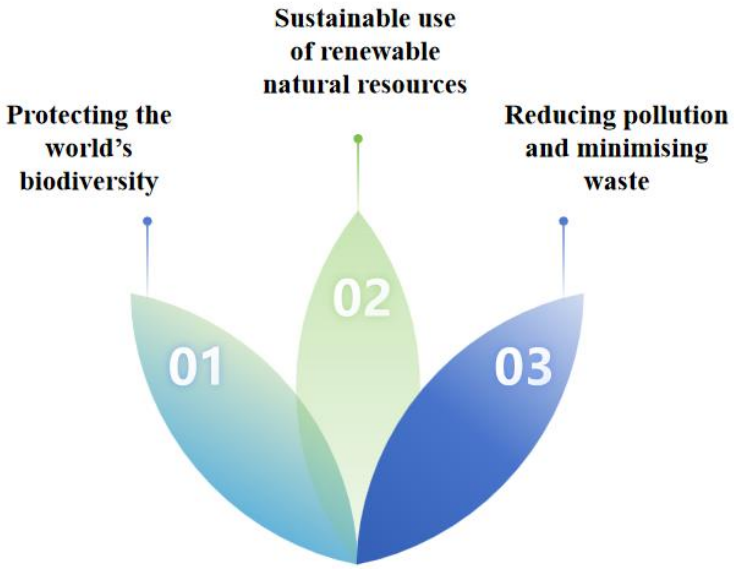

Figure 2. Basic Functions of WWF

The annual illegal trade in wild flora and fauna amounts to approximately 150-200 billion US dollars. According to the data from the Thin Green Line organization, rhino poaching in South Africa has increased by nearly 9000% in the past decade, leading to the killing of approximately 1000 park rangers. Over a million wild animals are captured and traded, causing severe damage to global biodiversity.

Due to the multifaceted, multi-level, and long-term data tracking requirements of our project, a high-density international collaborative network is essential. This study needs an internationalized database to accommodate lifecycle data ranging from electronic identification generation to destruction for both plants and animals. WWF has established partnerships with numerous countries and organizations, reaching grassroots zoos and nature reserves. Hundreds of countries have been involved in or sponsored actions carried out by WWF.

In Henan province, 1.93 million parrots now possess legal "identification cards[10]." A total of 530 breeders have obtained permits for artificial breeding, and 193.68 million special identifiers have been issued. When parrots are ready for sale, breeders equip them with a unique leg ring, featuring a barcode carrying essential identity information, including a unique number, species, photo, and place of origin. With these credentials, parrots can engage in legal transactions, contributing to an improvement in the living standards of residents.

By scanning the drug traceability code on pharmaceutical packaging, people can track drug information. Improving algorithms to enhance the storage capacity of blockchain has inspired us to construct a data network and apply mathematical models to track wildlife.

Based on the following case studies, analyze the costs and benefits of these projects will be analyzed, and represented in Table 4:

Table 4. Wild Animal Population Quantity Table

Region	Name of protected animals	Initial population size / pcs. or initial price/¥	Protection test time	Protection test duration/years	Current population size / pcs. Or current legal price/¥	Means of protection	earning rate
A Nature Reserve, Southwest China	Mammal	12 (pcs.)	1986-1999	13	16 (pcs.)	Electronic ID records, far-infrared automatic photography	28.60%
Xizang	Tibetan antelope	50000 (pcs.)	2020-2013	13	200000 (pcs.)	Electronic ID records, Satellite tracking, drone aerial survey, far-infrared automatic photography	300%
Northeast China	Wild northeast tiger	14 (pcs.)	1990-2014	24	27 (pcs.)	Wilderness release archives, Electronic ID, far-infrared automatic photography	92.90%
Whole China	Wild giant panda	1596	2003-2013	10	1864	Electronic ID records, far-infrared automatic photography, Fecal DNA recognition	16.80%
	(Captive giant panda)	-164 (pcs.)			-375 (pcs.)		-128.70%
Shangqiu, Henan, China	Farmed parrot	35 (price)	2020-2022	2	90 (price)	Foot ring of electronic ID，Farmed, and manual statistics	157%

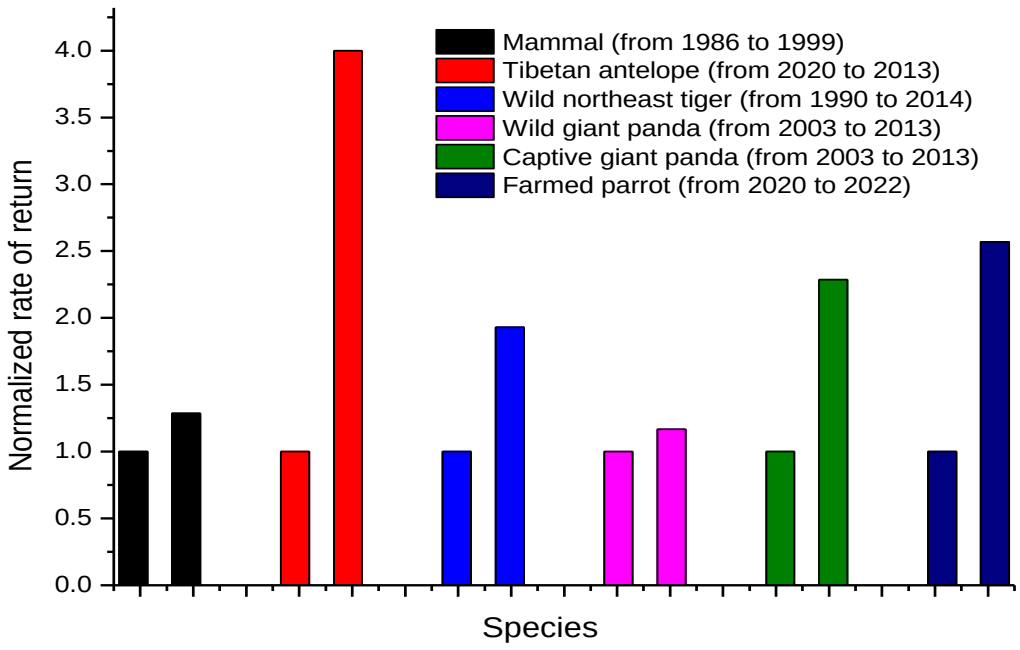

Figure 3. Comparison Chart of Wild Animal Numbers

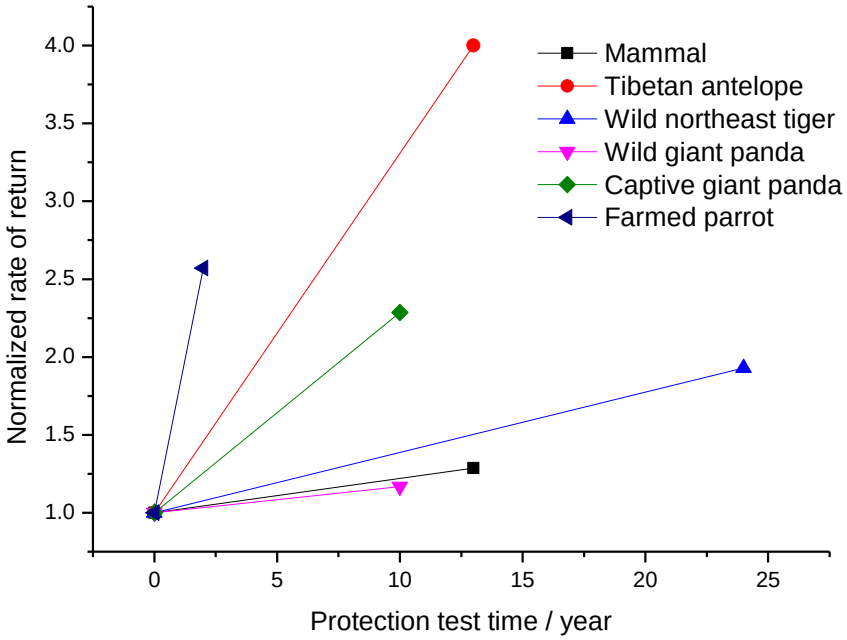

Figure 4. Rate of Return —— Time Chart

From Figures 3 and 4, it can be observed that projects employing relevant tagging or electronic ID technologies have achieved varying degrees of positive returns. The rate of return appears to be directly correlated with the implementation time of protective measures, with generally higher returns over longer periods. Additionally, the rate of return is positively associated with the endangered status and reproductive capacity of the protected animals. Endangered populations, usually smaller in number, often exhibit poorer recovery capabilities, as is in species like the giant panda and Amur tiger. By contrast, species with strong reproductive capabilities, such as parrots and Tibetan antelopes, show robust recovery trends.

Furthermore, artificially bred populations generally exhibit faster recovery abilities compared to those in the wild. What's more, in some countries with relevant laws, legitimate animal breeding and trading. Consequently, after implementing the project, the population size or resulting revenue function can be expressed by using the formula (10).

$$f(t) = f(0) \cdot (1 + k_1 k_2 k_3 \alpha)^t \tag{10}$$

$f(0)$ represents the population size or economic gains before the implementation of the project. t represents the time of project implementation (measured in years). α represents the baseline growth rate of revenue after project implementation, which can be set at 0.1. k_1 represents the recovery difficulty coefficient for endangered species, with values ranging from 0.1 to 0.3. k_2 represents the reproductive capacity coefficient of the species, with values ranging from 1 to 10. k_3 represents the technological coefficient of the electronic ID used in the project. Depending on the type of electronic ID (such as electronic QR codes, leg rings, ear tags, RFID, etc.), it takes values within the range of 1 to 3.

It can be inferred that if WWF implements the "Electronic ID" five-year plan, the initial management costs, time costs, and financial costs may be relatively high. However, as the project progresses and time passes by, with the establishment of a more comprehensive database of wild animal "ID" information, the management complexity and technological requirements for WWF are expected to decrease. The financial investment is likely to stabilize, and project returns will gradually increase.

Furthermore, as the illegal wildlife trade diminishes following the implementation of the project, WWF is anticipated to attract more international funding and collaborative partnerships. The

economic benefits can then be utilized to expand the organization's scale and invest in more environmental projects. This, in turn, can create additional employment opportunities, achieving a simultaneous increase in both economic and social benefits.

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is an international agreement that includes approximately 38,000 species listed in its appendices. Over 12,000 species are frequently traded, constituting 58% of all species in the animal appendices and 28% in the plant appendices. Asia and Europe serve as the largest markets for the trade in wild fauna and flora, accounting for around 70% of the total trade volume. Notably, the trade volume of wild flora represents a staggering 81% of all wild biota worldwide.

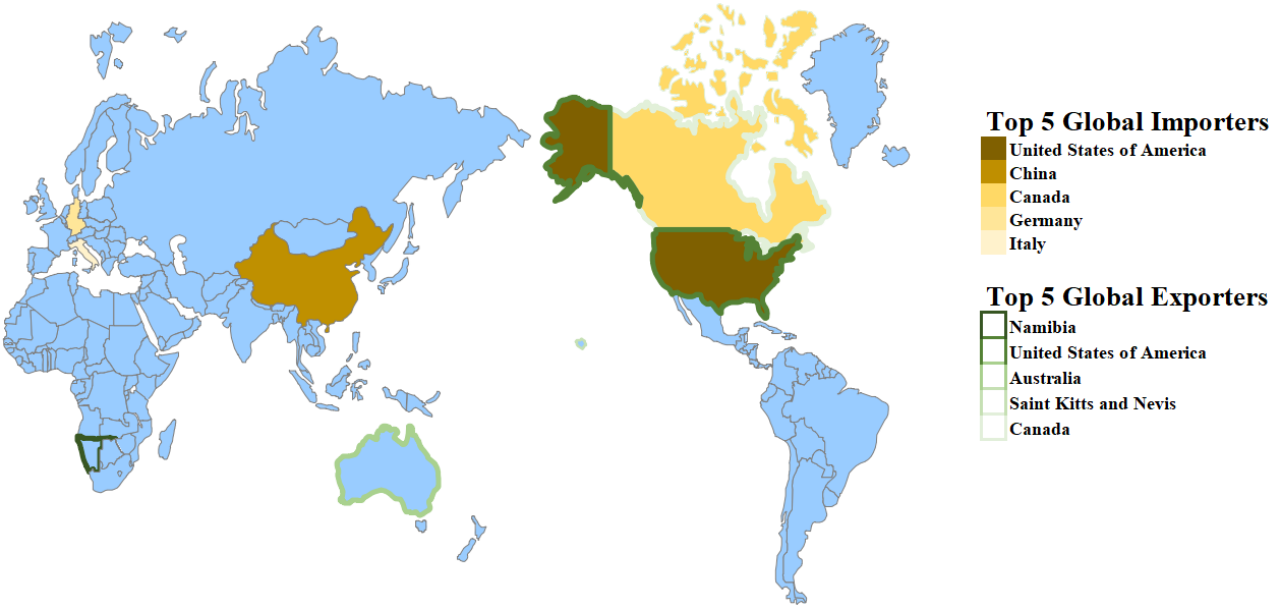

Figure 5. Top Five Global Importing and Exporting Countries of Wild Animals, 2013-2023

As shown in Figure 5, the lack of effective regulation in the wildlife trade results in the loss of biodiversity, triggering various issues such as social, ecological, and international conflicts. If WWF adopts our project and provides unified control and traceability for global wildlife, it will gain a significant social reputation and international influence. More importantly, it will earn support and investment from environmentalists and advocates of freedom and altruism worldwide.

4. Conclusion

This study evaluated three major clients—World Wide Fund for Nature (WWF), China Wildlife Conservation Association (CWCA), and the National Forestry and Grassland Administration—using resources, power, and interest as key indicators. By quantifying these indicators with specific data such as financial expenditure, policy documents, and conservation activities, WWF was identified as the most aligned client.

Case studies demonstrated that implementing electronic identification (ID) technologies significantly enhances wildlife conservation. Longer project implementation and species with strong reproductive capabilities yielded higher returns. Artificially bred populations recovered faster than wild ones, and projects using electronic IDs achieved positive returns over time.

Adopting the "Electronic ID" five-year plan by WWF is expected to stabilize financial investments and increase returns as a comprehensive wildlife ID database is established. This initiative will attract international funding, reduce illegal wildlife trade, and foster global collaboration, enhancing WWF's social reputation and influence.

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