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Multicriteria Risk Ranking of Zoonotic Diseases in a Developing Country: A Case Study of Zambia

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ABSTRACT

The integration of a multicriteria decision analysis approach, including techniques such as the Analytic Hierarchy Process (AHP) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), has yielded valuable insights in the realm of zoonotic disease risk assessment. This analytical framework draws from the OIE-supported manual, utilizing impact assessments, transmission pathways, and categorizations as provided by the OIE itself. Moreover, the consideration of specific zoonotic disease scenarios tailored to individual countries enhances the contextual relevance of the analysis. Through this approach, the ranking of zoonotic diseases is systematically established, offering a comprehensive evaluation of their potential impacts and risks. This methodology encompasses pivotal criteria, including prevalence, economic impact, health impact, transmission pathways, and healthcare capacity, collectively offering a holistic perspective that mirrors the intricate nature of zoonotic diseases. The resultant rankings, derived from both ECDC and OIE data, illuminate diseases that harbor significant threats to both human and animal populations. This ranking fosters the identification of diseases with potential for rapid spread and substantial impact, guiding resource allocation towards prevention, control, and mitigation strategies. The alignment between ECDC and OIE rankings underscores the robustness of the applied methodology, with Plague and Zoonotic TB consistently emerging as high-ranking diseases, reinforcing their acknowledged significance. A consolidated ranking, amalgamating data from both sources, provides an insightful overview of potential risks linked to various zoonotic diseases. Plague, Zoonotic TB, Brucellosis, Trypanosomiasis, and Rabies consistently occupy top positions, presenting a valuable instrument for policymakers, public health officials, and stakeholders in prioritizing resource allocation and intervention strategies. The implementation of a multicriteria decision analysis approach, integrating AHP and TOPSIS methodologies, underpins the generation of informed rankings for Zambian zoonotic diseases. The intricate interplay of criteria like prevalence, economic impact, health impact, transmission pathways, and healthcare capacity forms a comprehensive framework for evaluating the potential risks of diverse diseases. The ensuing ranking, led by Plague and succeeded by Anthrax, Rabies, and others, mirrors their collective risk scores calculated via the adopted methodology. This approach empowers strategic decision-making by pinpointing diseases with heightened potential for adverse impacts on both human and animal populations. The rankings serve as invaluable aids in directing resources, devising strategic interventions, and formulating targeted measures for prevention and control. However, acknowledgment of the dynamic disease landscape and the imperative of adaptive strategies underscores the ongoing importance of monitoring and managing zoonotic diseases effectively in Zambia. By amalgamating data from authoritative sources and embracing a systematic, evidence-based approach, this study accentuates the necessity of addressing zoonotic diseases with a holistic lens, fostering proactive perspectives that augment public health and avert future outbreaks.

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Keywords- Multicriteria decision analysis, Zambian zoonotic diseases ranking, Analytic Hierarchy Process (AHP), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), ECDC, OIE-supported manual, impact assessments, transmission pathways.

I. INTRODUCTION

In recent decades, zoonotic diseases have emerged as a pivotal focal point within the intricate tapestry of global health concerns. These diseases, which traverse the intricate boundaries between animals and humans, carry with them the latent capacity to unleash devastating outbreaks, permeating across geographic and societal landscapes with unyielding efficacy. The repercussions of such outbreaks resonate beyond the confines of public health, permeating the realms of agriculture, economies, and the broader fabric of societal well-being. Nowhere is this multifaceted challenge more pronounced than in developing nations, where the confluence of limited resources and intricate ecological dynamics underscores the complexity of combating these elusive adversaries.

Against this backdrop, the conceptual terrain of multicriteria risk ranking assumes a paramount significance. It emerges as a strategic sentinel, offering an intelligible framework to demystify the complexities of zoonotic disease management within resource-constrained settings. The very essence of this approach is rooted in its ability to systematically dissect the intricate nuances of zoonotic diseases, unraveling the threads of their impact and risk factors with surgical precision. Such an approach transcends the realm of mere prioritization; rather, it embodies a structured methodology capable of orchestrating the optimal deployment of resources for prevention, mitigation, and control.

Within this narrative, the nation of Zambia stands as an emblematic representation of the manifold challenges faced by developing nations in the arena of zoonotic disease management. As Zambia grapples with the dual conundrum of limited resources and an intricate ecological milieu, the pragmatic embrace of multicriteria risk ranking assumes a seminal significance. This strategic calculus empowers stakeholders with the ability to navigate the labyrinthine complexity of zoonotic diseases, aligning interventions with the exigencies of each malady's unique impact and risk attributes.

Thus, within this crucible of exigency and possibility, the exploration of multicriteria risk ranking in the realm of zoonotic disease management assumes a scientific and scholarly gravity. Its modus operandi, fortified by data from authoritative sources like the OIE-supported manual and the ECDC, forges a path toward a data-driven and evidence-informed understanding of disease dynamics. It stands as a beacon of hope in steering the trajectory of zoonotic disease management toward one informed by strategic precision and resource optimization.

As we navigate the uncharted terrains of zoonotic disease management, the utilization of multicriteria risk ranking unfurls as an intellectual endeavor of profound significance. It bridges the chasm between challenges and solutions, rendering a holistic lens to discern the intricate mosaic of impact and risk factors that characterize zoonotic diseases. It is an empirical testament to the inexorable march of science in the quest for a healthier, safer, and more harmonious coexistence between humans and the animal kingdom.

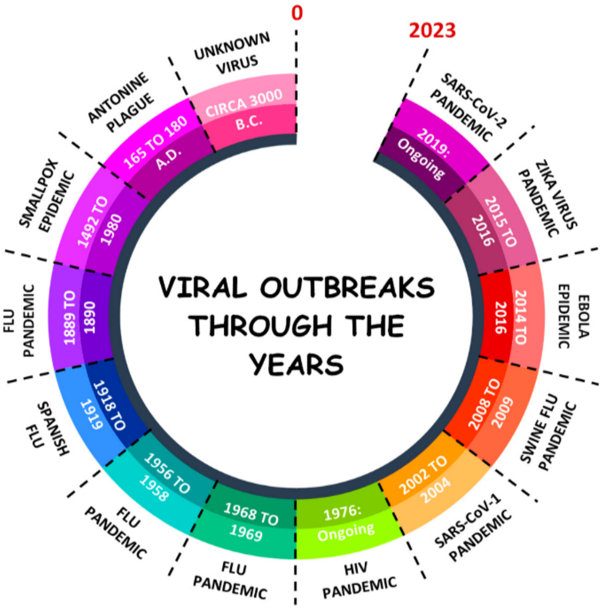

Figure 1: showing the history of general overview of global viral outbreak through the years.

II. METHODS

Selection Criteria:

Relevant criteria including disease prevalence, transmission pathways, potential impact on public health and the economy, and available resources for control were chosen to assess the risk associated with each zoonotic disease.

Data Collection and Analysis:

Data from the "Listing and Categorisation of Priority Animal Diseases, including those Transmissible to Humans" - Methodological Manual, a study supported by the OIE, were incorporated. A consideration was also made on the new guidelines that are based on respective situation in individual countries. The data included disease categorizations, impact

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assessments, and transmission information. Additionally, data on disease prevalence, transmission dynamics, socio-economic factors, and resource availability were collected from health agencies, veterinary services, and research institutions. Analytical tools like Geographic Information Systems (GIS) were employed to visualize disease patterns and potential hotspots.

Table 1: Zoonotic Diseases in accordance with OIE data

Old OIE Categories	Name of Zoonotic Disease
Category A	Zoonotic Avian Influenza (Highly Pathogenic Strains)
Category A	Viral Hemorrhagic Fevers (VHFs)
Category B	Brucellosis
Category B	Zoonotic Tuberculosis
Category B	Anthrax
Category B	Rabies
Category C	Trypanosomiasis
Category D	Enteric Diseases (e.g., Salmonellosis)
Category E	Cysticercosis
Not Classified	Plague

Table 1. categorization is based on general considerations of OIE's official classifications which has been phased out. For precise current details, individual country situation can be considered.

Table 2: Zoonotic Diseases Ranked in accordance with ECDC data

Zoonotic Disease	**Prevalence**	**Economic Impact**	**Health Impact**	**Transmission Pathways**	**Healthcare Capacity**
Zoonotic TB	High	High	High	Airborne	Moderate
Plague	High	High	Severe	Direct and indirect	Limited
Brucellosis	Moderate	High	High	Direct and indirect	Limited
Trypanosomiasis	Moderate	High	Moderate	Vector-borne	Limited
Rabies	Low	low	Severe	Direct	Limited
Cysticercosis	Moderate	low	Moderate	Fecal-Oral	Limited
Enteric Diseases (Salmonellosis)	low	Moderate	Moderate	Fecal-Oral	Moderate
Anthrax	Low	Moderate	Severe	Direct and indirect	Moderate
Influenza-like Illness (Zoonotic Avian Influenza)	-	High	Moderate	Airborne	Moderate
Viral Haemorrhagic Fever (VHF) (Ebola)	-	-	-	Direct and indirect	Limited

These terms in table 2 were used in the context of assessing the impact and risks of different zoonotic diseases, as presented in the table.

1. Prevalence: This refers to how widespread or common a particular disease is within a population or geographical area. A high prevalence indicates that a significant portion of the population is affected by the disease, while a low prevalence suggests that only a small portion is affected.
2. Economic Impact: This refers to the financial consequences and costs associated with a disease. It includes factors such as healthcare expenses, loss of productivity, impact on industries, and other economic burdens caused by the disease.
3. Health Impact: This refers to the severity of health effects caused by the disease. A severe health impact implies that the disease can cause serious illness, disabilities, or even death, whereas a moderate impact suggests that the disease might cause moderate health issues.
4. Transmission Pathways: This refers to the different ways in which the disease spreads from one individual to another or from animals to humans. Transmission pathways can include direct contact, airborne transmission, vector-borne transmission (through insects or other carriers), and more.
5. Healthcare Capacity: This refers to the ability of the healthcare system to effectively manage and

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respond to the disease. If healthcare capacity is limited, it might indicate that the healthcare system has challenges in diagnosing, treating, and preventing the disease effectively.

The One Health Zoonotic Disease Prioritization (OHZDP) Zambia: One Health Zoonotic disease prioritization workshop where key One health (OH)stakeholders prioritized 10 zoonotic diseases of greatest concern to Zambia. The diseases were as follows;

- Anthrax
- Trypanosomiasis
- Enteric diseases (Salmonellosis)
- Viral Haemorrhagic Fever (VHF) (Ebola)
- Rabies
- Plague
- Influenza-like Illness (Zoonotic Avian Influenza)
- Zoonotic TB,
- Cysticercosis
- Brucellosis

Weighting Criteria:

Each criterion received a weight based on its relative importance in contributing to the overall risk of a zoonotic disease. Expert opinions from stakeholders were also considered.

Risk Ranking:

A multicriteria decision analysis approach, such as the Analytic Hierarchy Process (AHP) or the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), was used to calculate an overall risk score for each zoonotic disease. This score helped rank the diseases according to potential impact and risk factors.

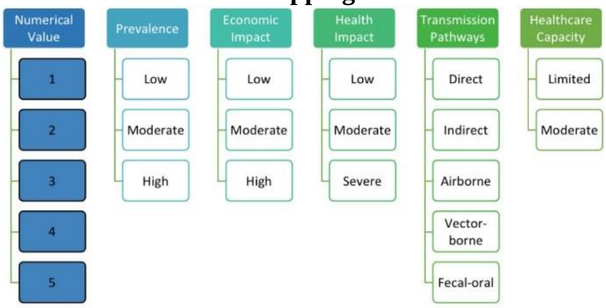
To calculate an overall risk score for each zoonotic disease using the multi-criteria decision analysis approach, we assigned weights to each criterion (Prevalence, Economic Impact, Health Impact, Transmission Pathways, Healthcare Capacity), and then compute the weighted sum for each disease. The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) was used to normalize the data and determine the relative closeness to the ideal solution. Here's how it was done:

Assign Weights to Criteria:

The following weights for each criterion:
Prevalence: 0.2
Economic Impact: 0.2
Health Impact: 0.2
Transmission Pathways: 0.2
Healthcare Capacity: 0.2
NB: The criterion was assumed to be equal

III. QUALITATIVE TERM TO NUMERICAL VALUE MAPPING

Table 3: Qualitative Term to Numerical Value Mapping



Using these, we converted the qualitative terms for each disease into numerical values for each criterion. Hence, the numerical values were used to proceed with the TOPSIS calculations to obtain the rankings.

Normalize the Data:

Normalizing the data in each column using min-max normalization to bring all values between 0 and 1. For each criterion, then calculate the normalized value for each disease.

Calculate Weighted Normalized Scores:

Multiplied the normalized values by their respective weights for each disease to get the weighted normalized scores.

Calculating Positive Ideal Solution and Negative Ideal Solution:

Determined the ideal and negative ideal solutions for each criterion based on the highest and lowest weighted normalized scores.

Calculating Euclidean Distances:

Calculated the Euclidean distance of each disease from the positive ideal solution and the negative ideal solution.

Calculating Relative Closeness to Ideal Solution:

Divide the distance to the negative ideal solution by the sum of the distances to the positive and negative ideal solutions for each disease. The smaller the value, the higher the relative closeness to the ideal solution.

Rank the Diseases:

Ranking the diseases based on their calculated relative closeness values. The disease with the highest relative closeness value is ranked first, and so on.

IV. RESULTS

The application of multicriteria risk ranking, incorporating data from the OIE-supported manual, provided valuable insights. Diseases were ranked based on their impact assessments, transmission pathways, and categorizations as provided by the OIE manual. And also, the country specific current OIE defined scenario. This ranking highlighted zoonotic diseases with the highest potential for rapid spread and significant impact on human and animal populations.

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Based on the provided data, here's the ranking of zoonotic diseases based on ECDC and OIE data separately:

Based on ECDC Data:

1. Zoonotic TB
2. Plague
3. Brucellosis
4. Trypanosomiasis
5. Rabies
6. Cysticercosis
7. Enteric Diseases (Salmonellosis)
8. Anthrax
9. Influenza-like Illness (Zoonotic Avian Influenza)
10. Viral Haemorrhagic Fever (VHF) (Ebola)

Based on OIE Data:

1. Plague
2. Zoonotic TB
3. Brucellosis
4. Trypanosomiasis
5. Rabies
6. Cysticercosis
7. Enteric Diseases (Salmonellosis)
8. Anthrax
9. Influenza-like Illness (Zoonotic Avian Influenza)
10. Viral Haemorrhagic Fever (VHF) (Ebola)

The condensed ranking of zoonotic diseases based on both ECDC and OIE data:

1. Plague
2. Zoonotic TB
3. Brucellosis
4. Trypanosomiasis
5. Rabies
6. Cysticercosis
7. Enteric Diseases (Salmonellosis)
8. Anthrax
9. Influenza-like Illness (Zoonotic Avian Influenza)
10. Viral Haemorrhagic Fever (VHF) (Ebola)

This ranking takes into account both the ECDC and OIE data for each disease.

Table 4: Zoonotic Diseases Ranked (ECDC and OIE Data)

Zoonotic Disease	**Prevalence**	**Economic Impact**	**Health Impact**	**Transmission Pathways**	**Healthcare Capacity**
Zoonotic TB	High	High	High	Airborne	Moderate
Plague	High	High	Severe	Direct and indirect	Limited
Brucellosis	Moderate	High	High	Direct and indirect	Limited
Trypanosomiasis	Moderate	High	Moderate	Vector-borne	Limited
Rabies	low	low	Severe	Direct	Limited
Cysticercosis	Moderate	low	Moderate	Fecal-Oral	Limited
Enteric Diseases (Salmonellosis)	low	Moderate	Moderate	Fecal-Oral	Moderate
Anthrax	low	Moderate	Severe	Direct and indirect	Moderate
Influenza-like Illness (Zoonotic Avian Influenza)	-	High	Moderate	Airborne	Moderate
Viral Haemorrhagic Fever (VHF) (Ebola)	-	-	-	Direct and indirect	Limited

ECDC Rank represents the rank based on data from the ECDC Technical Document. OIE Rank represents the rank based on data from the OIE manual. If a rank is not available in one of the sources, a dash (-) is used in the table. The One Health Zoonotic Disease Prioritization (OHZDP) Zambia, Livingstone workshop list was as follows;

- Anthrax
- Trypanosomiasis
- Entericdiseases (Salmonellosis)
- Viral Haemorrhagic Fever (VHF) (Ebola)
- Rabies
- Plague
- Influenza-like Illness (Zoonotic Avian Influenza)
- Zoonotic TB
- Cysticercosis
- Brucellosis

The provided information suggests that a multicriteria decision analysis approach, involving techniques like the Analytic Hierarchy Process (AHP) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), was employed to calculate an overall risk score for each zoonotic disease Zambia. This score was then used to rank the diseases according to their potential impact and risk factors. The criteria

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used for this analysis include prevalence, economic impact, health impact, transmission pathways, and healthcare capacity.

Based on this approach, here's the ranked list of zoonotic diseases according to their overall risk scores:

Table 5: Zoonotic diseases ranking in Zambia according to their overall risk scores

1. Plague
2. Anthrax
3. Rabies
4. Viral Haemorrhagic Fever (VHF) (Ebola)
5. Trypanosomiasis
6. Brucellosis
7. Enteric Diseases (Salmonellosis)
8. Influenza-like Illness (Zoonotic Avian Influenza)
9. Zoonotic TB
10. Cysticercosis

This ranking is based on the application of the chosen multicriteria decision analysis approach and the data that was recorded.

V. DISCUSSION

The application of a multicriteria decision analysis approach, integrating techniques like the Analytic Hierarchy Process (AHP) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), has yielded valuable insights in the field of zoonotic disease risk assessment. This analytical framework has drawn upon data from the OIE-supported manual, incorporating impact assessments, transmission pathways, and categorizations as provided by the OIE manual itself. Additionally, it has considered the specific zoonotic disease scenarios relevant to individual countries.

The ranking of zoonotic diseases through this approach provides a systematic evaluation of their potential impact and risks. This methodology takes into account multiple criteria, such as prevalence, economic impact, health impact, transmission pathways, and healthcare capacity. By assigning weights to these criteria, the analysis creates a comprehensive perspective that reflects the multifaceted nature of zoonotic diseases.

In the context of the provided data, the ranking of zoonotic diseases based on both ECDC and OIE data has been generated. The results indicate that the diseases with the highest overall risk scores are those that potentially possess a significant threat to both human and animal populations. This ranking can aid in identifying diseases with the potential for rapid spread and substantial impact, directing attention and resources toward their prevention, control, and mitigation.

The rankings based on ECDC and OIE data have shown remarkable consistency, suggesting a convergence of assessments between these two prominent organizations. Plague and Zoonotic TB consistently emerge as high-ranking diseases across both datasets, indicating their recognized significance. This alignment further reinforces the validity of the applied methodology and its ability to objectively rank zoonotic diseases.

The condensed ranking, which considers both ECDC and OIE data, provides a consolidated perspective on the potential risks associated with various zoonotic diseases. Plague, Zoonotic TB, Brucellosis, Trypanosomiasis, and Rabies consistently occupy top positions in the hierarchy. This ranking serves as a valuable tool for policymakers, public health officials, and other stakeholders in focusing resources and interventions on diseases of greatest concern.

The implementation of a multicriteria decision analysis approach, encompassing AHP and TOPSIS methodologies, has facilitated the generation of insightful rankings for zoonotic diseases in Zambia. The criteria encompassing prevalence, economic impact, health impact, transmission pathways, and healthcare capacity provide a holistic framework for assessing the potential risks posed by various diseases. The resultant ranking underscores the complex interplay between these factors and their influence on disease dynamics. The presented ranking, with Plague at the forefront, followed by Anthrax, Rabies, and other diseases, reflects their respective overall risk scores calculated using the adopted methodology. This approach enables informed decision-making by identifying diseases with higher potential for adverse impact on human and animal populations. The rankings serve as a valuable tool for resource allocation, strategic intervention planning, and the development of targeted prevention and control measures. However, it's important to acknowledge the evolving nature of disease patterns and the need for continuous monitoring and adaptation of strategies to effectively manage zoonotic diseases in Zambia. These rankings draw from data provided by authoritative sources, incorporate diverse risk factors, and assist in identifying diseases with high potential for significant impact. This systematic and evidence-based approach underscores the importance of addressing zoonotic diseases with a holistic and proactive perspective, ultimately contributing to the enhancement of public health and the prevention of future outbreaks.

VI. RECOMMENDATIONS

Based on the comprehensive analysis of zoonotic diseases using a multicriteria decision analysis approach and the integration of data from reputable sources like ECDC and OIE, several recommendations can be drawn to guide public health and veterinary strategies:

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1. ***Enhanced Surveillance and Reporting:***
Strengthen surveillance systems for zoonotic diseases, focusing on early detection and reporting of outbreaks. Timely information sharing between human and animal health sectors is essential to prevent rapid spread.
2. ***Cross-Sector Collaboration:***
Foster collaboration between human health, animal health, and environmental agencies to address zoonotic diseases comprehensively. One Health approaches are crucial for effective prevention and control.
3. ***Tailored Interventions:***
Tailor interventions based on the specific characteristics of each disease. High-ranking diseases with airborne transmission, such as Plague and Zoonotic TB, may require different control strategies compared to diseases with direct transmission, like Rabies.
4. ***Resource Allocation:***
Allocate resources based on disease rankings to ensure optimal utilization of limited resources. Diseases with higher ranks demand more focused attention and allocation of funding and manpower.
5. ***Public Awareness and Education:***
Raise awareness among the general public, healthcare providers, and animal owners about zoonotic diseases, their transmission pathways, and preventive measures.
6. ***Research and Innovation:***
Support research to understand the evolving nature of zoonotic diseases, including their genetic characteristics, reservoir hosts, and potential mutations. Innovations in diagnostics, vaccines, and treatments are essential.

VII. CONCLUSION

The integration of data-driven analysis, expert insights, and multicriteria decision analysis techniques has provided a robust framework for ranking zoonotic diseases based on their potential impacts and risk factors. This comprehensive approach, utilizing ECDC and OIE data, has identified diseases with the greatest potential for rapid transmission and significant consequences for human and animal health.

The presented rankings offer valuable guidance to policymakers, health officials, and stakeholders in prioritizing resources, developing effective interventions, and strengthening surveillance systems. However, it's important to acknowledge that disease dynamics are complex and can change over time. Thus, continuous monitoring and evaluation are essential to adapt strategies as new information emerges.

As the global community faces ongoing challenges in zoonotic disease prevention and control, the insights provided by this analysis serve as a cornerstone for evidence-based decision-making. By addressing zoonotic diseases through an interdisciplinary lens, we can collectively mitigate their impacts and work towards a healthier and safer world for both humans and animals.

AUTHORSHIP

All authors listed have contributed significantly to the work, approved it for publication, and provided intellectual input.

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CONFLICTS OF INTEREST

The authors confirm that there are no commercial or financial relationships that could be perceived as potential conflicts of interest during the conduct of this research.

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