SAFETY ASSESSMENT OF THE CENTRILIZED STORAGE FACILITY FOR DISUSED SEALED RADIOACTIVE SOURCES IN UNITED REPUBLIC OF TANZANIA

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1. INTRODUCTION

Sealed radioactive sources (SRS) are widely used in United Republic of Tanzania in agriculture, industry, medicine and research. Once SRS are no longer in use, they are declared as disused, and they are transferred to the central radioactive management facility (CRMF) belonging to Tanzania Atomic Energy Commission (regulatory body) and managed as radioactive waste. In order to reduce the risk associated with disused sealed radioactive sources (DSRS), the first priority would be to bring them to appropriate controls under the regulatory body. When DSRS are safely managed, regulatory body need to make assessment of the likelihood and potential impact of incidents, accidents and hazards for proper management plan. One of the main challenges faced by regulatory bodies resides in the ability to make priority due to mult-criteria consideration. The paper applies Analytical Hierarchy Process (AHP) for assessing and allocating weights and priorities for solving the problem of mult criteria consideration for management plan. Using pairwise comparisons, the relative importance of one criterion over another can be expressed [1]. The method allows decision makers to provide judgments about the relative importance of each criterion and to estimate radiological risk by using expert's judgments or probability of occurrence. AHP is the step by step manner where the resulting priorities are shown and the possible inconsistencies are determined.

2. HAZARDS AGAIST SAFETY OF CRMF

Hazards which are likely to occur to the facility include terrorist activity, earthquake, civil disorder, flood, cyclones, lightning, landslides, fire outbreaks, power failure, building collapse, and strong wind.

In August 7, 1998, two nearly simultaneous massive bomb attacks happened to the U.S. embassies in Nairobi, Kenya and Dar es salaam-Tanzania killing a hundreds of people and wounding thousands people. [2]. Also 2013 two churches in Arusha town-Tanzania were bombed by massive bombs .These facts are evidences that Terrorism is likely event that can occur to the storage facility.

In 1997, hundreds of people were rendered homeless after floods swept their houses in the Bwawani village of Arusha. The rain also destroyed hundred acres of farms sweeping away grain and legume crops as well as some livestock. Also Heavy rain fell on Tuesday 21 January and Wednesday 22 January 2014 in the Manyara, Morogoro and Dodoma region of Tanzania, causing severe floods. The worst affected area was Kiteto district near Arusha region .All these facts provide evidence of flood to be likely event to occur to the facility.

A fire hazard on the facility is a likely event to occurs as like to other workplace [3]. The situation that increases the likelihood a fire at the area of storage includes electrical system installed, flammable solvent, smocking and terrorist attack.

In Tanzania, the problem of anti-nuclear is becoming big due to lack of public awareness. At the end of 2012, the residents of the village near uranium mine in Bahi Makulu and Illindi particularly an area called Mashamba Mapya expressed their objection of the uranium mining plans in several gatherings and were collecting signatures for demonstration, because of fearing health problems associated with uranium mining. In case of central radioactive management facility, the facility is outside the town of Arusha, in an under populated area but there are people living near the facility and they are complaining about the facility of being near.

3. METHODOLOGY

The paper applies Analytical Hierarchy Process (AHP) for ranking potential hazards based on the following criteria: occurrence probability, potential impact and prevention/ mitigation cost. The relative importance of each hazard is selected based on expert argument and author experience resulted from scientific point of view. The method allows decision maker to provide judgments of about relative importance of each criteria [4]. The weights of importance of criteria are also determined by using pairwise comparisons. The priority vector is driven from comparison matrices by using eigenvector method. Some key and basic steps involved in this methodology are:

3.1. State the problem.
Tanzania has been facing difficulties regarding the prioritization for risk reduction strategy. These difficulties are due to the mult criteria consideration before a decision making.

3.2. State the objective and its outcome.
Objective; Prioritization risk reduction strategy
Outcome; making risk management plan

3.3. Identify the criteria that influence risk estimates.
The concept of risk is the combination of the probability of occurrence of the harm and consequence of that harm. If the consequence of the incident is known, the product of the consequence and the estimated likelihood (allowing for the control measures) gives an estimate of the risk posed by the initiating hazard. The control measures need to be independent. From this fact, three criteria have been chosen; Occurrence probability, Potential impact and prevention /mitigation cost.

3.4. Structure the problem in a hierarchy of different levels constituting goal, criteria and sub-criteria (potential hazards)

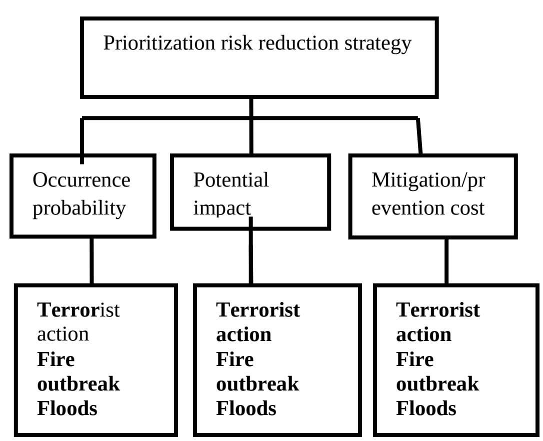

Figure.1.Hierarchy of criteria and potential hazards

3.5. Compare each element in the corresponding level and calibrate them on the numerical scale. This requires **n(n-1)/2** comparisons, where n is the number of elements with the considerations.

If we have n hazards, A_1, A_2 …A_n, whose probability of occurrence are P_1, P_2… P_n respectively, then pair matrix of pair wise ratios can be formed whose rows give the ratio of probability for each hazard with respect to all others.

	A_1	A_2	…	A_n	
$[A_1]$	P_1/p_1	P_1/p_2	…	P_1/P_n	$[P_1]$
$[A_2]$	P_2/p_1	P_2/p_2	…	P_2/P_n	$[P_2]$
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
$[A_n]$	P_n/P_1	P_n/P_2	…	P_n/P_n	$[P_n]$

$= n\,[P_1 \;\; P_2 \;\; \dots P_n \;\;]^T$

The diagonal elements are equal to one and the other elements will simply be the reciprocals of the earlier comparisons. Rating the relative "priority" of the criteria is done by assigning a weight between 1 (equal importance) and 9 (extreme importance) to the more important criterion, whereas the reciprocal of this value is assigned to the other criterion in the pair.

Table.1. preferences made on 1-9 scale

Intensity	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective
3	Somewhat more importance	Judgment slightly favor one over the other
5	Much more importance	Judgment strong favor one over the other
7	Very much more importance	Judgment very strong favor one over the other
9	Absolutely more importance	The evidence favor one over the other
2,4,6,8	Intermediate value	When compromise is needed

The relative ratio scale derived from a pair wise comparison reciprocal matrix of judgments is driven by solving

$AX= n X,$

To make X unique, normalization has been done

3.6. Perform calculations to find the maximum Eigen value, consistency index CI, consistency ratio CR, and normalized values for each criteria/alternative.
Consider ($AX= \lambda_{max} X$) where

- A is the comparison matrix of size n *n, for n criteria, also called priority matrix
- X is the Eigenvector of size n*1,also called priority vector
- λ_{max} is the maximum Eigen value, $\lambda_{max} \in \mathbb{R}$ **>n,** then

➢ The consistency index, CI, is calculated as

$$CI = (\lambda_{max} - n)/(n - 1)$$

Where λ max is the maximum Eigen value of the judgment matrix

➢ Then, the Consistency Ratio, which is a comparison between Consistency Index and Random Index, can be calculated from this formula

$$CR = CI/RI$$

Random Index (RI); given from Saaty book Random Index [5]

Table.2. Random consistency indices (SAATY 2005)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

If the value of Consistency Ratio is smaller or equal to 10%, the inconsistency is acceptable. If the Consistency Ratio is greater than 10%, need to revise the subjective judgment.

4. ANALYSIS USING AHP

The analysis is performed based on effects of weights on the main considerations.

4.1 Ranking of Criteria

Three criteria have been chosen by considering the objective of the study; Occurrence probability, Potential impact and prevention cost. According to author opinion, occurrence probability is somewhat more important compared to potential impact and much more important when compared to prevention cost. Potential impact is slightly much more important compared to prevention cost.

Pair wise comparison matrix for criteria has been made. Below are abbreviations that have been used.

A. Occurrence probability, B. Potential impact C. Prevention or mitigation cost

Table.3.Comparison matrix given criteria and preferences

Criteria ranking	A	B	C	Priority vector
A	1	3	5	0.626488
B	0.333333	1	4	0.279796
C	0.2	0.25	1	0.093716

λ_{max}=3.087778, Consistency Index CI =0.044389, Consistency Ratio (CR) =0.076

4.2 Ranking for Hazards

Hazards have been ranked from questionnaire given to the expert.

4.2.1 Occurrence probability

From the questionnaire terrorist activity has high probability of occurrence when compared to other hazards. Fire outbreak, Floods and Civil disorder have equal chance of occurrence.

4.2.2Potential Impact

According to author terrorist activity has higher consequence when compared to other hazards. Example terrorist activity can cause also fire hence when terrorism is compared to fire hazards; terrorism has higher impact to the facility. Terrorism has much more impact when compared to floods and civil disorder. Fire and Floods have equal consequence since both can break level 1 of defense in depth of the facility.

4.2.3Prevention cost

It is hard to prevent terrorism in the country. To prevent terrorism needs a lot of money, resources and qualified personnel but to prevent fire it is possible since needs small investment like buying smock detector, fire extinguisher and vehicles for emergency preparedness. Therefore combating terrorism is much more cost when compared to fire and floods. And fire prevention is less costless compared to flood. Civil disorder is slightly costly when compared to Fire and floods

Comparison matrices for hazards; Abbreviations used;

A: Occurrence probability, B: Potential impact

C: Prevention or mitigation cost
a: Terrorist action, b:.Fire outbreak, c:Floods, d: Civil disorder

Table.4. Comparisons matrices for hazards given criteria and preferences

A	a	b	c	d	Priority vector
a	1	3	3	3	0.5
b	0.3333	1	1	1	0.1667
c	0.3333	1	1	1	0.1667
d	0.3333	1	1	1	0.1667
	λ_{max}=4, CI=0 , CR= 0				
B	a	b	c	d	Priority vector
a	1	4	5	7	0.6193
b	0.25	1	1	3	0.16259
c	0.2	1	1	3	0.1557
d	0.14285	0.333	0.333	1	0.06237
	λ_{max}=4.1196, CI=0.03987, CR=0.044				
C	a	b	c	d	Priority vector
a	1	4	3	2	0.45855
b	0.2	1	0.5	0.33	0.09344
c	0.333	2	1	0.33	0.14325
d	0.5	3	3	1	0.3047
	λ_{max}=4.1215, CI=0.040466,CR=0.045				

The thirds step to find priority of the hazards. The priority vector of each hazard is multiply by each column of the corresponding criteria.

Table.5.Final AHP ranking of hazards

	A	B	C	criteria weight	Priority vector
a	0.5	0.619302	0.4585 53	0.6264 88	0.529496
b	0.166667	0.162596	0.0934 43	0.2797 96	0.158666
c	0.166667	0.15573	0.1432 56	0.0937 16	0.161413
d	0.166667	0.062373	0.3047 49		0.150426

5. CONCLUSION

Therefore, terrorist action has to be given first priority in risk reduction strategy followed by Flood which is followed by fire outbreak. The Information provided by experts helps to rank hazards according to probability of occurrence, potential impact and mitigation cost. The strength of the AHP method lies in its ability to incorporate both qualitative and quantitative data in decision making. AHP present a powerful tool for weighting and prioritizing hazards in terms of occurrence probability. However, AHP also has some weak points. AHP requires data based on experience, knowledge and judgment which are subjective for each decision-maker. The qualitative analysis of these potential hazards in terms of potential impacts and prevention cost is highly subjective and may differ from one expert to another.

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