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RESEARCH ARTICLE

Design of Technical and Scientific Support Organization (TSO) for Supervision of Nuclear Power Plant Construction

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ABSTRACT - Electricity is a fundamental necessity that requires a continuous and reliable supply. Nuclear energy, a renewable energy source, holds significant potential for electricity production in Indonesia. According to Government Regulation No. 79/2014 on the National Energy Policy, plans for the construction of Nuclear Power Plants (NPPs) in Indonesia are set to commence after 2025. A Technical and Scientific Support Organization (TSO) plays a critical role in supervising NPP construction, as outlined by the International Atomic Energy Agency (IAEA, 2018). A TSO is an organizational unit, department, or institute that primarily focuses on nuclear and radiation safety, providing technical and scientific support to regulatory functions. This study identifies key criteria for TSOs to effectively supervise NPPs, utilizing the Analytical Hierarchy Process (AHP). The criteria are categorized into three perspectives: Safety, Commissioning and Operation, and Human Resource and Management, with respective weights of 0.604, 0.210, and 0.186. The findings highlight safety as the most critical perspective, essential for ensuring the safe commissioning and operation of NPPs and associated facilities. This research provides a technical framework to guide the development of TSOs in compliance with applicable regulations, contributing to the safe and sustainable development of nuclear energy in Indonesia.

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1.0 INTRODUCTION

Electricity is a fundamental necessity of modern life. Almost all human activities are supported by electricity, including household chores, the industrial processes, offices operations, transportation, government services, and more. Indonesia continues to rely heavily on coal-fired power plants for electricity generation [1]. Coal is a finite, non-renewable resource that is depleting due to continued exploitation. Coal-fired power plants currently contribute the largest share of electricity production in Indonesia. According to Ministry of Energy and Mineral Resources of the Republic of Indonesia, the projected coal demand for 2022 was 188.9 million tons. The demand is forecasted to rise to 195.9 million tons in 2023, 209.9 million tons in 2024, and decline slightly to 197.9 million tons in 2025. Meanwhile, coal demand from the electricity sector is projected to increase to 119 million tons in 2022, 126 million tons in 2023, and around 140 million tons in 2024 before decreasing to 128 million tons in 2025 [2]. Indonesia's coal reserves are projected to be depleted by 2040, primarily due to a lack of new exploration. In 2021, coal resources total 113 billion tons, with proven reserves reaching 33 billion tons. At the current exploitation and production rate of 500 million tons per year, coal reserves are expected to deplete even faster. In the last 10 years, there has been a decrease in the discovery of new coal mining areas. This is due to the high risks associated with coal mining, the large investments required, and the lengthy return-on-investment periods. Moreover, coal emits more carbon dioxide (CO_2) per unit of energy produced than any other fossil fuel. Coal combustion is one of the biggest contributors to greenhouse gas emissions. It contributes to global climate change [3]. Coal-fired power plants also produce large amount of slag and ash, and emit other dangerous and harmful gases [4]. Based on Government Regulation No. 79 of 2014 (PP 79/2014), one of the main policies of the National Energy Policy is to ensure energy availability for national needs by increasing exploration of resources, including fossil fuels, new energy, and renewable energy sources [5]. For this reason, nuclear energy is becoming increasingly popular for certain countries to diversify their energy production [6].

Indonesia faces the challenge of fulfilling energy demands that are environmentally friendly and sustainable. Nuclear energy is considered environmentally friendly as it is free of greenhouse gas emissions, has a relatively small land footprint, does not disrupt the ecological balance, and produces waste that is managed and regulated under clear guidelines. Based on The Government Regulation No. 79 of 2014 (PP 79/2014) on National Energy Policy states that plans for the construction of nuclear power plants in Indonesia will begin after 2025 [5]. Indonesia plans to construct a NPP to address the nation's electricity needs. The NPP will offer substantial power generation capacity, serve as a catalyst for regional growth and development, fulfill national energy demands, and contribute to the reduction of greenhouse gas

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emissions. The primary goals to be achieved in preparing for the construction of the NPP are to maintain competence and acquire nuclear safety knowledge that complies with advanced international practices [7]. Countries considering the use of nuclear energy for electricity production need to make significant efforts in developing industrial and regulatory infrastructure to meet the international obligations and to ensure the peaceful and safe use of nuclear energy [8].

Technical and Scientific Support Organization (TSO) is needed to carry out supervision in the construction of nuclear power plants [9]. According to IAEA Technical Document No. 1835, TSO is an organization or organizational unit designated, or recognized by regulatory agencies and/or governments, to provide expertise and services to support nuclear and radiation safety and all associated scientific and technical matters, to regulatory agencies [9]. As an organizational unit, TSO can be internal or external. TSOs provide the basis for requirements and measures to protect people and the environment from radiation risks, also to ensure the safety of facilities and activities that lead to radiation risks, especially nuclear facilities [10]. TSOs assist regulators in evaluating applications for commissioning and operating permits for NPP construction. The licensing for nuclear installation and the utilization of nuclear materials is governed by Government Regulation No. 2/2014 [11]. Based on Government Regulation No. 5/2021 concerning the Implementation of Risk-Based Business Licensing, the Nuclear Energy Supervisory Agency has the authority to oversee the construction of NPPs [12]. According to the International Atomic Energy Agency (2018), Nuclear Energy Regulatory Agency has the authority to oversee the construction of NPPs and can be assisted by TSO [9]. Based on Electricity Engineering Competency Standard Guideline for Electricity Assessors Number 447 K/24.DJL.4/2017 concerning Electrical Engineering Personnel Competency Standard Guidelines for Electricity Assessors, that Nuclear Energy Regulatory Agency is responsible for issuing regulations for the construction of nuclear power plants in Indonesia based on the TSO [13]. Therefore, identifying the criteria for effective NPP supervision is crucial.

High levels of security arise from the intricate interaction between sound design, operational reliability, and human effort [14]. An effective, independent regulatory body is essential to fulfill all authorization and inspection responsibilities. Comprehensive national legislation should cover all aspects of nuclear safety, security, safeguards, and civil liability for nuclear-related damage. Competent regulatory bodies base their decisions on independent safety assessments developed internally or by the external TSO [15]. The regulatory body must establish siting requirements. Approval criteria for NPP concepts should be defined and the licensing process should be established [8]. The development of TSO is a particular challenge for a new country starting nuclear power plant development. The three main challenges typically encountered are time constraints, limited human resources, and economic factors. Competent resources that must be able to contribute to the development of a TSO will often also be involved on the part of the nuclear operator. The national regulatory system must be both technically robust and sustainable over the long term. Reliance on vendor country technical support can be a solution in the short term, but can be a problem in the medium and long term [16]. Indonesia currently lacks formal solutions or models for the TSO function and relies on experience-based guidelines [9]. National TSO capacity is a powerful tool for consolidating the medium and long-term effectiveness of regulatory control [16].

The identification and evaluation of TSO criteria for providing support in NPP supervision have not been extensively researched in Indonesia. In order to make informed decisions, decision-makers must define the problem, identify needs and objectives, establish evaluation criteria and sub-criteria, consider alternative actions, and engage relevant stakeholders [17]. This study uses AHP to break down complex multi-criteria problems into a hierarchical structure. A hierarchy represents a complex problem in a multi-level structure, where the top level defines the goal, followed by factors, criteria, sub-criteria, and alternatives. Therefore, the main objective of this research is to identify the TSO criteria for supervising nuclear power plants. This research discusses TSO criteria, with the results producing a technical rating to determine the essential criteria TSOs must meet for supervision in compliance with applicable regulations.

2.0 METHODS AND MATERIAL

Currently, there are limited studies on TSO criteria for the supervision of NPPs in Indonesia. This study aims to identify the criteria for TSOs in the supervision of NPPs. The basis for identifying these criteria includes the Specific Safety Requirements No. SSR-2/1 (Rev. 1) on the Safety of Nuclear Power Plants: Design [18], the Specific Safety Requirements No. SSR-2/2 (Rev. 1) on the Safety of Nuclear Power Plants: Commissioning and Operations [19], and various International Atomic Energy Agency (IAEA) technical documents. This document is intended for organizations involved in the design, mnufacture, construction, modification, maintenance, operation, decommissioning, analysis, verification and testing, provision of technical support, and regulatory oversight of NPPs.

To determine the criteria, several rounds of questionnaires were designed and distributed to respondents involved in the development of TSOs in Indonesia. Seven respondents from the Nuclear Energy Regulatory Agency were tasked with completing the questionnaire for AHP data input. The results from the questionnaires were processed using the AHP method and pairwise comparison to determine the most important criteria for TSO design. The research flowchart is shown in Figure 1.

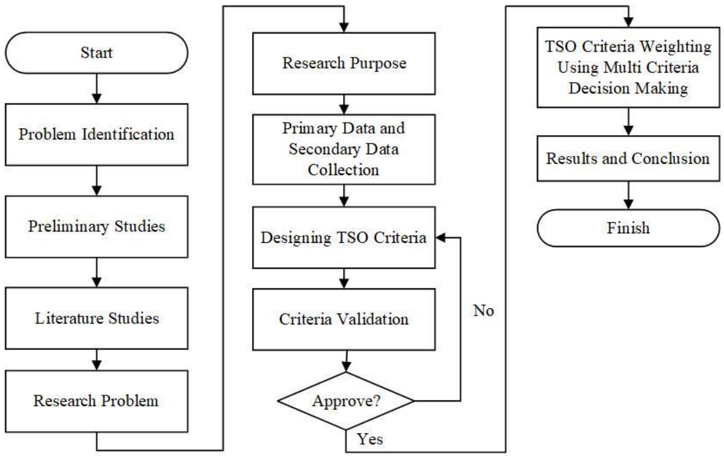

Figure 1. Research Flowchart

3.0 RESULTS AND DISCUSSION

Discussions were held with experts from the Nuclear Energy Regulatory Agency to select the criteria. These criteria were divided into three perspective groups: Safety, Commissioning and Operation, and Human Resource and Management. As a result of these discussions, 10 criteria were selected for each perspective, leading to a total of 30 initial criteria deemed important for designing TSOs in Indonesia. The criteria were assessed by prioritizing their importance, using the following scale: Not Important at All (1), Somewhat Unimportant (2), Quite Important (3), Important (4), and Very Important (5). Furthermore, using the natural cut-off method, criteria with weighting values below the cut-off were eliminated. The mean importance level of the criteria is presented in Table 1.

Table 1. Mean Level for Importance Criteria Table

Perspective	Criteria	Degree of Importance					Total	Mean
		1	2	3	4	5		
Safety [16]	Radiation protection on design	0	0	0	0	7	35	5.00
	Application of defence in depth	0	0	0	1	6	34	4.86
	Provision for construction	0	0	0	1	6	34	4.86
	Features to facilitate radioactive waste management and decommissioning	0	0	0	1	6	34	4.86
	Design basis for items important to safety	0	0	0	0	7	35	5.00
	Internal and external hazard	0	0	0	0	7	35	5.00
	Design basis accident	0	0	0	0	7	35	5.00
	Safety classification	0	0	0	0	7	35	5.00
	Qualification of items important to safety	0	0	0	0	7	35	5.00
	Accident management programme	0	0	0	2	5	33	4.71
Commissioning and Operation [17]	Operational limits and conditions	0	0	0	0	7	35	5.00
	Performance of safety related activities	0	0	0	0	7	35	5.00
	Periodic safety review	0	0	0	2	5	33	4.71
	Equipment qualification	0	0	0	0	7	35	5.00
	Ageing management	0	0	0	0	7	35	5.00
	Consideration of objectives of nuclear security in safety programmes	0	0	0	0	7	35	5.00
	Management of radioactive waste	0	0	0	0	7	35	5.00
	Material condition and housekeeping	0	0	1	1	5	32	4.57
	Chemistry programme	0	0	0	2	5	33	4.71
	Maintenance. testing. surveillance. and inspection	0	0	0	0	7	35	5.00
Human Resource and Management [17]	Management system	0	0	0	0	7	35	5.00
	Structure and functions of the operating organization	0	0	0	1	6	34	4.86
	Staffing of the operating organization	0	0	1	0	6	33	4.71
	Safety policy	0	0	0	0	7	35	5.00
	Qualification and training of personnel	0	0	0	0	7	35	5.00

Table 1. Mean Level for Importance Criteria Table

Perspective	Criteria	Degree of Importance					Total	Mean
		1	2	3	4	5		
	Monitoring and review of safety performance	0	0	0	1	6	34	4.86
	Management of modifications	0	0	1	1	5	32	4.57
	Programme for long term operation	0	0	0	1	6	34	4.86
	Feedback of operating experience	0	0	0	2	5	33	4.71
	Outage Management	0	0	1	1	5	32	4.57

$$\text{Cut-off Point} = \frac{(\text{Maximum Mean Value} + \text{Minimum Mean Value})}{2} = \frac{(5.00 + 4.57)}{2} = 4.786 \tag{1}$$

For the criterion whose value that above the cut-off value will be selected as a criterion in the next round research questionnaire. The selected criteria can be seen in Table 2.

Table 2. TSO Selected Criteria for Providing Support in Indonesia

Perspective	Safety	Commissioning and Operation	Human Resource and Management
Criteria	Radiation protection on design	Operational limits and conditions	Management system
	Application of defence in depth	Performance of safety related activities	Structure and functions of the operating organization
	Provision for construction	Equipment qualification	Safety policy
	Features to facilitate radioactive waste management and decommissioning	Ageing management	Qualification and training of personnel
	Design basis for items important to safety	Consideration of objectives of nuclear security in safety programmes	Monitoring and review of safety performance
	Internal and external hazard	Management of radioactive waste	Programme for long term operation
	Design basis accident	Maintenance, testing, surveillance, and inspection	
	Safety classification		
	Qualification of items important to safety		

The AHP has clear requirements that affect both the hierarchy and the priorities within the structure [20]. AHP hierarchical structure is shown in Figure 2.

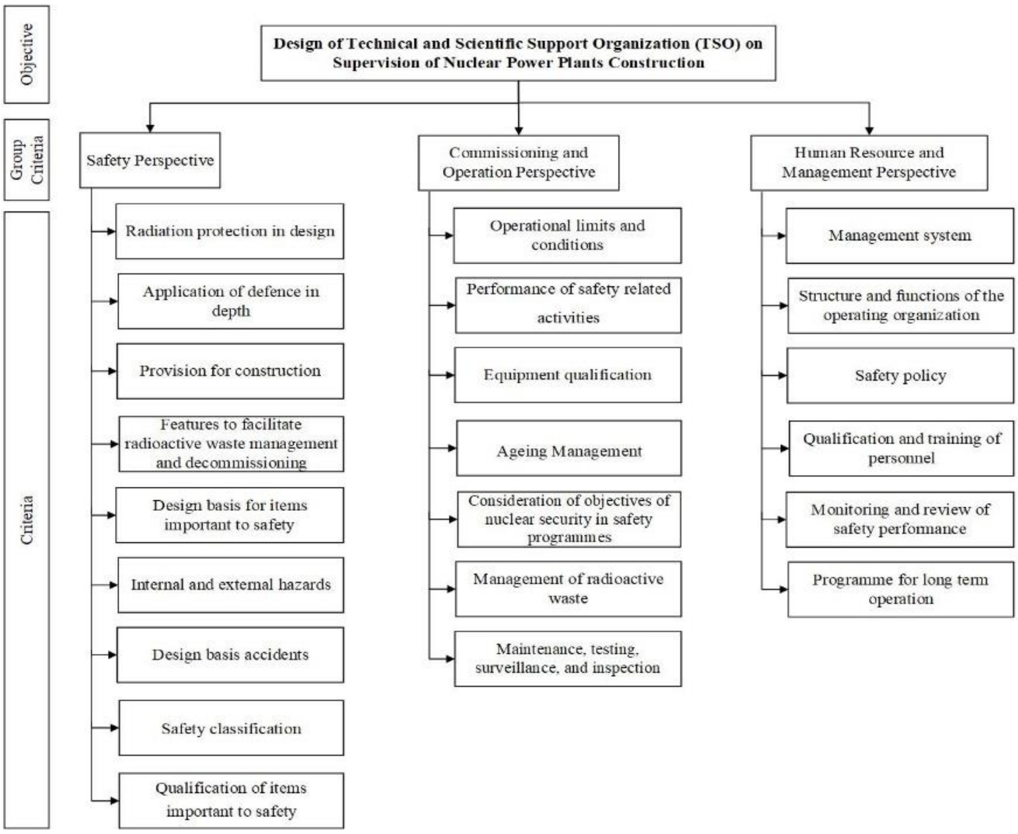

Figure 2. AHP Hierarchical Structure

The weighting process aims to determine the relative importance of each criterion. A higher weight value indicates a greater level of importance. Criteria weighting, conducted using pairwise comparison, is considered consistent if the Consistency Ratio (CR) value is less than 0.1 [21]. Pairwise comparison data from respondents were processed using the Expert Choice software, which performs mathematical calculations to assign relative weights to the criteria based on the respondents' input. Expert Choice, developed by Thomas Saaty and Ernest Forman in 1983 and provided by Expert Choice Inc., facilitates accurate and systematic evaluation of criteria [22]. The weighting results for each perspective and criterion are presented in Table 3.

Table 3. Criteria Weight

Perspective	Weight	Criteria	Criteria Weight
Safety	0.604	Radiation protection on design	0.113
		Application of defence in depth	0.221
		Provision for construction	0.060
		Features to facilitate radioactive waste management and decommissioning	0.065
		Design basis for items important to safety	0.130
		Internal and external hazard	0.079
		Design basis accident	0.149
		Safety classification	0.098
		Qualification of items important to safety	0.085
Commissioning and Operation	0.210	Operational limits and conditions	0.316
		Performance of safety related activities	0.158
		Equipment qualification	0.114
		Ageing management	0.094
		Consideration of objectives of nuclear security in safety programmes	0.106

Table 3. Criteria Weight

Perspective	Weight	Criteria	Criteria Weight
Human Resource and Management	0.186	Management of radioactive waste	0.092
		Maintenance, testing, surveillance, and inspection	0.121
		Management system	0.162
		Structure and functions of the operating organization	0.136
		Safety policy	0.267
		Qualification and training of personnel	0.160
		Monitoring and review of safety performance	0.166
		Programme for long term operation	0.199

Based on the weighting results, scores were obtained for each perspective and criterion. In the context of NPP supervision, the most critical perspective is safety. The safety perspective focuses on preventing unintended conditions or events that could cause the release of radioactive material during commissioning activities in NPPs. It primarily addresses essential risks and hazards. The criterion with the highest weight is the application of defense in depth. A key element of defense in depth is a plant design that ensures the effective performance of safety functions under normal, abnormal, and accident conditions (IAEA, 1996). Defense in depth is designed to compensate for unavoidable potential human and mechanical failures. It ensures that facilities are designed, manufactured, constructed, and operated to be safe not only during normal operations but also capable of effectively managing a wide range of potential incidents. Advanced safety systems and devices are incorporated to mitigate risks from human error, equipment failure, and malfunctions, as well as natural phenomena such as earthquakes, tornadoes, and floods. On the other hand, the criterion with the lowest weight, according to experts, is provision for construction. Provisions for construction and operation must consider relevant experience gained from the construction of other similar installations and their associated structures, systems, and components. When adopting best practices from related industries, it is essential to demonstrate that these practices are suitable and specifically applicable to nuclear contexts.

4.0 CONCLUSION

Based on the main findings and literature studies, the TSO model was designed to monitor the development of NPPs. This design incorporates an in-depth review of all selected criteria from the referenced sources. The study identified that regulatory bodies providing support are inseparable from three critical perspectives: Safety, Commissioning and Operation, and Human Resource and Management. TSOs, in their role of supervising NPPs, must prioritize the safety perspective. Nuclear safety must adhere to the highest standards to protect workers, the public, and the environment from harmful ionizing radiation potentially released by NPPs and other nuclear installations. This article aims to contribute to the body of knowledge on developing support systems for NPP supervision. While it may not be feasible to apply all the identified requirements to NPPs that are already operational or under construction, this study serves as an initial step in identifying key criteria for effective support in NPP supervision. However, caution is necessary, as modifying approved designs may not always be practical. Future research could explore additional perspectives and criteria to enhance NPP supervision further. It could also contribute to a deeper understanding to support decision-making processes and implement protective actions that ensure public and environmental safety.

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