

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

Eileen Onggaria^{1,3}, Novandra Rhezza Pratama^{1,4} and Djoko Hari Nugroho^{2,5}

¹Department of Industrial Engineering, Universitas Indonesia, Depok 16424, Indonesia

²Nuclear Energy Regulatory Agency, Jakarta 11120, Indonesia

³eileen.onggaria@ui.ac.id, ⁴novandra@ui.ac.id, ⁵d.harinugroho@bapeten.go.id

Abstract. Electricity is one of the basic needs that must be maintained continuously. Nuclear energy as a source of new and renewable energy is one of the electricity producers with a huge potential in Indonesia. Based on The Government Regulation No. 79/2014 (PP 79/2014) on National Energy Policy states that plans for the construction of Nuclear Power Plant (NPP) in Indonesia will begin after 2025. Technical and Scientific Support Organization (TSO) is needed to provide supervision in the construction of NPPs (International Atomic Energy Agency 2018). TSO is an organizational unit, a department or an institute, that supports regulatory functions. Its expertise and activities focus mainly on nuclear and radiation safety, and provides technical and scientific support. This paper proposes important criteria based on applicable regulations for TSO in conducting supervision using Analytical Hierarchy Process (AHP), which is divided into three perspectives: Safety, Commissioning and Operation, and Human Resource and Management, with weights of each perspective 0.604, 0.210, and 0.186. This research produces a technical rating in determining the basic importance criteria that must be possessed by TSOs, with safety as the most important perspective that must be satisfied to ensure the safe commissioning and operation of NPPs and its facilities.

Keywords: Nuclear Power Plant, Technical Scientific and Support Organization, Energy, Safety, Regulatory Body

30. Introduction

Electricity has become a basic human need and a part of human life. Almost all human activities are supported by electricity, starting from house chores, the industrial sector, offices, transportation, government agencies, and all other activities. According to [1], Indonesia still has a high dependence on electricity production from coal-fired power plants. Coal is a non-renewable energy resource that can be used up if exploited continuously. In terms of electricity production, the coal-fired power plant contributes the most percentage of the electricity needs in Indonesia. According to Ministry of Energy and Mineral Resources Republic of Indonesia, data on the plan for coal demand in 2022 is 188.9 million tons. In 2023 the demand is forecasted to 195.9 million tons, in 2024 is 209.9 million tons, and in 2025 is 197.9 million tons. Meanwhile, coal demand from the electricity sector is expected to increase to 119 million tons in 2022, some 126 million tons in 2023, and around 140 million tons in 2024 before falling to 128 million tons in 2025 [2]. On the other hand, Indonesia's coal reserves are expected to be exhausted around 2040, mainly because there is no new exploration. In 2021, coal resources total 113 billion tons, with proven reserves reaching 33 billion tons. With conditions of exploitation and production of 500

million tons per year, the depletion of coal reserves will be even faster. In the last 10 years, there has been a decrease in the discovery of new coal mining areas. Some of the reasons are the coal mining process has a high risk, requires a large investment, and takes a long time to return the investment. Besides, on the environmental side, coal emits more carbon dioxide (CO₂), 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 The Government Regulation No. 79 of 2014 (PP 79/2014), one of the main policies of the National Energy Policy regarding the availability of energy for national needs that can be met by increasing exploration of resources, potential and/or proven reserves of energy, both from fossil types and new energy and renewable energy [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 an environmentally friendly energy because it is free of greenhouse gas emissions, has a relatively small footprint, does not disturb the balance of the ecosystem, and its waste is managed and controlled according to clear regulations. Based on The Government Regulation No. 79 of 2014 (PP 79/2014) on National Energy Policy states that plans for the construction of NPPs in Indonesia will begin after 2025 [5]. NPP will be built in order to fulfill the electricity needs in Indonesia. NPP has a large power generation capacity and functions as a driver of regional growth and development. The construction of the NPP is expected to be able to meet national energy demand and reduce greenhouse gas emissions. The primary goals to be achieved in preparing for the construction of the NPP, is to maintenance competence and to acquire nuclear safety knowledge that would comply with advanced international practice [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 community 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 otherwise recognized by a regulatory body and/or a government, to provide expertise and services to support nuclear and radiation safety and all related scientific and technical issues, to the regulatory body”* [9]. As an organizational unit, TSO can be internal or external. TSOs provide basis regulations and measures to protect people and the environment from radiation risks, also to ensure the safety of installations and activities that lead to radiation risks, especially nuclear facilities [10]. TSO will assist regulators in evaluating applications for commissioning permits and operating permits for NPP construction. Licensing for Nuclear Installation and Utilization of Nuclear Materials is contained in 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 (BAPETEN) 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 BAPETEN is responsible for issuing regulations for the construction of NPPs in Indonesia based on the TSO [13]. Thus, it is necessary to identify the criteria for the NPP supervision.

High levels of security are the result of a complex interplay of good design, operational reliability, and human effort [14]. An effective independent regulatory body should be developed to fulfil all approval and control duties. The country should implement comprehensive national legislation that addresses all aspects of nuclear safety, nuclear security, safeguards and civil liability for nuclear damage. Competent regulatory bodies base their decisions on independent safety assessments developed internally or by the external TSO [15]. The regulatory body should define siting requirements. Approval criteria for NPP concepts should be defined and a licensing process should be established [8]. The development of TSO is a particular challenge for a new country starting nuclear power plant development. Three main obstacles that generally occur are time scale, scarcity of 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 needs to be technically relevant and sustainable over a time scale of several decades. 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]. In Indonesia itself, there are currently no solutions or models for the TSO function, only experience-based guidelines [9]. National TSO capacity is a powerful tool for consolidating the medium and long-term effectiveness of regulatory control [16].

Identification and evaluation of criteria of TSO for providing support in NPP has not been extensively researched in Indonesia. A good decision can be applied when decision makers know and define: the problem, the objective of the decision, the criteria and sub-criteria for evaluating the alternatives, the alternative actions to be taken, also stakeholders and groups involved [17]. In this study, complex multi-criteria problems are solved using AHP in hierarchies. A hierarchy can be defined as representation of a complex problem in a multi-level structure. The first level in a hierarchy started as the goal, then followed by factor levels, criteria, sub-criteria, and so on, down to the last level of alternatives. Therefore, the main purpose of this research is to identify the TSO criteria for supervising nuclear power plants. This research will discuss the TSO criteria, where the results of this research will produce a technical rating which is then used to determine the basic criteria that must be possessed by TSOs in carrying out supervision based on applicable regulations.

31. Methods

Currently there are not many studies related to TSO criteria in the supervision of NPPs in Indonesia. This study will identify the criteria for TSO in the supervision of NPP. The basis used in identifying the criteria are the Specific Safety Requirements No. SSR-2/1 (Rev. 1) on Safety of Nuclear Power Plants: Design [18] Special Safety Requirements No. SSR-2/2 (Rev. 1) on Safety of Nuclear Power Plants: Commissioning and Operations [19], and International Atomic Energy Agency Technical Documents. This document is intended for organizations involved in the design, manufacture, construction, modification, maintenance, operation, and decommissioning of NPP, in the analysis, verification and review, and in the provision of technical support, and regulatory authorities of NPPs. In determining the criteria, multiple rounds of questionnaire were designed and filled out by respondents who were involved in designing TSOs in Indonesia. Seven respondents from Nuclear Energy Regulatory Agency in charge of filling the questionnaire for the AHP data input. Furthermore, the results of the questionnaire were processed using the AHP method and pairwise comparison, to determine the important criteria in designing TSO. Research flowchart is shown at Figure 1.

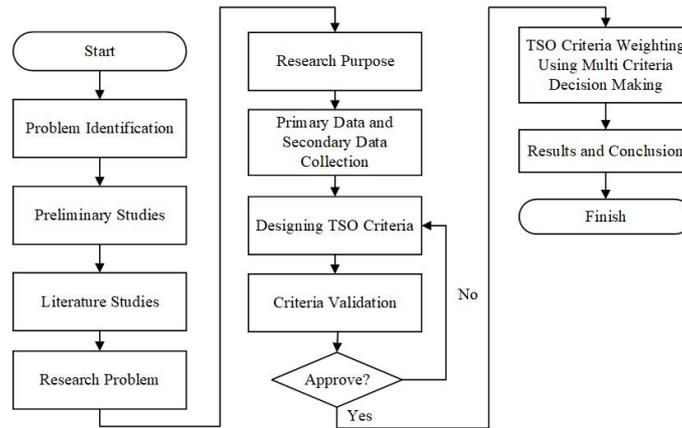


Figure 1. Research flowchart

32. Result and Discussion

In selecting the criteria, discussions were held with experts from the Nuclear Energy Regulatory Agency. These criteria are divided into three perspective groups, namely: Safety, Commissioning and Operation, and Human Resource and Management. The result of the discussion is the selection of 10 criteria for each perspective, with a total of 30 initial criteria that are considered important for designing TSOs in Indonesia. Criteria are determined by prioritizing interests with the following assessments: Not Important at All (1), Somewhat Unimportant (2), Quite Important (3), Important (4), and Very Important (5). Furthermore, by using natural cut-off method, the weighting value of the criteria below the cut-off will be eliminated. The mean level for importance criteria is shown in Table 1.

Table 1. Mean Level for Importance Criteria

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

Table 1. Mean Level for Importance Criteria

Perspective	Criteria	Degree of Importance					Total	Mean
		1	2	3	4	5		
Human Resource and Management [17]	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
	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
	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

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

$$= \frac{(5.00 + 4.57)}{2}$$

$$= 4.786$$

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	Monitoring and review of safety performance

	security in safety programmes	
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.

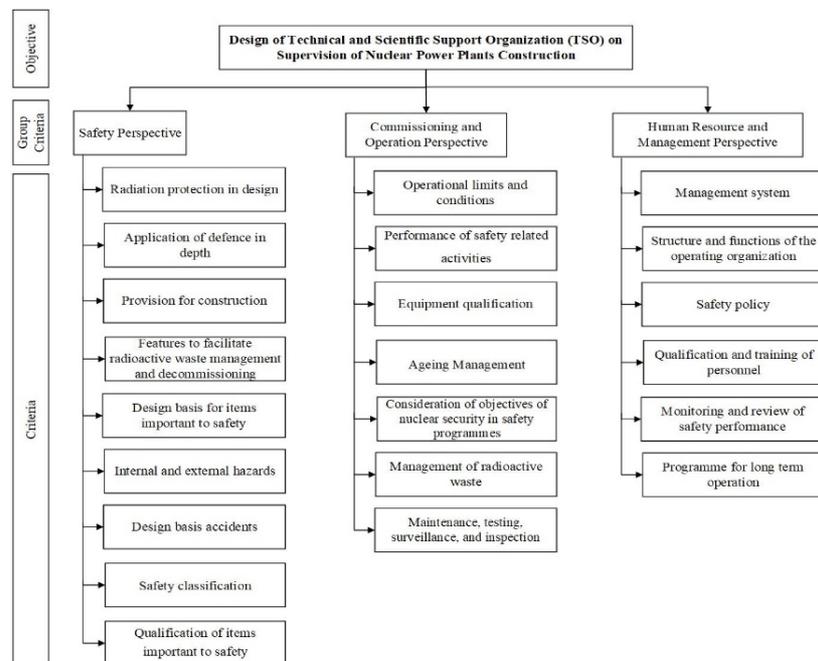


Figure 2. AHP Hierarchical Structure

Weighting aims to determine the level of importance of each criterion. The higher the weight value, the more important the criterion is. Criteria weighting by using pairwise comparison is considered consistent if the value of the Consistency Ratio (CR) < 0.1 [21]. By using Expert Choice software, the pairwise comparisons of each respondent were recorded, then data processing was carried out based on the results of the answers from all respondents. Expert Choice performs mathematical calculations on the data and assigns relative weights to the criteria. Expert Choice was designed by Thomas Saaty and Ernest Forman in 1983, provided by Expert Choice Inc [22]. The weighting results of each perspective and criteria can be seen 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
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		
Management of radioactive waste	0.092		
Maintenance, testing, surveillance, and inspection	0.121		
Management system	0.162		
Human Resource and Management	0.186	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 are obtained from each perspective and criteria. In carrying out NPP supervision, the most important perspective is safety. Safety perspective focuses on unintended conditions or events that cause radioactive material to be released from commissioning activities in NPPs. It is mainly concerned with essential problems and dangers. The criterion with the highest weight is application of defence in depth. A key element of defence in depth is a plant

design that supports an efficient way to perform safety functions under normal and abnormal operating conditions and in accidents (IAEA 1996). Defence in depth is applied and designed to compensate for unavoidable potential human and mechanical failures. Defence in depth ensures that facilities are designed, manufactured, constructed, and operated so that they are not only safe during normal operations, but also capable of safely dealing with a wide variety of potential incidents. Advanced safety systems and devices are installed to protect against human error, equipment failure and malfunction, taking into account natural phenomena such as earthquakes, tornadoes, and floods. Meanwhile, the criterion with lowest weight according to expert is provision for construction. Provisions for construction and operation shall take into account relevant experience obtained in the construction of other installations and their associated structures, systems, and components. Adopting best practices from other related industries is important, as it is necessary to demonstrate that the practices are suitable for specific nuclear applications.

33. Conclusion

From on main findings and literature studies, the TSO model was designed to monitor the development of NPP. This design took into account an in-depth review of all selected criteria from the source mentioned. We found that regulatory bodies in providing support inseparable from three important perspectives: Safety, Commissioning and Operation, and Human Resource and Management. TSO in carrying out NPP supervision must prioritize the safety perspective. Where, nuclear safety must be assured to the maximum levels of safety that can be achieved, to protect the workers, the public and the environment from harmful effects of ionizing radiation that can be released from NPPs and other nuclear installations. This article is expected to add references related to the development in providing support for NPP supervision. Although it might not be feasible to apply all requirements to NPP that are already in operation or under construction. The current study can be interpreted as a first step in the research on basic important criteria for providing support in NPPs. However, this study should be treated with discretion as it may not be possible to modify a design that has already been authorized by regulatory body. Future research could further examine more perspectives and criteria related in conducting NPPs supervision. It could also contribute to a deeper understanding to support decision making on protective actions to ensure public and environment safety.

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