Mapping Construction Schedule and Critical Paths in Reactor Design for Nuclear Plant Risk Evaluation

Preliminary Study for Nuclear Power Plant Construction Risk Evaluation: Construction Schedule Mapping and Critical Path Analysis

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1. Introduction

The Indonesian government has set a plan to build the first Nuclear Power Plant (NPP) in 2032 [1]. As a technology importer and a newcomer in the implementation of NPPs, Indonesia faces serious challenges, especially related to the long construction duration and cost overruns due to delays. This is exacerbated by the lack of experience and capability in providing adequate resources for such projects [2].

This study aims to map construction schedule data for nuclear power plant projects using information extracted from the paper 'Impact of modularization and site staffing on construction schedule of small and large water reactors' by Stewart et al. and to analyze the critical paths of three reactor designs, namely PWR12, Westinghouse AP1000, and Nuscale, using the Primavera 6 scheduling application. The study provides a quantitative basis for identifying potential delay risks and structural complexities in nuclear power plant construction by comparing the number and composition of critical activities across these designs. These findings will serve as the foundation for further risk analysis—including Monte Carlo simulations—and support decision-making in selecting reactor designs that best align with Indonesia's construction conditions, ultimately contributing to the national energy transition.

2. Methods

Although still in its early stages, this research focuses on data mapping to support risk analysis in nuclear power plant projects. The initial approach involves mapping construction schedule data extracted from the paper "Impact of modularization and site staffing on construction schedule of small and large water reactors" by Stewart et al. Unlike previous studies that solely estimated the duration of various reactor designs, this study employs the data to construct detailed construction schedules in Primavera and analyze the critical path for three reactor designs (PWR12, Westinghouse AP1000, and Nuscale). This approach provides a more in-depth evaluation of the potential risk of delays in construction, with the evaluation results serving as a basis for determining the risk factors to be considered in further research.

2.1 Construction Schedule Data Mapping

The data used are taken from the paper "Impact of modularization and site staffing on construction schedule of small and large water reactors" by Stewart et al., which includes 226 construction activities. Each activity is equipped with information on the duration of the work, predecessors, and Fraction Required Complete. For example, if the activity "yardwork" has a duration of 240 days with a Fraction Required Complete of 0.5, then the activity "field painting" can be started after the "yardwork" has been running for 120 days. The data has been mapped into the Primavera 6 scheduling application, which produces a Gantt diagram depicting the relationship between activities and critical path information from the project schedule.

2.2 Critical Path Analysis and Risk Determination

From the mapping in Primavera 6, an analysis was conducted to identify the critical path, which is the longest path that reflects the sequence of the most crucial activities in the construction of a nuclear power plant. This critical path will be used as a basis for determining activities that are vulnerable to risk. The next stage, which is still in progress, involves identifying risks through a literature study using the PRISMA method, considering indicators such as regulations, environmental conditions, and supply chains that are relevant to Indonesia's risk profile. These adapted risks will later be used in further risk analysis using the Primavera Risk Analysis application and Monte Carlo simulation to measure their impact on project duration.

3. Result and Discussion

Construction schedule mapping was performed on the Primavera 6 application for three reactor designs, namely Pressurized Water Reactor 12 (PWR12), Westinghouse AP1000, and NuScale. In the calendar setting, a 5-day work week system with 8 working hours per day was used. The results of this mapping produced a critical path for each design, which is described as follows:

3.1 PWR12

The following is a series of construction activities included in the critical path of the PWR12 design:

Table I: Critical Path of PWR12 Design

Account	Activity Description
211. Site Preparation	
A.211	Yardwork
212. Reactor Containment Building	
A.212.13	Substructure
A.212.141	Superstructure concrete
A.212.15	Containment liner
A.212.3	Shield building
A.219.	Passive cooling pool
215. Primary Auxiliary Building and Tunnels	
A.215.13	Substructure
A.215.141	Superstructure concrete
A.215.21	Plumbing & Drains
221. Reactor Equipment	
A.221.1	RPV Structure + Support
A.221.3	RPV Internals
222. Main Heat Transfer and Transport System	
A.222.13	Steam generators
223. Safeguard System	
A.223.1	Residual heat removal
A.223.4	Containment spray
A.223.5	Combustible gas control
229. Reactor Plant Equipment	
A.229.1	Containment vacuum pump
A.229.2	Containment flooding & drain
A.229.3	Reactor Cavity Cooling System
A.229.4	Refueling Equipment
A.229.5	He Purification Equipment
A.229.6	He Circulator
252. Air, Water, Steam Service System	
A.252.1	Air system
A.252.4	Plant fuel oil system

In the PWR12 design, the activity in the Reactor Plant Equipment account is the segment with the longest duration, making it a critical point in the construction schedule.

3.2 Westinghouse AP1000

The following is a series of construction activities included in the critical path of the Westinghouse AP1000 design:

Table II: Critical Path of Westinghouse AP1000 Design

Account	Activity Description
211. Site Preparation	
A.211	Yardwork
218J. Main Steam and Feedwater Pipe Enclosure	
A.218J.13	Substructure
A.218J.141	Superstructure concrete
A.218J.146	Interior walls
A.218J.147	Doors/Windows
A.218J.149	Painting
A.218J.21	Plumbing and Drains
A.218J.24	Lighting and Service Power

In the Westinghouse AP1000 design, the activity in the Main Steam and Feedwater Pipe Enclosure account has the longest duration, making it a critical component in the overall schedule.

3.3 NuScale

The following is a series of construction activities included in the NuScale design critical path:

Table III: Critical Path of NuScale Design

Account	Activity Description
211. Site Preparation	
A.211	Yardwork
212. Reactor Containment Building	
A.212.13	Substructure
A.212.141	Superstructure concrete
A.212.15	Containment liner
A.212.3	Shield building
215. Primary Auxiliary Building and Tunnels	
A.215.149	Painting
A.215.227	Safety HVAC-Piping and Misc. items
218E. Emergency Feed Pump Building	
A.218E.143	Exterior walls
218J. Main Steam and Feedwater Pipe Enclosure	
A.218J.13	Substructure
A.218J.141	Superstructure concrete
A.218J.145	Roofing
A.218J.146	Interior walls
A.218J.147	Doors/windows
A.218J.149	Painting
218T. Ultimate Heat Sink Structure	
A.218T.145	Roofing
221. Reactor Equipment	
A.221.1	RPV Structure + Support
222. Main Heat Transfer and Transport System	
A.222.12	Primary system piping
A.222.13	Steam generators
A.222.14	Pressurizer
223. Safeguard System	
A.223.4	Containment spray
A.223.5	Combustible gas control
228. Reactor Plant Miscellaneous Items	
A.228.4	Reactor Plant Insulation
229. Reactor Plant Equipment	
A.229.1	Containment vacuum pump
A.229.2	Containment flooding & drain

In the NuScale design, the activity on the Main Steam and Feedwater Pipe Enclosure account again shows the longest duration, making it the main element in the critical path.

3.4 Implications for Risk Analysis

Based on the results of mapping and critical path analysis, there are significant differences in the composition of the critical path between the three reactor designs. For the PWR12 design, the activity in the Reactor Plant Equipment account is the longest segment, while in the Westinghouse AP1000 and Nuscale designs, the Main Steam and Feedwater Pipe Enclosure accounts dominate as critical paths. This finding indicates that these segments are vulnerable points that have the potential to cause significant delays if a disruption occurs. In addition, the results of mapping schedules in Primavera P6 provide several findings, including:

1. Nuscale designs that have the highest number of activities on the critical path indicate higher structural complexity or more critical points to control, thus potentially increasing the risk of delays.
2. The PWR12 design with a moderate amount of activity may indicate a complex structure but is more focused on certain critical segments.
3. The Westinghouse AP1000 design, having the fewest activities on the critical path, indicates a simpler or more integrated approach, potentially reducing the risks associated with delays.

4. Conclusions

This study has successfully mapped the construction schedule on the Primavera 6 application for three reactor designs, namely PWR12, Westinghouse AP1000, and NuScale, using a calendar setting of 5 working days per week and 8 working hours per day. From the mapping results, a critical path was obtained for each design, which showed significant differences in the number and composition of critical activities.

In the PWR12 design, the segment in the Reactor Plant Equipment account is the critical point with the longest duration, while in the Westinghouse AP1000, the critical path is dominated by activities in the Main Steam and Feedwater Pipe Enclosure accounts. The NuScale design shows the largest number of activities in the critical path, indicating higher structural complexity and greater potential risk of delays. These findings provide a quantitative basis for determining critical areas in NPP construction projects and become the foundation for further risk analysis development.

Although this research is still in its early stages, the results obtained have provided a clear picture of the sequence of critical activities in each reactor design. These findings are expected to support the risk identification and mitigation process in the next research stage, so that it can later help decision making in selecting the reactor design that best suits construction conditions in Indonesia.

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