Causes & mitigation strategies of NPP construction schedule delay: Gap analysis between domestic and international project

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1. Introduction

Recently, nuclear power capacity worldwide is increasing steadily with 52 reactors under construction due to economic efficiency, reliability and closeness to nature, without carbon dioxide emissions over full life cycle as a base load source of electricity. Seventeen countries are currently building nuclear power plants, and 52 reactors were under construction as of 1 July 2020. However, all reactors under construction in at least 10 of the 17 countries have experienced mostly year-long delays. At least 33 (64 percent) of all building projects are delayed [1]. The schedule delay led to many undesirable effects on the project and its stakeholders such as lawsuits between parties, increased costs, loss of revenue, construction termination, and reputational damage [2]. The scope of this research is to identify and compare the delay factors and the effective mitigation strategies between a domestic and an international project.

2. Background

2.1 Definition of construction delay

Construction delay can be defined as the time over-run either beyond the completion date specified in a contract or beyond the date that the parties agree upon for delivery of a project [2].To the owner, delay means loss of revenue through lack of production facilities and rentable space or dependence on present facilities, while to the contractor, delay means higher overhead costs due to longer work period, higher material costs through inflation, and labor cost increases [3].

2.2 Causes of construction delay

Hossen et al. examined nuclear power plant construction schedule delay for turnkey international project and identified 4 main delay factors, 12-sub-factors and 32 sub-sub factors. The first level, the main contractor contributes the highest risk, followed by utility, regulatory authority, and financial and country factor, the top 5 most important sub-sub-factors, which are as follows: policy change, political instability and public intervention, uncompromising regulatory criteria and licensing documents conflicting with existing regulations, robust design document review procedure, redesign due to error in design and design changes [2].

Murali study identified 10 most important causes of delay in Malaysian construction industry: (1) contractor's improper planning, (2) contractor's poor site management, (3) inadequate contractor experience, (4) inadequate client's finance and payments for completed work, (5) problems with subcontractors, (6) shortage in material, (7) labor supply, (8) equipment availability and failure, (9) lack of communication between parties, and (10) mistakes during the construction stage [4].

2.3 Mitigation strategies

Edwin et al. identified the major delay mitigation strategies between successful project and unsuccessful project. In the successful project, close project supervision, conducting capacity building training, proper logistics management, top management's support, uses of suitable time estimation skills were ranked in descending order, while in the unsuccessful project, timely payments of completion certificate, proper planning of project financial arrangements, conducting capacity building training, proper presentation of information during tendering, timely procurement and supply of materials and equipment were ranked in descending order [5].

Assaf et al. examined causes of delay in large construction projects in Saudi Arabia and recommended some strategies to be carefully controlled: for owners, pay progress payment to the contactor on time, minimize change orders during construction, avoid delay in reviewing and approving of design document, check for resources and capabilities before awarding the contract to the lowest bidder, for contractors, control of labor shortage and productivity, proper management of financial resources and cash flow, accurate planning and scheduling, site management and supervision [3].

3. Methodology

3.1 Questionnaire design

Data were gathered through a questionnaire, which consists of 3 parts. Part I is for general information of respondents. Part II is related to identifying delay causes derived from literature review and discussion with experts. Part III includes mitigation strategies for each delay factor mentioned in part II to mitigate the delay and minimize the undesirable effects.

For identifying impact on delay factors and the effectiveness of mitigation strategies, 5 Likert scale was adopted.

3.2 Delphi method

Delphi method was carried out by conducting questionnaire surveys among 23 respondents who have NPP construction experiences, answers were made based on the intensity of the contribution to the delay factors and the effectiveness of mitigation strategies.

Table 1. Important delay factors in NPP project.

Main Cause	Domestic		International		gaps	
	Mean	Rank	Mean	Rank	Differ.	Rank
Inadequate completion of design and frequent design change	4.13	1	4.17	1	0.04	10
Changes in policy & enhanced requirements and a delay in approval from regulatory body	3.94	2	3.94	2	0.00	11
Slow procurement, manufacturing of equipment and delivery to the site for installation	3.31	4	3.67	3	0.36	3
Difficulty in managing subcontractor chain	2.69	9	3.06	7	0.37	2
Quality issues related to manufacturing and construction	2.81	7	2.94	9	0.13	8
Shortage of manpower and insufficient number of staff	3.13	6	3.33	4	0.20	6
Corruption and collusion in nuclear supply chain	1.94	11	1.94	12	0.00	11
Poor contract management and project management	2.44	10	2.67	11	0.23	5
Delay in approval of design documents	3.44	3	3.28	6	0.16	7
Lack of communication and interface control among parties	2.75	8	3.00	8	0.25	4
Lack of skilled and experienced labors : Low productivity under poor environment	3.25	5	3.33	4	0.08	9
Different weather and language barrier and culture gap	1.69	12	2.94	9	1.25	1

Table 2. Mitigation strategies of inadequate completion of design and frequent design change.

Mitigation Strategy	Domestic		International		gaps	
	Mean	Rank	Mean	Rank	Differ.	Rank
Thoroughly review the design by experienced designer	3.56	4	3.67	2	0.11	4
Control design interface among parties	3.50	5	3.44	5	0.06	5
Reflect lessons learned from previous project	4.00	2	4.06	1	0.06	5
Improve communication and coordination among relevant departments	3.44	6	3.56	4	0.12	3
Define clear scope and responsibility management of design change	4.13	1	3.61	3	0.52	1
Ensure participation of manufacturer and construction expert in initial stage of design	3.63	3	3.33	6	0.30	2

Table 3. Mitigation strategies of changes in policy & enhanced requirements and a delay in approval from regulatory body.

Mitigation Strategy	Domestic		International		gaps	
	Mean	Rank	Mean	Rank	Differ.	Rank
Regularly check changes in government regulation/laws and act	3.44	5	3.50	5	0.06	4
Prior consultation with regulatory body to reach a consensus	3.25	6	3.78	2	0.53	1
Make a good relationship with regulatory body	3.63	2	3.39	6	0.24	2
Submit documents as soon as possible for approval	3.50	4	3.67	3	0.17	3
Rapidly respond to regulatory body's comment	3.88	1	3.89	1	0.01	5
Prepare for collapse of nuclear supply chain	3.56	3	3.55	4	0.01	5

4. Results & Discussion

Table 1 shows the ranking of the delay factors through the survey. In the domestic project, inadequate completion of design and frequent design change was ranked as the first followed by changes in policy & enhanced requirements and a delay in approval from regulatory body, and delay in approval of design documents. In the international project, the highest-rated is inadequate completion of design and frequent design change followed by changes in policy & enhanced requirements and a delay in approval from regulatory body, and slow procurement & manufacturing of equipment and delivery to the site for installation. There's no significant difference in terms of delay factors between the domestic and the international project.

Table 2 shows the mitigation strategies of inadequate completion of design and frequent design change. In the domestic project, define clear scope and responsibility management of design change (1st Rank), reflect lessons learned from previous project (2nd Rank), ensure participation of manufacturer and construction expert in initial stage of design (3rd rank). On the other hand, in the international project, reflect lessons learned from previous project (1st Rank), thoroughly review the design by experienced designer (2nd Rank), define clear scope and responsibility management of design change (3rd Rank). No matter how well a project is managed, design change are considered to be inevitable in the construction, however, if the responsibility for the design change is unclear, people who involved in design change tend to procrastinate it before the responsibility is clear. It also leads to arguments, schedule delay as well as cost overrun, that's why clear scope and responsibility management is prioritized as the most important mitigation strategies in the domestic project.

Table 3 shows the mitigation strategies of changes in policy & enhanced requirements and a delay in approval from regulatory body. In the domestic project, rapidly respond to regulatory body's comment (1st Rank), make a good relationship with regulatory body (2nd Rank), prepare for collapse of nuclear supply chain (3rd Rank), while in the international project, rapidly respond to regulatory body's comment (1st Rank), prior consultation with regulatory body to reach a consensus (2nd Rank), submit documents as soon as possible for approval (3rd Rank). The Shin-Hanul unit 1 has recently received an operating license from the regulatory body and it took 15 months after the completion of construction due to strengthened safety issues by regulator. To minimize the impact on construction schedule, the effective mitigation strategies derived from this study should be taken.

5. Conclusion

This study found that both projects have similarities and differences in terms of delay causes and mitigation strategies. The following delay causes were identified in common with both projects: inadequate completion of design and frequent design change, changes in policy & enhanced requirements and a delay in approval from regulatory body and slow procurement & manufacturing of equipment and delivery to the site for installation. To mitigate the identified delay factors, following mitigation strategies were evaluated as the most important in common with both projects: contract with qualified and experienced subcontractor, reflect lessons learned from previous project, clearly define scope and responsibilities, use of skilled and experienced labors on similar project, and accurate and prompt decision. These findings will help project managers to understand different risks between the domestic and the internal project. The risk factors identified in this study need to be closely monitored and controlled with appropriate mitigation ways to avoid or reduce the schedule delay.

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