EXECUTIVE SUMMARY

Projects are being executed in power and infrastructure sectors worldwide in contract mode involving specialized & professional agencies. Execution of projects is inherently complex and dynamic, involving multiple agencies along with multiple feedback process and nonlinear relationships. The problems encountered during the execution right from project planning to commission of the projects are dynamic. As a result, schedule delays and cost overruns are occurred in completion of projects even use of advanced techniques in design, construction and management areas. Day to day sharp incremental demand of power is forcing the power sector to reduce the project construction time. Project delay is directly related to the cost. Delay from target schedule causes rise in target cost. The project schedule delay is identified as key element in project execution strategies/ models.

Government of India has not opened the nuclear sector projects/plants to private firms fully. Participation of the other public sectors and private sectors are limited. Projects have been executed by Government of India (GOI) institutions only in past. In present also, the projects are being executed by GOI institutions with limited private/public partnership. GOI has planned to open 15 units out of 55 units to private firm with special conditions in future. GOI is in the process of amendments in respective laws to consider the active participation of private firms. Shortage of energy mix, coal, oil & gas and increase in import price of energy mix are worry for India. GOI is now concentrating on nuclear energy in addition to other non-conventional sectors.

The two research objectives "to analyse the applicability of in-practice project execution models in infrastructure & power sector for Indian nuclear sector projects" and "to develop a project execution model for Indian nuclear sector and validate" are framed to carry out the research.

Three basic contract concepts/philosophies are derived in project execution in commercial point of view. In first concept, the owner calls for a competitive bidding for the development phase of the project. The main scope of the contractor in this stage is to deliver a basic design package. After completing the basic design package, the owner calls for another competitive bidding for the implementation phase which includes Detailed Engineering, Procurement and Construction. In second concept, the owner contacts simultaneously with two contractors for the development phase. Therefore, the owner handles two basic design packages. After completing these packages, the owner calls for a competitive bidding only between the two contractors and the final contract is awarded to one of them. Third one is similar to the first one except that same contractor carries out the two phases. After delivering the basic design package, the owner and contractor negotiate the contracting approach for the implementation phase. Sometimes the two parties do not reach an agreement. In this case, the owner calls for competitive bidding for implementing the project based on the basic design package.

Engineering Procurement & Construction (EPC) and Engineering Procurement Construction Management (EPCM) project execution models are being practiced largely in construction sector.

Engineering Procurement & Construction (EPC) contract strategy is fixed priced lump sum contract. The contractor is responsible for constructing the project according to the design package prepared during the engineering stage and equipment & materials are purchased during the procurement stage. EPC contract is based on the concept of "single point of responsibility". The EPC contractor is responsible for designing the facility, building the structure, buying & installing the equipment, performing all construction & commissioning activities, testing, training to operators and handing over the complete drawings and operations manuals. The EPC contractor is a general contractor who performs the work directly with help of his own staff or indirectly with help of vendors and subcontractors. He is the only single point of responsibility for the project authority. The owner has little authority to intervene during the project execution. In fact, the more the owner intervenes, more likely the contractor claims additional cost and time.

In EPC contract, the allocation of most of the risk is to the contractor. The contractor puts higher contingency to account for these risks, therefore the cost of EPC is usually higher. The EPC contract strategy concentrates the project objective, time and cost only. Since there is no incentive for betterment, he ignores the technical parameters like quality, safety etc.

Engineering Procurement Construction Management (EPCM) contractor is not responsible for constructing the project. EPCM contractor manages the construction which is done by other parties. He acts as the owner representative and creates on behalf of the project authority (owner) a direct contractual relationship between the project authority and construction contractors, subcontractors and suppliers. The project authority is totally responsible for construction. The owner pays the fixed amount to EPCM contractors for his service and make the payment to the trade and construction contractors directly or reimburses the actual though EPCM contractor.

The economists define EPC contract as Firm Fixed Price (FFP) and EPCM as Cost Plus Fixed Fee (CPFF). The hybrid version of EPC (FFP) and EPCM (CPFF) is proposed by researchers known as Cost Plus Incentive Fee (CPIF) contract. The Engineering Contractor (EC) gets a specified contract sum for the entire scope of work. The cost risk is born by the EC. In EPC (FFP), other than agreed cost, there is no financial performance incentive for the EC.
At the other end reimbursable type contracts such as EPCM (CPFF) contracts has the cost risk allocation . In a EPCM (CPFF) contract, the owner reimburses the Engineering Contractor for all purchase orders, sub-contracts and other costs associated with the project scope as actual or agreed upon. The cost risk is totally born by the owner. The owner pays the EC a fixed amount for EPCM services.

Engineering Procurement Construction (EPC) and Engineering Procurement Construction Management (EPCM) modes are in practice worldwide in execution of the projects in infrastructure & power sectors including nuclear sector. These models have been tried in past to execute the projects in Indian nuclear sector but schedule delays and costs overrun has been found. It is also

noticed that these contract strategies/models cannot be directly adopted in Indian nuclear sector because of a number of constraints & limitations. Specialized professionals' expertise is required to manage the nuclear project, especially nuclear components of the project.

It is found from the literature review that EPC and EPCM models are in-practice in construction sector globally. Project Management Information System (MIS) is not well considered in these models. Factors for delays, lack of commitment, inefficient site management, poor site coordination, improper planning, lack of clarity in project scope and lack of communication are identified as most critical factors. These factors are known but no mechanism is developed to address these factors. No project execution model is available for Indian nuclear sector.

The nuclear sector is a specialised technology sector among the infrastructure & energy construction sectors. Limited manpower is working in this sector. Further nuclear projects have limited population in sampling point of view. In order to get the right representation, nuclear sector projects are taken as population. Experienced executives engaged in nuclear projects are the target respondents. The judgmental, a non-probability sampling is found most appropriate for collecting the data. It is assumed that there is an even distribution of characteristics to get more accurate and representative sample. The underlying assumption is "respondents are from nuclear sector executive and have sufficient project execution experience". To counter the biased nature of judgmental sampling, contactors and consultants are also included in the sampling process in addition to project authority.

The population size is about 3500. The sample size of 1000 is targeted as respondents which is 16% of the population. The questionnaires are communicated by post, email and personal delivery to/from project authority, consultants and contractor. Out of 555 valid responses, 225 responses from project owners, 187 from consultant and 143 from contractors are received. This represents 16% of the population and 55% of sample size.

The objective of the study is to identify the relative importance of delay factors and strategic factor in Indian nuclear sector projects. The study is however restricted to Indian nuclear sector projects. Due to non-availability of earlier published/ entrusted document/data of nuclear projects in India, a questionnaire survey approach is exercised to establish the impact of various attributes on project performance. A set of questions are framed to ascertain the impact of these attributes individually on project schedule and the feedback on strategic factors are also complied for model formation. 10 key attributes related to delay, eight attributes related to strategic factors and two cost- schedule relationship & coordination are identified under three categories namely project authority/owner, consultant and contractor.

A five point Likert scale (1-strongly agree, 2-agree, 3-neutral, 4- disagree, 5-strongly disagree) is adopted. Respondents are requested to rank the importance and impact of a particular attribute on delay and strategic attributes. The Cronbach's Appha is calculated for internal consistency estimate of reliability. Value of Cronbach's Alpha is found to be .967, which comes under the excellent reliability category (High Stakes Testing). Descriptive statistics namely Relative Importance Index (RII) has been used to test the relative importance of attributes.

Ten selected factors responsible for project schedule delay are identified and analysed by using RII method. The responses are analysed separately for project authority/owner, contractor, and consultant and as well as combined one. On comparison, it is found that respondents have same opinion on some points, but also they have different opinion on other points. Some attributes are fully accepted by all respondents and also some are rejected strongly by most of respondents. Overall responses show that first main cause of delay is "delay due to poor/backward project planning & scheduling" which is accepted by both consultant and contractor respondents but it is not accepted by project authority respondents. Respondents as a consultant has different opinion about the attribute "Delay due to lack of communication among the involved agencies" as compared to project authority and contractor respondents. The attribute "Delay due to poor site coordination with other

agencies" has ranked as third major cause of delay. This attribute is ranked closely by contractor and project authority respondents, but it is not accepted by consultant respondents. "Delay due to external social & political factors" is ranked on fourth step. Only owner respondents have ranked an attribute "Delay due to inefficient purchase & procurement system" at first place. All respondents have accepted in one voice "Delay due to lack of commitment among project authority/owner" is least important cause. This is a surprising fact that consultant & contractor respondents are agreeing with the project authority.

Two similar studies have been carried in past in conventional construction sector to identify the causes of delay in projects. No such published study is available in nuclear sector. A comparative study shows that "Delay due to lack of commitment among project authority/owner" is accepted as main cause of delay by two researchers of non-nuclear construction sector but same is rejected by respondents in nuclear sector. All respondents have different opinion on "Delay due to inefficient site management", "Delay due to lack of clarity in project scope/process/ technology" and "Delay due to lack of communication among the involved agencies".

The comparative study shows that causes of delays in conventional construction sector do not match with those of nuclear sector. The project execution models (EPC/EPCM) which are workable in conventional construction sector may not be applicable in Indian nuclear field.

The second objective of the study is to identify the attributes contributing the formation of proposed model for project execution in Indian nuclear sector. Eight attributes which can play a major role in formulation of project execution model are identified. Result shows that respondents has same opinion on some points and also have different opinion on the other points. The respondents have put stress on incorporation of Management Information Systems (MIS) and effective use of project management tools. They have accepted that professional training is essential for engineers and staff. The respondents also suggest to keep Quality Assurance (QA) as an independent agency. A separate agency should be established to address the social &

political issues which are one of the major causes of project delays in nuclear sector.

Important factors causing the delays in projects are taken from outcome of ranked analyses of delay factors. Constraints and limitations in nuclear sector are also identified. The views on the relevant attributes are also included in the formation of project execution model. The numbers of models are worked out to address the analyzed factors as much as possible. Each model is checked for the attributes applicability. An optimum model is developed and tested.

The systems are divided into two parts, conventional system and nuclear system in the proposed model. Conventional system are those system where consultants, designers, suppliers, contractors are available in the market. The execution shall be carried in EPC (Engineering Procurement and Construction) mode. Architectural & civil design of buildings, construction of buildings, procurement of conventional systems like air conditioning & ventilation system, steam boiler & water system, electricity generation & switchgear system etc. shall be covered under conventional systems. On the other hand, proposed model has nuclear system where either vendor are no available or items can not to be subcontracted to outside vendor due to technology & secrecy constraints. The execution of these systems cannot be carried out in EPC or EPCM mode of execution. The execution shall be done in house with help of outside selected, specialised & trusted vendors. Management Information System (MIS) equipped with latest project management tools has major role in this model. MIS is kept in central position of model. The online project monitoring & control system of MIS not only coordinates the various activities but also keeps the project schedule and cost in control. Quality Control (QA) is kept as an independent agency direct reporting of head of project in order to meet the stringent QA norms. R&D, awareness agency and professional training are kept outside the core project execution. Four ranked attributes related to delay and six ranked attributes related to strategic factor and four major constraints in Indian nuclear field are addressed in this model.

Responses, 109 in numbers are collected for testing of proposed model. Data are collected, comprises 52 numbers through seminars, 11 numbers by conducting the interviews and 46 though feedback questionnaires.

The complete model along with the delay factors has been presented in a seminar. Project professionals working the nuclear sector and having experience more than 5 years have attended the seminar. 52 professional have responded their views about the model. The eight attributes, collected during development of model are selected along with three more relevant added attributes to get the responses. 94% professionals agree that the model is a practical model and can be implemented for project execution in nuclear field. The originality of this model is also accepted by all respondents. 98% respondents agree that implementation of this model will be able to control the project delays.

Hypothesis testing for proportions is used to check the validity of model. The hypothesis for 5 % level of significance is formulated and checked. The hypothesis testing result shows that the proposed model is optimum & valid model for implementation in Indian nuclear sector and confirms the validity of the model.

Eleven personal interviews are conducted with senior executive from nuclear project sector. The professional have more than 20 years of experience in the nuclear sector. Ten out of eleven executives agree that the model is a practical model for implementation. All executives have confirmed that the implementation of this model is able to control the project schedule

The information has been shared with the BARC management during the development of model. Respondents suggestions, separation of conventional project activities from nuclear one, in-house design & procurement of nuclear components, independent QA, implementation of MIS in phase manner & its integration with PM tools and independent R&D activities are being implemented in BARC in phase manner. Project execution site does not have role in whole project life cycle. They work with the contractors on the basis of

drawings, document & guidelines approved by design office/ head office. Six questions relevant to site project execution team are selected among the questions requested during seminar presentation. The attributes, "MIS can play a great role for coordinating & controlling the project schedule" and "Implementation of this model in nuclear sector will be able to control the schedule" are vetted strongly by respondents. "Professional management training shall be must for all engineers & staffs involved in project" and "Quality Assurance shall be kept as independence agency to meet the stringent safety requirement" are also vetted. These attributes are addressed in the project execution model. Respondents do not agree with attributes "Involving a professional management agency (third party) to take care of project monitoring & control will help in project execution" . This attribute is not considered in the model.

Inapplicability of in-practice models of conventional construction sector in Indian Nuclear sector is analysed. The optimum model is developed based on response received from the respondents working in nuclear projects. Causes for project delay are analysed. Facts in Indian nuclear sector responsible for delays are also identified. Response on attributes required to draw an outline of model are analysed. The graphical analyses and cost benefit analyses are carried out to check the feasibility of model. The empirical testing, seminar, personal interviews and feedback process are carried out to check the validity of model. Hypothesis testing is carried out.

It is concluded that in-practice models of conventional construction are not applicable in Indian Nuclear sector project and proposed model is a valid model to execute the projects in Indian nuclear sector by GOI institutions.

Government of India (GOI) has planned 55 units to execute through public and private sectors. GOI has planned to execute in-house 40 Units of total capacity of 45,000MW in coming 10 years. The future market of the application of this research is more than Rs. 6,00,000 Cr. by year 2025.

"Design of MIS system according to organisation structure of GOI institution and its implementation" and "Failure / success analyses of applicability of this model in Indian nuclear sector for GOI institutions" are topics for research in future.