STANDARDIZATION OF FOSSIL-FUEL POWER PLANT PROJECTS ACCORDING TO LEAN CONSTRUCTION PRINCIPLES

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ABSTRACT

The peculiarities of construction industry cause many none-added value activities that reduce the efficiency of construction projects. These activities are real threats to corporate success and sustained growth. Therefore becoming lean and improving overall performance is indispensible in today's competitive market. Construction of fossil-fuel power plants is a complicated task susceptible to including many non-added value activities. So survival and growth in such industries is hardly achievable without having a new paradigm to execution of these projects.

This paper discusses application of lean construction principles (LCP) into fossil-fuel power-plant projects in engineering, procurement and construction (EPC) phases. Partial implementation of LCP in engineering phase is achieved through standardization of design process. Consequently manufacturing power-plant main equipments that were considered a make-to-order (MOD) task has been changed to a make-to-stock (MOS) activity which greatly improves quality and reduces cost and lead time in manufacturing. Further work is being pursued to utilize LCP in preparing for construction and building power plants islands. The paper discusses a case study in MAPNA Group which involves quantification of LCP utilization in various power-plant activities and the way it has improved overall corporate performance in these projects. Finally it is shown how gained benefits are transferred as value to customers.

KEYWORDS

Lean construction, standardization, fossil-fuel power plant projects.

INTRODUCTION

According to new production philosophy, there are two kinds of phenomena in all production systems: conversions and flows. Both aspects have to be considered in design, control and improvement of production systems, (Koskela, 1992). Lean production focus on two types of conversions: design as the main process of information conversion and production that is the main process of material conversion (Crowley, 1998).

In production processes there are two types of activities: value-adding activities and some others that do not add any value for the end user. The competitiveness in

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new production philosophy is improved by identifying and eliminating non value-adding activities that is called MUDA or waste. Experience shows that non value-adding activities dominate most processes; usually only 3 to 20 % of steps add value (Ciampa, 1991). There is a fact that there are more non-value adding activities than value adding and this moves the focus of optimization from the value generation to the reduction of waste (Bertelsen, 2002).

Traditional managerial principles have focused only on conversions. In this view all activities are treated as though they are value-adding conversions. Table (1) is provided the summary of comparison between traditional and the new production philosophies.

Table 1: Comparison Between Traditional View to Production and Lean Approach (Koskela, 1992)

	Production activities	**Control way**	**Control aim**	**Improvement time-cycle**	**Control criteria**
Traditional view	Operations or functions	operation-by-operation	Least costs	Periodic	Productivity
Lean production	Material and information flow processes	For minimal Variability and cycle time		Continuous	Waste and value

After production, the necessity of becoming lean in construction industry was proposed by Alarcon et al. in 1993 (Koskela, 1993). Construction is defined as production of unique products which is remarkably limited to a sequence of rigid assembly operations, where cannot be interchanged. Also it takes place in a chaotic and impermanent environment of the construction site. No two projects are alike and their look and feeling and details as well are different (Bertelsen, 2002).

The ignorance of flows in traditional managerial concepts caused three categories of critiques: sequential method of project realization, lack of quality considerations and segmented control. As a consequence, construction is characterized by a high share of non value-adding activities, low productivity, non-optimal flows and consequently low level of reliability (Koskela, 1992) (Picard, 1996) (Howell, 1998).

It is shown that two thirds of Swedish plumbers' working time in construction site is spent on such non-value generating activities, a fact which is confirmed by studies of the erection of prefabricated concrete walls on a Danish construction site (Bertelsen, 2002).

The goal of lean construction is better meeting customer requirements while using less of all resources. To do this the experiences gained from lean production principles are applied in construction. This will result in a new project delivery system that can be utilized in any kind of construction projects especially in complex, uncertain, and quick projects (Howell, 1999). In summary it can be said that lean construction lies on an agile and reliable delivery system which challenges the trade of quality, price and time in capital projects.

Main principles of lean construction could be summarized as below:

- Simultaneous design of product and process
- Commitment to providing specific deliverables
- Increasing reliability by clarifying the flow of work
- Focus on the whole system (of construction) performance rather than its elements
- Decentralizing of decision making processes

Therefore it can be stated that lean construction is a new way of thinking that upon implementation provides feedbacks leading to new understandings. This new understandings will result in better actions and consequently to a new set of feedbacks and understanding (Ballard, 2007) (Koskela, 1999). Figure (1) shows these relations.

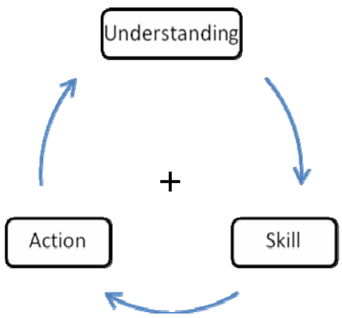


Figure 1: Reinforcing Loop For Increasing Skill By Applying Lean

EPC CONSTRUCTION PROJECTS

There are two main processes in a construction project: design process and construction process. Design process is a stage-wise refinement of technical specifications where vague needs and wishes are transformed into requirements, then to detailed designs. Simultaneously, this is a process of problem detection and solving. Construction process is composed of the flows of material to the site, including processing and assembling on site and work processes of construction teams (Koskela, 1992).

Capital Construction projects are usually done by EPC contractors whom do the design and engineering, procurement and construction of projects as a whole. Complexity of these projects requires a high level interaction and integrity between each phase. Ballard in 1993 mentioned that EPC projects should not be performed sequentially and in separate phases but the interdependencies and tradeoffs between phases should be considered (Ballard, 1993). Supposing a non-overlapping sequence between design, procurement and construction will encourage a misconception which leads to low integrity and interaction between phases and therefore lack of productivity.

STANDARDIZATION OF EPC PROJECTS

According to Ballard's experiences during the construction phase of EPC industrial projects, construction projects have two characteristics: first, the disruption and waste caused by poor quality and delivery of offsite resources, specifically design documents and permanent plant materials and equipment and second, construction industry is in some ways not completely shifted from craft to mass production. He also stated the lack of standard work methods is one sign of the dominance of the craft production model (Ballard, 1993).

Performance improvements are usually accompanied with a totally controlled processes and flows. Such controlled processes and flows "means standardization of processes" (Ballard, 1993). Construction standardization by coordinating all of the processes and flows could make an advantage for implementing and developing the projects in the real condition of site (Crowley, 1998) (Simonsson, 2007).

Standardization of different phases in construction facilitates concurrent engineering. Love et al. in a study in 1998 show that concurrent engineering could make considerable improvements in procurement and construction (Love, 1998). Concurrent engineering is a primitive model that reduces the time of project implementation (Ballard, 1993). Due to help of standardization in increasing the integration in all process, information flow and communication would be more fluent. So the concurrent engineering would be done more effectively.

STANDARDIZATION OF E IN EPC POWER PLANTS PROJECTS

Design or engineering phase is considered as a process of converting information into technical specifications or a flow of information (Tzortzopoulos, 2005). This flow generates value to client, because it is a direct part of contract which in EPC projects is paid by client.

Standardization of engineering activities means implementing similar projects with pre-designed and optimal documents which do not belong to any specific project or site but are accounted as a typical and generic reference for all projects of one kind.

Ballard in his 2007 paper for implementing lean on capital projects provides some recommendations according to his findings for each phase of such projects. For design phase, his recommendations include:

- making work flow predictable through reliable promising and lean production control;
- designing product and process simultaneously;
- and producing detailed engineering outputs from an integrated database (Ballard, 2007).

An efficient way to implement these recommendations is standardization of design or engineering phase and its related actions and functions.

Required technical documents for procurement and construction are made in E-phase (Engineering) and its standardization will accompany an obvious and comprehensible flow of further works and actions. Though the essence of capital construction projects makes them unique and one-of-a-kind, they have many repetitive parts that are similarity of construction projects and mass production.

Standardizing the design of repetitive parts will reduce the work pressure in project implementation and helps project managers to have more chance for thinking about their decisions and optimizing the performance of projects as a whole rather than sub-optimization. Such standardization reduces the required cost and time to do engineering tasks such as conceptual design, basic design, detailed design, etc. Therefore these documents can be used in every new contract proposal or project with a slight customization where the preparation cost and time is indeed less than engineering of the whole project.

Basic design activities that lead to preparation of procurement, erection, commissioning and operation documents are done in the E phase of EPC projects. These documents are utilized in procurement and construction phases of the projects and consequently for operation and maintenance. Figure (2) shows the application of these documents in the project phases.

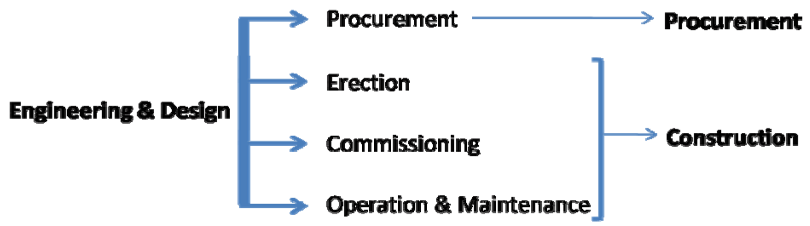


Figure 2: Utilization of Prepared Documents In E Phase In Other Phases

"Design management", "changes in requirements and design process", and "client requirements consideration" are orderly related to transformations, flow, and value view or TFV triad (Tzortzopoulos, 2005).

These aspects of project become leaner through standardization because:

- Design management will be more efficient because the process and interactions are clear from the early stages of projects
- Standardization of projects will narrow the changes in client requirements.
- Client requirements will not be so immature because they are already considered in the pre-designed plans according to previous experiments

Design characteristics indicate more uncertainty and interdependency in construction design than construction production that make design process more problematic (Koskela, 2000). Some effects of these factors could be improved by standardization as presented in Table (2):

Table2: Design Problematic Factors and the Effect of StandarDization On Them

Problematic Factors	**Effect of Standardization**
Interactions without complete information	Access to a good deal of verified information from the early stages of the project
Lacking or delayed requirements from the client	Having an understanding from the client requirements (because projects are similar in main aspects)
Some disciplines are bottleneck	Having less bottlenecks (because the projects are pre-designed)
Changes in design objectives or criteria	Eliminate design changes or make them less
Variability due to internal affairs of design offices	Dissociate the design of projects from current engineers of design office ideas and knowledge

Due to utilization of E-Phase documents in all other phases, it is clear that the accuracy and completeness of the prepared documents will greatly affect the efficiency of activities in other phases. Figure 3 (Woodward, 1997) displays the savings potential in life of a project that indicates the savings is more remarkable in E-Phase than other phases.

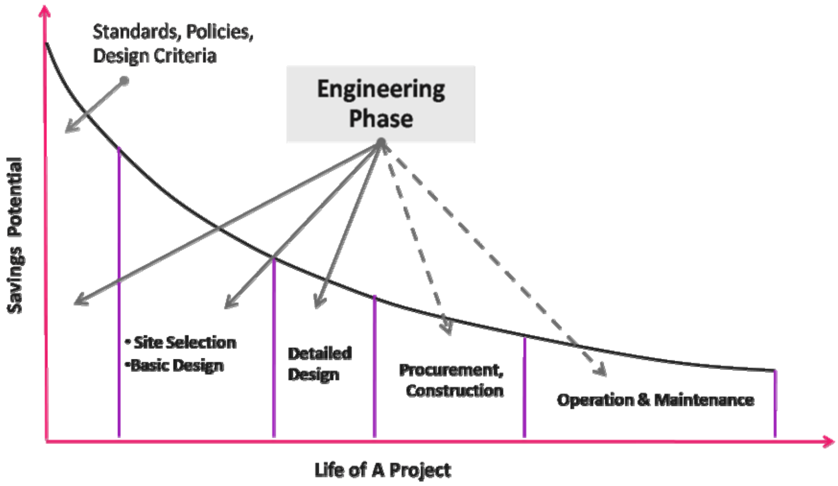


Figure 3. The Effect of StandarDization In Terms of Saving Potentials with Life of A Project

Therefore it is worthwhile to optimize the integrity of the documents in E-Phase. It conveys that standardization of required documents for power plant construction affects other phases in many aspects like efficiency and effectiveness. In addition to improve E-Phase itself, standardization improves the whole project performance in such dimensions as: quality improvement, time reduction, cost improvement, and potential optimization of space requirements for construction.

CASE STUDY: STANDARDIZATION OF E-PHASE AND ITS RESULTS

Standardization of E-Phase is implemented by an Iranian general contractor company (GC) engaged in development and implementation of combined cycle power plants under EPC scheme. The islands of combined cycle power plants includes: gas and steam turbines, generators, control systems and heat recovery steam generators (HRSG) and main and auxiliary cooling systems. Figure (4) shows a schematic picture of a typical combined cycle power plant (CCPP).

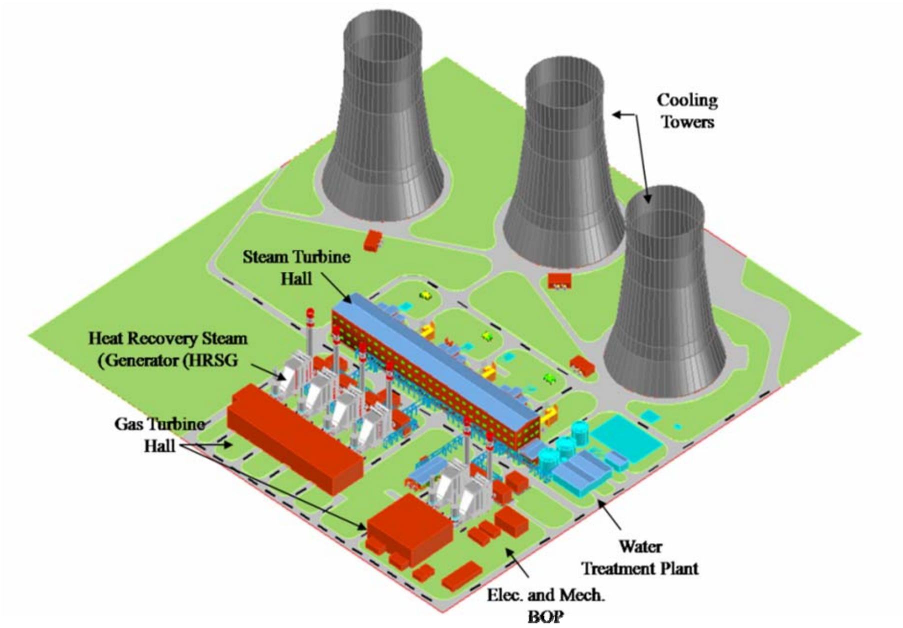


Figure 4: Scheme of Combined Cycle Power Plant

The under-study GC is a conglomeration of the parent enterprise and its 29 subsidiaries that has constructed or has under-construction more than 60 projects covering more than 49000MW. It has 86% shares of Iran's total nationwide grid capacity. This contractor realized the necessity of E-Phase standardization according to gained experiences during constructing its projects and as a result NIAM[1] scheme was codified and implemented.

The organizational structure of the case and also the flow of information, material and equipments between each corporation are shown in figure 5. The subsidiaries of two divisions, Engineering & Manufacturing and Construction are seen in the figure. In engineering and manufacturing division there are several subsidiaries which make power plant equipments like turbine, generator, electrical and control instruments, boiler and H.R.S.G, and other equipments. The construction division includes power plant construction and engineering companies.

Manufacturing in heavy and complex industries is usually make-to-order. As is seen in figure 5 engineering documents are made in design and engineering division and flow to equipments manufacturers. By standardization of these documents, manufacturing of these equipments including turbine, generator, electrical and control systems is standardized so they can be produced make-to-stock almost in a batch production method. Boilers and H.R.S.Gs due to their dependency to site conditions cannot be made in a make-to-stock fashion however standardization has me it possible to procure some of their required components using a batch method.

In addition in construction division standardization of engineering documents cause power plant construction and development more efficient and with minor inherited characteristics from construction projects peculiarities.

[1] Persian Acronyms for Mapna Standard Power Plant

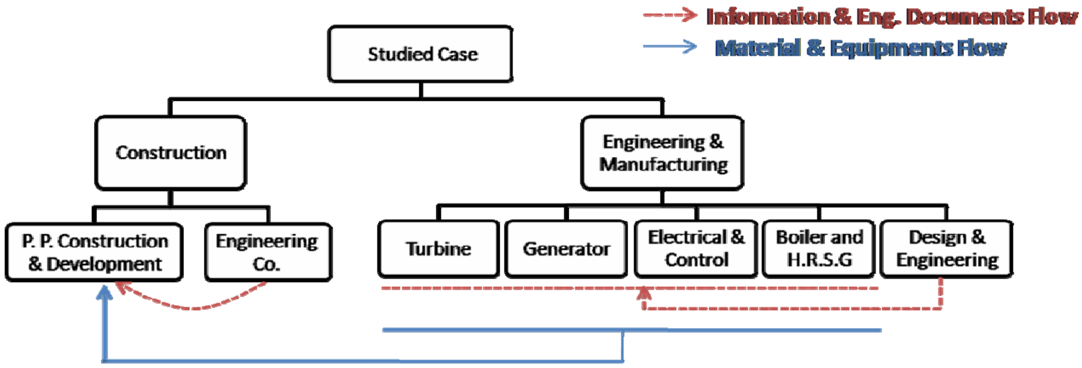


Figure 5: Flow of Information, Material and Equipments In Studied Case

NIAM DESCRIPTION

NIAM is a pre-designed power plant which its documents can be utilized in any projects in one type. This scheme tries to provide the basic design of the power block and also its standardized documents. In this scheme designs and technical specifications of various power systems are standardized and optimized. It includes the standardization of different power plant islands like: turbine, generator and their auxiliaries, bus duct transformer, HRSG[1], electrical and control systems, electrical and mechanical BOPs, main and auxiliary cooling, and equipments' layout and their relations with each other.

NIAM scheme is formed to improve and develop the quality of engineering with getting feedbacks from implemented projects. The main achievement of this scheme is construing power plant development as an integrated format capable of addressing each project's specific conditions within an optimum framework.

As mentioned before, Standardization of E-Phase could affect other stages of power plant construction. Table (1) shows the percentage of standardization of E-Phase and its reflection to other phases in the case study.

To evaluate the level of standardization a survey was done in the Corporate engineering department that is responsible for producing engineering documents for each power plant island. The survey questioned the available amount of engineering documents and the time required to produce them prior and after implementation of NIAM Scheme. The results are displayed in Table (3). The greater percentages indicate higher level of standardization and the remained percentage to 100% means the required special modifications necessary for preparing documents for a specific project. The overall percentage standardization are 69.7%, 64.6% and 50.7% for engineering, procurement and construction respectively.

Table 3: Percentage of Standardization of E-Phase and Its Reflection to Other Phases

Power Plant Islands	E	P	C
Turbine / Generator	98	95	90
Boiler (HRSG)	60	50	40
Instrumentation & Control	95	92	75

[1] Heat Recovery Steam Generator

Main & Unit Transformer	95	95	70
Mechanical and Electrical Balance of Plant	50	40	30
Water Treatment Plant	50	40	30
Main & Aux. Cooling	40	40	20
Average	69.7%	64.6%	50.7%

DISCUSSION ON IMPROVEMENTS ACHIEVED BY NIAM

Implementing lean principles in NIAM scheme and standardization of power plant projects are achieved through performing the following activities:

- Coordinating flow of information in several technical meetings with manufacturers to obtain critical information about equipments dimensions and their main specifications.
- Designing 3-dimentionals models of all equipments, turbine hall and power block site
- Designing 3-dimentional model of equipments layout in turbine hall and overall site layout
- Designing 3-dimentionals scheme of connections between equipments, including: cabling and piping of power block
- Preparing 2-dimentional plots from 3-dimentional cross sections
- Evaluating detailed designs provided by different contractors with regard to 3-dimentional models of basic designs

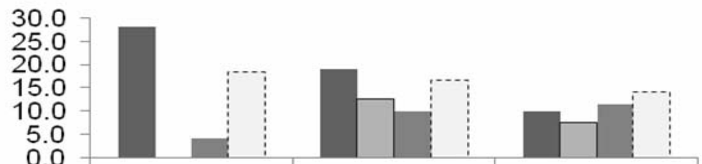
These activities result in developing a standardized power block in power plant which yields the following gains:

- Applying up-to-dated design standards
- Power plant continuous improvement with the use of previous projects experiments and feedbacks
- Reducing equipments diversities and improving the operation conditions
- Having enough time (without project time pressures) to provide complete and optimized with least executive interruptions
- Facilitating execution of engineering phases in each project
- Facilitating proposal preparation for tenders, pricing, supplier selection, etc.
- Minimizing the effect of personal ideas
- Confirmation of special site condition with proposing pre-designed alternatives and implementing minor changes and modifications
- Fast and clear coordination between equipment and material suppliers.

Time reduction, optimization of space requirements, cost and quality improvements compared to previously executed projects before standardization are measured according to above advantages. The gained results are depicted in figure (6). It shows that standardization of power plant projects designs reduce the time of E-Phase of future projects about 28% which is accompanied by time reductions in erection and operation phases. According to this figure the improvements in E-Phase is more than others except for cost improvements which has the highest level in operation and maintenance. Finally the achieved improvements in operation and maintenance, converts to net value and deliver to the client of projects directly.

Through usage of this scheme the time and cost of projects in tendering, contracting and implementing stages is reduced because there is no need to design the projects from scratch and it will be applicable in all projects with slight changes according to site conditions and specific requirements of the client. It reduced the required spaces for the whole power plant in the preparation stage.

NIAM contributes to management of the knowledge of project-based enterprises considerably. Due to different conditions of the projects, knowledge documentation and transfer in project-based organization is a difficult and tedious task. Standardizing project engineering activities facilitates transferring of gained knowledge and lessons learned from one project to another. In addition with making the projects specifications fix and stable, knowledge retention and utilization will be done more efficient (Gann, 2000).



	Engineering	Erection and Comissioning	Operation and Maintenance
Time Reduction	28.3	19.2	10.0
Optimization of Space Requirements		12.5	7.5
Cost Improvement	4.3	10.0	11.7
Quality Improvements	18.3	16.7	14.0

Figure 6: Percentage of Achievements by Applying Lean Principals In Power Plant Construction

Such a standardization eliminates the trade-offs between quality improvement and cost and time reduction. There is a dominant belief among project managers that project cost reduction come only with compromising quality features. It is clear that by doing so the overall quality of the project and therefore customer satisfaction is lost. The results of NIAM show that time and cost reduction can be done simultaneously by quality improvements even if its amount is minor.

BECOMING LEANER

It is clear that becoming lean is not a temporary process and needs continual actions. The leanest organization can hardly claim that it has reached the leanest point. The discussed case in this article has to attempt leanness in its managerial processes in procurement and construction too.

It was mentioned that construction executes a production which is considerably locked to rigid sequence of assembly operations that cannot be interchanged (Bertelsen, 2002). So Standardization of procurement processes and the sequence of construction simultaneously within E-Phase can increase the integrity of projects as a whole. Also mapping the flow of needed activities and labors to erection of islands and their connections to construct a power plant leads to eliminating non-added value activities.

SUMMARY AND CONCLUSION

This paper addressed the necessity of implementing lean construction principles in development of fossil-fuel power-plant projects in engineering, procurement and construction (EPC) phases. Standardizing design and engineering activities in fossil-fuel power-plants that were considered a unique set of tasks for each project, converts these activities to the routine jobs that easily can be customized. As a result manufacturing power-plant main equipments such as gas and steam turbines, generators, control and electrical systems and HRSGs are transformed to make-to-stock (MOS) activities. This shift results in considerable improvements in quality, cost and lead time reduction in manufacturing. The paper discussed a case study in MAPNA Group, a general contractor, and quantified the lean achievements through LCP utilization in various power-plant activities. It was discussed that how LCP usage improves overall corporate performance in these projects. Whilst standardization has mainly encompassed engineering tasks by 69.6% further work has to be performed to utilize LCP in preparing for construction and building power-plants islands. The paper displayed LCP utilization in engineering tasks result in 28.3% time reduction, 4.3% in cost improvement and 18.3% in quality improvement. Similar results are realized in erection and commissioning, and operation and maintenance which convey great motivation to continue LCP utilization in procurement and construction phases.

ACKNOWLEDGEMENT

The authors would like to express their special gratitude towards Mr. Haj-Mohammadi from MAPNA Group for fruitful discussions and technical contributions.

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