

A Conceptual Model to Capital Projects Conception based on Front-End Loading and Lean Concepts

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The pre-planning phase, focusing on strategic guidelines and basic definitions of capital projects, has been the object of attention from large companies, in order to improve project outcomes and decrease its risks. In this context, this paper points out a conceptual framework to the preplanning stage of capital projects, focusing the introduction of Lean Construction concepts and methods in the Front End Loading methodology (FEL), widely used in large industrial projects. Although lean concepts and tools are speedread throughout building construction projects, its concepts and tools are not inherent to the methods applied in capital projects feasibility analysis, as well as to its preliminary definitions. From the analysis of possible synergies between these methods, a model is described for managing the conception phase, which prioritizes the introduction of concepts and tools of Concurrent Engineering, Set-Based Design, and Target Costing, supported by techniques which are generically called “Value Improving Practices”. The model presented is innovative since it allows the introduction of lean mentality in the design of capital projects, establishing guidelines for the implementation of tools that are not normally known and used in the design of large projects.

Key Words: Front End Loading, capital projects, project definition phase.

Introduction

The development of capital projects, which is usually oriented towards industries such as mining, gas, oil and energy, has been the point of particular attention by large corporations, with emphasis on the improvement of portfolio management of their projects.

In the context of capital projects may be included large construction projects, which have some particular features. As an example, their purpose and requirements may change during operational phase, urban conditions may imply in new operational and environmental conditions, and these aspects should be considered in earlier stages of project definition. Construction projects deal with geographical differences, including materials availability, work conditions, environmental constraints, as well as special supply requirements. The Capital project deals with great degrees of complexity since leads with a large number of unpredictable variables.

In some cases, construction projects managerial and technological complexity leads to the definition of specific contractual relationships, such as design-build systems, addressing particular design coordination skills and new procurement methods (Alharbi, Emmitt and Demian, 2015).

From this perspective, emphasis has been given to the initial stage of feasibility study and schematic design of these large projects. This initial stage, or preplanning phase, is directly associated with managing the projects portfolio. Hence, the methodologies focus on the analysis of the business attractiveness, project alignment with the company’s strategies and the preliminary definition of costs and CAPEX (Capex Expenditure), as previous steps in order to define the preliminary engineering solutions.

Although, these methods are well known, in most projects their implementation does not imply the use of concepts that prioritize quality and performance assurance, integrated with the minimization of activities that do not add value, principles essential to lean thinking.

In this context, this paper presents a conceptual framework for the development of the initial phase of capital projects. The work starts from an analysis of synergies between a method already widely used in large companies, namely Front End Loading, and the structure of Lean Delivery Production System (LPDS).

The paper presents a brief explanation of Front End Loading, and a more detailed explanation of the steps of the methodology is presented in references (Clerecuzio and Lammers, 2008, George et al., 2008, IPA, 2018, Aghimien et al, 2018). As a next step, it is outlined a conceptual proposal for the use of techniques and tools compatible with that of Lean Thinking in FEL methodology, prioritizing the application of concurrent engineering concepts. Some guidelines, to be used with target costing and set based design techniques are presented.

Summary of Concepts on Front End Loading (FEL)

Front End Loading (FEL) is developed in three phases (FEL 1 to 3), among which there is a “gate” for decision making. A schematic representation of the method is shown in Figure 1. About 75% of possible projects composing companies’ portfolio do not cross the FEL 1 gate to FEL 2, and about 25% of the projects do not go from FEL 2 stage to FEL 3, and in the FEL 3 gate only 1% of projects are approved for implementation; a fact which occurs either due to lack of business attractiveness, due to difficulty to find a viable technological solution, or even due to the fact that not all possible alternative solutions have been explored.

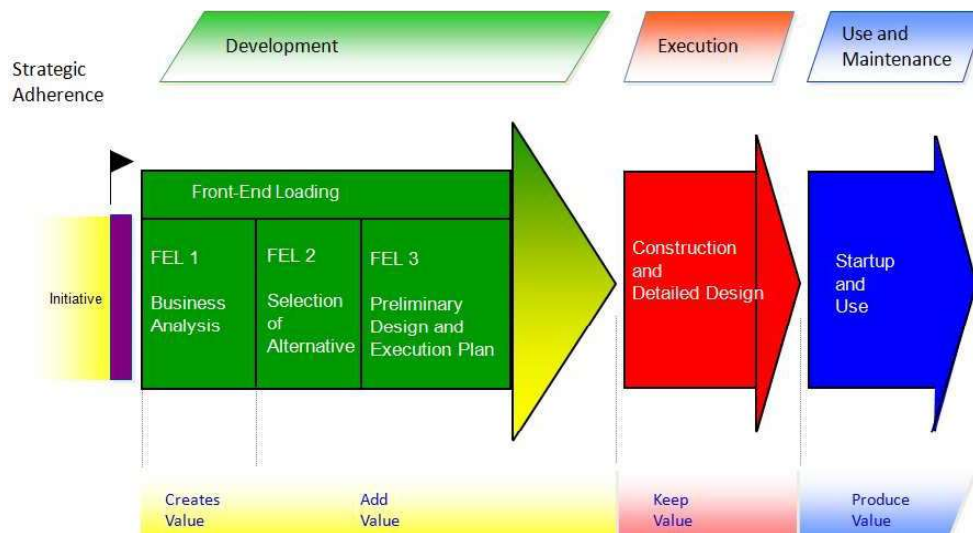


Figure 1 – Schematic representation of front end loading methodology – (IPA, 2018)

In summary, the initial stage (FEL 1) implies the definition of the scope and purposes of the project, and an initial estimate of the amount of investments, providing a range of variation in the cost of the project ranging from -25% to +40%. In this phase a business feasibility analysis is performed, by calculating key indicators of business viability, such as IRR (Internal Rate of Return), NPV (Net Present value), IPV (Investment Present Value) and discounted Payback, among others. This phase should assure that project development guidelines match with company portfolio management strategies and goals.

The FEL 2 stage involves the analysis of technological and constructive solutions associated with the development, ending with the selection of one of these solutions and with the basic definitions (project briefing) of the facilities. This stage anticipates variation in Project costs, ranging from -15% to +25%. In addition, it is conducted the selection of VIP's (Value Improving Practices) to be used in the development of the project's basic engineering.

The final phase of the pre-planning stage (FEL 3) refines the engineering solution selected in FEL 2. More VIP's are selected to be considered in the development of basic design. The procedures use to provide a variation in the project costs of ranging from -10% to +10%, in addition to consolidating the business' key indicators of viability.

Lean Project Delivery System (Ballard, 2008, Gomez et al., 2018) is a prescriptive model for managing construction projects, considering project definitions, resources, and constraints since the early stages.

A schematic summary of the project management structure is pointed out in Figure 2.

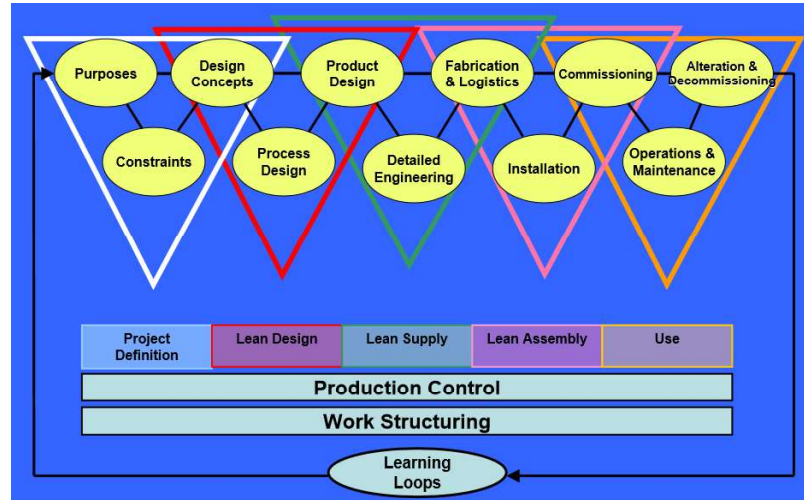


Figure 2 – The Lean Project Delivery System (Ballard, 2008)

Each step is deployed in processes detailed in the references (Ballard, 2008). The method is characterized by the integration between the stages of design, design, planning, and production in the sites, prioritizing the introduction of the concepts of concurrent engineering, reduction and costs, and constructability improvement.

Conceptual Model for the phase of feasibility analysis and development design

This section presents conceptual aspects of the proposed model for the design of capital projects. The guiding premise is the possible synergy between the Front End Loading and Lean Project Delivery System stages, particularly in the first two phases, Project Definition and Lean Design (Ballard and Kim, 2007 a and b). From a comparison between the two methods, it is possible to propose lean thinking concepts that can be used in FEL methodology. The steps are schematically represented in Figure 3.

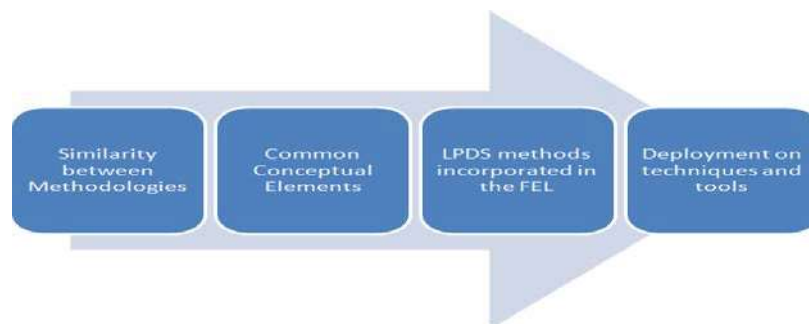


Figure 3 – Steps followed to model proposition – (Romero, 2017)

FEL work structure was described above. Lean Production Delivery System (LPDS) was described in the literature in the last ten years, beginning with the seminal work of Ballard (2008). In short words, LPDS is a project management model which highlights earlier stages of project definition, assuming lean thinking basic concepts. The model stresses the integration of project strategy, design definitions and lean supply, considering all phases of a project from concept to operation. As a framework, LPDs is deployed on a set of interdependent functions (at a system level), rules for decision making and procedures and implementation tools (Ballard, 2008).

In both conceptual frameworks, earlier stages of project decision making and design are prioritized, and great attention is given to the definition of project goals that are aligned with stakeholder's requirements and values.

The FEL 1 phase is similar to the Project Definition phase in the LPDS structure, it creates value to the project design. In the FEL 1 phase, as mentioned above, the main purpose is to define the scope and the objectives of the development aligned with a cost estimate and with the calculation of the business' key indicators of viability. In the LPDS structure, the Project Definition phase has a main purpose the define of the aims, means and constraints, also focusing on the target cost in order to achieve the customer's need. In this stage we can introduce the "target costing" concept of LPDS in FEL.

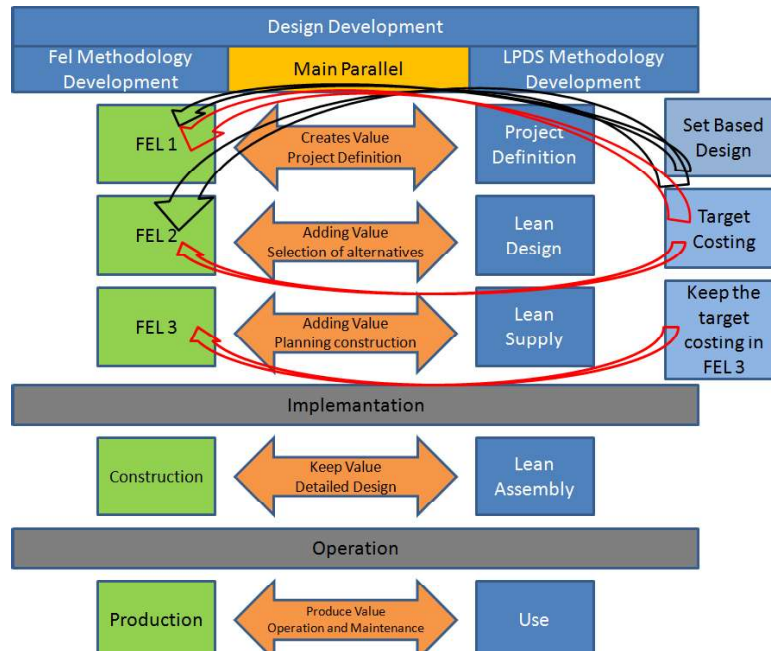


Figure 4 – Schematic representation of the comparison between FEL x LPDS - (Romero, 2017)

The FEL 2 phase is somewhat equivalent to the "Lean Design" stage in the LPDS structure, value is added by selecting an alternative for the development of basic engineering and development of basic designs. On the other hand, LPDS tools are introduced and continuously refined by using Target Costing and Set Based Design. In FEL 2 basic design solutions are outlined, to be developed "downstream" in next project definition phase.

The third phase (FEL 3) has equivalence in the "Lean Design" and "Lean Supply" stages of LPDS, with the development of the basic engineering.

Once a possible equivalence of the phases of FEL with LDPS is defined, lean thinking principles can be used in the dynamic of work of Front End Loading. Some prominent aspects are briefly mentioned below.

A first aspect deals with the establishment of the working team. The FEL methodology is already concerned with the creation of multidisciplinary and multifunctional teams, covering agents of the entire life cycle of the development. However, LPDS can originate the idea of assuming new contractual relationships between the agents, based on introducing a lean thinking culture, in which stakeholders have a holistic view of the project. The definition of an organizational structure per project (project-focused) and the matrix structures are best suited to this philosophy, giving priority to the figure of a Project Manager with great authority.

With a defined team, we then have the next phase, where the preliminary concept of the project is aligned with the needs, means and constraints, through modules defined by the LPDS literature, such as

Determination of the Needs and Values of the Project, Project Criteria and Project Design.

Some guidelines can be outlined:

- a) The Project Definition phase will be managed by the Project Manager, who is responsible for the project design to the client. Estimates of costs and schedule will be prepared and integrated into the design and development of the project, instead of being drawn up regularly after the project development.
- b) The principle of target costing will be introduced, as further detailed below.
- c) Several alternatives of project design will be evaluated. If that is intrinsic to FEL 2 stage, it has introduced the concept of working concurrently with the various alternatives, instead of choosing one among several, by using the principle of set based design.
- d) The FEL methodology provides for the use of specific methods and tools, which in Industry are known as “Value Improving Practices”. In another paper (Romero and Andery, 2009), the authors demonstrated that these practices can be perfectly used in the context of Lean Project Delivery System and, rightfully so, by being used in the context of Front End Loading, can be implemented from a “lean” perspective.

From the ideas briefly outlined above, we further comment below the use of “target costing” and “set based design” within the FEL methodology.

Use of target costing and set based design in front end loading

Traditionally, the costs for project implementation and project schedule are managed the same way. Both are usually defined retrospectively, from the preliminary definitions of the project, rather than being used as project constraints considered from the first stage of design and feasibility study. Alternatively, target costing provides means for fixing the cost and the time in alignment with the goals and values of the stakeholders and of the project design (Ballard, 2006). Thus, in addition to ensuring from the initial stages of design that the cost will be a goal and not merely a monitored parameter, there is an opportunity to reduce rework, manifested in redefining the very concept of the project, or its constructive solutions when the maximum feasible cost is exceeded.

This traditional way of working – Project (design) – Estimate – Re-work has been a wasted time because the cost has been the “output” of the project. Target costing, extensively explained in recent literature, is a cost management practice that aims at development based on target cost (drive), thereby reducing work that adds no value to processes and waste of time, as shown in the Figure 5.

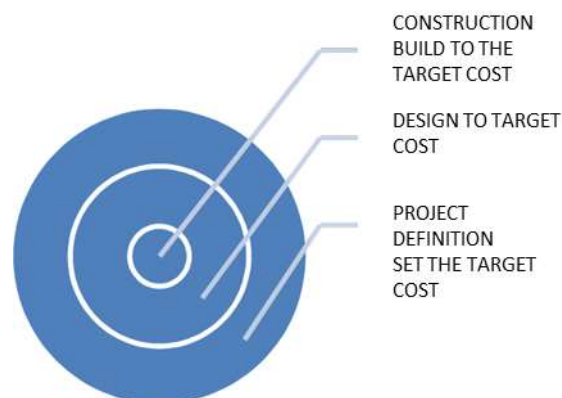


Figure 5 – Application and development of Target Costing - (Romero, 2017)

Some premises are assumed. The use of VIP's facilitates the introduction of the target costing concept into the Front End Loading methodology. This introduction will be made from the first stage of the method (FEL 1), when preliminary definitions of investments provide a first criterion for establishing the target cost. The work dynamics of Front End Loading, where the Entrepreneur defines the financial aspects of investment attractiveness at a first moment, facilitates the use of the target costing principles.

Ballard (2006), and others authors such Olivia et al. (2016) highlights some basic principles for target costing implementation. From what we understand, these principles present great synergy with Front End Loading basic concepts. Some of them should be briefly analyzed:

- a) Accordingly, to Ballard, the client evaluates the business case and decides whether to fund a feasibility study. This action is inherent to FEL 1, where, as remarked herein above, basic business indicators are defined, and strategic guidelines are outlined.
- b) The feasibility study involves all key members (designers, contractors, and client stakeholders) of the team that will deliver the project if the study findings are "positive". This feature is inherent to FEL, where the work team must be defined in earlier stages of Project Definition. New contract relationships can be studied to be applied to external members of the working team. The feasibility study produces a detailed budget aligned with scope. First, budgets appear in Front End Loading Phase 2, and, if the Project is approved, detailed cost analysis is conducted in phase 3 of the methodology.
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- e) All team members understand the business case and stakeholder values. That is an aspect of lean philosophy that should be focused in Front End Loading, since the methodology, although is concerned with team alignment, has a weak commitment with the understanding by all members of project values and constraints.

The use of set based design

Set Based Design has as main purpose guiding the development process of the project without setting an initial project solution, but several simultaneously. Thus, the project teams develop and communicate sets of solutions in parallel, often on an independent basis. As development advances, the project team gradually applies the project constraints and filters the solutions presented, based on the knowledge gained and lessons learned. Step by step, we come to a project solution that satisfies the various constraints set in the design stage. In addition to reaching an optimal solution, this structure of thought reduces rework. Figure 6 below we present the structure of the proposed conceptual model, with the assumption of development of projects through the Front End Loading (FEL) methodology with emphasis in LPDS process.

The model also suggests the use of Value Improving Practices as support techniques to the development of target costing and set based design methods. A detailed explanation is given in Romero and Andery (2009). As mentioned above, the VIP's are conducive to cost optimization and selection of engineering alternatives, hence their potential to use in both target costing and set based design.

Front End Loading phases in which the various practices can be applied, as well as their use within Target Costing and Set Based Design. It includes data from research done by an institution of management and audit of capital

projects (IPA, 2018), indicating potential gains in performance indicators of the developments, from the statistical analysis of a database of capital projects.

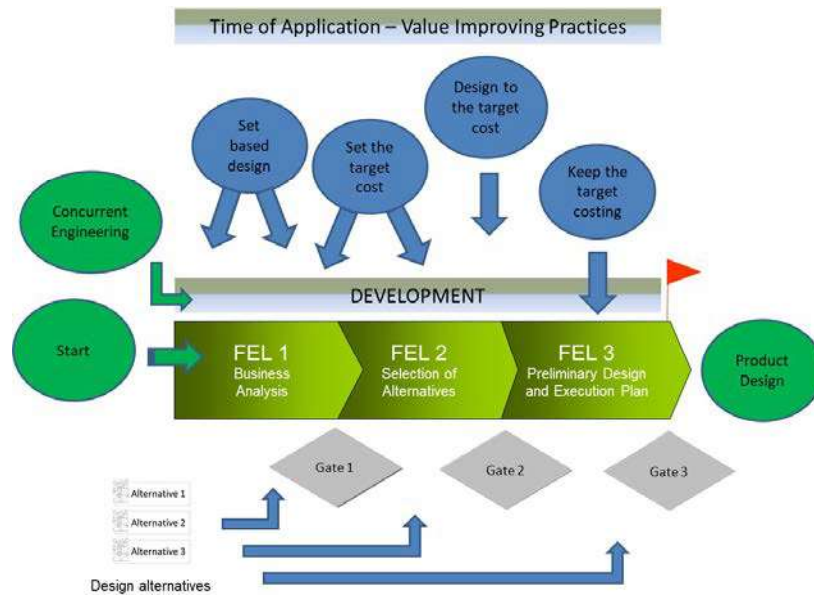


Figure 6 – Conceptual framework of proposed model - (Romero, 2017)

We see that most of the VIP's can be used both within Target Costing and Set Based Design. Among the VIP's indicated, one is noteworthy because statistically that has represented greater impact on reducing costs of capital projects: Constructability Review. Indeed, it has been applied to 60% of capital projects studied by IPA (IPA, 2018). It is noteworthy the fact that, besides having an impact on cost reduction – hence its use as a way to implement the target costing -, the use of this tool often involves reducing project schedule. In practical terms, “Constructability Review” is a multidisciplinary analysis usually performed by a team other than the one in charge of the projects of the development, which will be developed in the FEL 2 phase, when the preliminary definitions of the project are initiated, and throughout the process of FEL 3 phase. It includes an analysis of the entire project life cycle, focusing attention on aspects such as design specifications that affect the constructability. On the other hand, it ends up being a tool that assists the management of procurement of equipment because it checks for potential errors in the specifications and in the procurement plans.

Conclusion

This paper has shown that two methodologies that address the stage of initial design and planning of capital projects share great similarities between them. Therefore, it is possible to envisage a new model to provide synergies between the two structures of work. In this case, Lean Project Delivery System concepts have been employed in the Front End Loading methodology. As highlighted aspects, we note the creation of multidisciplinary teams embedded with a “lean thinking”, the use of specific tools (Value Improving Practices) from a lean overview, and the introduction of target costing and set based design concepts, which were briefly outlined.

As a result, we expect a conceptual framework that will guarantee the return of the investments in the project, allowing the conduction of the subsequent stages – detailed definitions of the developments' engineering and their implementation, with higher probability of success.

References

- Aghimien, D. et al. (2018). Challenges for Front End Loading in Construction Project Delivery. Proceedings of the Fourth Australasia and South-East Asia Structural Engineering and Construction Conference. Brisbane, Australia.
- Alharbi, M., Emmit, S. and Demian, P. (2015). What is architectural management? Towards a pragmatic definition. *Engineering, Construction and Architectural Management*, 22 (2), 151 – 168.
- Ballard, G. (2008). The Lean Project Delivery System. Proceedings of Lean Construction Journal.
- Ballard, G. and Kim, Y. (2007). Roadmap for Lean Implementation at the Project Level. CII Research Report.
- Ballard, G. and Kim, Y. (2007). Implementing Lean on Capital Projects. Proceedings of International Conference of the International Group for Lean Construction, IGLC 15, Michigan, USA.
- Ballard, G. (2006). Rethinking Project Definition in Terms of Target Costing. Proceedings of International Conference of the International Group for Lean Construction, IGLC 14. Santiago, Chile.
- Clerecuzio, C. and Lammer S, P. (2008). Front End Loading: Myths and Misconceptions. Technical Paper. URL <http://www.mustangeng.com>
- George, R., Bell, L. and Back, W.E. (2008). Critical Activities in the Front-End Planning Process. *Journal of Management in Engineering*.
- Gomez, S., Ballard, G., Naderpajouh, N. & Ruiz, S. (2018). Integrated Project Delivery for Infrastructure Projects in Peru. Proceedings of 26th Annual Conference of the International Group for Lean Construction. Chennai, India.
- IPA (2018) – Independent Project Analysis. The IPA Institute – Advanced Project Knowledge. URL [http:// www.ipaglobal.com](http://www.ipaglobal.com).
- Oliva, C.A., Granja, A.D., Ballard, G. & Melo, R.S.D. (2016). Assessing Suitability of Target Value Design Adoption for Real Estate Developers in Brazil. Proceedings of 24th Annual Conference of the International Group for Lean Construction. Boston, USA.
- Romero, F. and Andery P. (2017). Managing and Developing Capital Projects. Proceedings of the 2017 ASC Region III Conference. Chicago, USA.
- Romero, F. and Andery, P. (2009). FEL. Front End Loading e LPDS – Lean Delivery Production System para concepção de projetos de empreendimentos. *Revista Mundo PM*.