ABSTRACT

Private and public sector owners of both facilities and infrastructure projects are facing increasingly complex challenges that are forcing a re-evaluation of the metrics, benchmarks, and expectations for life cycle performance in their projects, beyond the conventional parameters of cost, time, quality, and safety. Some of these challenges include: more limited and tighter economic and financial resources; higher levels of project complexity; rapidly changing technologies that affect both products and processes; increasingly restrictive laws and regulations; and the emergence of international standards, such as ISO 9000 and ISO 14000. To overcome these challenges, owners are seeking new strategies, new processes, and new tools to enhance the effectiveness and efficiency of the delivery and operation of capital projects at all life cycle stages.

Within many currently available strategies, processes, and tools, the development of a comprehensive and integrated Project Definition Package (PDP) has emerged as a crucial cornerstone for enhanced capital project performance. Developed through research sponsored by the National Science Foundation (NSF) and the Construction Industry Institute (CII), this paper presents a formal, explicit, systemic, and systematic approach for project definition. The paper discusses the relationships between the PDP and the Project Execution Plan (PEP), the Project Design Package (PDSP), the Production Process Plan (PPP), and the Project Work Breakdown Structure (PWBS), as the project is defined from both a product and a process perspectives. Then, the paper discusses a framework and methodology that:

- identifies and defines a set of parameters that define the short-term and long-term performance of capital projects;
- identifies and defines a set of external and internal influences that affect the performance of capital projects;
- identifies and defines the principal stakeholder perspectives on project performance;
- describes a formal process for developing the PDP through alignment and consensus building.

KEYWORDS:

Capital Projects; Project Definition; Performance Parameters; Influences.

INTRODUCTION

Increasingly, private and public sector owners are seeking higher levels of effectiveness, efficiency, productivity, and profitability in all of their operations, in response to the requirements posed by a global economy, their markets, and their clients in their specific business niche. To achieve these goals, owners depend on the quality and performance of their facilities (e.g., industrial, building, or residential facilities), and also, on the quality and performance of the civil infrastructure projects that support them (e.g., water supply, sewage, waste, gas, electricity, solid waste disposal, communications, etc.). However, in delivering these projects, and then in operating and maintaining them throughout their service life, owners are facing increasingly complex challenges that are forcing a re-evaluation of the metrics, benchmarks, and expectations for life cycle performance in their projects, beyond the conventional parameters of cost, time, quality, and safety. Some of these
challenges include: more limited and tighter economic and financial resources; higher levels of project complexity; rapidly changing technologies that affect both products and processes for the built environment; increasingly restrictive laws and regulations, particularly regarding environmental conservation and protection; and the emergence of international standards such as ISO 9000 and ISO 14000.

To overcome these challenges, owners are seeking new strategies, new processes, and new tools to enhance the effectiveness and efficiency of the delivery and operation of capital projects at all life cycle stages: from initial project definition and planning; through design, procurement, construction, commissioning, and start-up; to operations, maintenance, and the ultimate decision to rehabilitate, retrofit, decommission, de-construct, or dispose, at the end of the project’s service life. As numerous research projects sponsored by the Construction Industry Institute (CII, 2000a) at various universities across the U.S. over the last decade have demonstrated, project definition is crucial to the successful outcome of a project, particularly if it is done well during the early stages of a project, not just as the project evolves.

The findings from these research efforts can be found in numerous publications (CII, 2000b) that address issues, among many others, such as: Scope Definition and Control (Pub. # RS6-2); Project Objective Setting (Pub. # RS12-1); Input Variables Impacting Design Effectiveness (Pub. # SD-26); Work Packaging for Project Control (Pub. # SD-28); Adaptation of Quality Function Deployment to Engineering and Construction Project Development (Pub. # SD-97); Pre-Project Planning (Pub. # SP39-2); Project Definition Rating Index (PDRI) for Industrial and Building Construction (Pub. # IR155-2 and IR113-2); Alignment During Pre-Project Planning — A Key to Project Success (Pub. # IR113-3); and Framework and Practices for Cost-effective Engineering in Capital Projects in the A/E/C Industry (Pub. # IR113-3). An analysis of these CII publications, and other publications from various sources found in the literature, reveals the importance of project definition. This importance is discussed next.

THE IMPORTANCE OF PROJECT DEFINITION

Project definition is the cornerstone of two tasks that are critical for capital project performance. The first task is the ability to influence the project outcome positively, in terms of potential savings in its Total Installed Cost (TIC) at project start-up, and in its Operation and Management Cost (O&M) throughout its service life, through the quality of the decisions and choices made. Figure 1 shows this influence vs. cost curve. These savings will not materialize because, without proper project definition during the planning phase, there is a higher potential for mistakes or bad decisions.

![Figure 1. Project Influence vs. Project Cost](Developed from (Hastak et al., 1998))
The second task is the ability to reduce project risks for the owner, by selecting the delivery system and contract type most appropriate for a capital project, based on the results of a comprehensive risk analysis (to establish types and levels of unacceptable and prudent reversible risks), and of a thorough risk profiling of key project work packages (to establish their level of impact and probability). Figure 2 shows the role of project definition in project risk analysis, profiling, and allocation/distribution, as the basis of delivery system and contract type selection.

As the figure also shows, risk analysis is based on the amount of available Data and Information (D/I), and also, of the available Knowledge and Experience (K/E), on a given capital project. This D/I&K/E stems from six possible sources: the Project Definition Package (PD_{efP}); the Project Team Definition (PTD); the Project Execution Plan (PEP); the Project Design Package (PD_{esP}); the Production Process Plan (PPP); and the Project Work Breakdown Structure (PWBS). These six elements provide the basis for a framework for integrated project definition. This framework is explained next.

**A FRAMEWORK FOR INTEGRATED PROJECT DEFINITION (IPD)**

Integrated Project Definition (IPD) is a complex effort that begins with understanding the perspectives of the key project stakeholders of a capital project (i.e., the Owner, Design, Construction, Vendors/Suppliers, and Operations Teams, and External Parties), and aligning them towards the common goals of the project through a process of team building and consensus building, within acceptable levels of tolerance and well-defined mechanisms for decision-making and conflict resolution. Then, IPD focuses on developing the PD_{efP}, the PTD, the PEP, the PD_{esP}, the PPP, and the PWBS in an integrated way, leading to an Integrated Project Definition Model (IPDM). This model results from coordinating and integrating the outputs from the respective efforts of each stakeholder (i.e., a 3-D model, a cost model, a time model, and a production process model of the...
capital project) into a cohesive whole. It also serves as the basis for procurement and construction of the capital project. The main elements of IPD, project stakeholders and the IPDM, are explained next.

**Project Stakeholders**

As mentioned previously, there are six principal stakeholders in a capital project: the Owner Team, the Design Team, the Construction Team, the Vendors/Suppliers Team, the Operations Team, and External Parties. As shown in Figure 3, these stakeholders interact in different ways throughout the various phases of the life cycle of the capital project.

![Figure 3. Project Stakeholders Perspectives on Performance](Developed from (Molenaar, 2000)]

The first and most important stakeholder is the Owner Team, which is the primary lead in the planning phase and an active participant in all subsequent phases. Their perspective provides the key point of departure for project definition. This team needs to solidly anchor the project within the vision, mission, strategic plan, and business plan of the organization that drive the project, and to clearly define the problem, need, or opportunity that triggered the project. Subsequent teams need to be responsive to the project drivers and trigger. The Design Team, composed of engineers, architects, and other specialty designers, is the primary lead in the design phase, and in some cases, is also involved actively in the planning and/or construction phases. Their perspective ensures that issues that will affect or have a potential to affect the design process are included in the definition of the project, and are addressed in a proactive way in the initial stages of the project. The Team of Vendors and Suppliers for the project mostly is involved actively in the design and construction phases, but can also contribute to the planning and operations phases. Their perspective ensures that issues that will affect or have a potential to affect the procurement process are included in the definition of the project, and are addressed in a proactive way in the initial stages of the project. The Operations Team, composed of users and operators of the facility, is the primary lead in the operations phase, and in some cases, is
also involved actively in the previous phases. Their perspective ensures that issues that will affect or have a potential to affect the operations and maintenance processes are included in the definition of the project, and are addressed in a proactive way in the initial stages of the project. Finally, the External Parties include stakeholders external to the project team who can affect the project delivery and operation in any way. These can include policy-makers, regulatory agencies, financial institutions, insurance and bonding companies, the community and general public, and the media, among others. In many projects, these perspectives tend to be addressed independently, and in a fragmented way. Effective project definition ensures that the perspectives of these six types of stakeholders are defined explicitly, formally, and systematically.

**Integrated Project Definition Model (IPDM)**

Figure 4 shows the complete set of elements that come together as the basis of the IPDM.

Development of the IPDM begins with the definition of the project’s physical context as determined by the project site (i.e., geographical location, surface and subsurface conditions, environmental issues, existing infrastructure, and surrounding activities or assets). In addition, it is necessary to also define the non-physical context that surrounds the project (i.e., community, social, cultural, political, public relations, economic, financial, legal, regulatory, policy, industrial, and technological issues), in order to ensure that the perspective of all external parties is included in the IPDM.

Then, several elements are defined, each ensuring that a specific stakeholder perspective is included in the IPDM: the PD_{O&O}, which includes the Owner and Operator Teams perspectives; the PEP, which includes the supply chain perspective; the PD_{DS}, which includes the Design Team perspective; and the PPP, which includes the Construction Team perspective. In conjunction with these tasks, the PTD establishes the main project team members. Also, as the PD_{DS} and the PPP are developed, the PWBS can be established.
Finally, the IPDM results from the integration of the 3-D model (developed primarily from the PD\textsubscript{efP}), the production process model (developed primarily from the PPP), and the cost and time models (developed from the PWBS), as a cohesive whole. Once fully developed, the IPDM provides the basis for procurement and construction of the capital project.

**PROJECT DEFINITION PACKAGE (PDP)**

Within the framework for IPD described in the previous section, the PD\textsubscript{efP} emerges as the critical element that determines the level of effectiveness and completeness of project definition. The PD\textsubscript{efP} is the result of a formal three-stage process of alignment and consensus building (within acceptable levels of tolerance and well-defined mechanisms for decision-making and conflict resolution), as shown in Figure 5. This process starts with a clear understanding of the vision, mission, strategic plan, and business plan of the organization that drive the project as the point of departure of the project. This establishes the enterprise perspective. Then, during the initial formation stage, the PD\textsubscript{efP} is defined from the Owner Operations Teams Perspectives. During the communication stage, the perspectives of the Design, Construction, and Vendors/Suppliers Teams are formally added to the PD\textsubscript{efP}, as well as the perspective from the key External Parties. The process concludes with the development of the final Integrated PD\textsubscript{efP} during the integration stage.

![Figure 4. Project Definition Process](developed from (Hastak et al., 1998))

The structure of the PD\textsubscript{efP} for a capital project can be represented as a three-dimensional matrix, defined by three elements: (1) six layers, each one representing a different stakeholder perspective for the project, as described in the previous section; (2) a vertical axis with twelve performance parameters that establish the desired level of performance for the project; and (3) a horizontal axis.
with six categories of external and internal influences that affect, or that have the potential to affect, the performance of the project. These last two elements are described next.

**Project Performance Parameters**

The twelve principal short-term and long-term performance parameters for a capital project are shown in Figure 5.

![Figure 5. Project Performance Parameters](developed from (Hastak et al., 1998)]

They can be grouped into four categories:

1. The Product Performance Parameters define in a formal and explicit way: (a) the physical and nonphysical contextual compatibility and response of the project, including compliance with all applicable laws, codes, and regulations, and response to the specific requirements of site conditions and local area context and practices; (b) the desired functional performance of the project, including the effectiveness in serving the people, activities, and processes housed, and in supporting the relationships among them; and (c) the desired formal/physical performance of the project, including the effectiveness of the site layout, spatial solution, and technologies, equipment, materials, and other resources used.

2. The Traditional Performance Parameters define in a formal and explicit way: (a) the desired cost performance of the project, including total installed costs (TIC), operations and maintenance costs (O&M), and life cycle costs; (b) the desired time performance of the project, including total delivery cycle time, and service life span; and (c) the desired performance of the project from a quality and reliability perspectives, including the satisfaction of all current and future stakeholders, and the prevention of partial or total failures.

3. The Delivery Process Performance Parameters define in a formal and explicit way: (a) the desired safety and security performance of the project, including protection of people, property, and the environment, and protection from natural and human-caused eventualities; (b) the desired risk performance of the project, which defines targeted levels of unacceptable and
prudent reversible risks; and (c) the desired performance of the project from a constructability and procurability points of view, and the corresponding levels of input required from these two areas to achieve these goals.

(4) The Life Cycle Performance Parameters define in a formal and explicit way: (a) the desired performance of the project from a commissioning, operability, and maintainability points of view, and the corresponding levels of input required from these two areas to achieve these goals; (b) the desired performance of the project from a health perspective; and (c) the desired sustainability performance, which defines targeted levels of resource use and consumption, waste generation and accumulation, and environmental impact.

Influences on Project Performance
The six principal categories of influences that affect or can affect the short-term and long-term performance of a capital project are shown in Figure 6.

These influences are:

(1) The set of project characteristics, which define the specific features, attributes, and qualities of the capital project as defined by the project’s industry sector (i.e., heavy/civil construction, industrial construction, building construction, residential construction, and land/real estate development), and by project type (i.e., new greenfield, and brownfield facility development projects; rehabilitation of deteriorated facilities to correct the effects of natural deterioration; retrofit of existing facilities to modify, expand, and/or upgrade them; emergency recovery projects to correct the effects of natural or human-caused disasters; projects to restore/ preserve/protect existing facilities with historical or cultural value; projects to correct environmental problems affecting, or caused by, existing facilities; and decommissioning, deconstruction or demolition to dispose of existing facilities).

(2) The set of project objectives, which define the integrated set of goals and objectives for the project, from an institutional, sub-organizational units, functional groups, individual team members, and external stakeholders perspectives.

(3) The project scope, which defines the project’s specific needs (primarily quantitative data and information), facts (constraints), preliminary concepts or strategies for achieving the goals,
satisfying the needs, and working within the facts, and areas of potential problems and opportunities.

(4) The physical context of the project, which defines the project’s geographical location, surface and subsurface conditions, environmental issues, existing infrastructure of utilities and services, and surrounding activities and assets.

(5) The non-physical context of the project, which defines the community, social, and political issues, and public relations, economic and financial issues, legal, regulatory, and policy issues, and industrial and technological issues, including the availability of labor, materials, equipment, and technologies that surround the project.

(6) The set of project risks, which defines the impact and probability of risks stemming from products used and processes followed in the project, risks stemming from the contract terms and conditions, and risks stemming from construction operations, processes and activities.

Project Definition Matrix

As mentioned previously, the structure of the PDefP for a capital project can be represented as a three-dimensional matrix, defined by the three elements described previously: (1) the six layers of stakeholder perspectives for the project; (2) the vertical axis of twelve performance parameters that establish the desired level of performance for the project; and (3) the horizontal axis of six types of external and internal influences that affect, or that have the potential to affect, the performance of the project. This matrix is shown in Figure 7.

![Figure 4. Project Definition Matrix](developed from (Hastak et al., 1998))
CONCLUSION

This paper provides private and public sector owners of both facilities and infrastructure projects, with a strategy, a process, and a tool to enhance the effectiveness and efficiency of the delivery and operation of capital projects at all life cycle stages. Owners that invest in thorough project definition will have a foundation for enhanced capital project performance, such as increased effectiveness, efficiency, productivity, and profitability. Thorough project definition can influence the outcome of a project in positive ways, particularly in helping achieve potential savings in its TIC, and in its O&M cost, avoiding the negative consequences of mistakes or bad decisions. In addition, project definition can help reduce project risks for the owner, by selecting the delivery system and contract type most appropriate for a capital project, based on the results of a comprehensive risk analysis, and of a thorough risk profiling of key project work packages.

At the same time, Owners need to acknowledge that integrated project definition is a complex effort that (1) begins with the understanding and alignment of the perspectives of the key project stakeholders of a capital project; (2) continues with the development of the PDedefP, the PTD, the PEP, the PDaP, the PPP, and the PWBS for the project, in an integrated way; and (3) concludes with an IPDM that brings together the 3-D, cost, time, and production process models of the project into a cohesive whole. This effort requires an investment of time, money, and effort that traditionally is not done. However, the benefits of thorough project definition far exceed its costs.

Finally, through the formal, explicit, and systematic process of alignment and consensus building, within acceptable levels of tolerance and well-defined mechanisms for decision-making and conflict resolution definition, Owners can establish the various stakeholder perspectives for the project, can define the twelve performance parameters that establish the desired level of performance for the project, and can define the six types of external and internal influences that affect, or that have the potential to affect, the performance of the project. The resulting PDedefP will increase the potential for Owners of reaping the benefits of increased effectiveness, efficiency, productivity, and profitability in the delivery and operation of their capital projects at all life cycle stages.

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