



Construction Industry Institute®

Input Variables Impacting Design Effectiveness

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Not printed with state funds

Input Variables Impacting Design Effectiveness

**Prepared by
Construction Industry Institute
Design Task Force**

**Publication 8-2
July 1987**

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The University of Texas at Austin.

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Printed in the United States of America.

First Printing July 1987

Second Printing April 1990

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SUMMARY

Design is a complex process involving the reconciliation of competing objectives and constraints, and is a major determinant of project success. Decisions that are made at early phases, including project initiation studies, the design contract, and basic engineering, have the highest influence on the project. These decisions and other constraints form input variables to design. Over 40 input variables were identified during the research effort that is the basis of this publication. The 10 input variables identified as having the greatest impact on design effectiveness are:

- Scope Definition
- Owner Profile and Participation
- Project Objectives and Priorities
- Pre-Project Planning
- Basic Design Data
- Designer Qualification and Selection
- Project Manager Qualifications
- Construction Input
- Type of Contract
- Equipment Sources

Design effectiveness is measured by design outcome parameters. The research identified 25 outcome parameters. The following seven were correlated with the 10 inputs, and then were used to weight their impact on design effectiveness.

- Final Project Schedule
- Constructability
- Quality of Design
- Final Project Cost
- Plant Start-Up
- Performance
- Safety

The research methodology included analysis of design procedures, and extensive data from four projects and summary data from 16 projects. The research objectives included: (1) subjective correlation of the input variables with the design outcome parameters; and (2) the development of recommendations to modify the negative impacts of the input variables. To attain these objectives, heavy participation by the industry was sought throughout the research. Additionally, owners, designers, and constructors from 21 companies participated in an experts' workshop to exchange views, rank the input variables, assess their impacts on various design outcome parameters, and make recommendations to influence in a positive manner the inputs.

Recommendations for influencing each input variable are presented separately. When taken together, these recommendations can be used as a guide on design effectiveness.

Several conclusions are made, among which are the following:

1. The owner, by far, is the major contributor of design input variables.
2. If early input variables are handled properly, other variables later in the project are positively impacted. Therefore, input variables must be properly managed as early as possible.
3. Companies can identify input variables to their type of projects and organizations, and develop steps to moderate the negative impact of these variables.
4. Owners should carefully identify project objectives and priorities so design outcome parameters will not compete and thereby reduce design effectiveness.

INTRODUCTION

Design is a complex and creative process in which the interplay of numerous factors, including physical, financial, and environmental constraints and technical and managerial knowledge, harmonize and result in plans, specifications, and models that are aimed at satisfying the owner's project needs. Effective design is the product of effective teamwork among the owner, the designer, and the construction contractor.

Design effectiveness is greatly influenced by pre-design and early design activities, when various input variables that may affect the entire design are fixed. Although the importance of these design input variables is generally recognized, their sources and behavior are not well established. This publication attempts to find answers to questions such as: (1) What variables have an important influence on design effectiveness and what are their sources? (2) How do the variables relate to each other and to the outcome of design? (3) What outcome parameters can be used as a practical measure of design effectiveness? (4) How do input variables impact design effectiveness and at what level? (5) How can the industry identify, control, and moderate the negative influences of these input variables? (6) What recommendations concerning input variables can be given to the industry to increase design effectiveness?

By analyzing data from several projects and by working closely with owners, designers, and contractors, the most important input variables were identified and defined. Design effectiveness also was defined, and parameters for measuring the design outcome were selected. The impact of the input variables on design effectiveness was assessed. These input variables were ranked according to the relative magnitude of their impact. The impact of each of these input variables on a particular outcome parameter also was determined. Owners, designers, and contractors provided over 60 recommendations on how best to manage the input variables in order to achieve more effective designs. More detailed information may be found in two related source documents available from CII (see References).

INFLUENCE OF EARLY DECISIONS

Many of the decisions made in the early phases of a project will have the greatest influence on that project as a whole. This phenomenon is expressed in Figure 1, which shows the changing influence of decisions throughout a project's life cycle. Typically, the level of influence of decisions decreases rapidly after the basic engineering phase because decisions made in the earliest phases of a project represent major commitments of resources. The activities that occur during these phases, such as scope definition, designer qualification and selection, and basic data development, can be thought of as *input variables* to the design function. More specifically, an input variable may be any action, event, or circumstance that directly or indirectly affects design.

The owner is a major contributor of the input variables, although the designer, the constructor, and certain key vendors may also contribute input variables as well. An example of an early input variable is the owner's budget, which is set during the early stages of project definition, even if the budget only consists of crude estimates. Surveys made during The Business Roundtable Construction Industry Cost Effectiveness (CICE) study indicate that owners often have unrealistic expectations for the accuracy of these figures.²

How well the design input variables are managed and executed will determine the overall effectiveness of design. Some input variables can affect other input variables. Thus, if the first input variables that occur in a project are handled correctly, then any variables that follow are more likely to have a positive impact on design effectiveness.

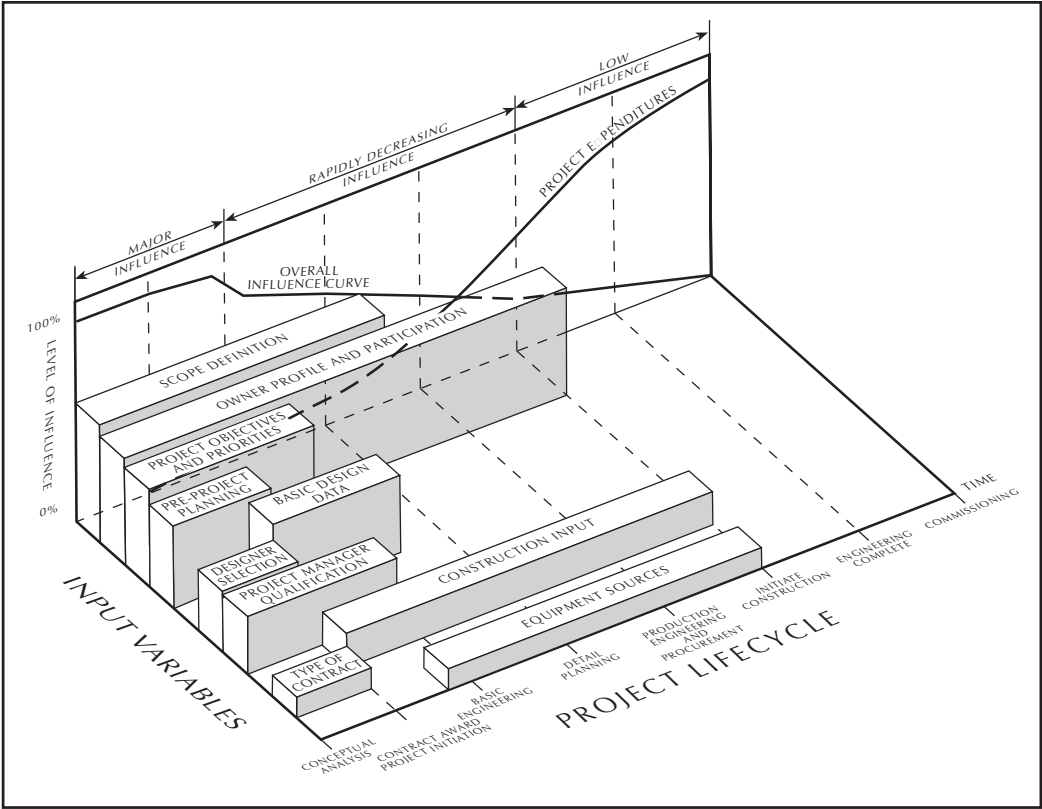


Figure 1. Initial Design Evaluation Criteria

INPUT VARIABLES AND DESIGN EFFECTIVENESS

The input variables that have the highest influence on design effectiveness often occur before design is initiated. Therefore, the owner is the primary source of input variables. The designer, certain key vendors, and the construction contractor also supply input variables to the design function, but to a lesser extent.

Over 40 input variables with a potential for impacting design were identified. One goal of the research, however, was to reduce systematically the number of variables by studying their correlations. Ten independent input variables survived this test, and their effects on design effectiveness were studied in greater detail.

Design effectiveness describes the relative success or failure of a particular design. The definition offered herein was developed with the aid of owners, designers, and construction contractors from a large number of CII member companies.

Design effectiveness is an all encompassing term to measure the results of the design effort, including input variables and design execution, against the specified expectations of the owner; the owner's expectations include such criteria as cost, schedule, quality, and others either explicit or implicit in the project objectives.

Assessing the impact of an input variable on design effectiveness requires measurable design outcome parameters. A questionnaire to CII member companies produced approximately 40 outcome parameters. Additional analysis and discussions with industry resulted in the list of outcome parameters presented in Appendix C. Seven of the outcomes, those most commonly used to measure design effectiveness throughout industry, were selected for this project.

Design effectiveness may be measured at two points in the project life cycle: (1) during project execution; and (2) after several years of operation. The latter is outside the scope of this report.

THE PROBLEM AND THE APPROACH

The need to understand and control variables having the potential to impair design effectiveness is unquestioned. Recognizing the magnitude of the problem, the research scope for this presentation included:

- Identifying the sources and types of input variables that have a large influence on design
- Correlating these variables with the outcome of design
- Determining the relative impact of each input variable studied
- Recommending factors that positively influence the input variables

Accomplishing these objectives required that the research scope include not only the examination of project initiation and pre-design planning phases (where the input variables are concentrated), but also early design phases and final design outcome. Additionally, the research approach needed continuous heavy industry participation to be successful. More than 80 professionals representing owners, designers, and construction contractors participated in the research efforts. Contributions from 21 CII member companies are summarized in Appendix D. As a result of this high level of participation, this report represents the views and judgment of numerous experienced professionals from various sectors of the industry.

SELECTED INPUT VARIABLES AND DESIGN OUTCOMES

Input Variables

Ten design input variables having a major impact on design effectiveness were identified from an extensive list gathered in the early stages of the research. These 10 variables are discussed below according to the magnitude of their impact on design.

1. *Scope Definition.* Preparation of the scope of work is primarily the responsibility of the owner and/or the owner's representative. The scope contains the work description and the intended operation of the facility. The scope of work establishes the basis for project plans, budgets, schedules, and reference points for later evaluation of results. Generally included in scope definition are: (1) type of project and description of facility; (2) process description, capacity, and product type and quality; (3) Basic Data availability and data available from previous projects; (4) primary and secondary objectives and priorities; (5) description of new state-of-the-art process equipment; (6) references on process fluids, materials of construction, and type of instrumentation; (7) automated system requirements and software development, if any; (8) description of any need to alter normal construction sequence; and (9) alternates being considered and their potential impact on scope.
2. *Owner Profile and Participation.* Owner participation is considered to be the quality of the owner's contribution and his readiness when that contribution is required. Each owner has unique qualifications, attitudes, and experience which describe his "owner profile." This profile includes the owner's management capabilities, decision timing, attitude toward and management of changes, project personnel continuity policy, construction and design experience, and the role the owner assumes in design and construction.
3. *Project Objectives and Priorities.* Project objectives should describe clearly what aspects are important to the owner and may include: (1) operational safety priority, unusual known hazards, and environmental requirements; (2) attainment of capacity, start-up guidelines, and cost; (3) level of technology; (4) utility, continuity, and spare equipment guidelines; (5) investment returns expected and priorities of investment vs. risks in operating cost,

capacity, utility, and quality; (6) project timing, transmittal dates and critical schedule milestones; and (7) expendability, aesthetics, expected life, and other related parameters.

4. *Pre-Project Planning.* Carried out by the owner and/or his representative (consultant), pre-project planning translates objectives and priorities into desired end results by defining what resources, methods, actions, and sequences are required, and establishes a framework for monitoring and controlling progress. It often includes various studies, selection of a designer, project organization, construction and procurement strategies, required operations and maintenance input, and selection of location as well as determining what other functional input might be required early in design. The most important documents in terms of fixing the input variables for the project are developed during the proposal stage.
5. *Basic Design Data.* Preparation of the basic design data is primarily the responsibility of the owner. Quality of basic design data includes firmness, completeness, and correctness. Basic data may consist of: (1) general plant identification, location, and structure of owner's organization; (2) general project summary; (3) process description, safety, quality, automation, software, maintenance requirements, and construction materials; (4) specific requirements of design, start-ups, shutdowns, site requirements, and handling of materials; (5) environmental data, waste disposal requirements, and safety; (6) utility, operation, and start-up and maintenance cost considerations; (7) general service and yard facilities; and (8) process flow sheets, supporting data, and other information, if applicable.
6. *Designer Qualification and Selection.* The designer is an important contributor to the input variables. A designer may be selected because of: (1) organization; (2) experience with similar projects; (3) knowledge of the technology; (4) project manager and project team qualifications; (5) pricing of services and proposed contract; and/or (6) design approach, capacity, readiness, and computer facilities.
7. *Project Manager Qualification.* The owner's project manager, representing the owner, is the individual responsible for successful project execution. His functions include: (1) heading the project team representing the owner; (2) guiding and coordinating the activities of all departments; (3) setting the goals and defining the project strategy; (4) obtaining the needed data; (5) identifying the problem areas and assigning responsibility; (6) maintaining communications and liaison with the owner; and (7) controlling the execution of the project.