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The Power of Design–Build

A Guide to Effective Design–Build Project Delivery Using the SAFEDB-Methodology

Sherif Hashem

BEP BUSINESS EXPERT PRESS

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To all fellow construction academics and practitioners all over the world who strive to grow and advance the construction project management profession at large.

To my dear father Attorney Fouad Fawzy Hashem (RIP), my dear mother Hoda Hanem Zein Eldin, my dear wife Laila Abdel Moneim Ayad (RIP) who stood by me while writing this book, and my dear sons Omar Hashem, Ahmed Hashem, and Karim Hashem with my best wishes to them for a brilliant future.

Abstract

Design–build is a powerful project delivery approach. Actuating such power, however, requires special skill and know-how, and is indeed a trade secret. This is what this book is all about. It provides the design–build professionals and academics with critical design–build knowledge and know-how, as well as with a practical and academically validated innovative design–build methodology, namely, the SAFEDB-methodology. The SAFEDB-methodology consists of three key components, namely, develop design–build solutions, fast-track design–build activities, and control design–build progress. The first component is concerned with evaluating candidate design–build options and selecting the most effective design–build solution. The second component looks deep into overlapping design and construction activities and introduces an effective overlapping strategy enabling maximum safe schedule compression. The third and last methodology component focuses on enhancing the design–build schedule reliability by taking into account potential schedule branching and inadvertent rework loops in a structured and proactive manner. The book is designed to provide the reader with actionable skills that can be applied in real-world business situations. It presents the SAFEDB-methodology in a clear, practical, and step-by-step manner, providing practical examples for the application of the methodology in real-life projects. It also provides a review of the design–build history, how to shape the design–build team, guidelines to winning the design–build competition, connection to the Project Management Institute's (PMI) *Project Management Body of Knowledge Guide* (*PMBOK® Guide*) project management model, in addition to cutting-edge design–build best practices and tricks of the trade for various civil engineering applications and project situations.

Keywords

axiomatic design, concurrent engineering, construction management, design–build, fast-track projects, GERT, *PMBOK® Guide*, project delivery, project life cycle, project management, project planning, project scheduling, risk management, SAFEDB-methodology, value engineering

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Preface

This book hits the high points of the design–build project delivery approach. It aims to actuate the power inherent in the process. The content of the book represents the outcome of the author's over two decades of practical experience and theoretical research and observation of the best practices and key pitfalls in the application of design–build in civil engineering projects. The book is designed to serve design–build academics and practitioners, the seasoned and the new to the process. It introduces an expert review of the key aspects of the design–build process at large, as well as an innovative design–build project management method, namely, the SAFEDB-methodology. The full benefit of the book is achieved by reading it as a whole; however, each part of it is designed to stand alone to convey a concept or provide a practical project management tool. It is worth mentioning that the author of this book is a co-author and formal contributor of the Project Management Institute's project, program and portfolio management global standards.

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I would like to thank Professor Dr. Ing. Gerhard Girmscheid at Zurich ETH University, Professor Dr. Donald N. Stengel at California State University, and Mr. Eric Jenett (RIP), the Project Management Institute (PMI) founder and PMI Project Management Professional No. 1, for their feedback, encouragement, and appreciation of this work.

I would also like to thank the Business Expert Press team, in particular Mr. Scott Isenberg, the executive acquisitions editor, for giving me the opportunity to publish this book, as well as for their vision and relentless commitment to bring the finest-quality knowledge and expertise to readers in the United States and all over the world.

PART I

Introduction to Design–Build: Process Definition, Design–Build Project Management, and Design–Build Best Practices and Success Strategies

CHAPTER 1

Design–Build: The Pathway from Vision to Reality

Preface

This chapter provides an overview of the design–build project delivery approach and begins with the definition of the design–build process and a review of its origin and evolution. In contrast to the common belief, design–build is neither a new nor a revolutionary process, but indeed the natural and sensible way of delivering construction projects. For a better understanding of the process, a comparison between design–build and the traditional design–bid–build methods is presented. It is the difference between how projects are delivered in each method that makes the difference in project results and what gives design–build the competitive edge. The chapter then moves on to address practical topics and common issues related to design–build. It provides guidelines for the selection of design–build as the way to go in the first place. Design–Build is not necessarily the best fit for all types of projects. Another presented practical topic is the distinct roles and responsibilities of the various parties in the design–build environment. Design–build requires a change in traditional functional roles, responsibilities, and indeed the mindset as compared to the traditional project delivery method. The chapter also highlights the power of the design and its unique inherent features mechanisms, which make the difference and enable achieving superior project results. Finally, the chapter presents a holistic review of the construction industry in the 21st century covering the status quo and the expected and recommended further advances in the years and decades ahead.

1.1 What Is Design–Build?

Design–build is a project delivery approach in which both project design and construction undertakings are carried out by a single entity. Design–build is currently the fastest-growing project delivery approach in the construction market in the United States and all over the world.

The secret behind such popularity of the method lies in the additional power it generates vide joining the forces of design and construction teams to design and construct structures, resulting in benefits to the Owner and the profession that cannot be achieved by completing the design and construction tasks separately. In today's construction marketplace, the traditional approach of delivering construction projects involves the appointment of a design firm to complete the project design drawings and specifications, and then soliciting bids from construction contractors and appointing a contractor to construct the works based on the completed design.

The design–build project delivery route changes and simplifies such approach. It involves appointing a single design–build entity to design and construct the works through a single design–build contract stating project scope and providing a high-level conceptual design and project-specific requirements of the Owner. The design–build entity becomes then responsible and liable for both the design and construction aspects of the business. The design–build scope of work typically involves developing the project conceptual design and Owner's requirement into detailed design and detailed specifications, obtaining construction permits, producing construction documentation, and completing all temporary and permanent constructions all the way down to construction completion, testing, commissioning, and handing over the completed project to the Owner. The design–build entity then becomes responsible for the performance of the completed works as well as for any defects that might appear in the works during an agreed defects liability period due to design or construction deficiencies, or both.

The Design–Build Institute of America defines Design–Build as a method of project delivery in which a single design–build entity works under a single contract with the project Owner to provide design and construction services. The design–build approach is also known in the construction industry as design and construct, engineering, procurement and construction (EPC), and turnkey.

The power of design–build stems from its ability to actuate certain inherent energies and capabilities otherwise squandered in other project delivery methods. This however requires the use of specialized knowledge and know-how to reap the benefits of the process. This is what this book is all about.

1.2 History and Evolution of Design–Build

Contrary to popular belief, design–build is neither a new nor a revolutionary approach.

Indeed, it is the oldest known form of building construction in the human history. After all, code of Hammurabi (1800 BC) addressed the design–build approach in assigning the ancient "master builders" absolute responsibility for both design and construction. Design–build is therefore regarded as a continuation of the "master builder" approach in which the ancient master builders, the architect or the built environment, used to be entrusted by Owners to design and construct buildings being totally and solely responsible for both the design and construction aspects of the process.

Famous examples of historical design–build works from the world's first civilizations include the Giza pyramids of Egypt (2675 BC) and the more recent Florence Cathedral in Italy (1296 AD). In fact, the vast majority of historical buildings and architectural landmarks were indeed delivered by the ancient master builders using the design–build project delivery approach.

Design–build continued to prevail and became the standard of project delivery in the construction industry until the 14th century. The first split of design from construction took place in Europe in the wake of the Industrial Revolution as a result of mechanization and the increased specialization in both the architectural design and the building construction aspects of the process. The first such split is attributed to the Italian Architect Leone Battista Alberti (1404–1472 AD) who recommended that the architect can and indeed should separate from the builder, and managed to convince his Owner to go that way. The product was the façade of the

Santa Maria Novella Church, the first system in history known to have been designed and built by two separate entities.

From this point on, the split-up between design and construction started to propagate, and over the years, it became the norm in project delivery. A first remarkable symptom of such propagation has been the establishment of professional societies for construction engineers, starting with the Society of Civil Engineers founded in the United Kingdom in 1771 AD, and other separate societies for construction contractors. In the interim, the split-up propagation has gradually taken its way to other aspects of the industry and continued to take place resulting in what we see nowadays from separate design and construction forms of contracts, separate codes and standards, and even separate engineering educational systems.

The first major comeback of the design–build approach took place late in the 19th century on the back of the spectacular Brooklyn Bridge, one of the largest suspension bridges in the United States, designed and built in New York City by the master builders John Augustus Roebling and his son Washington Roebling, and completed in 1883 AD.

The 20th century has seen a remarkable spread of the design–build project delivery approach all over the world, especially in the field of major infrastructure and heavy civil engineering projects. According to recent studies, around 50 percent of the major nonresidential construction projects in the United States and the European Community in both the private and public sectors are indeed delivered using the design–build method. The 20th century has also seen the establishment of the first ever design–build society, that is, the Design–Build Institute of America (DBIA). DBIA was established in 1993 AD in Pennsylvania, USA. Its membership encompasses both design and construction professionals, in addition to academics and project Owners. The DBIA is the world's leading organization that defines, teaches, and promotes best practices in the design–build industry.

1.3 Design–Build Versus Other Project Delivery Approaches

Construction projects can be delivered using a variety of project delivery approaches.

The basic concept behind the design–build project delivery approach can best be understood by comparing it to other traditional construction project delivery approaches. At the moment, the most popular project delivery approaches world-wide in addition to design–build are design–bid–build approach and construction management (CM) approach, which are indeed an add-on set of services to the first two approaches rather than a distinct project delivery approach as discussed later in this section. The following paragraphs describe and discuss the three concepts at a somewhat high level, addressing their philosophy and components, key advantages and disadvantages, and comparing the design–build to design–bid–build approaches; so the benefits of the design–build approach become more explicit.

1.3.1 The Design–Build Project Delivery Approach

In the design–build project delivery approach a design–build contractor is responsible for completing the project's detailed design and the physical construction of the project under a lump-sum fixed price agreement and within a fixed time frame. The Owner translates his functional, quality, serviceability, design criteria, and end-product performance requirements into a high-level tender document or request for proposal (RFP) consisting of terms of reference, programmatic requirements, outline specifications, and a set of conceptual design plans. This is usually undertaken through an outsourced design consultant, commonly termed as the bridging consultant, as he bridges the gap between the Owner and the design–build entity. The bridging consultant assists the Owner in making sure that his vision and requirements are adequately documented in the tender documents and in supporting the competitive tendering and award process.

Once the design–build contract is awarded, the design–build contractor becomes responsible and liable for both the design and construction aspects of the business, ensuring site safety and appointing his own subcontractors, suppliers, independent design checkers, independent quality control parties, and specialist consultants in addition to his other responsibilities under the contract. This single-source scenario lowers the risk to the Owner and provides the design–build entity with the flexibility to develop the design and construct the project both effectively and efficiently.

In large civil engineering projects, the formation of the design–build entity can take various shapes and forms, commonly a team of a construction entity and a design consultant with the construction entity as lead.

As a result, projects can be completed faster, as the Owner saves the time to prepare the detailed design and at a lower cost as the design–build entity is in control of the design and hence will try his best to price and build the project at the lowest cost possible. Any errors or omissions in the design, construction, or both would rest with the design–build contractor with no entitlement for time, cost, or both compensation. During construction, the Owner involvement shall be limited to high-level oversight using his own in-house resources supported by a trusted consultant to interface with the design–build contractor, administer the contract, monitor progress, safeguard Owner's interests, and resolve any issues that may arise during the course of the contract. The oversight consultant would usually be the original bridging consultant who is most familiar with the Owner requirements and the design intent. Design–build is the suitable and recommended project delivery approach if the project is time sensitive and if the Owner's primary focus is on the end product's performance and functionality rather than end-product looks and aesthetics.

Figures 1.1 and 1.2 provide a high-level overview of the design–build approach and life cycle.

1.3.2 The Design–Bid–Build Project Delivery Approach

In the design–bid–build project delivery approach the process starts with the Owner appointing a design consultant under a design professional services agreement to prepare a detailed tender documentation or RFP including detailed design plans, detailed specifications, terms of reference, and programmatic requirements. In a second step the tender is floated and a contractor is selected usually with the assistance of the design consultant who would support the competitive tendering and contract award process. In design–bid–build, the professional liability for the design rests with the consultant; however, he is not party to the construction contract executed between the Owner and the contractor. Therefore, on entering into a construction contract with the contractor, the Owner indeed warrants the sufficiency and correctness of the design documents and assumes liability for

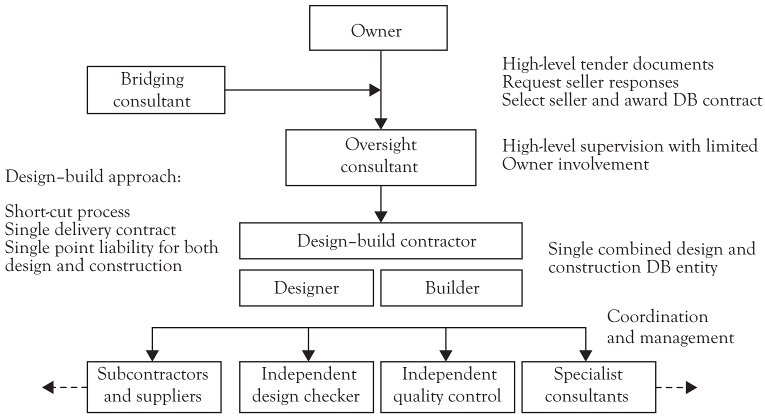


Figure 1.1 Overview of the design–build project delivery approach

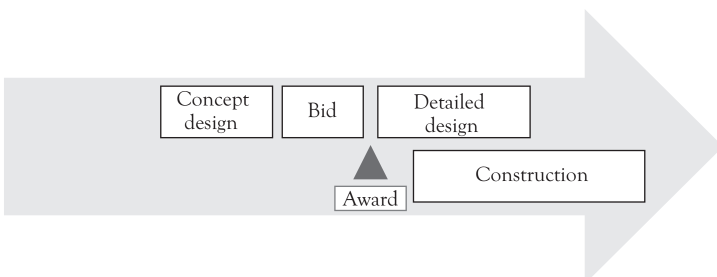


Figure 1.2 Overview of the design–build approach life cycle

defects in them. Once the construction contract is awarded, the construction contractor becomes responsible for the construction of the project in strict compliance with the tender documents, signed contract, and the stipulated contract price and time frame. The contractor shall be responsible to construct the project, mobilize resources, procure materials, ensure site safety, perform quality control, and appoint subcontractors and suppliers. He will be liable to construct the project safely in accordance with the contact documents; however, he will not be liable for design inadequacies or shortcomings. Any errors or omissions in the design information included in the tender documentation will be the Owner's responsibility and furthermore will automatically entitle the contractor to the additional time and or cost required to rectify such errors and omissions. During the course of the contract, the Owner and the design consultant will remain responsible to provide clarifications on the design intent and answer any technical queries that may be raised by the contractor. Moreover, in design–bid–build, the Owner would need to appoint a supervision consultant to provide a team of site supervision engineers and technicians to ensure that the design is implemented properly, answer technical questions, review the contractor material and shop drawing submittals, check the particulars of the contractor's work on a day-to-day basis, and conduct detailed contract administration in addition to his other responsibilities under the contract. Despite the lengthy process, high coordination efforts, and multiple contracts being required to deliver the project, design–bid–build remains the preferred project delivery approach if the project is not particularly time sensitive, and if the Owner wants to remain involved in developing the project design and influencing the end product's details and aesthetics.

Figures 1.3 and 1.4 provide a high-level overview of the design–bid–build approach and life cycle.

CM is not really a project delivery approach in itself, but an add-on set of services that can be used by the Owners to manage any combination of design–build and design–bid–build projects. Construction management services include preparation and coordination of bid packages, scheduling, cost control, value engineering (VE), evaluation, preconstruction services, and construction administration. Another form of CM is the construction management at risk (CMR) in which the construction manager guarantees to the Owner the cost of the project or projects in what's

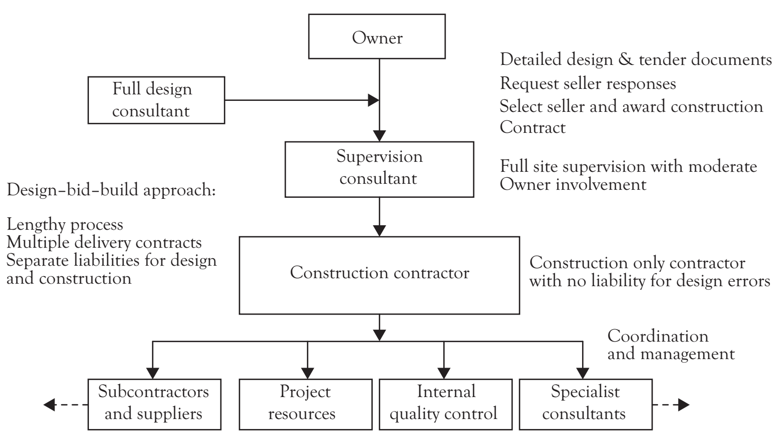


Figure 1.3 Overview of the design–bid–build project delivery approach

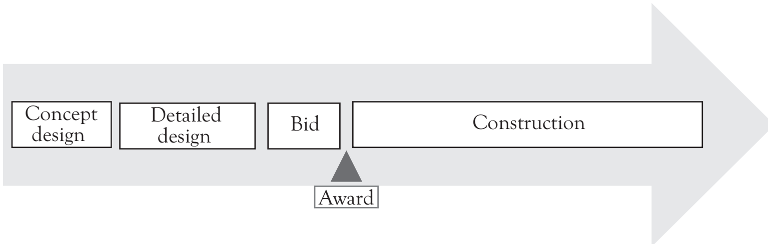


Figure 1.4 Overview of the design–bid–build approach life cycle

commonly termed as GMP or guaranteed maximum price agreement. Construction management services are invariably provided by a construction manager who would be a person, corporation, or entity directly appointed by the Owner to provide construction management services. Depending on the prevailing jurisdiction, the construction manager shall have a basic legal form such as a trade license or commercial registration; however, design services for any project shall be performed by a licensed architect or engineer and the Owner shall contract directly with the architect or engineer. In recent years, and in the wake of the popularity and the widespread use of project management, CM has started taking new designations and labels such as Project or Program Management Consultancy (PMC) and Project Management and Construction Management Consultancy (PMCM), which provide the same set of construction management services, however, adding to them certain more strategic project management services, roles, and functions primarily related to linking corporate strategy to operations and applying modern portfolio, program, and project management standards and methodologies.

Figure 1.5 provides a high-level overview of the CM approach.

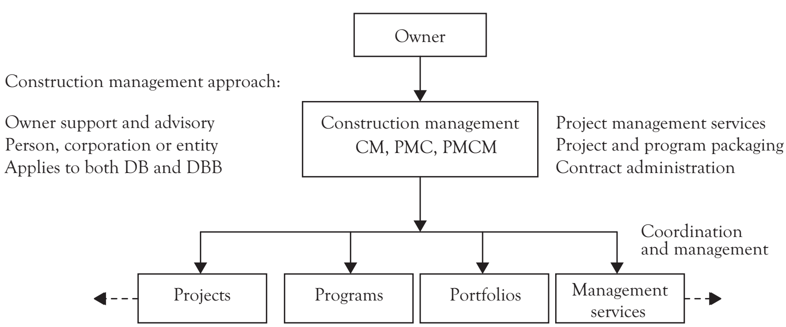


Figure 1.5 Overview of the construction management approach

1.3.3 Comparison of the Design–Build and the Design–Bid–Build Approaches

The fundamental advantage of design–build over design–bid–build is its ability to deliver projects faster. The design–build time saving (TS) is achieved through overlapping design and construction periods. The typical project delivery elements remain the same in both approaches, namely design, bidding or award, and construction; however, the order of implementing such elements varies as shown in Figure 1.6. The project delivery's schedule shortening also results among other factors, including the collaboration of design and construction teams, in project delivery cost saving (CS). Figure 1.6 illustrates how such TS or project overall delivery time shortening is achieved.

Moreover, Table 1.1 provides insights and a comparison of the key parameters, conditions, and practical issues related to the design–build and design–bid–build project delivery approaches.

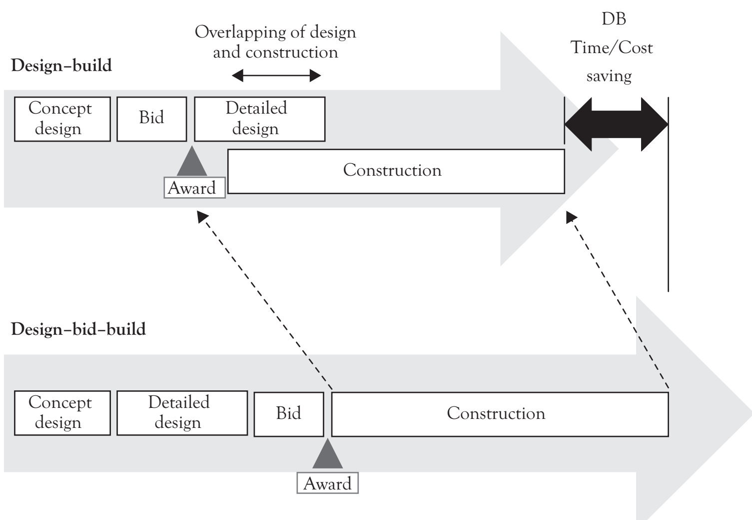


Figure 1.6 Comparison of design–build and design–bid–build time lines

Table 1.1 Comparison of design–build and design–bid–build parameters and practical issues

Phase	Design–build	Design–bid–build
Tendering and award Phase	Single-point of responsibility for the works by the designer and the builders, thus less difficulty in attributing design and or construction faults after completion	Dual points of responsibility, one for design and another for construction, thus a higher probability for dispute should faults occur after construction
	Invariably awarded through a lump-sum fixed-price type of contract, which offers greater certainty as to final cost	Could be lump-sum fixed price or re-measured unit price type of contract with less certainty as to final cost
	Cost of design professional services borne by the design–build contractor	Cost of design professional services borne by the Owner
	Price comparison during tendering and award can be tricky as the technical proposals submitted by the design–build tenderers can vary in value to the Owner for the money invested	Price comparison during tendering and award is simple and reasonable as pricing is based on a specific set of plans and specifications
	Design–build contracts require to be very carefully drafted to fully and clearly reflect the Owner's requirements in order to ensure that the outcome end product is as envisioned by the Owner	Design–bid–build contracts are usually fully detailed including a full design of the end product, thus a higher certainty that the Owner will get what he wanted
	The cost of developing a design–build tender can be substantial, and will probably be included in the tenderers lump-sum bids	The cost of developing a design–bid–build tender can be reasonable as quantities of the final design are fixed
	Requires special design–build contract forms describing the roles and responsibilities of the parties in a design–build environment	Can utilize any of the well-established forms of contract for traditional construction-only projects

(Continued)

Table 1.1 Comparison of design–build and design–bid–build parameters and practical issues (Continued)

Phase	Design–build	Design–bid–build
Design and construction phase	In the event of major design defects being discovered in the completed project, the Owner will have access to substantial financial resources through the design–build contractor to cover his claim.	In the event of major design defects being discovered in the completed project, the Owner will only have access to a limited financial resource of the designer's professional liability insurance
	A substantial loss in Owner's control inevitably takes place during design and construction of the project	A high level of Owner's control during the design and construction phases of the project
	Design by the same party responsible for construction, thus a single-point joint and several responsibilities and clarity in attributing any faults in the works	Design by the design consultant who remains liable for any design faults discovered during or after construction
	Design takes account of the preferred construction means and methods, thus leading to speedier and economical construction	Design assumes or dictates certain construction means and methods that might restrict construction options
	Cost of design professional services borne by the design–build contractor	Cost of design professional services borne by the Owner
	Design by the same party responsible for construction, thus a single-point joint and several responsibilities and clarity in attributing any faults in the works	Design by design consultant who remains liable for any design faults discovered during or after construction
	Design takes account of the preferred construction means and methods	Design assumes or dictates certain construction means and methods
	Speedier and more economical design and construction project delivery	Longer time and higher cost design and construction project delivery

1.4 Guidelines for Adopting Use of the Design–Build Approach

In spite of the immense advantages of the design–build project delivery approach, it is not necessarily and unconditionally the best choice for Owners in all cases and for every project. For instance, FIDIC (The International Federation of Consulting Engineers) recognizes the design–build delivery system as a sound approach to the construction, but does not unconditionally recommend it above other systems. There are cases where the traditional design–bid–build project delivery approach would be the better way to go. Design–build must not be used without regard to its suitability and associated risks, nor should it be used as a substitute for proper project planning and due diligence. The Owner's team should have sufficient knowledge, experience, and capacity to take an informed and well-thought decision with regard to selecting and adopting the best and most suitable project delivery approach. The following points aim to aid the Owner's team in this regard through a range of guidelines and practical considerations surrounding this matter. Points are expressed in the form of common design–build risks and proposed mitigation strategies. They would serve as a checklist for Owners in the process of adopting design–build.

1. Project type and nature

   In design–build, requests for proposal (RFPs) are typically brief, consisting of a set of conceptual design drawings, design criteria, and outline specifications focusing on the end-product performance requirements. The design–build entity is then required to develop the project's detailed design and construction methodology in any suitable way that satisfies the RFP. In highly aesthetical projects, the risk is that the actual end product may differ from that wished for by the Owner, despite its compliance with the RFP requirements. A mitigation strategy would be to make the RFP more detailed and crystal clear as to the Owner's vision of the appearance of the end product. That would be achieved by including in the RFP a somewhat developed design such as preliminary design (40 percent to 60 percent) instead of the typical less-detailed conceptual design (20 percent to 30 percent), in addition to highly visual means such as three-dimensional (3D) perspectives. If the

Owner's vision and expectations are still too complicated to describe in the said way, it would be safer to complete the detailed design through a design consultant and to go for the traditional design–bid–build method. An example for adopting design–build would be a water-treatment-plan project, whereas an example for adopting design–bid–build would be a theater or an iconic high-rise building.

2. Local market design–build maturity
   Certain design–build projects require experienced design–build firms with vast experience in the project's application area. If an adequate number of such firms are not available locally and willing to participate in the tender competition, this would limit the efficiency and suitability of adopting the design–build approach. A mitigation strategy would be to invite qualified international design–build firms, to simplify the proposal submission requirements, to change the project's procurement strategy, to include several work packages, for example, foundations, civil works, electromechanical works, finishes, fit out works, etc. Providing a somewhat developed design package, such as a preliminary design (40 percent to 60 percent) or even more, would be a practical solution; however, again this scenario somewhat defeats the purpose of going for design–build and calls for completing the detailed design and adopting traditional design–bid–build. An example for adopting design–build and inviting qualified international design–build tenderers would be the design and construction of a high-standard world-class highway project, whereas an example for adopting design–bid–build would be the case of inviting international tenderers, which would result in a major exceeding of the allocated project budget. An alternative, and as seen in practice with remarkable success, is to have the design completed abroad by international consultants and the construction completed through a local main contractor of vast local experience.
3. Owners' design–build familiarity
   In certain construction markets and construction industry sectors, design–build is still emerging and not very common to many owners. This lack of familiarity with the process causes reluctance to adopt the design–build approach in the first place. This is usually due to the fear of change and departure from traditional project procurement

methods and ways of doing business, in addition to the understandable lack of in-house resources and expertise that are capable of managing design–build projects effectively. The recommended course of action to mitigate such situation would be two-fold. On the one hand, design–build firms are to promote the design–build approach in the construction market through a sales and marketing effort. This would include providing presentations and free awareness seminars to Owners' decision makers and technical staffs. Through the process, Owners' awareness will increase and design–build champions from the Owners' decision maker circles will show up and support going for design–build. On the other hand, Owners with limited or no design–build experience are to best hire a competent project management team or consultant with adequate expertise and proven track record in delivering design–build projects of similar size and nature successfully. In addition, it would be prudent for Owners to provide their staffs with specialist design–build training and awareness training program. To safeguard and enrich the Owner's organizational process assets, design–build techniques, experiences, and lessons learned should be monitored, recorded, analyzed, and added to the organizational lessons–learned knowledge base.

4. Project external stakeholders

   Projects usually exist under local jurisdictions and in the presence of active external stakeholders including local authorities, utility service providers, and governmental bodies. Obtaining environmental permits, planning utility diversions, and securing land acquisition are all typical tasks completed during the detailed design stage. In design–build, major issues related to any of such elements can well lead to project delay if not failure. Therefore, such elements should not be left to the design–build contractor to fully deal with. As a mitigation measure, a thorough planning and fact-finding effort should be conducted by the design–build firm to anticipate and address major factors that may impact the project. Undefined or ill-defined risky elements should be identified and mitigated prior to contract award. Residual risks transferred to the design–build contractor should be manageable and should be made clear to the tenderers in the RFP. If site conditions are too complicated or if multiple stakeholders with undefined requirements exist, it would be prudent not to go for design–build. An example for this is building an urban expressway system in the middle of a busy city; it would be prudent to go for traditional design–bid–build. Whereas building and expressway in a rural area or between cities would be an ideal candidate for adopting the design–build project delivery approach.

5. Pragmatic project delivery drives

   Several surveys were conducted by various groups in the academia to find out the key drivers that urge Owners to go for design–build. Regardless of the sector whether private or public and irrespective of project size and nature, it was found that there is a set of tangible and intangible factors that drive the decision to adopt the design–build project delivery approach, namely: (a) shortening project duration: to decrease the overall project design and construction completion time; (b) single point responsibility: to have one entity responsible for the project design and construction delivery especially in complex projects; (c) reducing project cost: to decrease the overall project cost as compared to other procurement methods; (d) ensuring constructability: to ensure that the designed project elements are highly constructible and preferred by the builders; and (e) reducing claims: to reduce claims and litigation due to separate design and construction entities and contracts.

Figure 1.7 illustrates such predominant key design–build selection drives.

Finally, it should be noted that the selection of the appropriate project delivery approach for a given project is indeed both art and science. It requires experience, expertise, and expert judgment. The final design–build selection decision remains the responsibility of the organization's senior decision makers.

1.5 The Roles of Owners, Contractors, and Consultants in Design–Build

The design–build project delivery approach alters the traditional roles and responsibilities of the Owner, the designer, and the contractor, owing to the rearrangement of the traditional project setup.

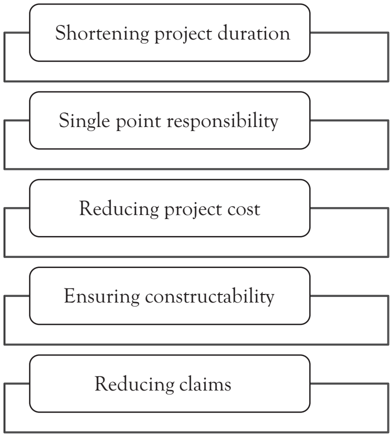


Figure 1.7 Predominant design–build selection drives

In design–build, the distance between the Owner and the designer gets wider and between the contractor and the designer gets closer. A bridging consultant element is introduced and the involvement of the supervision or oversight consultant is reduced. In these somewhat unusual conditions, key to success is the integration and good definition of the roles and responsibilities of the various parties to enable them to operate effectively, efficiently, and collaboratively to form a high-performance team.

In design–build, like any other business, the roles and responsibilities of the parties are governed by the signed contracts. However, in reality, there is always another parallel set of functional roles and responsibilities that enable the parties to function like a high-performance team. The following paragraphs provide a review and discussion of the key functional roles, responsibilities, and limitations of the various parties in the context of design–build. This review and discussion are meant to build the context, promote team building, and enhance chances of project success. Parties covered include the Owner, the bridging consultant, the oversight consultant, and the design–build entity with two components, namely, the design consultant (the designer) and the construction contractor (the builder).

The Figure 1.8 provides an overview of the design–build core-team parties.

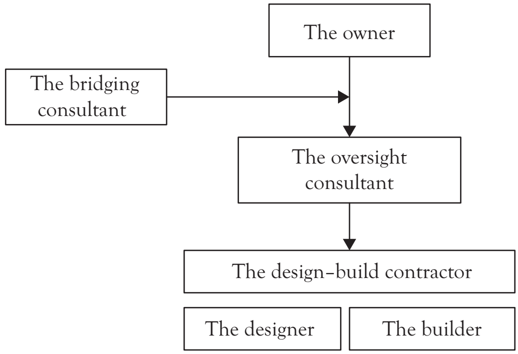


Figure 1.8 Overview of the design–build core-team parties

1.5.1 The Role of the Owner

The following list provides a high-level review of the key Owner's functional roles, responsibilities, and limitations in the context of design–build:

1. The Owner is responsible for clearly expressing the intent of the design and for the adequacy and completeness of the RFP.
2. The Owner must also cooperate with the design–build contractor, so that the contractor's schedule is not slowed down or otherwise hindered. To that end, the Owner must respond more quickly to needs of the design–build contractor than in a traditional design–bid–build construction contract.
3. The Owner enters into direct contracts with the other parties involved in the process. Such contracts should clearly define the scope of services and should highlight the "nontraditional" roles and responsibilities of both the Owner and the contracted parties.
4. The Owner has a primary obligation to understand the complexity of this delivery method by becoming an "Informed Purchaser" and to be committed to the upfront efforts required to clearly define the scope of the desired work and the procurement of a design–build contractor.
5. In design–build, the Owner has to understand that he gives up a level of control over the final design development process in favor of potential cost and schedule advantages. Depending on the contract

agreement, the Owner may exert a limited level of control though milestones or gateway reviews.

6. The Owner's in-house engineering staff developing the parameters for procurement and producing the RFP should be adequately trained and experienced to perform such a key task. Otherwise, the services of a trusted independent bridging consulting engineer should be sought to ensure maximum efficiency at this critical stage of the project delivery.
7. The Owner however may delegate certain authorities to the oversight consultant acting as the supervision and contract administration engineer. Such delegated authorities are to be formalized and communicated to the affected parties.
8. The Owner shall provide timely payments and approvals in accordance with the signed contracts. If the Owner wishes to instruct any changes to the agreed scope of work, it will require the issuance of pertinent formal variation orders. The time and cost impact of such variation orders shall be assessed and agreed with the affected party, and may result in changes to the cost and time baselines.

1.5.2 The Role of the Bridging Consultant

The following list provides a high-level review of the key bridging consultant's functional roles, responsibilities, and limitations in the context of design–build:

1. The bridging consultant acts as the Owner's agent and trusted adviser.
2. The bridging consultant can be a design consultant with project management capacity, or a project management consultant with in-house or outsourced engineering capacity. Either way it shall have adequate design–build procurement and project management expertise.
3. The Bridging Consultant assists the Owner with the planning, investigation, design criteria, conceptual design, and outline specifications leading to a sufficiently detailed RFP reflecting the Owner's vision and requirements so that the design–build bidders can accurately understand and price the works.

4. The bridging consultant performs project procurement. That includes developing a procurement strategy, soliciting bids, prequalification and shortlisting of bidders, evaluating technical and financial bids, and recommending the preferred design–build bidder to the Owner for contract award.
5. During the design–build contract implementation duration, the bridging consultant acts as the Owner's representative and the engineer as defined in the FIDIC forms of contract. Key duties include monitoring project progress and performance, resolving contractual issues, risk management, stakeholder management, and signing off completed works.

1.5.3 The Role of the Oversight Consultant

The following list provides a high-level review of the key oversight consultant's functional roles, responsibilities, and limitations in the context of design–build:

1. The oversight consultant acts as the site supervision and contract administration engineer during the design–build contract implementation phase.
2. The oversight consultant assumes the capacity of the engineer's representative as defined in the FIDIC forms of contract. Authorities vested in the engineer's representative are to be formalized by the engineer and communicated to the affected parties.
3. The oversight consultant oversees the design–build contractor's day-to-day activities. This includes reviewing contractor's submittals, conducting quality and safety inspections, payment verification, monitoring program, and performing contract administration.
4. The oversight consultant also functions as a technical adviser safeguarding the RFP design intent throughout the project. This is achieved by continuous monitoring, spot checking, and providing technical services such as design reviews, technical clarifications, and proactive involvement and endorsement of the project's testing and commissioning process.

5. In design–build, the level of oversight is reduced as compared to the traditional design–build–bid projects. Therefore, the level of service conducted by the oversight consultant is expected to be of a somewhat high level, focusing on general compliance with the requirements, terms, and conditions stipulated in the RFP and the applicable codes and standards.

1.5.4 The Role of the Design–Build Design Consultant (the Designer)

The following list provides a high-level review of the key design–build design consultant's functional roles, responsibilities, and limitations in the context of design–build:

1. The design–build design consultant may be the design–build entity's prime or lead.
2. The design–build design consultant produces certain designs for the design–build team during the tender phase, upon which the design–build team bases its price. During implementation, the design consultant has the responsibility to maintain the same or a higher level of cost efficiency.
3. Design–build design consultant acts as the architect or engineer of record liable for the project design and is the party that provides the professional indemnity or liability insurance.
4. The design–build design consultant should perform his duties with utmost integrity. In design–build environment, the designer might come under pressure from the construction contractor to cut corners on account of safety or compliance. In no case shall ethical standards be compromised.
5. The design–build design consultant develops the concept design provided in the RFP into final detailed design and detailed construction specifications.
6. The design–build design consultant is responsible for the full compliance of his furnished designs with the design criteria and functional and operational requirements set forth in the RFP and the signed design–build contract.

7. The design–build design consultant is responsible for the safety, integrity, correctness, technical adequacy, and coordination of his furnished designs and design documentation.
8. The design–build design consultant shall discuss, consult, and coordinate with the design–build construction contractor to ensure high constructability of the designed project elements as well as to develop the most effective design–build solutions.
9. The design–build design consultant shall adhere to the stipulated design deliverable submission key dates, taking into account any required gateway, client or authority reviews and approvals, and the time durations associated therewith.
10. The design–build design consultant shall support the construction process.

1.5.5 The Role of the Design–Build Construction Contractor (the Builder)

The following list provides a high-level review of the key design–build construction contractor functional roles, responsibilities, and limitations in the context of design–build:

1. The design–build construction contractor is commonly the design–build entity's prime or lead.
2. The design–build construction contractor is responsible for managing the construction site, procurement of construction materials, and providing the required resources.
3. The design–build construction contractor agrees with the design–build design consultant on certain key information including specific preferred materials or construction means and methods. The design–build construction contractor has the responsibility to honor such information.
4. The design–build design construction contractor should share with the designer information about his past experiences, special expertise, organizational capacities, and relevant process assets.
5. The design–build construction contractor is responsible for the project construction management including safety, program, control of

quality, provision of material and equipment acquisition, and training own and Owner's personnel in operation and maintenance of the completed works and provision of the necessary warranties.

6. The design–build design construction contractor should perform his duties with utmost integrity. In a design–build environment, the contractor might tend to put the designer under pressure to tweak design on account of safety or compliance. In no case shall ethical standards be compromised.
7. The design–build design construction contractor shall proactively participate in VE and constructability sessions to ensure most effective project implementation.
8. The design–build design construction contractor should fully comply with the designs, specifications, and technical recommendations made by the designer.
9. The design–build construction contractor shall support the design process.

The above design–build functional roles and responsibilities should be reviewed by all of the parties involved. A best practice is to discuss and refine such roles and responsibilities early in the project, and then to include them in a "Project Charter" document to be endorsed by senior executives and maintained by the various project teams.

1.6 The Power of Design–Build

The power of design–build stems from its ability to actuate certain inherent people and process energies and capabilities that are otherwise squandered in other project delivery methods. The sources of such power are tangible and intangible, direct and indirect. Design–build is simply the natural instinctive way of delivering construction projects. It reflects the way we have originally been created, way before the modern ages of industrialization, let alone the current age of computer and Internet. Hence, the power of design–build is actually the result of the fact that it invites getting back to the roots of human behaviors and attitudes, mechanisms, and ways of doing business. It recalls and revives the natural basic principles and qualities of working together toward achieving a

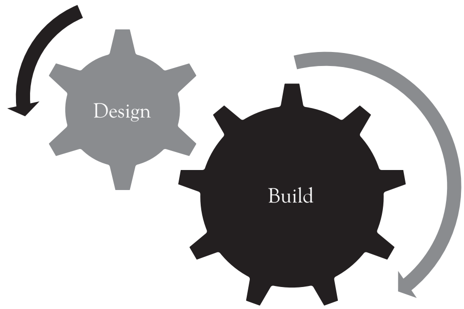


Figure 1.9 The power of design–build

common objective, distributing work tasks sensibly to the parties that can best handle them, and eliminating nonproductive actions and acts for a while until the task is accomplished.

The power of design–build could be attributed to the following key values, mechanisms, and characteristics inherent to the design–build process, which make it a popular and powerful approach able to outperform other project delivery methods:

1. Teamwork
   In design–build, everybody is in the same team. The designer and the builder are together and on the same boat having the same goals and objectives starting with winning the project's tender competition and securing the design–build contract, all the way down to delivering a successful and profitable project that meets or exceeds the Owner's expectations. When challenges are encountered during the course of the project, pointing fingers is not an option; everyone works on developing solutions and getting through the problems. Moreover, in the design–build environment, the professionals involved enjoy the real practicing of engineering. They design and build freely with a great feeling of ownership and achievement. The teamwork spirit and sense of job satisfaction promoted by the design–build approach lead to creativity, enhanced team morale, and increased productivity.
2. Accountability
   The design–build entity components, the designer and the builder components, are jointly and severally accountable for the successful project delivery, including safety, performance, quality, cost, and the

timely completion. As the same entity that designs the project also builds the project, there tends to be a higher sense of accountability within the project team and more attention given to design economics, achieving progress and constructability aspects. The single point of accountability is also a big advantage to the Owners and reduces chances of claims and disputes.

3. Stability

   The design–build entity is involved from start to finish including both the original designer and original contractor on board, which enhances project stability. Chances for the detrimental change of contractors or designers during the course of the projects are significantly reduced. Moreover, given the typical lump-sum price arrangement of design–build contracts, chances for the destabilizing effects of scope changes or changes due to design flaws are also greatly diminished.

4. Specialism

   Design–build firms are experts in both the design and construction aspects of the application area. There is a tremendous advantage to having in the same project team designers who can think like builders and builders who can think like designers. Well-established design–build firms are to be distinguished from design firms teaming up with contractors in a design–build venture for the first time. The latter will require conscious orientation, training, and team-building efforts to ensure results.

5. Efficiency

   In design–build, efficiency is the name of the game. Design–build entities exert their utmost efforts to reduce project cost and time to enable them win the design–build tender competition in the first place. This is achieved in a way similar to the process of VE. In design–build, most of the VE takes place during the tendering stage. Studies reveal that in major civil engineering projects, design–build can save up to 15 percent of the project cost and 30 percent of the overall project delivery time. In design–build, most of the CS takes place during the tendering stage due to the intensive VE carried out by the competing design–build tenderers, whereas most of the TS takes place during implementation due to fast-tracking or overlapping of design and construction activities by the design–build contractors.

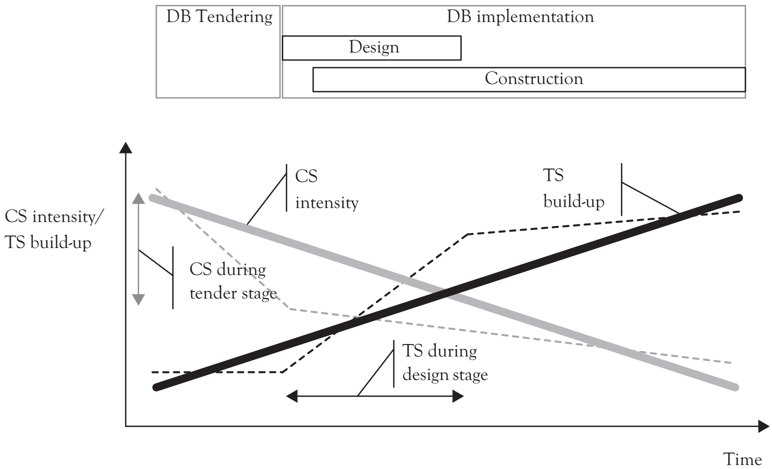


Figure 1.10 Design–build (DB)—analytic cost- and time-saving (CS and TS) profiles

Figure 1.10 illustrates the design–build CS- and TS-indicative profiles along the tendering and implementation stages time line. The areas under the dashed or trend lines represent the overall amount of CS, TS, or both.

The outcome of the qualitative paradigms in Figure 1.10 translates into tangible project results in terms of TS and CS. There is evidence from numerous large civil engineering projects that suggest that such savings would be in the range of 5 percent to 10 percent of the project cost and 10%–20% of the project time when compared to the traditional design–bid–build method. A meticulous academic study completed by Mark D. Konchar at Pennsylvania State University under a post-doctoral research entitled "A Comparison of United States Project Delivery Systems" yielded the following figures (Konchar 1997):

- The design–build unit cost (final project cost divided by the area) is at least 4.5 percent less than that of CMR and 6 percent less than that of design–bid–build.
- The design–build construction speed (facility gross square footage divided by the construction time) is at least 7 percent faster than CMR and 12 percent faster than design–bid–build.

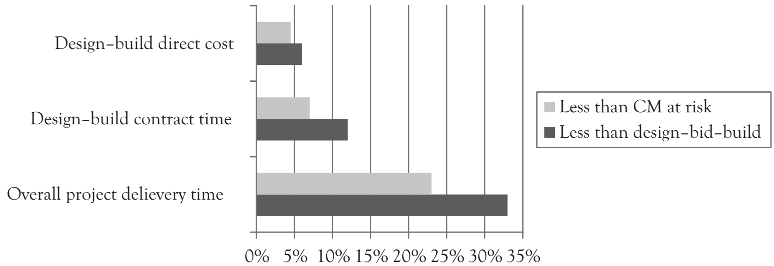


Figure 1.11 Design–build—time and cost savings compared to other project delivery approaches

- The design–build overall project delivery speed (facility gross footage divided by the overall design and construction time) was at least 23 percent faster than CMR and 33 percent faster than design–bid–build.

Figure 1.11 illustrates such TS and CS percentages.

In commercial and industrial projects generating income, such TS and CS percentages can translate into substantial dollar value when taking into account the increased benefits and profits achieved by the early operation of the completed projects, thus the early starting of attaining revenue. Design–build can therefore have tangible positive impact on the project's business model including feasibility, return on investment, and payback period. If the project is particularly time sensitive, such as a stadium for a major sport event, a project delivery TS that enables the timely completion and handover of the project before the sports event scheduled start date can be just invaluable. However, for Owners and design–build firms to reap the benefits of the process, they need to possess the skill and in-depth understanding of the design–build method, or what can be called the design–build "know-how." The design–build process is not as simple as it may seem. It takes learning, training, and experience to actuate the power of design–build, and the reward can be enormous.

1.7 The Construction Industry in the 21st Century

We have already seen the start of the construction industry in the 21st century. There is obviously a spectacular advancement in the information technology and communications track. Highly pictorial 3D modeling of structures and animated visualizations have become commonplace. Real-time sharing and exchanging of documents and information have become easier than ever, thanks to the World Wide Web and the infrastructure of mega servers. Worldwide scattered virtual project teams working out of offices across the globe and communication through web-based means and teleconferences have become business as usual. Access to information and knowledge through digital libraries and shared information on the web has simply changed the state of access to knowledge beyond expectations.

The first years of the 21st century have also seen a major breakthrough in the emergence of building information modeling (BIM), which is a process involving the generation and management of digital representations of physical and functional characteristics of buildings followed by control and facility management that extend throughout the building life cycle. The start of the 21st century has also seen a tremendous boost to environmental awareness through focus on buildings' sustainability in what is commonly known as green building. This is concerned with reducing the buildings' carbon footprint by using sustainable construction materials, sustainable designs and techniques, promoting the use of local resources, recycling waste, and reducing pollution and the use of water.

However, despite such interesting modernization efforts, the substance of the construction industry itself appears to be somewhat lagging behind Owners' expectations and behind other major industries. Most construction projects all over the world are still seeing time and cost overruns. At the micro-level, the way construction gets done has not in essence changed that much in 50 years. Training and efficiency of most construction workers and intermediate-level professionals are very much the same for the same period. At the macro-level, the construction industry does not appear to have realized the levels of advancement and productivity surges achieved in other major industries such as manufacturing and information technology. The good news is that there appears to be ample conscious efforts exerted by both the academia and the practice to change the current situation. Such efforts are proceeding in parallel in the three key business pillars of people, process, and technology (Figure 1.12).

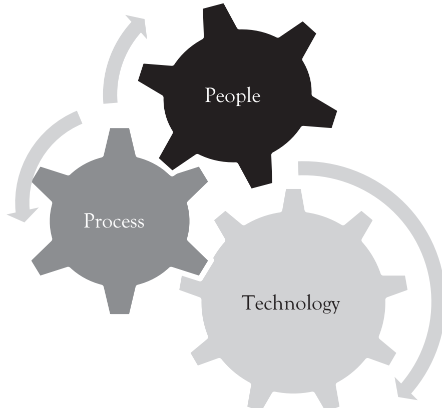


Figure 1.12 Interactions of people, process, and technology

On the people front, recent years have seen a remarkable increase in the interest of design and construction professionals about enhancing their qualifications and acquiring new knowledge and skills. This trend is expected to continue and intensify. It includes going for both academic and professional training and credentials such as graduate and post-graduate degrees, chartered status, and project management credentials. Online education and training have become commonplace and helped enlarge the training platform across the globe. Moreover, most modern companies nowadays provide in-house training programs for employees, commonly on essential areas such as safety and quality. The product of all such efforts however has not yet flourished in full and got the industry to where it wants to be. There is still a remarkable gap between the theory and the practice, and reluctance by many to put what was learnt into practice. In the years and decades to come, the focus in the industry should be to try and close such gaps to ensure that knowledge and experiences gained do not go astray. Innovation, creativity, and thinking out-of-the-box practices should be encouraged and documented. Despite the enormous technological advancement, achieved or yet to be achieved, the critical asset for organizations shall always remain its people. After all, engineering is human, and it is people who make or break businesses.

On the process front, the construction industry has seen some serious efforts in the late decades of the 20th century to develop sophisticated construction and project management processes to manage and control projects.

This included developing a range of quality management systems, such as ISO and Six Sigma, and project management systems, such as Project Management Institute's (PMI) *Project Management Body of Knowledge Guide* (*PMBOK Guide*®) or Prince2®. These positive efforts however have in part been overshadowed by their own inherent complexity, as well as by the general tendency in the construction marketplace to make projects more complicated though increased governance and multiple stakeholders. This has led to process deficiencies leading to project delays. The focus in the 21st century should therefore be on ensuring effectiveness and efficiency of the used processes, rather than further complicating them. Academics and professional organizations shall need to focus on simplifying and streamlining processes. The amount of process applied in a project should be optimized to achieve projected results without unjustifiably overburdening the project team. Processes should hit the highpoints and achieve maximum positive impacts with the least amount of effort, or more for less. The SAFEDB-Methodology presented in this book is meant to be a step in this direction.

On the technology front, in recent years, the construction industry has seen great achievements related to construction technologies, computer software, and communication means. Construction has seen numerous emerging construction technologies such as high-performance self-compacting concrete, carbon fiber reinforced polymers (CFRP), a wide range of construction chemicals, and advanced trench-less directional drilling. Computer software has taken large steps with the new versions of computer aided design (CAD) systems, planning programs, presentation software, and structural analysis software. Communication has seen a major revolution in the wake of the phenomenal advancement of online communications, which have made the world appear like a small village. Productivity rates, however, remain the main drawback. Construction is still widely regarded as a slow and labor-intensive industry. This requires revisiting and placing more focus on the current ways of doing things. For instance, current concretes still require weeks to cure, road pavements still consist of multiple layers, and traditional construction materials such as steel sections and reinforced concrete are still dominating the scene. The status quo is expected to change in the years and decades ahead with new ways of building brought about by the industry.

One of the first glories of the construction industry in the 21st century is the spectacular Burj Khalifa, the tallest man-made structure in the world of

Figure 1.13 Burj Khalifa, the tallest tower in the world (Khalifa 2010)

829.8 m (2,722 ft.) height (Figure 1.13). It just symbolizes the contemporary era and the state-of-the-art in the building arena. Burj Khalifa was built between 2004 and 2010 in Dubai, the United Arab Emirates (Khalifa 2010).

At the threshold of the 21st century, the construction industry is embracing change. The rate of change and innovation is bound to increase as time goes by. We are in an exciting period of our construction industry, which currently accounts for more than 10 percent of the global gross domestic product (GDP), and this number is set to further increase. The continuing advancement and integration of people, process, and technology, the key business pillars, over the years and decades to come, are likely to bring about wonders and maximize productivity rates to levels that are unimaginable at this stage.

1.8 Summary

Design–build is neither a new nor a revolutionary process, but indeed the natural and sensible way of delivering construction projects. The design–build project delivery approach enables the favorable collaboration of design and construction professionals as well as the overlapping of the design and construction process components. This results in cost and time benefits and efficiencies not available in other project delivery methods. Design–build is not necessarily the categorical best fit for all types of projects; thus, a decision on the appropriate project delivery method still needs to be made on a case-by-case basis. Design–build changes the classical roles and responsibilities of the various parties, and requires a mindset adjustment. The power of design–build stems from its ability to actuate certain inherent people and process energies and capabilities that are otherwise squandered in other project delivery methods. The future of the construction industry is very promising; however, it remains subject to achieving progress in the lagging aspects of the people, process, and technology key pillars of the construction business.

CHAPTER 2

Project Management in Design–Build Projects

Preface

This chapter provides a high-level overview of modern project management with focus on its application in design–build projects. The chapter starts with the basic definition of the term project management as perceived by major professional organizations as well as by the author. Project management has several technical definitions; however, it remains in essence the application of proactive and organized commonsense actions and steps to achieve project objectives. It overall revolves around the key three pillars of any business, namely, people, process, and technology. The chapter then moves on to present the big picture or the framework of modern project management for construction projects, in line with Project Management Institute (PMI)'s project management model. The project management framework consists of a system of integrated project management processes, process groups, and knowledge areas applied to project activities along the project life cycle. In addition, the chapter provides guidelines to the application of such generic project management model in design–build projects, and proposes a supplementary project management process that is specific to the design–build projects. Aiming to focus on project delivery, the chapter discusses the project management team organization in design–build projects and recommends an effective top team setup. Moreover, the chapter focuses on the people side of the business by addressing the attributes of the effective design–build project manager. Finally, the chapter addresses the importance of ensuring project alignment with the organizational strategies at all times.

It also highlights certain project management best practices and provides an expert focus on issues related to the design–build project delivery approach.

2.1 What Is Project Management?

The definition of the term Project Management has been subjected to numerous interpretations by project management professionals and academics. However, the consensus in this regard is that project management is not really a new concept or technique, but indeed an instinctive human effort that has always been practiced naturally and informally by builders along the history to put up buildings or create products to serve predefined uses and purposes. From a civil engineering perspective, this would cover all the efforts exerted by architects, engineers, and project managers along the human history to deliver projects until today. The basic principles of the project delivery have not really changed much, namely, Owner satisfaction, functionality, fitness for purpose, and the timely delivery of projects within budget and to the required quality standards. Moreover, the typical elements of the project life cycle obviously remained the same: initiate, plan, implement, monitor and control, close out, and hand over to the Owner or the end user.

Modern structured project management as we know it today has only been developed and consciously practiced since the middle of the 20th century. That is when project management was initially deployed by the U.S. Department of Defense in the military systems and space development fields. In the following years and decades and in response to the industry's enthusiasm about project management, practitioners and academics started serious and collective efforts to identify, organize, promote, and document project management methodologies and best practices. Several project management organizations and associations were established around the world with the objective of promoting project management through training, education, forums, and most importantly through issuing de facto process-based project management standards. Such organizations included the PMI established in the United States in 1969, the Projects in Controlled Environments methodology (PRINCE2) established in the United Kingdom in 1989, and more recently the Project Management Association of Japan (PMAJ) established in Japan in 2005.

Each of such project management bodies has adopted a different approach and school of thought as to how to best manage projects and enhance their chances of success. This included a different definition of the term project management reflecting their understanding and approach toward project delivery. Following is a high-level review of how project management has been defined by key global project management organizations.

PMI in the USA has a somewhat tactical definition of project management as the application of knowledge, skills, and techniques to project activities to meet the project requirements. The objective is to execute projects effectively and efficiently utilizing specific project management processes, tools, and techniques. PMI regards project management as a stand-alone profession that applies to any application area (PMBOK® Guide 2012).

PRINCE2 in the UK gives a fairly holistic definition of project management focusing on the human side of the business, defining project management as the planning, monitoring, and control of all aspects of a project and the motivation of all those involved in it to achieve the project objectives on time and with the specified cost, quality, and performance (PRINCE2, 2013).

PMAJ in Japan gives a more descriptive definition of project management getting into the details of the process in defining project management as the professional capability to deliver, with due diligence, a project product that fulfills a given mission, by organizing a dedicated project team, effectively combining the most appropriate technical and managerial methods and techniques and devising the most efficient and effective work breakdown and implementation routes (PMAJ 2013).

No matter what the project management definition or approach is, the bottom line remains that effective project management is always about maintaining an optimum balance among the three fundamental elements of any successful business endeavor, namely, people, process, and technology (Figure 2.1).

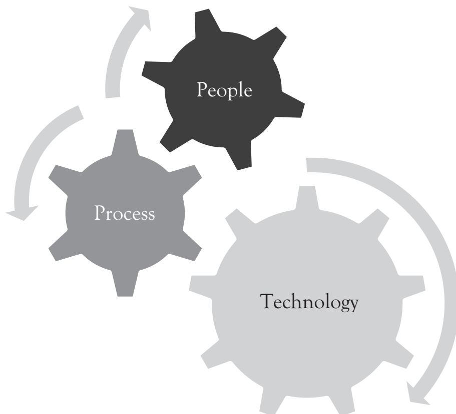


Figure 2.1 Interactions of people, process, and technology

The people element of the model represents the human aspect of the process. It is about selecting the right project team with the required skills and the right attitudes to implement the project effectively. It also includes providing leadership; defining roles, responsibilities, and accountabilities; and doing the actions and activities to retain the team and keep it informed and motivated throughout the project life cycle. At the core of the people's aspect lies the effective management of project stakeholders. This includes planning, identification, management, and continuous engagement of project stakeholders whether individuals or originations, positive or negative, internal or external.

The process element is the key differentiator that gives organizations the advantage and competitive edge. Process describes the know-how of project delivery, including project initiation, planning, executing, monitoring, controlling, and closing. It defines the organization's project management maturity, performance standards, and the ability to deliver projects in a systematic and controlled manner. Process is the secret behind organizations' long-term survival and continuation of success. People and technology change all the time; however, process remains to integrate new people and new technologies, thus enabling continuation of a consistent superior level of service (Brown 2008). Therefore, this book places ample emphasis on the process side of the business, the key differentiator for companies that strive for survival and growth in a fiercely competitive marketplace.

The technology element represents the technological infrastructure and tools required to deliver the project. This includes the required computer software and hardware; telecommunication network; office equipment; technical references; office equipment all the way down to specific trade know-how; testing labs; and construction tools, plant, and equipment. Availing sufficient amounts of the right technology required to plan, monitor, control, and implement the project is key to successful project delivery. Technology takes its way to company profile and forms a key part of the organizational assets.

In the years and decades to come, the practice of project management is expected to continue to grow rapidly and gain more and more popularity. Scores of organizations and individuals are currently seeking and obtaining project management credentials. This wider application of project management is an important factor in the maturing of project management as a profession. PMI is currently the world's largest and most influential project management organization setting the standard in the field of project management. This status is defined by PMI's number of members and credential holders, extensive academic and market research programs, chapters and communities of practice, and the worldwide spread and popularity of its project management global standards. The next section presents an outline for a project management process that is aligned with PMI's *Project Management Body of Knowledge Guide* (*PMBOK® Guide*) providing the standard for project management.

2.2 The Project Management Framework

The effective implementation of project management requires having a clear understanding of the project management big picture in which management of single projects originates.

The background here is that in today's marketplace, most modern organizations implement their strategic expansion and growth business objectives through projects. Such projects are usually organized in a hierarchical project structure. The project structure consists of three levels, namely, a first level including a number of high-level portfolios, each underlain in the second level by a number of programs, and still each underlain in the third level by a number of individual projects.

For example, a Public Works Authority would have a number of high-level portfolios for key business elements such as highways, water or wastewater works, and public buildings. The highways portfolio would have a program for local roads and another for expressways, the water or wastewater works portfolio would include a program for water works and another for wastewater, and the public buildings portfolio would have separate programs for schools and hospitals. Each program would then include a number of projects of well-defined products or services.

As such, project management in its broad term indeed involves three distinct levels of project management methods, namely, portfolio management at the portfolio level, program management at the program level, and the more common single project's project management at the project level (see Figure 2.2). The Project Management Institute (PMI) has developed a series of global standards for each of such project management levels, namely, The Standard for Portfolio Management for managing portfolios; The Standard for Program Management for managing programs; the most popular *PMBOK® Guide*, which is concerned with managing single projects. It would be worth mentioning that the author of this book is a formal contributor to the development and review of all three PMI global standards and a subject matter expert of the *PMBOK® Guide*—Fifth Edition.

Moreover, the following Figure 2.3 illustrates the key elements of the project management global structure, that is, portfolios and portfolio management, programs and program management, and single projects and project management. It should be noted that in reality, details of such

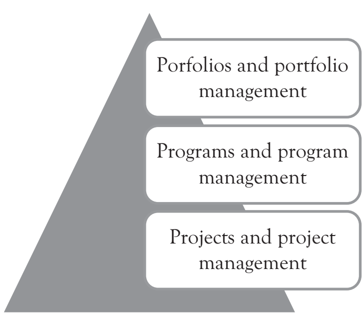


Figure 2.2 The big picture project management pyramid

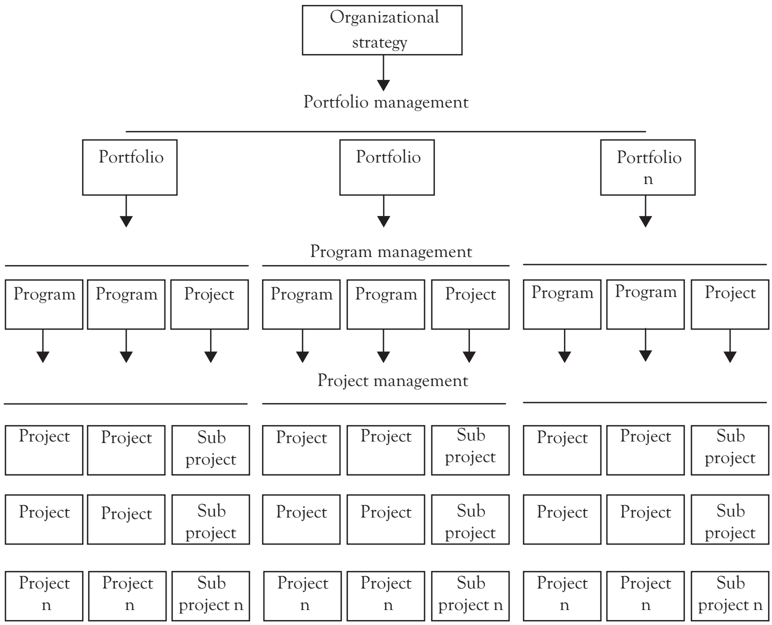


Figure 2.3 The global project management framework

project management global structure might change in a variety of ways most commonly by including hybrid elements such as sub-portfolios, sub-programs, and sub-projects as well as by inserting operational and non-project works at the various levels of the hierarchy.

The following paragraphs provide a high-level review of the definition and management framework of the key components of the project management big picture in line with the PMI approach. This is followed by a deeper look into project management for single individual projects that form the vast majority of the project management efforts in the construction industry, including the design–build projects.

Portfolios and portfolio management: A portfolio is a group of related programs or major projects or operations that are assembled together to facilitate the effective management of that work in order to meet strategic business objectives. Portfolio strategy is to be aligned with the organization's strategic business objectives. The portfolio components may not necessarily be interdependent. An organization may have more than one portfolio, each addressing a unique aspect of the organizational strategies and objectives. Portfolios may consist of a set of past, current, and future portfolio components, that is, they are of an ongoing nature. Therefore, portfolios do not have a life cycle; however, they affect and influence program and project existence and life cycles through the dominant and overruling portfolio governance. Portfolio management is concerned with firstly assuring that programs and projects are selected, prioritized, and resourced in line with the organizational strategic objectives. Portfolio management is about doing the right work, rather than doing the work right, which is left to the lower-level program and project management efforts. This includes the identification, categorization, evaluation, and finally selection of portfolio components that can best accomplish organizational strategies. The Portfolio management team's primary role is then to balance the conflicting demands between programs and projects and to strategically allocate resources and funds based on organizational priorities and capacities. Portfolio management has a key focus on portfolio governance and portfolio risk management, and a key mandate to monitor, control, and ensure the continuous alignment of the portfolio components with the predefined and overruling organizational strategy.

Programs and program management: A program is a group of related individual projects managed together in a synchronized manner in order to achieve efficiencies, benefits, and levels of control that cannot be realized by managing such projects individually. Program strategy is to be aligned with the parent portfolio strategic objectives. Program components are necessarily interdependent and affect the progress and outcome of each other. A program may encompass two or more interdependent projects, each producing deliverables that address an integrated element of the program objectives. A program is a time-bound endeavor, that is, it has a specific duration to achieve its objectives and deliver its benefits, and therefore has a typical life cycle. The typical program life cycle includes preprogram preparations, program initiation, program setup, delivery of program benefits, and finally program closure. Program management is defined as the centralized coordinated management of a group of interdependent projects to achieve the program's goals, objectives, and desired benefits. The mission and advantage of program management are optimization of the cost, schedule, and administration effort to deliver projects, thus outperforming managing and delivering such projects separately. This is achieved through the application of program governance and the systematic application of program management processes toward initiating, planning, executing, controlling, monitoring, and closing programs and all their subsidiary projects and components to achieve program benefits. The program management team's primary role is to provide governance, support, and guidance to the program components; manage project interdependencies and interfaces; ensure that the program structure and the management resources and processes are adequate at all times; and to orchestrate and integrate the project outputs to result in integrated program benefits in the most effective manner.

Projects and project management: A project is defined as a temporary endeavor carried out to produce a unique product, service, or result undertaken as an integrated part of a parent program. Project strategy is to be aligned with the parent program's strategic objectives. A project is a time-bound endeavor, that is, it has a specific duration to achieve its objectives and deliver its end product, and therefore has a typical life cycle. The typical project life cycle includes an initiation phase of mobilization and startup activities; an intermediate phase during which project works are procured and completed progressively in small steps in a coordinated manner and in accordance with a detailed time schedule; and a final phase of testing, commissioning, and project closure. Projects may vary in size or nature; however, always maintain their indicated inherent characteristics and typical life cycle (Figure 2.4).

Project management, as also discussed in Section 2.1 earlier, has a PMI definition as the application of knowledge, skills, and techniques to execute projects effectively and efficiently. It is a strategic competency for organizations, enabling them to tie project results to business goals—and thus, better compete in their markets. The aim here is managing a single individual project located within a parent program or portfolio. For the purpose

Figure 2.4 Typical project life-cycle phases

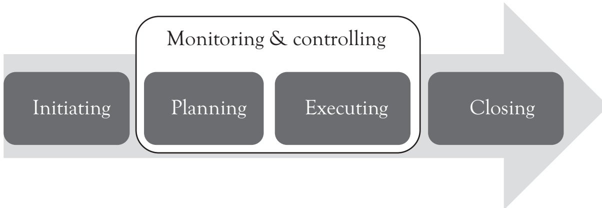


Figure 2.5 Project management process groups

of this book, a further focus shall be placed on project management in the context of single projects, which is the most common and widely used project management endeavor and which also covers the design–build projects. This is achieved through the systematic application of five project management process groups, namely, initiating, planning, executing, controlling and monitoring, and closing, as shown in Figure 2.5.

The project management team's primary role is to ensure the timely completion of the project within budget and to the required project quality. According to PMI's project management model as outlined in the *PMBOK® Guide* and its *Construction Extension* (*PMBOK® Guide* 2000), this is achieved through the application of a wide range of project management processes falling under 14 project management knowledge areas and spread over the above-mentioned five process groups, as shown in Table 2.1.

Table 2.1 The project management framework—project management knowledge areas, processes, and process groups

Main root	Project management knowledge area (KA)	Project management process	Process group
Project management framework KAs, processes, and process groups	KA01 Integration	KA0101 Project Charter	Initiating
		KA0102 Project Management Plan	Planning
		KA0103 Direct and Manage Work	Executing
		KA0104 Monitor and Control Work	Monitoring & Controlling
		KA0105 Integrated Change Control	Monitoring & Controlling
		KA0106 Close Project or Phase	Closing

Table 2.1 The project management framework—project management knowledge areas, processes, and process groups (Continued)

Main root	Project management knowledge area (KA)	Project management process	Process group
	KA02 Scope	KA0201 Plan Scope Management	Planning
		KA0202 Collect Requirements	Planning
		KA0203 Define Scope	Planning
		KA0204 Create WBS	Planning
		KA0205 Validate Scope	Monitoring & Controlling
		KA0206 Control Scope	Monitoring & Controlling
	KA03 Time	KA0301 Plan Schedule Management	Planning
		KA0302 Define Activities	Planning
		KA0303 Sequence Activities	Planning
		KA0304 Estimate Activity Resources	Planning
		KA0305 Estimate Activity Durations	Planning
		KA0306 Develop Schedule	Planning
		KA0307 Control Schedule	Monitoring & Controlling
	KA04 Cost	KA0401 Plan Cost Management	Planning
		KA0402 Estimate Costs	Planning
		KA0403 Determine Budget	Planning
		KA0404 Control Costs	Monitoring & Controlling
		KA0404 Control Costs	Monitoring & Controlling
	KA05 Quality	KA0501 Plan Quality Management	Planning
		KA0502 Perform Quality Assurance	Executing
		KA0503 Control Quality	Monitoring & Controlling

(*Continued*)

Table 2.1 The project management framework—project management knowledge areas, processes, and process groups (Continued)

Main root	Project management knowledge area (KA)	Project management process	Process group
	KA06 Human Resources	KA0601 Plan HR Management	Planning
		KA0602 Acquire Project Team	Executing
		KA0603 Develop Project Team	Executing
		KA0604 Manage Project Team	Executing
	KA07 Communication	KA0701 Plan Communications Mgmt.	Planning
		KA0702 Manage Communi-cations	Executing
		KA0703 Control Communi-cations	Monitoring & Controlling
	KA08 Risk	KA0801 Plan Risk Manage-ment	Planning
		KA0802 Identify Risks	Planning
		KA0803 Qualitative R Analysis	Planning
		KA0804 Quantitative R Analysis	Planning
		KA0805 Plan Risk Responses	Planning
		KA0806 Control Risks	Monitoring & Controlling
	KA09 Procurement	KA0901 Plan Procurement Mgmt.	Planning
		KA0902 Conduct Procurements	Executing
		KA0903 Control Procurements	Monitoring & Controlling
		KA0904 Close Procurements	Closing
	KA10 Stakeholders	KA1001 Identify Stakeholders	Initiating
		KA1002 Plan Stakeholder Mgmt.	Planning
		KA1003 Manage Stakeholder's Engagement	Executing
		KA1004 Control Stakeholder's Engagement	Monitoring & Controlling

Table 2.1 The project management framework—project management knowledge areas, processes, and process groups (Continued)

Main root	Project management knowledge area (KA)	Project management process	Process group
	KA11 Safety	KA1101 Safety Planning	Planning
		KA1102 Safety Plan Execution	Executing
		KA1103 Safety Admin and Records	Closing
	KA12 Environment	KA1201 Environmental Planning	Planning
		KA1202 Environmental Assurance	Executing
		KA1203 Environmental Control	Monitoring & Controlling
	KA13 Financial	KA1301 Financial Planning	Planning
		KA1302 Financial Control	Monitoring & Controlling
		KA1303 Administration and Records	Closing
	KA14 Claims	KA1401 Claim Identification	Planning
		KA1402 Claim Quantification	Planning
		KA1403 Claim Prevention	Monitoring & Controlling
		KA1404 Claim Resolution	Closing

In practice, the project management endeavor is conducted by the project management team using three key project management documents generated early in the project, namely, the Project Charter, the Project Scope Statement, and the Project Management Plan. This is supported by a project management information system (PMIS) and a range of project policies, procedures, metrics, measures, and the associated practical project management and contract administration forms and templates. Figure 2.6 highlights such key project management documents.

The Project Charter nominates the project manager and provides key project information and guidelines such as a brief project description, project purpose, budget, duration, milestones, success criteria, key stakeholders' list, in addition to high-level project risks and requirements.

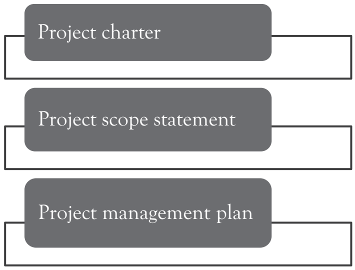


Figure 2.6 Key project management documents

The Project Scope Statement provides a detailed project scope description, project deliverables, assumptions, constraints, exclusions, and acceptance criteria. When completed, it serves as a baseline for later changes to the project scope during the course of implementation.

The Project Management Plan is key to the focal project management document developed under KA01 Integration Management and includes a specific subsidiary management plan for each of the remaining 13 knowledge areas, namely, KA02 through KA14. It stipulates the adopted project management processes and how they are used and applied to drive the project. The Project Management Plan is tailored by the project management team to identify the processes required to satisfy the specific project needs as well as to align with the program objectives and the applicable organizational process assets, standard policies, and lessons learned. The Project Management Plan is a live and iterative document that is subject to continuous monitoring and enhancement throughout the entire project life cycle following Deming's continual improvement plan–do–check–act continual improvement cycle (Figure 2.7).

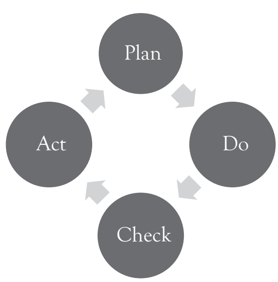


Figure 2.7 Deming's continual improvement plan–do–check–act cycle

In the 21st century, the practice of project management is expected to continue to grow rapidly and gain more and more popularity. The value of project management has already been established in the construction industry all over the world to the point that it has become indispensable for organizations to implement their strategic plans and manage and control their investments. The PMI's suite of global standards provides an excellent reference in this regard.

2.3 Guidelines for Using the PMBOK® Guide in Design–Build Projects

The *PMBOK® Guide* is meant for any type of project whether design or construction.

According to the *PMBOK® Guide*, each project is unique and has its own parameters and characteristics such as scope, budget, duration, risks, stakeholders, and quality requirements. From a project management perspective, the *PMBOK® Guide* also states that each project also has its own project manager, project charter, project scope statement, project management plan, a dedicated project management process group, and project life cycle. In design–build, project charter and project scope statement remain the same as in traditional projects and obviously cover both the design and construction aspects of the business. On the other hand, the project management team composition, the project management plan, and the project life cycle get heavily affected by the design–build process and hence require expert tailoring, adjustment, and elaboration.

Traditional construction projects have a single project life cycle and involve a single focus on building the project based on readily available complete design. In design–build, the project management process becomes dual, involving what could be described as two projects in one, namely, a design project producing the project design documentation, and a concomitant and overlapped construction project producing the physical project construction product. Both projects are managed simultaneously under a single overall synchronized design–build project. The *PMBOK® Guide*, Fifth Edition, addresses the design–build scenario, and regards it as two overlapping project phases, each having its own life cycle and typical project management process groups, namely, initiating, planning, executing, monitoring and controlling, and closing.

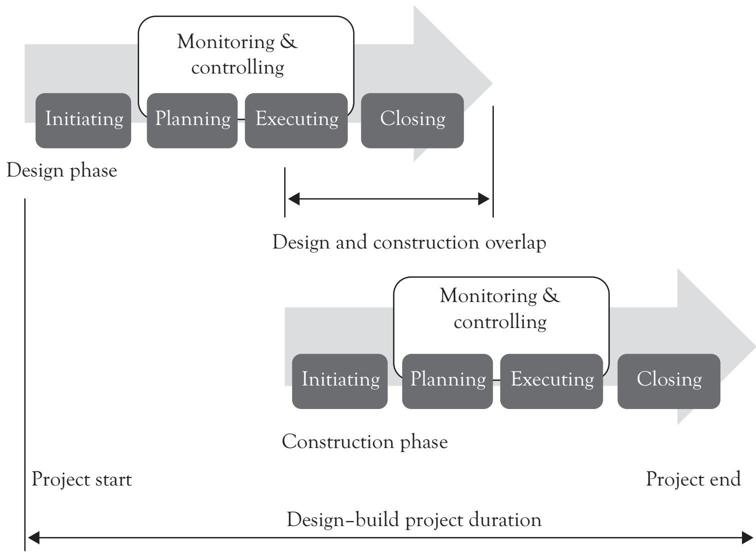


Figure 2.8 Project management process groups in design–build projects

This scenario is illustrated in Figure 2.8.

Likewise, in design–build, two life cycles for the design and construction phases will exist in a similar interaction and overlapping fashion. The interaction and overlapping of such project management process groups and project life cycles create a unique and rather complex project management situation that needs to be managed and controlled effectively throughout the design–build project's duration. In design–build, the project management team's primary role will be to ensure the synchronization of the design and construction efforts and managing their overlapping and interaction. From a project management perspective, the bottom line here is that despite the separate design and construction project management processes and project lifecycles, the design and construction efforts should still be provided in a seamless and integrated way to deliver project benefits in a continuous incremental manner to achieve project objectives.

While the *PMBOK® Guide* identifies the approach of modeling design–build projects by dealing with them as overlapped project phases, it leaves the method of applying this scenario with the project teams. The following set of guidelines and best-practice tips aim to assist the design–build project management in managing the phased and overlapped project management process groups and project life cycles of the design and construction project phases:

- Assign a dedicated project manager for each of the design and the construction phases, headed by a design–build project manager. The collaborative efforts of the design and construction teams can be instrumental in this regard.
- Divide the design phase into a series of design packages to enable a continuous transfer of design information to construction in an incremental fashion. This process can involve a fair amount of risk; thus it requires a high level of control over operations. This is discussed in detail later in this book under the SAFEDB-methodology chapters.
- Combine the design phase and the construction phase individual project (phase) management plans into a combined integrated design–build project management plan. This will enable putting everyone on the same page and an effective management of the interdependent design and construction activities.
- Combine the design phase and the construction phase critical path method (CPM) time schedules creating a combined integrated design–build schedule with combined resource pools, milestones, and critical path. Any delay or slippage in an upstream design activity should find a schedule rectification and recovery along its downstream design and construction activities.

Treating design–build projects in the above-described overlapped phased fashion is considered the best practice in the design–build industry at the moment. Reaping the benefits of the process however requires a high level of clarity within the project and harmony within the project team.

The *PMBOK® Guide* explains that the development of a project management plan involves developing a special project management subsidiary plan for each of the project management knowledge areas (apart from Integration Management), and then integrating such subsidiary project management plans into a comprehensive project management plan covering all knowledge areas. In design–build, the development of such a comprehensive project management plan becomes a more challenging task as it also requires the synchronization of the project's design and construction project management plans.

Hence, the process would start by each of the design and construction teams separately developing own project management plans in a draft form, and then start interacting with the other side to exchange information and synchronize efforts. The procedures and mechanisms for such interaction would take an incremental zigzagging form involving initial independent assessments, followed by a series of coordination sessions and refinements leading to production of a combined and coordinated project management plan document that is both known and understood by both the design and construction teams. The combined project management plan document shall define the team-specific as well as the common project management roles and responsibilities requiring action from both sides.

In line with the above discussion, this section of the book introduces a supplemental project management process addressing the unique nature of the design–build projects. This supplemental process is named KA0102* DB Project Management Plan and is to be annexed to the KA0102 Develop Project Management Plan project management process under the Project Integration Management knowledge area. Table 2.2 describes this adjustment.

Table 2.2 Adapting PMBOK® guide for design–build projects—a supplemental design–build project management process

<table>
<tr><th>Process group</th><th>Project management knowledge area (KA)</th><th>Project management process</th></tr>
<tr><td>Planning</td><td>KA01 Integration</td><td>KA0102* DB Project Management Plan</td></tr>
<tr><td colspan="3">Inputs:
1. Design project management plan
2. Construction project management plan
3. Organizational process assets
Tools and techniques:
1. Expert judgment
2. Facilitation techniques
3. Synchronization techniques
4. Zigzagging progression
5. Coordination sessions
Outputs:
1. Design–build project management plan</td></tr>
</table>

While developing the combined design–build project management plan, the project team will realize that certain subsidiary plans cannot indeed be effectively completed in the absence of a due input from the design and the construction side of the business and therefore must be conducted jointly. These subsidiary plans will most probably include key knowledge areas such as time management, cost management, and risk management. Other knowledge areas can well be added to the list depending on the project nature, circumstances, and other enterprise environmental factors.

2.4 Project Management Team Setup in Design–Build Projects

In the project management big picture, organizational structures take several styles.

Organizational structure styles reflect the chosen interaction between the organization's projects and the organization's functional management units, for example, design, planning, finance, and so forth. The most common organizational structure styles used by most modern organizations are the matrix organization and the projectized organization. Both styles assume the presence of a project manager for each project. In the matrix organization, the project team is provided by functional units, and the project manager's authority is affected by the involvement of the functional managers. In the projectized organization, project team is hired externally for the sole purpose of the project, and the project manager has full authority over the project resources and proceedings reporting directly to top management. Other possible organizational structures take place anywhere between these two basic styles.

Figures 2.9 and 2.10 illustrate the matrix and the projectized organizational structures at a high level.

In traditional "construction-only" or "design-only" projects, the project manager is mainly responsible for his side of the business only, namely, the design or the construction aspect. In design–build, the project manager's role develops into a lot more complicated one, similar to the program manager's role. It requires an integrated project management approach that deals with the inherent design–build threefold mission including the

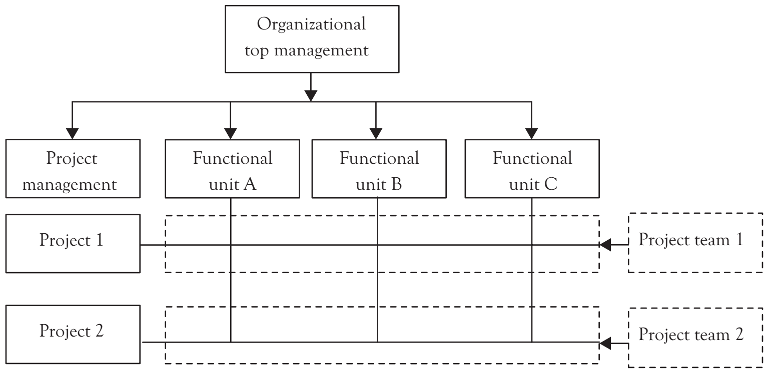


Figure 2.9 Organizational structures—matrix organization

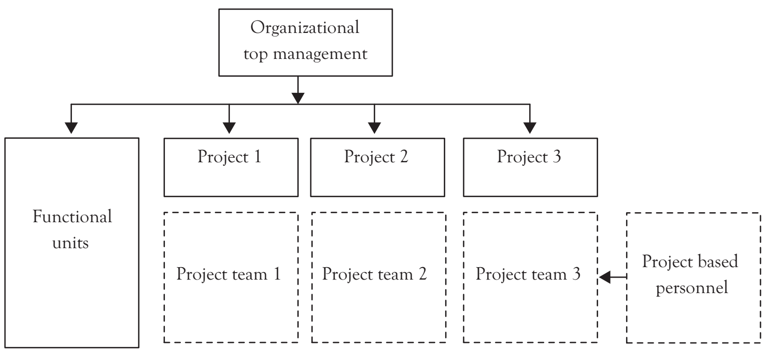


Figure 2.10 Organizational structures—projectized organization

full-scale management of both the design and the construction aspects of the project, in addition to managing the critical integration and interaction between the design and the construction teams and tasks.

As discussed in the previous section, in design–build, the project management effort becomes dual, involving what could be described as two projects in one, namely, a design project producing the project design documentation, and a concomitant and overlapped construction project producing the physical project construction product. Both projects are required to be managed simultaneously under a single overall synchronized design–build project management setup.

The best practice in this respect is to have a project management setup that involves a dedicated project manager for each of the two aspects of the business, that is, a design project manager for the project design, and a construction project manager for the project physical construction, headed by an overall design–build project manager. The project management trio will then be assisted by typical project management and supporting sub-teams including standard project management disciplines such as planning, cost, quality, safety, stakeholders, and risk management. This arrangement also takes care of the common issue of the lack of project managers in the industry who are highly experienced in both design and construction. Having specialized and dedicated design and construction project managers ensures that tasks are assigned to the parties that can best manage it, and distributes the work load logically so that each project manager can have a better focus on the works under his direct remit. Design and construction project managers will have to interact continuously and work collaboratively. Moreover, and in order to strengthen communication and interaction between the design and construction teams, it is recommended to assign a strategic design–build coordinator position that will have the mandate of supporting and coordinating the efforts of the design and construction teams and to ensure a steady and timely flow of information both ways. That would include both technical matters such as processing the technical queries initiated by the design and the construction teams, as well as nontechnical procedural matters such as managing the meeting strategy, monitoring compliance with the quality management system, and coordinating the timely conduction of gateway reviews.

Figure 2.11 illustrates an overview of the recommended design–build project management team composition and the interaction between the team components.

Other typical project management business units and positions remain valid and active; however, they are not shown in the organogram in Figure 2.11 to maintain the focus on the design–build aspect of the business. Such business units and positions would include area and functional managers in addition to other typical roles in the construction industry such as cost, quality planning, contracts, legal, risk, procurement, human resources, quantity surveying, secretarial, document control, stakeholder management, and other project delivery and project management functions.

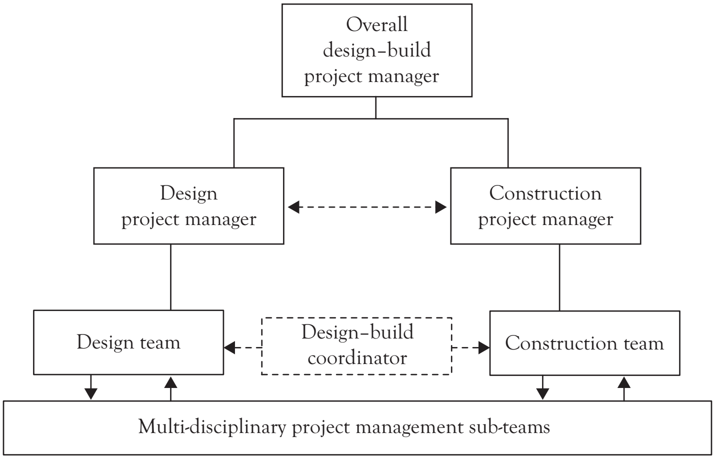


Figure 2.11 Project management structure in design–build projects

2.5 Attributes of the Effective Design–Build Project Manager

In general terms, the project manager's role is obviously crucial and key to project success. The role is usually very demanding and involves direct responsibility for the project outcome. It includes managing the end-to-end delivery of the project both vertically across management levels and horizontally across disciplines of all business units. This requires a combination of both strategic and tactical actions and skills. In design–build, the role becomes further challenging. The range of the design–build project manager's responsibilities is significantly wider than those in traditional design-only or construction-only projects. The design–build project manager has to manage the project design and project construction in addition to the integration and interaction between the design and construction teams and activities.

At the macro-level, the design–build project manager has the key responsibility of developing an adequate and effective combined design–build project management plan and to ensure that the power of the design–build is actuated throughout the project life cycle. At the micro-level, he must perform continuous close monitoring of day-to-day project activities and proceedings; ensure the effective interaction between the design and the construction teams; and gather and analyze performance

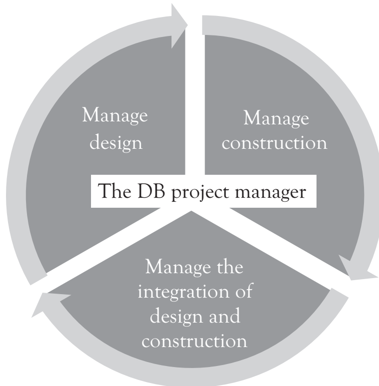


Figure 2.12 The threefold design–build responsibilities of the design–build project manager

information and metrics so as to ensure that the project is on track, on time, and on budget at all times throughout the project life cycle.

Figure 2.12 illustrates the threefold design–build responsibilities of the design–build project manager in design–build projects.

For the design–build project manager to be able to handle such a challenging role effectively, he needs to have or acquire a specific range of skills, competencies, and attributes. The following points provide a review and discussion of the issues surrounding this subject from a design–build perspective with a wider applicability for project managers in general:

1. Application area knowledge
   The application area refers to the application to which project management is applied. For example, a project manager responsible for building houses or apartment buildings should understand the construction industry, including standards and regulations important to that industry and those types of construction projects. A project manager leading a large highway project must know a lot about the principles and challenges of that application area. The same goes for other application areas such as highway construction, airport construction, railways, high-rise buildings, shopping malls, health care projects, and so forth. Additionally, in design–build projects, the project manager must have adequate design, construction, and design–build project delivery understanding and experience. Lack

of familiarity with any of such three areas can well limit the project manager's ability to anticipate risks and make sound decisions related to the project, leading to project complications and reduced efficiency.

2. General management knowledge

   The project manager should possess general management knowledge and skills. He should understand important topics related to financial management, accounting, procurement, sales, marketing, contracts, manufacturing, distribution, logistics, the supply chain, strategic planning, tactical planning, operations management, organizational structures and behavior, personnel administration, compensation, benefits, career paths, and health and safety practices. On some projects, it will be critical for the project manager to have substantial experience in one or several of these general management areas. In design–build projects, commercial acumen becomes indispensable when it comes to weighing the options and selection of the most cost-effective design–build solutions. The design–build project manager should be able to make an educated judgment on the commercial efficiency and the hidden costs or risks associated with the proposed solutions or materials.

3. Understanding the project environment

   The project environment differs from organization to organization and project to project, but there are some skills that will help in most project environments. The effective project manager needs to understand the organizations he works with and how services are provided in such organizations. He needs to understand how the various involved organizations work within their social, political, and physical environments. He must be comfortable leading and handling change, since most projects introduce changes in organizations and involve changes within the projects themselves. In design–build, the effective project manager should create a common project-specific culture of success that embraces the features and cultures of the design and construction components of the design–build team, which commonly represent two different organizations. He should then proactively monitor and spot changes in the involved organizations that might affect the project and respond to them upon their occurrence to reduce their impact on the project situation.

4. Interpersonal and communication skills
   Achieving high performance on projects requires soft skills and effective communication. Some of these soft skills include effective communication, influencing the organization to get things done, leadership, motivation, negotiation, conflict management, and problem solving in a consistent management style. The project manager must be able to lead his project teams by providing vision, delegating work, creating an energetic and positive environment, and setting an example of appropriate and effective behavior. Project managers must be able to motivate different types of people and take decisions quickly and accurately with a clear definition of accountability. The effective project manager must be visionary and a relationship builder, and must have the experience and ability to assess people and situations beyond their appearances. In design–build, the project manager must ensure that the design and construction teams communicate effectively as one team working toward a common objective. At the technical level, the project manager must be able to communicate effectively with both the designers and the builders using their own technical terminology.
5. Project management methodology
   Effective project management requires the application of a sound project management methodology. The effective project manager should ensure that such sound methodology exists and is implemented across the project. The project management methodology should be crafted carefully to address project needs and hit all and only the high points that affect project success.

It is the project manager's responsibility to carefully determine the amount of process and governance to be applied. Too much process can overburden the project and slow it down, whereas too little process can lead to project failure. In design–build, the project management methodology should embrace both sides of the business, namely, design and construction, and to ensure the effective interaction between the two disciplines in a controlled manner. Methodology should also adopt best-practice project management tools and techniques that are specific to the design–build project delivery approach. The SAFEDB-Methodology presented later in the book belongs to this category.

Finally, the effective design–build project manager must have an in-depth understanding of the design–build project delivery approach. He must be passionate about the design–build process and should exert utmost effort with unshaken determination to unleash and actuate the power of design–build.

2.6 Aligning Projects with Strategic Objectives

Markets are in a constant state of change, and so are the organizational strategies. Organizations throughout the world are losing billions in wasted project spending. One of the biggest contributing factors to this waste is the lack of alignment between projects and the organizational strategies. From a project management perspective, it should be realized that projects have roots into such organizational strategies. Projects are typically initiated in response to an organization's strategic plan, which was translated into initiatives including project portfolios, programs, and projects. The portfolio management process associated with planning and feasibility studies sets the priorities and timing for initiating various projects to meet the overall objectives of the organizations. Any subsequent change to strategy will likely cascade down giving reason to initiate certain new projects or eventually affect, amend, or terminate certain ongoing projects. Strategy changes may impact project time and cost; however, global benefits to the organization in the longer term usually offset and counterbalance such impact.

Figure 2.13 illustrates the strategic pyramid within which projects exist.

Organizational strategies and strategic objectives are deeply influenced by market demands and resource constraints. In the real-world practice, once the project is initiated, market pressure dictates timely completion of the project facility. Among various types of construction, the influence of market pressure on the timing of substantial completion of the project and commissioning the facility is most obvious in the industrial

Figure 2.13 Aligning projects with organizational strategic objectives

construction. Demand for an industrial product may be momentary or time bound, and if a company does not hit the market first, there may not be demand for its product later. With intensive competition for national and international markets, the trend of industrial construction moves toward shorter project life cycles, particularly in technology-intensive industries. Most construction contracts involve special penalty clauses for delay and even worst for liquidated damage.

Aligning projects with the organizational strategy is therefore a part of business that should be given utmost attention. The project management team should closely monitor changes or potential changes to organizational strategies and strategic objectives and respond to them in a timely manner using a strict change-management process. The effective monitoring and controlling of change should also consider the potential trade-offs between schedule crushing or acceleration and the related cost benefits, damage control, or enhanced return on investment. The early identification of strategy changes requiring a change to the project time or scope can be very useful, that is, given the established fact that the impact of change can be mitigated much more efficiently at an early stage of the project life cycle rather than at later stages. It is noted that the impact of strategy changes can relate to actions taking place after project completion, namely to the operation and maintenance of the completed facility. These should also be taken into account to avoid surprises at the project handover time.

Figure 2.14 illustrates the impact of strategy changes on projects.

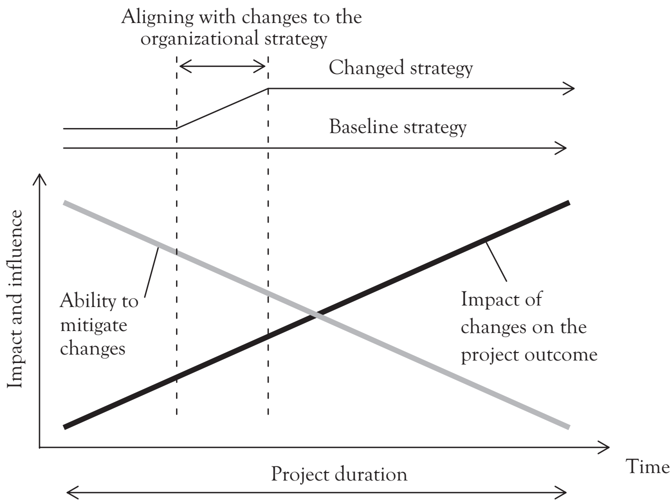


Figure 2.14 Impact of strategy changes on projects

In design–build projects, aligning with strategy can be an even more challenging task. In order to gain time, some owners would tend to forego thorough planning and feasibility study so as to proceed with design–build projects with inadequate definition of the project scope. That is done on the premise that the balance of planning and feasibility efforts can be completed by the design–build contractor. This tactic should be avoided as it can lead to abandoning projects before completion, and the associated loss of capital and reputation. Therefore, the owners should obtain the expertise of project management professionals to provide adequate planning and feasibility studies prior to soliciting bids and awarding projects. These professionals should have the experience and the ability to determine what information must be established by the owner and what can be safely left to the design–built entity to develop.

2.7 Summary

Project management has several technical definitions; however, it remains in essence the application of proactive and organized commonsense actions and steps to achieve project objectives. It all revolves around the key three pillars of any business, namely, the people, the process, and the technology. According to PMI's project management model, the project management framework consists of a system of integrated project management processes, process groups, and knowledge areas applied to project activities along the project life cycle. Given the dual nature of the design–build process, the design–build project management team setup and methodology should take account of both the design and the construction sides of the business and required interaction between the two. The design–build project manager should have a solid understanding of both the design and the construction aspects of the business, as well as of the theory and application of design–build project delivery approach. Finally, aligning projects with the organizational strategies at all times is of paramount importance.

CHAPTER 3

Design–Build Best Practices and Success Strategies

Preface

Design–build is a powerful process that has proven over the years to be able to bring about outstanding benefits and efficiencies. This does not happen automatically, and not every design–builder can really deliver the design–build promise. This chapter provides a range of design–build best practices and success strategies that can be very useful to all design–builders, whether seasoned or new to the process. Aiming to match how the business really goes in practice, the chapter is structured into two distinct parts addressing the two typical project stages, namely, the pre-contract award stage and the post-contract award stage. Each of such two stages has its own features, issues, and challenges. This chapter highlights the key points and provides knowledge and tricks-of-trade techniques related to both stages that can be instrumental to the design–builders as well as to Owners. During the precontract award stage, key topics covered include the crucial project go or no-go decision, choosing the right design–build partner, preparing the design–building teaming agreement and how to win the design–build tender competition. Whereas the key topics covered for the post-contract award stage include mobilizing and developing project teams, project delivery guidelines and best practices, risk management in the design–build environment, and design–build key performance indicators (KPIs) and critical success factors. This chapter is meant to provide the reader with useful insights into the design–build project delivery approach from a practical real-life perspective.

3.1 Design–Build during the Precontract Award Stage

This section looks into the contemplation, teaming up, and tendering stage, which precede the design–build contract award. Decisions made by the businesses at this stage will have long-lasting effects or impact on project success as well as on achieving business goals and objectives. This critical stage has its own features, challenges, and pitfalls, which require utmost attention by all the parties involved. Key topics covered include the crucial go or no-go decision, choosing the right design–build partner, preparing the design–building teaming agreement, and how to win the design–build tender competition.

3.1.1 Go or No-Go Decision

This is the first big decision in the process, whether or not to go for a given prospective design–build project in the first place.

This question differs from that discussed in Section 1.5, which looked into whether or not to go for the design–build approach. This section focuses on whether or not to go for a particular design–build project prospect or a request for proposal (RFP). The importance of such decision for the business could not be stressed further. In a very short period of time, usually a couple of days if not a couple of hours, organizations are required to make the strategic go or no-go decision. The best practice to deal with such situation is to follow a pre-engineered process. Give yourself the time and the right to look through the RFP in a structured manner with a clear, objective, and unbiased mind. Design–build prospects are often exciting and even irresistible to technical professionals given the opportunity it provides to designers and builders to get creative and demonstrate their skills and experiences. The same passion and excitement involves company executive and business leaders since design–build projects often have a large monetary value, thus a quick win when it comes to achieving turnover objectives. That is all good and fine; however, it should not result in rushing to commitment or jumping to conclusions.

When it comes to making the go or no-go decision, due diligence is the name of the game. An objective expert assessment of the project risks related to its size, nature, location, scope, requirements, constraints, complexity, time, budget, and most importantly the end-product acceptance criteria is absolutely indispensable, that is, to ensure alignment with strategy and establish the organization's preparedness, capacity, and capability to carry out the project. On the other hand, it is also absolutely essential to know the Owner and understand the project motivation, funding source, driving force, and any conflict-of-interest issues surrounding the project to assess whether or not it is worth pursuing. Remember that the devil is in the details, and not all what glitters is gold.

A sound go or no-go process is one that aims to rationalize the go or no-go decision making by hitting the high points. That would take the form of a prospect examination and reporting checklist. Checklist to include three key groups of questions targeting three key areas of evaluation, namely, the Owner, the project, and the tendering design–build organization itself. The Owner group looks to evaluate the Owner or contracting agency with the aims to evaluate and identify any concerns, risks, or conflict-of-interest issues. The project group investigates the project particulars, boundaries, constraints, risks, and specific requirements in addition to the specific design–build features and parameters of the project. And, the organization group involves an honest self-assessment of the tendering organization's reasonable readiness to carry out the project safely and successfully.

Table 3.1 provides a proposed framework for a go or no-go decision-making checklist in line with the above background information. Moreover, and in further alignment with the best practice in the field, a numerical evaluation was proposed to enable transferring evaluation into numbers and then conclude the recommended course of action based on a pre-defined threshold percentage.

Following are proposed scoring guidelines:

1. A total score of 70 percent yields a recommended go decision.
2. A score of less than five on any single field flags up a reason for a potential no go.
3. Scoring to be completed independently by different expert evaluators followed by a meeting.

The shown percentages and questions are thought to yield a reasonable score to support the go or no-go decision. However, organizations can add

Table 3.1 Go or no-go decision template

Project name	XYZ Expressway Project	Prospect No.	001-yyyy
Evaluation by	John Doe	Date	mm.dd.yyyy

Evaluation area	Evaluation question	Score 0 to 10
Owner [30%]	Is the Owner known to the organization?	…
	Does the Owner have a good payment record?	…
	Does the Owner have a good market reputation?	…
	Does the Owner have a large future project portfolio?	…
	Does the Owner have the financial capability to fund the project?	…
	Does the Owner have a good project management maturity?	…
	Does the Owner have a good design–build understanding?	…
	Does the Owner have a good record of timely approvals?	…
	Weighted average	….(1)…. %
Project [40%]	Is the tender period adequate to develop a DB proposal?	…
	Are project requirements reasonable and clearly described?	…
	Are performance and acceptance criteria clear and achievable?	…
	Are the project completion date and milestones realistic?	…
	Are the applicable laws, rules, and regulations acceptable?	…
	Is the degree of the required fast-tracking achievable?	…
	Is the proposed design and construction budget realistic?	…
	What is the local economy condition at the project location?	…
	Does the project align with the corporate strategic plan?	…
	Weighted average	….(2)…. %
Organization [30%]	Does the organization have similar experience?	…
	Does the organization have adequate resources?	…
	Does the organization have sufficient financial capacity?	…
	Can the organization perform with minimal subcontracting?	…
	Can the organization perform with minimal subcontracting?	…

Evaluation area	Evaluation question	Score 0 to 10
	Does the organization have a suitable design–build partner?	…
	Does design–build align with the corporate strategy?	…
	Does the project achieve corporate profitability objectives?	…
	Weighted average	….(3)…. %
	Total score	(1) + (2) + (3)%

or delete any of the proposed questions or change the proposed weighting percentages. At the end of day, there is no substitute for expert judgment by the organization's top management and business leaders.

A recap of the presented concepts is as follows.

1. Go/no go is the first big decision in the process.
2. The best practice to deal with the go or no-go decision is to use a pre-engineered process.
3. A sound evaluation process would focus on Owner, project, and the organization itself.
4. A numerical solution can be useful; however, it is no substitute for expert judgment.

3.1.2 Choosing the Right Partner and Forming the Design–Build Team

Choosing the right design–builder partner is the first and foremost key to project success.

That goes for both the case of the designer and the contractor choosing each other to form a design–build entity, as well as for the case of the Owner's selection of a design–build entity to carry out a project. This chapter looks into this matter for both situations, and provides a review of best practices and tricks of the trade in this regard. The power of design–build stems from its constructive approach, which is able to stimulate the interaction between the project stakeholders toward better results and to bring them together toward achieving project success as a common objective. The hypothesis here is that in design–build, the design–build partner is the companion on the road to success: you get there together or both parties fail. The contractual, legal, financial, and pragmatic aspects however remain there and should not be underestimated.

When it comes to selecting a design–build partner, think of joint ventures (JVs).

Companies choose to enter JVs in order to share strengths, minimize risks, and increase competitive advantages in the marketplace. JVs are initiated by the parties' entering a contract or an agreement that specifies the JV goals and the roles and responsibilities of the JV parties and the contract scope and limitations.

From a design–build perspective, the basics and motivations of the JV concept exist in reality, although the contractual arrangements between the parties might differ. For the effective implementation of design–build and in order to reap the full benefits of the process, the keyword is collaboration.

3.1.2.1 Contractors' and Designers' Selection of Their Design–Build Partner

The selection of a design–build partner is a major business decision for the parties involved. The relationship usually starts when strategies of both organizations intersect. A party invites the other to join forces to bid for a design–build project, and the communication is initiated. Organizations then start evaluating each other, the potential business relationship, and the project itself for compliance with business strategy. The relationship between contractors and designers to create a design–build team can take many forms and shapes; however, the following are the most common team formation modes and are all acknowledged in the design–build industry:

1. Contractor led: The construction contractor is the prime contracting entity, and the designer acts as a subcontractor under a design professional services agreement. This is the most common form of design–build entity.

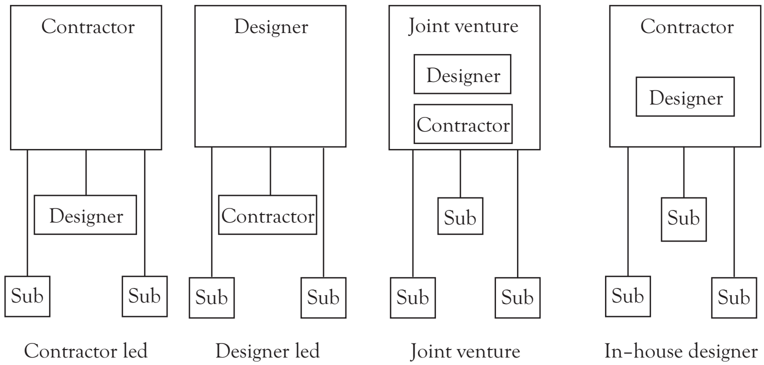


Figure 3.1 Design–build team formation modes

2. Designer led: The designer is the prime contracting entity, and the construction contractor acts as a subcontractor under a construction contract agreement. This is a rare form; however, it exists in reality especially in highly architectural projects.
3. JV: A JV between the construction contractor and the designer under a JV agreement and an agreed percentage split. Again, this form is not very common, and when it exists the share of the designer component is usually very small.
4. In-house: An in-house design and construction capability taking place within an integrated design–build organization. This is the ideal form of a design–build entity and is quite common in the industry especially in the private residential housing business and in giant multinational construction companies.

Figure 3.1 illustrates the above design–build team formation modes.

The first three modes of design–build entity relationship, namely modes 1, 2, and 3, require selection of a design–build partner. The form of relationship would understandingly somehow affect the attitudes of the parties while deciding to work with the selected partner. However, experience shows that the factors affecting partner selection are essentially the following:

- Trust
- Integrity

- Technical ability
- Design–build experience
- Financial strength
- Partner's personnel
- Marketability to owner
- Management proficiency
- Similar objectives
- Similar culture
- Located close

The above list would serve as a checklist for organizations during the course of design–build partner selection. Organizations might wish to add other factors to the list. Top management vision and expert judgment however remain indispensable.

3.1.2.2 Owners' Selection of a Design–Build Partner

Owners' selection of a design–build contractor or business partner is guided by Owner's expectations. They look for a partner who is capable and committed to deliver the design–build promise. All basic expectations of traditional project delivery approaches remain, and the design–build adds more demanding expectations. Owners' selection of a design–build partner is again a major business decision. This is particularly true for Owners considering design–build for the first time. To them it is regarded as a sort of innovation and departure from standard ways of doing business, which associates additional risks. The burden however remains on the design–build entity to understand the Owner's design–build expectations and to address them consciously and satisfactorily.

A research work has been conducted by the author to study Owners' attitudes toward design–build. It focused on public-sector organizations in the Middle East as the most common source of design–build undertakings, and posed the key question of "Why do Owners decide to go for the Design-Build approach instead of other traditional project delivery methods?" Research revealed that the following selection factors are the driving force that guides Owners' decisions and portrays their design–build expectations, and in the shown order of importance:

- Shorten duration: to reduce the project time as compared to other methods
- Reduce cost: to reduce the overall project cost as compared to other methods
- Reduce claims: to reduce chances for claims by the contractor due to design errors
- Establish cost: to fix the project budget before completing the detailed design
- Establish schedule: to fix the project time frame before completing the detailed design
- Constructability/innovation: to benefit from the designer's and builder's interaction
- Reduce coordination efforts: to reduce the effort and risk involved in coordination

With the above in mind, it could be concluded that the factors guiding Owners' selection of the design–build entity are its ability to deliver the project in a shorter time, lower cost, with less or no claims, establish time and cost early in the process, enhance constructability and exercise innovation, and last but not the least to work independently and with minimum Owner supervision.

A recap of the presented concepts is as follows:

1. Choosing the right design–builder partner is key to project success.
2. Contractors and designers select their design–build partners based on their trust, integrity, technical ability, design–build experience, and other logical factors.
3. Owners select their design–build partners based on their ability to deliver projects in a shorter time, lesser cost, with minimal claims and other logical factors.

3.1.3 The Designer–Builder Teaming Agreement

Teamwork is good. However, in business, it should be documented.

In design–build, the teaming agreement is a legal document signed by the designer and the builder in advance of the decision to pursue the design–build project. It serves as a vehicle to permit the designer and the builder organizations to establish the necessary ground rules for working together as a team to win and then implement the design–build project. The teaming agreement is not a substitute for the subsequent contract agreement that the designer and the builder execute if they are awarded the contract. However, the terms, conditions, and understandings stipulated in the signed teaming agreement will serve as an important reference while negotiating the actual contract. Therefore, the teaming agreement should be drafted carefully with the potential project implementation contract agreement in mind. The following paragraphs look into teaming agreements and provide guidelines, recommendations, and discussion of the key features of such a vital document.

1. Format and formality of the agreement
   The teaming agreement could be worded by the parties using a language similar to a standard memorandum of understanding or even better by tailoring a standard form of agreement recommended by a professional organization such as Design–Build Institute of America (DBIA). Once finalized and the terms and conditions agreed, the agreement should be signed and sealed in duplicate by senior authorized signatories of the two parties. Once signed and sealed, the agreement becomes a legal document binding to the parties and confirming their decision to pursue the project. In every agreement, there may come a time of disagreement. Therefore, the agreement should include a mechanism for dispute resolution. That would start with an effort toward an amicable settlement, and being a legal document, a procedure for third-party arbitration.
2. Terms and conditions of the agreement
   Terms and conditions of the teaming agreement are similar to those of a typical memorandum of understanding. The teaming agreement should contain basic information areas such as details of the parties,

purpose, project name and brief, date, location, and key personnel. Moreover it should identify lines of communication, agreement duration, limitations, exclusions, in addition to the scope of services to be provided by each party, commercial arrangement related to the split of the proposal cost, liability for professional errors, and finally the agreed termination and dispute resolution mechanisms. It should be noted that the cost of preparing the design–build proposal can be substantial, therefore, should be agreed upfront between the parties in a balanced manner. The agreement should also address the parties' involvement and interface with the client during the tender period and the way ahead should the project is won. That would give both parties the level of clarity they need to proceed with the proposal with comfort and enthusiasm, as well as to reduce chances of disagreement down the road. Finally, the agreement should be clear about the tender strategy in terms of the need for the parties to mutually approve the proposal. This could be the case, or otherwise the design–build lead will have the final say, while the other party submits a separate internal proposal to the lead as a subcontractor or subconsultant, irrespective of the actual price tendered by the lead to the owner to perform the entirety of the design–build works.

3. Confidentiality and proprietary information
   A key aspect of the design–build teaming agreement is confidentiality and the critical protection of proprietary information. In design–build, unlike other traditional methods, the design–build solution is developed during the tender period and can include innovative design, construction, and pricing or scheduling practices and techniques. Consequently, leaking information about the pursued proposal strategy can be detrimental to tendering endeavor. On the other hand, the proprietary information provided by the owner should only be used for the purposes of preparing the proposal and performing the project. It is therefore a best practice to have the involved parties and all the involved individuals to sign a strict confidentiality agreement undertaking to keep the confidentiality of the proposal.

Finally, despite the teaming agreement, trust and confidence of the teaming parties in one another remain indispensable and the cornerstone for working out a successful design–build proposal. Trust and confidence can go a long way in igniting the team spirit within the design–build team and can well serve as an energy-saving mechanism as opposed to scrutiny and controls.

A recap of the presented concepts is as follows:

1. Teaming agreement is required to organize the roles and responsibilities of the design–build team components during the tendering and proposal development phase.
2. Teaming agreement is a legal document; however, it is not a substitute for a formal contract agreement to be signed between the designer and the builder when a contract is won.
3. The teaming agreement should be written carefully following an agreed form of agreement to address all the relevant issues and topics.
4. Teaming agreement should be supported by a confidentiality agreement to be signed by the parties involved to protect the proposal innovations and the Owner's proprietary information.
5. Trust and confidence remain the cornerstone for a successful design–build teaming.

3.1.4 Winning the Design–Build Tender Competition

Winning the design–build tender competition is a different game from that of winning traditional construction contracts. In traditional contracts, the focus is on pricing of the project elements based on fully developed designs and specifications and a fixed time frame, while as in design–build the tenderer has much more room for creativity and manipulation in a dynamic competition environment. Key to success in design–build tendering is to adopt a winning tendering strategy and to have in place a capable and integrated tender team. The tendering strategy should be one that is realistic and pragmatic with a great deal of focus on identifying and utilizing the right means, methods, technologies, and special expertise to produce an unbeatable design and construction offering able to deliver the project in the shortest time and least cost possible. On the other hand, the tender team will need to be multidisciplinary, having on board expert-level design and construction professionals with full understanding of the nature of the type of project under study, and well versed with the principles and mechanisms of the design–build process. Design–build tendering is more demanding than traditional tendering and requires more time and effort; however, it is much more exciting and its reward can be enormous to all parties involved including Owners, design–build entities, and the industry at large.

When it comes to design–build tendering, think value engineering (VE).

VE is broadly defined as a structured effort aiming to achieve the optimum balance among the required functions, performance, quality, safety, sustainability and scope requirements, with the time, cost, and resources necessary to accomplish such requirements. In simplified terms, VE is commonly and widely expressed as the relationship between function and cost, namely:

$$\text{Value} = \text{Function}/\text{Cost}$$

Where value is defined as the reliable performance of functions to meet customer needs, function as the natural or characteristic action performed by a product or service, and cost as the expenditure necessary to produce a product or service meeting customer needs.

VE was originally called value analysis by its inventor Larry Miles in 1947. The basic idea is that if you want to increase the value of an item, you either improve its functionality or reduce its cost. In the context of design–build tendering, the design–build tenderer should focus on ways to reduce the cost required to achieve the functions identified by the Owner. Function is to be kept at exactly the required level stated by the Owner in the RFP. In the heat of the moment, and wanting to impress the Owner, some tenderers feel tempted to offer the Owner a higher-quality product exceeding what is indeed required at a higher cost thinking that this will impress the Owner and affect the contract award decision. This is a myth, at least for large civil engineering projects. No gold plating should be attempted. In competitive bidding, technically acceptable tenders will proceed to financial evaluation, and the lowest bidder wins. Some contracting agencies use a point system giving a separate score to the technical proposal aiming to acknowledge technically superior proposals. The reality is, do not count too much on this and stay focused on being the lowest price bidder.

Price is king. Value advocates might disagree with this statement; however, if the objective is to win the tender competition, sticking to this slogan is the recommended way to go. If the tenderer still feels strongly about a much higher function at a slightly cost proposal, he can always submit a separate alternative tender proposal in addition to and on top of a main fully compliant tender package sticking to the required and stated functional requirements.

In traditional projects, VE is conducted by the design consultant alone during the design phase, and/or by the construction contractor alone during the construction phase. At no point do designers and contractors get the chance to work together to develop a value engineered solution. In design–build, VE is conducted collaboratively by teams of designers and contractors within the design–build entity both before and after contract award, which makes the effort much more effective. This is one of the key reasons behind the power of design–build and what gives it an edge over the traditional design–bid–build method. Figure 3.2 illustrates a comparison between the pattern of VE efficiency in design–build versus the same in design–bid–build.

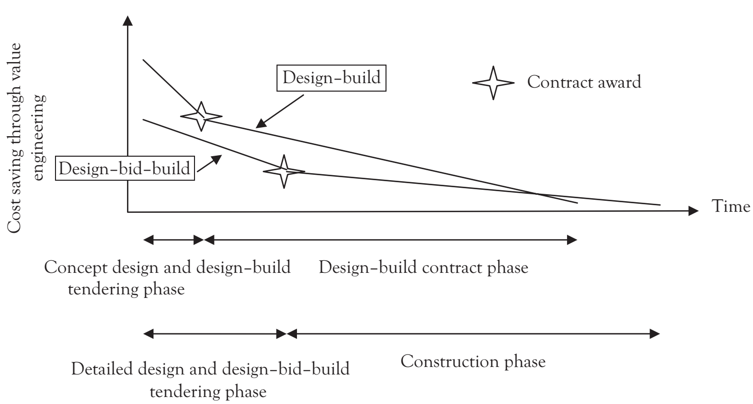


Figure 3.2 Pattern of value engineering efficiency—design–build versus design–bid–build

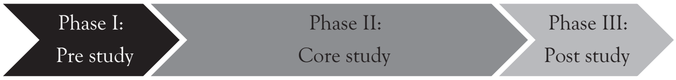


Figure 3.3 The standard value engineering model

Therefore, toward a winning design–build tender, the design–build tendering team needs to possess in-depth understanding of the principles of the VE process. The multidisciplinary tendering team, usually 5 to 10 professionals, would ideally be led or supported by a qualified, specialized, and experienced VE expert. The benefits of such a strategic role can be enormous.

The standard VE model consists of three basic phases, namely, the pre-study phase, the core VE study phase, and the post-study phase, as shown in Figure 3.3.

Such phases are discussed below in some detail in a design–build tendering context. Adherence to the explained model phases in line with the Owner's furnished design–build RFP will assure maximum benefits toward a winning design–build tender.

Phase I: Pre-study (preparation, information gathering)

I.1 Understand project RFP requirements and set tender strategy
I.2 Produce a list of key elements to undergo tender VE analysis
I.3 Select a tender VE team and fix time frame

Phase II: Core study (functional analysis, creativity, evaluation, development)

II.1 Develop a number of potential alternatives for each of the selected key elements
II.2 Conduct functional analysis to verify and confirm feasibility of alternatives and their satisfaction of functional requirements (see Table 3.2)
II.3 Produce a least-cost comparison of the feasible alternatives (see Table 3.3)
II.4 Select the lowest cost feasible alternatives for each work element
II.5 Present VE report to management for approval

Phase III: Post-study (implementation, presentation, follow-up)

III.1 Implement the approved lowest-cost alternatives
III.2 Finalize and submit the tender technical and financial proposals
III.3 Monitor and follow-up tender status

Tables 3.2 and 3.3 provide sample working tools for the processing of VE.

Finally, it should be noted that all other tendering tools, techniques, and best practices such as go–no-go decision making, the application of lessons learned, utilizing organizational process assets, Owner care, expert judgment, avoiding gold-plating, optimizing resources, and using the

Table 3.2 Sample functional analysis matrix

Criteria	Alternative A Prefabricated sandwich panels	Alternative B Standing seam metal roof	Alternative C Fiber glass roofing
Constructability	Y	Y	Y
Weather resistance and durability	Y	Y	Y
Thermal resistance	N (thus no go)	Y	Y
Fire resistance and safety	Y	Y	Y
Flexibility in applying	Y	Y	Y
Maintenance	Y	Y	Y
Aesthesis	Y	Y	Y
Ease of installation	Y	Y	Y
Timely availability	Y	Y	Y

N, no; Y, yes.

Table 3.3 Sample least-cost comparison of feasible alternatives

Item #	Description Warehouse roofing system	Alternative A Prefabricated sandwich panels	Alternative B Standing seam metal roof	Alternative C Fiber glass roofing
1		No go	$280k	$320K
2	……	……	……	……
3	……	……	……	……
n	……	……	……	……

most competitive construction material and workmanship rates and unit prices for the various work elements remain valid in design–build tendering and should be strictly adhered to.

A recap of the presented concepts is as follows:

1. Design–build tendering is a challenging and dynamic process.
2. When it comes to design–build tendering, think VE.
3. The power of design–build lies in its ability to boost the effectiveness of the VE process by allowing it to take place both before and after contract award, and be conducted by teams of designers and builders rather than by the designers and the builders separately.
4. In design–build, value is created by keeping function at exactly the required level defined by the Owner, and reducing cost.
5. Basic principles and best practices of conventional tendering processes apply.

3.2 Design–Build during the Post-Contract-Award Stage

Once the design–build contract is awarded, the clock starts ticking and a whole range of actions and activities becomes due. This is the time for the winning design–build contractor to go on the stage and start immediately discharging his obligations under the design–build contract. It is time to deliver. While general project delivery best practices remain applicable, there are certain issues, actions, and activities that are specific to delivering design–build projects. This section addresses a range of critical aspects related to the design–build project delivery including mobilizing and developing project teams, project delivery guidelines and best practices, risk management in the design–build environment, and design–build KPIs and critical success factors.

3.2.1 Mobilizing and Developing the Design–Build Team

The first and most important step in the design–build project implementation phase is mobilizing and developing the project team. In design–build, the project team has got to hit the ground running.

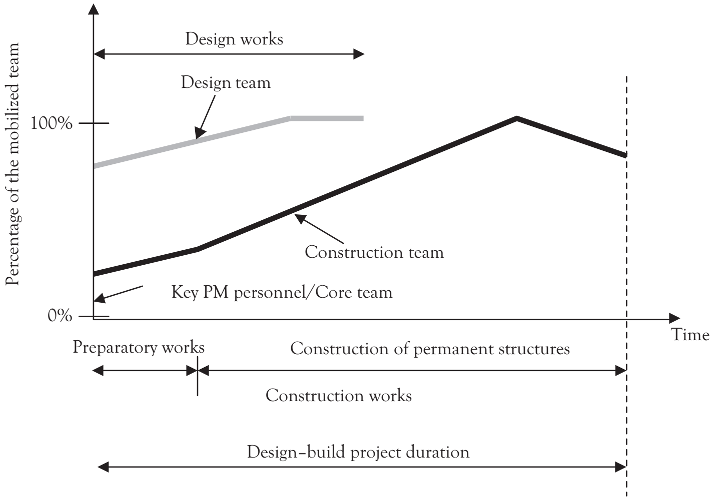


Figure 3.4 Design–build team mobilization pattern

In design–build, mobilizing project teams can be a challenging task if staffing is not well planned. While mobilizing labor construction personnel and labor can ramp up gradually, the mobilization of the team management key positions and the design team has got to be swift, almost instant. After all, it is the team top management that runs the show and orchestrates the design–build effort, and it is the design team that first goes on the stage and starts producing design information to enable early start of the construction of the permanent structures on site. Figure 3.4 illustrates a comparison between the patterns of the design team mobilization ramp up versus the same for the construction team.

On the other hand, being a newly developed team, the design–build team will inevitably have to go through the team development process. In the team development arena, Tuckman's team development model has proven over the years to be very valid. According to Tuckman's model, there are four inevitable stages that teams have to go through, namely, forming, storming, norming, and performing (Tuckman 1965). From a project delivery perspective, the goal is to reach the performing stage as early as possible in the project duration. Performing is the point where teams become productive, knowledgeable, motivated, and able to function as a unit and resolve issues collaboratively in a way to get the job done smoothly. High-performance teams act collaboratively to achieve

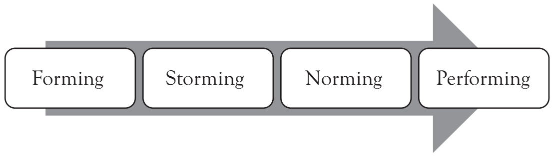


Figure 3.5 Tuckman's team-building model (Tuckman 1965)

business objectives. That goes for both teams of individuals working on a particular task, or in the bigger picture for teams of organizations working together to deliver a particular project. This becomes a particularly challenging task in design–build projects given the high level of team interaction and collaboration required.

Figure 3.5 illustrates Tuckman's team development model.

In design–build, and as discussed earlier in the book, the core project delivery team consists of the Owner, the bridging consultant, the oversight consultant, and the two components of the design–build entity, namely, the design consultant (the designer) and the construction contractor (the builder).

Applying Tuckman's model in the design–build project delivery context, the forming stage is the stage taking place right after contracts are signed between the parties. At this stage. the team behavior is driven by a desire to build trust, be accepted by the others, and avoid controversy or conflict. The forming stage usually lasts for a short period and goes smoothly.

The storming stage is the project's most critical stage where conflicts between the parties start to emerge, mainly due to lack of understanding of own and other parties' roles and responsibilities. The storming stage is necessary to the growth of the team; however, it should be exceeded as quickly as possible for the sake of project success.

The norming stage occurs at the end of the storming stage when the team has reached an adequate level of mutual and clear understanding of own and other team players' roles and responsibilities, and when the way forward is agreed. Norming is followed by the targeted performing stage.

In the performing stage the team becomes comfortable, competent, autonomous, and able to perform the decision-making process effectively. Maintaining such a status will however require close monitoring that extends beyond this point to capture the expected random cases of reverting to the storming stage, and to deal with such cases instantaneously by exercising leadership.

The role of top management and project leadership in the above process is very important. Team development should be in the core of the organization's focus to ensure project success.

A recap of the presented concepts is as follows:

1. Mobilizing project team needs to be swift and well controlled to ensure a project strong start.
2. Project management core team and most of the design team task force need to mobilize on contract award whereas the construction team may mobilize gradually.
3. The design–build team at large goes through a challenging process of team building and development. This needs to be realized and managed in a proactive and conscious manner.

3.2.2 Delivering the Design–Build Project—Guidelines and Best Practices

The successful delivery of design–build projects is the most challenging part of the entire process. It is where promises are made and the theory is examined.

In today's marketplace, many organizations and professionals realize the benefits of the process; however, when it comes to implementation, questions start to arise, and fewer can really deliver. The good news is that all established guidelines and best practices associated with the successful project delivery of construction projects in general still apply to design–build. It is only that there is a set of specific mechanisms and competencies that are unique to the design–build process and need to be realized, understood, and applied by all parties involved for superior project results. This section focuses on such specific design–build mechanisms and competencies that are unique to the more dynamic design–build process. The review is structured following the powerful people, process, and technology business model that is applicable to any successful business endeavor.

3.2.2.1 People

In the traditional design–bid–build method, the post-award project delivery phase involves the Owner, the supervision consultant, and the contractor. Project teams are most likely familiar with and well accustomed to working within such a traditional trio. In design–build, a fourth stakeholder is introduced, namely, the designer, and rules of the traditional game change. This could cause confusion and inefficiencies within the teams involved unless a conscious effort is exerted to manage such change and enable project success. The following guidelines and best practices would assist in this regard:

1. Top management commitment: Senior executives of the various parties involved should demonstrate commitment to the design–build process, promote trust and team spirit, as well as support the mindset change associated with the design–build project delivery approach.
2. Design–build orientation and training: Project teams should be oriented, trained, and educated on the design–build process and the differences between it and other project delivery systems. This effort should be documented and be part of the project management plan.
3. Colocation: Project teams should be colocated as much as practically possible. This is to promote effective communication, facilitate design reviews and the swift resolution of project issues, as well as to enable the unhindered interaction between design and construction professionals.
4. Team formation and profile: Design–build requires a higher-than-usual project team profile with outstanding skills, education, experience, creativity, and flexibility. Project team formation should take account of this requirement and ensure soundness and sufficiency of the collective skill set available.
5. Design–build expertise: Design–build involves a specific way of doing business that is different from other traditional methods. Therefore, having on board a number of design–build experts at key positions is absolutely necessary to streamline the process and avoid process pitfalls.

3.2.2.2 Process

The design–build project delivery process is more complicated than the traditional design–bid–build. In addition to the general best practice processes, the design–build process involves process add-ons that are specific to it. These are required to make the system work. That includes the interface between internal and external stakeholders and promoting the effective interaction between the design and the construction teams as well as between the design and the construction activities. The following guidelines and best practices address a number of such process add-ons:

1. Interface management: In design–build, suitable project management processes should be developed to address and enable the direct interface between the design–builder and key internal and external stakeholders. This is to reduce bureaucracy and insert flexibility into the system.
2. Design review and approval: The design–build project management process should clearly address the Owner's role in the design review and approval process. In design–build, this is usually limited to high-level phase gate reviews and certain aesthetics-related aspects. It is a best practice to stipulate a parallel fair and impartial third-party peer review of designs for compliance with the design–build contract. This is to reduce chances for disputes if detailed reviews are conducted by the Owner.
3. Change management: Design–build requires a strict change management process. The process should be able to detect and formalize any deviation from the baseline established in the contract documents. This includes scope additions, omissions, substitutions, or alterations.
4. Quality management system: In design–build, quality management system should encompass both design and construction activities, in addition to the critical design and construction interaction. This is to ensure that such critical interaction is conducted in a well-defined and controlled manner.
5. Design–build tools and techniques: The implementation of design–build projects requires the use of specialized tools and techniques

that are specific to the design–build process. Such tools and techniques should be encouraged and documented in the project management plan. The SAFEDB-methodology presented in this book belongs to such specialized design–build tools and techniques.

3.2.2.3 Technology

The design–build project implementation process is technology-rich. The use of technology in design–build ranges from the information technology (IT), to communications means, all the way down to the core technologies applied to develop and operate the project itself. Technology is one of the key cornerstones that make the difference in project implementation. The following guidelines and best practices address the use of technology in design–build projects:

1. IT infrastructure: The IT infrastructure requirements for design–build projects are different from those for design–bid–build, in terms of both capacity and structure. As to capacity, the IT system should have adequate capacity and speed to handle the continuous static and online transfer of the design drawings and design documentation normally of very large file sizes. As to system setup and structure, the IT system would best be structured in two distinct drives or domains, one for design and another for construction. Design progresses within the design domain, and when any part of it is ready to go to construction, it gets released in a controlled manner to a home within the construction domain. Likewise, any feedback from the construction domain to the design domain gets released in a controlled manner to a home within the construction domain. Moreover, the IT infrastructure should include advanced communications platform to support the team colocation concept in case some members or elements of the team are inevitably located remotely.
2. Computer software: In design–build, the range of the required computer software expands to include design programs. An inventory should be carried out at the beginning of the project to identify the design software requirements. This would typically include the latest

versions of the design computer programs required to complete the design of all the engineering disciplines involved.

3. Testing laboratories: In design–build, the role of testing laboratories is of prime importance. The design–builder is ultimately responsible for the quality and durability of the works. It is therefore essential that that the design–builder maintains own testing labs in addition to any third-party labs deployed by the Owner. This is to ensure good quality of the work and enable a smooth progress.
4. Building Information Modeling (BIM) in design–build: At early stages of the design–build project, the image of the end product might not be clear in the project team's mind. BIM, or the building information modeling technology, can be instrumental in this regard. In BIM, information on the end product can be shared visually and with clarity, inspiring the team and putting everyone on the same page.
5. Specialist technologies: In design–build, having a specialist or advanced technology can be decisive in winning and implementing projects. Such advanced technologies should be protected and copyrighted by the design–builders and transferred to the Owner if required by the design–build contract.

A recap of the presented concepts is as follows:

1. The successful delivery of design–build projects is the most challenging part of the entire process.
2. The general project implementation best practices applicable to other project delivery methods remain valid in design–build projects. Design–build however has its own add-on best practices.
3. Adopting and implementing the established design–build practices is key to avoid process pitfalls and enhance the chances of project success.
4. People, process, and technology remain the basic three pillars of any successful business endeavor.
5. The project team may add or indeed develop new best practices to best fit project needs.

3.2.3 Risk Management in Design–Build Environment

Risk management is a core element of any project management method. This section provides an overview of the principles of the risk management process in general, and then moves on to discuss project risks that are unique to the design–build project delivery approach. The need for a sophisticated risk management model (RMM) and structured effort increases as projects increase in size and complexity. Many organizations in the industry have over the years developed a mature risk management culture and maintained well-established risk management methodologies eventually supported by modern computer-based risk management programs. However, many others lag behind in this regard, and only deal with "risks" when they materialize and become "issues," putting projects at a constant state of panic and risk exposure, which naturally results in project delays and cost overruns. The effective project risk management is key to achieve project objectives.

Project risk management is a structured and proactive method of predicting risks, classifying risks, and mitigating risks. It involves both quantitative and qualitative methods of ranking risks according to their potential to adversely affect project success. The standard project RMM consists of three logical steps, namely, risk identification, risk analysis, and risk response, as shown in Figure 3.6. The risk management process starts at the project inception and the risk monitoring and controlling proceed along the project life cycle. During the course of the project, new risks are identified and other earlier identified risks get mitigated or simply disappear and hence get removed from the project's risk register.

3.2.3.1 First Risk Management Model Step: Risk identification

Construction is one of the most risky industries. Large construction projects invariably attract numerous project risks of various sources and take several forms and shapes. It is therefore of utmost importance for the project team to identify and prepare for potential project risks upfront in a proactive manner before they hit the project. The worst situation occurs when a risk crops up and has not been identified ("Huh, we didn't think about that!"). Risk identification is the first and most important

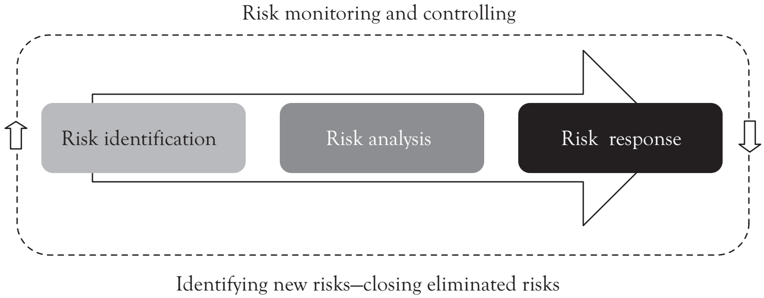


Figure 3.6 The standard risk management model (RMM)

step of the project risk management process. A project risk is defined as an uncertain event that if materialized will have a positive or a negative impact on one or more of the project objectives. The risk identification process starts with extensive data gathering to identify all potential project risks or uncertain events that might affect the project whether internal or external, technical or nontechnical, direct or indirect, major or less severe. The list of identified risks can get very long and complicated; therefore, it is best practice to do the data gathering using a predefined risk breakdown structure or RBS. The RBS is a hierarchically organized depiction of the identified project risks arranged by category. It serves as more than just a "database" for identifying risks as it also provides a vehicle for risk analysis and reporting, and risk comparison across projects. Table 3.4 illustrates an example of a RBS for a typical construction project. RBS is proposed by the author to be structured to align with the 14 project management knowledge areas discussed in Chapter 2.

The RBS shown in Table 3.7 can serve as a start to risk data gathering. The list of risk categories under each knowledge area can then be extended and further decomposed into risk subcategories as necessary and according to the outcome of the data gathering. Data gathering is a key effort that should be given adequate time and resources as necessary to exhaust the risk identification endeavor. The common data-gathering tools and techniques include a thorough review of contract documents, interviewing, brainstorming, assumptions, strengths/weaknesses/opportunities/threats (SWOT) analysis, analytical techniques, expert judgment, and examining the organizational process assets for risk registers of previous similar projects.

Table 3.4 Risk breakdown structure

Main root	Knowledge area	Risk category
Risk break down structure	KA01 Integration	KA0101 Project Abolition
		KA0102 Deficient Project Plan
		KA0103 Regulatory Changes
	KA02 Scope	KA0201 Design Errors
		KA0202 Scope Reduction
		KA0203 Scope Creep
	KA03 Time	KA0301 Schedule Delays
		KA0302 Force Majeure
		KA0303 Changes
	KA04 Cost	KA0401 Escalation
		KA0402 Estimating Errors
		KA0403 Penalty Exposure
	KA05 Quality	KA0501 Failed Tests
		KA0502 Warranty Exposure
		KA0503 Subcontractor Works
	KA06 Human Resources	KA0601 Shortages
		KA0602 Labor Strikes
		KA0603 Skills Deficiency
	KA07 Communication	KA0701 Data Loss
		KA0702 Network Failure
		KA0703 Deficient Plan
	KA08 Risk	KA0801 Unidentified Risks
		KA0802 Deficient Risk Responses
		KA0803 Unknown Risks
	KA09 Procurement	KA0901 Material Shortages
		KA0902 Shipping Interruptions
		KA0903 Long Lead Items
	KA10 Stakeholders	KA1001 New Stakeholders
		KA1002 Changed Requirements
		KA1003 Difficult Stakeholders
	KA11 Safety	KA1101 Language Barrier
		KA1102 Unqualified Personnel
		KA1103 Major Incidents
	KA12 Environment	KA1201 Natural Disasters
		KA1202 Changed Regulations
		KA1203 Public Complaints

(*Continued*)

Table 3.4 Risk breakdown structure (Continued)

Main root	Knowledge area	Risk category
	KA13 Financial	KA1301 Late Payments
		KA1302 Negative Cash flow
		KA1303 Owner Defaulting
	KA14 Claims	KA1401 Late Notification
		KA1402 Resorting to Arbitration
		KA1403 Poor Documentation

The output of the risk identification process is a primary entry to the project "risk register." Risk register is the primary project risk document. It encompasses identified risks, along with the risk management information generated in the subsequent risk analysis and risk response processes.

3.2.3.2 Second Risk Management Model Step: Risk Analysis

Risk analysis is the second stage in the risk management process where the identified RBS project risks are assessed and analyzed. The outcome of risk analysis feeds back into the risk register developing it a step forward. There are two broad categories of risk analysis, namely, qualitative and quantitative. Both methods hinge on looking into the probability of occurrence and extent of impact of each of the identified project risks, however, as the names imply, in quantitative and quantitative manners, respectively. Qualitative risk analysis assesses project risks qualitatively with the objective of placing them on a descriptive high to low scale so as to guide risk management prioritization. Quantitative risk analysis aims to assess project risks quantitatively using numerical estimations with the objective of sizing out risks and expressing them in terms of time and money. The best practice in risk analysis is to think of risk as either a "threat" or eventually an "opportunity." Threats are to be managed and mitigated, and opportunities are to be maximized. Following is a more in-depth review of the nature and mechanisms of qualitative and quantitative risk analysis.

3.2.3.2.1 Qualitative Analysis. Qualitative risk analysis assesses the severity of the identified project risks by examining their probability of occurrence and corresponding impact on project objectives if they materialize. Each identified risk in the project RBS is assigned a

Table 3.5 Probability and impact matrix—Indicative values

Probability		Risk severity				
Very high	90%	4.5%	9%	18%	36%	72%
High	70%	3.5%	7%	14%	28%	63%
Moderate	50%	2.5%	5%	10%	20%	40%
Low	30%	1.5%	3%	6%	12%	24%
Very low	10%	0.5%	1%	2%	45	8%
		5% Very low	10% Low	20% Moderate	40% High	80% Very high
						Impact

Legend: Very low | Moderate | High

percentage for probability (x) and another for impact (y). Risk severity is then calculated by multiplying x and y (i.e., xy). Risk levels can also be classified into low-, moderate-, and high-risk level categories according to certain threshold limit values to be identified in line with the project conditions and the organization's risk appetite and risk management policy. The probability and impact matrix, shown in Table 3.5, illustrates the probability and impact concept.

The project risk register is then to be updated by assigning a risk severity percentage against each listed risk. For example a 56 percent risk severity would represent the product of 80 percent probability and 70 percent impact. Risks are then to be sorted in descending order placing the highest risk severity percentages at the top of the list, followed by moderate and low risk levels (Table 3.4).

The key challenge in qualitative analysis is the quality of risk data. The use of low-quality risk data may result in misleading results. Availing high-quality reliable risk data requires a conscious effort by the team including referring to historical information and the application of sound data-gathering techniques including seeking multiple source assessments, Monte Carlo simulation technique, and exercising expert judgment.

3.2.3.2.2 *Quantitative Analysis.* Quantitative risk analysis is the process of numerically analyzing and assessing the time and cost impact of the risks identified and prioritized by the qualitative analysis. Quantitative risk analysis gives the organization an insight into risks in tangible and practical terms not provided by qualitative analysis. However, they can be fairly laborious and time consuming. It is therefore the project manager's responsibility to set the strategy in this regard. As in qualitative analysis, the quality and reliability of the data used in assessing risk time and cost impact estimates are critical to avoid misleading results. There are several tools and techniques to estimate risk impact with reasonable accuracy. For the purpose of this book, the practical and relatively simple program evaluation and review technique (PERT) model is recommended. PERT is an estimation technique that uses a weighted average of three cost or time impact estimates to come up with a final reasonable estimate, namely:

1. The most optimistic estimate (O) where everything goes right
2. The most pessimistic estimate (P) taking on board multiple adverse conditions
3. The most likely estimate (M) given normal problems and opportunities

The resulting PERT estimate is then calculated in a manner in which the most likely estimate is weighted four times as much as the other two values, namely:

$$\text{PERT weighted average} = \frac{\text{Optimistic} + 4\ \text{Most Likely} + \text{Pessimistic}}{6}$$

For example, let us say you estimate the cost of a risk to be most likely $100. The best case if risk is substantially mitigated is $80. The worst case if actual impact proves to be much worse than originally anticipated is $150. The PERT estimate is then (80 + 4(100) + 150)/6. The answer is 630/6, or $105. Notice that the number was pulled a little toward the far extreme of the pessimistic estimate, but not by much, since the result is still weighted heavily toward the most likely value. The same exercise can be applied to time impact in terms of delay to milestones or project completion date. The risk register shall then be updated accordingly assigning a time and cost impact against each identified risk, as shown in Table 3.6.

Time and cost impact should be addressed through time and monetary contingencies to be embedded into project plan. The next step is to plan risk responses.

3.2.3.3 Third Risk Management Model Step: Risk Response

Risk response analysis is the third and last stage in the risk management planning process. It is concerned with developing responses to project risks. The risk response process starts with deciding on the appropriate

Table 3.6 Risk register—adding the outcome of qualitative risk analysis

Risk identification RBS			Risk analysis			
			Qualitative risk analysis			
Main root	**Knowledge area**	**Risk category**	**Probability x**	**Impact y**	**Probability × impact xy**	**Risk level H/M/L**
RBS	KA01	…..	…..	…..	…..	High
	KA02	…..	…..	…..	…..	Moderate
	KA03	…..	…..	…..	…..	Low

RBS, risk breakdown structure.

strategy to deal with the various types of project risks. The project manager's selection of the right risk response strategy and course of action is key to project success. The most common strategies for risk response are avoidance, mitigation, transfer, and acceptance. Each of these risk response strategies has application areas where it best fits. For instance and in general terms, avoidance and mitigation strategies would be suitable for dealing with major and critical risks, while transfer and acceptance are more suited to deal with moderate- and low-risk severity. A good understanding of the four strategies is therefore essential for organizations and project managers. The four risk response strategies are further described as follows:

1. Avoidance
   Risk avoidance is the most daring risk response strategy. It is designed to deal with risks of combined high impact and high probability. Risk avoidance actions might involve more detailed project planning, changing project scope, and adopting alternative approaches all the way down to canceling parts or the whole of the project. For example, land acquisition issues. If acquiring a piece of land to build a small yet key part of say a highway interchange is established to be problematic as the landlord has other plans for it, it would be wise to look into adjusting the interchange layout to eliminate the need for such a piece of land. Another example would be time sensitivity risks. If building the entire mega mall development would put the project at risk of missing a major world event, it would be sensible to divide the project into phases in which certain less vital parts are completed at a later stage after the event.

2. Mitigation

   Risk mitigation is a proactive risk response strategy. It focuses on taking proactive actions and measures to reduce the impact, the probability, or both of occurrences of the identified adverse risks. This can take the form of regular inspections, strict quality assurance, multiple sign offs, and carefully written contract terms and conditions. An example of risk mitigation would be the risks related to Owner reluctance to take over the completed works at the end of the project. A risk mitigation measure would be to secure multiple inspections and sign-offs of completed parts of the works as the project progresses.
3. Transference

   Risk transference is about shifting certain risks to a party that is best situated to manage such risks. This occurs when the organization establishes its inability to accept a risk, be it technical, commercial, or legal. The common form of risk transference is insurance policies, bonds, and performance warranties. An example for risk transference would include price escalation. In a rapidly changing market or in long-duration contracts it would be fair to include a provision for price escalation matching the hike in the prevailing consumer price index (CPI), thus transferring the risk back to the Owner who can best manage by fairly adjusting contract price and availing additional funds.

Once the risk responses are established and a specific action is developed, the risk register shall be updated accordingly, as shown in Table 3.7.

It is noted that a primary risk response addressing a certain risk element may have a favorable impact on other risks in the list. That should be indicated in the risk register. Finally, each risk element in the risk register should be assigned a risk "Owner" to ensure accountability. Risks must be monitored and controlled throughout the project life cycle. New risks developed during the course of the project should be added to the list and managed in the same manner, while other risks may be deleted if confirmed to be not materialized and the reasons for them no longer exist (Table 3.8).

3.2.3.4 Design–Build and Risk Management

Design–build is itself a risk management action. In design–build, Owners transfer the risk of design errors and omissions to the design–build entity.

Table 3.7 Risk register—summing up the outcome of quantitative risk analysis

Risk identification RBS			Risk analysis					
			Qualitative risk analysis				Quantitative analysis	
Main root	Knowledge area	Risk category	Probability *x*	Impact *y*	Probability × impact *xy*	Risk level H/M/L	Time impact (days)	Cost impact ($)
RBS	KA01	…..	…..	…..	…..	High	…..	…..
	KA02	…..	…..	…..	…..	Moderate	…..	…..
	KA03	…..	…..	…..	…..	Low	…..	…..

Table 3.8 Risk register—adding the outcome of risk response

Risk identification RBS			Risk analysis						Risk response		
			Qualitative risk analysis				Quantitative analysis				
Main root	Knowledge area	Risk category	Proba-bility *x*	Impact *y*	Proba-bility × impact *xy*	Risk level H/M/L	Time impact (days)	Cost impact ($)	Resp1	Resp 2	Resp *n*
RBS	KA01	…..	…..	…..	…..	High	…..	…..	Avoid		Mitigate
	KA02	…..	…..	…..	…..	Moderate	…..	…..	Mitigate	Mtgt	
	KA03	…..	…..	…..	…..	Low	…..	…..			Transfer

This is achieved by putting the two ultimately accusatorial parties, the designer and the contractor, in the same team. This risk transfer action has both a primary "risk transfer" effect regarding the risk of design errors and omissions, and a positive secondary "risk mitigation" effect on a number of key project risks including project time, cost, and quality. The following paragraphs provide insights into the design–build risk management on each of such three key project risk areas:

1. Project time:
   Design–build allows Owners to transfer the risk of delays in completing the detailed design and construction documentation to the design–builder. In the traditional design–bid–build, the risk of design delays rests with the Owner who has to manage the design process and issuance of the construction tender documentation. Design–build tenders are floated using a high-level, short-duration, and somewhat controllable conceptual designs and outline criteria.
2. Project cost:
   Design–build allows Owners to transfer the risk of additional costs due to design errors and omissions to the design–builder. In the traditional design–bid–build, the risk of design delays rests with the Owner who has to manage the design process and issuance of the construction tender documentation. Design–build tenders are floated using a high-level, short-duration, and somewhat controllable conceptual designs and outline criteria.
3. Project quality:
   Design–build allows Owners to transfer the risk of project quality and end-product performance to a single entity that is responsible for the quality of both design and construction. In the traditional design–bid–build, quality and performance issues are usually claimed by the designers and the contractors to be the fault of the party. In design–build the responsibility for quality, performance, and achieving the design intent rests with the design–build entity.

Design–build is the better risk allocation arrangement for Owners. It shifts several risks to the design–build entity, the party that is better positioned to manage them. The need for the design–build contractors to deploy a sound and sophisticated project risk management system is therefore of paramount importance. Risk management is a more rigorous exercise in design–build than in traditional design–bid–build projects.

A recap of the presented concepts is as follows:

1. Risk management is the core element of any project management method.
2. RMM consists of risk identification, risk analysis, and risk response.
3. Design–build shifts much of the project risks to the design–build entity.
4. The need for risk management increases as projects increase in size and complexity.
5. The risk management effort in design–build is higher than that in traditional projects.

3.2.4 Design–Build SMART Key Performance Indicators and Critical Success Factors

In the construction industry, measuring success of the project implementation process is quite focused on satisfying the iron triangle of time, cost, and quality. The hypothesis here is that satisfying such three key factors leads to client satisfaction and achieving organizational objectives. The design–build project delivery approach maintains such focus, and even provides improvements and added benefits on all three tracks. Furthermore, design–build promises three additional benefits to the Owners over the traditional design–bid–build method, namely, reducing claims, reducing coordination efforts, and creating value by allowing the interaction between design and construction teams and activities. During project implementation, all six success factors should be closely monitored to ensure that the process is working, and that the power of design–build is indeed actuated. This can be achieved by deploying a system of design–build SMART KPIs benchmarking the indicated six success factors against the same if the traditional design–bid–build was used.

KPIs are business metrics used to evaluate factors that are crucial to the success of a business or a project. They are a fundamental component of monitoring and controlling project performance and ensuring that projects are on track. SMART in this respect refers to KPIs being Specific, Measurable, Agreed, Realistic, and Time bound. Specific means that a KPI should refer to a specific aspect of the business. Measureable means that it can be measured by counting or statistics. Realistic means that it can be achieved given the project conditions in general. And Time bound means that measurement should be linked to specific periods of time.

KPIs are widely used in the construction industry to monitor project health on key areas such as cost, time, quality, safety, environment, responsiveness, client satisfaction, and other areas. The focus in this book is only on measuring the effectiveness of the application of the design–build method as compared to the traditional design–bid–build method. The baseline for such comparison would be the performance levels achieved by the design–bid–build method. Baseline data could be based on historical records from projects completed by the organization, or by referring to published performance data. The outcome of the comparison is a percentage. A positive value of such percentage indicates success, whereas a zero or a negative value would indicate that the application of the design–build process is not working effectively and requires review and corrective action.

The following paragraphs set forth six proposed design–build SMART KPIs and how they are calculated and provide simple indicative application examples:

DB SMART KPI 1: Reduced cost

This KPI refers to the reduction in cost achieved by the use of design–build using the following equation: DB SMART KPI 1 = (Cost in DBB – Cost in DB)/Cost in DB. For example, for the construction of a reinforced concrete floor slab, design–build would enable a slab thickness reduction from 30 cm to 26 cm, so the KPI = (30 cm – 26 cm)/26 cm = +15.4%. A positive value indicates saving.

DB SMART KPI 2: Reduced time

This KPI refers to the reduction in execution time achieved by the use of design–build using the following equation: DB SMART KPI 2 = (Time in DBB – Time in DB)/Time in DB. For example, for the construction of a multistory building, design–build would enable a building story construction time reduction from 12 days to 10 days, so the KPI = (12 days – 10 days)/10 days = +20%. A positive value indicates saving.

DB SMART KPI 3: Improved quality

This KPI refers to the improved quality achieved by the use of design–build using the following equation: DB SMART KPI 3 = (Defects in DBB – Defects in DB)/Defects in DB. For example, for the construction of a reinforced concrete multistory building, design–build would enable reducing the number of defective works in concrete elements requiring repair or rework from seven cases per month to five cases per month, so the KPI = (7 cases/m – 5 cases/m)/5 cases/m = + 40%. A positive value indicates improvement.

DB SMART KPI 4: Reduced claims

This KPI refers to the reduction in the filed construction claims by the use of design–build using the following equation: DB SMART KPI 4 = (Claims in DBB – Claims in DB)/Claims in DB. For example, for the construction of a multistory building, design–build would enable a reduction of cost and time claims from 25 heads of claims to 15 heads of claims, so the KPI = (25 hoc – 15 hoc)/15 hoc = +66%. A positive value indicates reduction of claims.

DB SMART KPI 5: Reduced coordination

This KPI refers to the reduction in the Owner's coordination effort by the use of design–build using the following equation: DB SMART KPI 5 = (RFIs in DBB – RFIs in DB)/RFIs in DB. For example, for the construction of a multistory building, design–build would enable a reduction of the RFIs (request for information) from 200 RFIs claims to 50 RFIs, so the KPI = (150 RFIs – 75 RFIs)/75 RFIs = +100 %. A positive value indicates reduction in coordination effort.

DB SMART KPI 6: Design–construction overlap

This KPI refers to the extent of overlapping between design and construction durations. The degree of overlap between design and construction is critical to project success. The higher the degree of overlap, the longer is the time allowed for construction and thus the probability of completing the project on time. Overlap is defined as a percentage of the design task duration. For the purposes of this KPI, 50 percent overlap, that is, starting construction after 50 percent of the beginning of the project design duration is considered to be the baseline yielding 100 percent success, whereas 0 percent overlap,

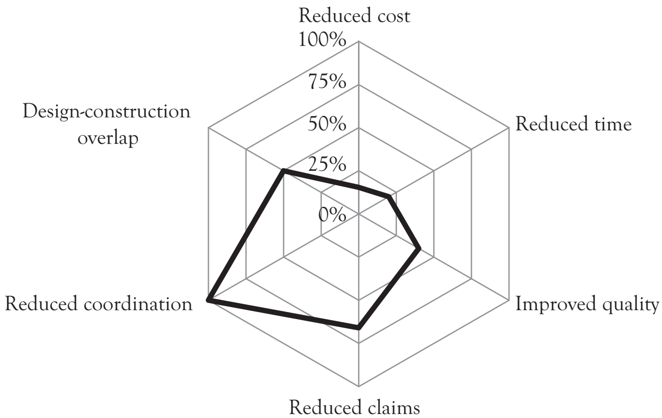


Figure 3.7 Overview of the design–build SMART key performance indicators

that is, starting construction after the entire project design is completed yields a KPI of 0 percent or complete failure. KPI can then be calculated using the following equation: DB SMART KPI 6 = (Overlap DB)/50%. For example, if construction starts at 75% of the design duration, that is, with an overlap of 25 percent, then the KPI = (25%)/50% = +50%, and so on. A positive value indicates that the design–build concept is being attained.

The radar graph shown in Figure 3.7 depicts a summary of the KPIs calculated in the above indicative examples.

In reality, a multitude of such examples could be calculated by the project team in a similar manner and then averaged out to assess a set of overall project DB SMART KPIs. KPIs should be assessed periodically at predefined milestones or at fixed time intervals, and then discussed to agree with the potential process improvements or corrective measures required to boost the power of the design–build.

3.3 Summary

Design–build is a powerful process that is able to bring about outstanding benefits and efficiencies; however, it requires particular knowledge and expertise. Design–build follows the two typical project stages, namely, the precontract award stage, and the post-contract award stage. Each stage has its key points and tricks-of-trade. The knowledge of such key points and tricks-of-trade can be instrumental to the project success. During the precontract award stage, key topics include the project's go or no-go decision, choosing the right design–build partner, preparing the design–building teaming agreement, and how to win the design–build tender competition. During the post-contract award stage, key topics include mobilizing and developing project teams, project delivery guidelines and best practices, risk management in the design–build environment, and design–build KPIs and critical success factors. This chapter provides the reader with practical insights into the design–build process.

PART II

The SAFEDB-Methodology: Methodology Overview and Description

CHAPTER 4

About the SAFEDB-Methodology

Preface

The SAFEDB-methodology is a systematic scientifically validated approach to the effective management of modern design–build civil engineering projects. It focuses on the unique nature of the design–build projects as opposed to traditional projects and provides a bolt-on design–build life cycle complementing and running parallel to the standard project management project life cycle applicable to all projects.

The methodology is based on a PhD dissertation developed by the author. It utilizes a combination of cutting-edge academic project management and operation research theories and extensive hands-on experience in the planning and implementation of large world-class design–build civil engineering projects. The term SAFEDB is derived from the PhD dissertation title reading "A Sound Approach to Formulation and Evaluation of planning for large civil engineering fast-track Design–Build projects."

This chapter aims to introduce the SAFEDB-methodology to the reader at a high level. It presents and discusses the methodology's background and motivation, philosophy and fundamental hypothesis, components and application guidelines, and lastly the methodology credibility and appreciation by key global professional and academic organizations as well as by significant individuals in the construction, design–build, and project management industries. Methodology components and mechanisms are discussed in detail in Chapter 5.

4.1 Methodology Motivation

The SAFEDB-methodology aims to advance the design–build industry.

A recent review of the design–build industry across the world yielded surprising and to some extent disappointing findings regarding the way design–build projects are being managed. While most design–build organizations appeared to have a basic understanding of the principles and mechanisms of the design–build process as a project delivery approach, very few of them maintained a specialized and scientifically validated approach to managing design–build projects effectively and efficiently. Instead, most projects are managed using general project management systems and methodologies. This situation has led in many cases to excessive rework cycles and significant schedule overruns. In a people–process–technology model, it would appear that the process and technology aspects are on the lower side, and a more of people-based management approach is being used relying heavily on skills and expertise of the project managers and project teams. The primary motivation of the SAFEDB-methodology is to address such process/technology gap in the design–build industry and to advance the state-of-the-art in the field of managing design–build projects (Hashem 2005).

The SAFEDB-methodology activates the power of the design–build process leading to better results.

4.2 Methodology Fundamental Hypothesis

The SAFEDB-methodology is based on an axiomatic hypothesis that is tested and proven to work.

The fundamental hypothesis of the SAFEDB-methodology is that the effective management of design–build projects lies in identifying the inherent design–build characteristics of the associated design and construction solutions, and using such characteristics to guide and govern project planning and management decisions. The inherent design–build characteristics of interest vary according to the project planning and management stage. In SAFEDB, stages of the design–build project planning and management effort include three key components, namely, selecting the best design solutions and related construction methods, determining the most effective design and construction activities overlapping strategy, and lastly the proactive planning of potential design–build schedule branching and rework loops likely to take place during the course of the project implementation. By doing so, the project proceeds on a sound and well-planned basis, thus leading to a greater control over operations and a greater confidence and commitment by the project team to implement the project plan. The SAFEDB-methodology key components are discussed in detail in the subsequent chapters.

4.3 Overview of the SAFEDB-Methodology Components

This section provides a high-level overview of the SAFEDB-methodology key components.

The SAFEDB-methodology has three components serving three key project planning and management areas, as shown in Figure 4.1. Themes and objectives of the SAFEDB-methodology components were identified further to an extensive research and in-depth understanding of the design–build process nature, goals, and practices. They address and hit the right buttons required to actuate the power of the design–build process, namely, (1) to ensure that the selected design and construction solutions are the best to serve their intended purposes; (2) to compress the schedule by the maximum safe, practicable application of overlapping of design and construction activities; and (3) to foresee and plan for the probable schedule problems related to conducting design and construction in parallel (e.g., design changes, design delays, etc.) and to accommodate the same into the project schedule. These goals are accomplished through the three methodology components, namely, (1) develop DB solutions; (2) fast-track DB activities; and (3) control DB work progress.

Figure 4.1 demonstrates the methodology components and their underlying concepts.

The full benefit of the SAFEDB-methodology is achieved by applying all of its three components, 1, 2, and 3. Nevertheless, the methodology can be applied in part, using one or two components only, in any desired combination as may be decided by the project team, that is, 1_2, 1_3, or 2_3. The SAFEDB-methodology runs along the standard

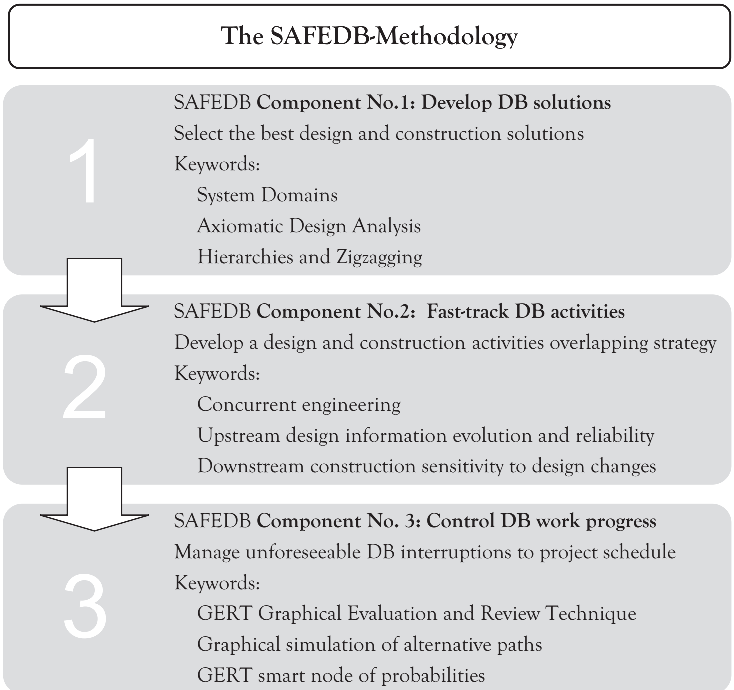


Figure 4.1 Overview of the SAFEDB-methodology components

project management life cycle applicable to all projects, and introduces a "bolt-on" life cycle addressing the specific nature of the design–build process. The SAFEDB-methodology's bolt-on life cycle is the element that makes the difference and actuates to power of the design–build approach and closes the gap in the current design–build project management industry.

Figure 4.2 illustrates the relationship between the two project life cycles.

Both life cycles are to be applied by the project management team in parallel. In this context, the standard project management lifecycle represents what would be termed as "business as usual" applicable to all projects, while the SAFEDB-methodology life cycle would then represent the "business unusual" side that takes care of the design–build aspect of the project. The standard project management life cycle framework has been discussed in detail in Chapter 2, and the SAFEDB-methodology key components are discussed in detail in the subsequent chapters.

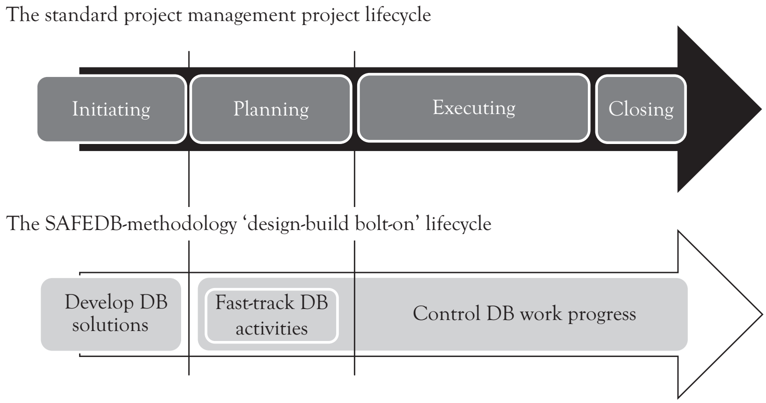


Figure 4.2 Overview of the SAFEDB-methodology components

Note: DB, design–build, Monitoring and Controlling applies and not shown for clarity

4.4 Methodology Industry Appreciation

The SAFEDB-methodology had received a remarkable industry appreciation.

The SAFEDB-methodology was first introduced to the industry by the Design–Build Institute of America (DBIA). The DBIA (www.dbia.org) is the number one professional organization in the world that defines, teaches, and promotes best practices in the design–build industry. An article entitled "New Planning Method Can Deliver Better Design–Build Projects Faster" praising and endorsing the SAFEDB-methodology was published by DBIA in their *Design-Build Magazine* and website in December 2005 introducing the methodology to the design–build industry (Hashem 2005) (Figure 4.3). The article was very well received by the industry at both the organizational and the individuals' levels.

At the organizational level, the SAFEDB-methodology was acknowledged and published by DBIA, which generated positive echoing in the industry world-wide including the translation of the article to other languages. The DBIA article about the SAFEDB-methodology was translated into Portuguese and published in Brazil by the Brazilian "mundo PM" project management magazine (Hashem 2005) under the title "O Poder do Design–Build," or the power of design–build. Such a title, "The Power of Design–Build," was invented by the author at the time and ever since has been associated with the

Figure 4.3 Design–Build Institute of America appreciation of the SAFEDB-methodology (Hashem 2005)

SAFEDB-methodology. Moreover, a part of the SAFEDB-methodology was published by the Project Management Institute (PMI, USA, www.pmi.com) in a PMI white paper entitled "Scientific basis to technical decision making: A crucial need for project management in the 21st century" (Hashem 2006).

At the individuals' level, numerous positive responses were received from practitioners and academics around the world. We highlight the feedback received from two world-class project management gurus, namely, Mr. Eric Jenett, the founder of PMI and PMI's credentialed Project Management Professional (PMP) No. 1, and Professor Dr.-Ing. Gerhard Girmscheid, the project management professor and chair/head of the Institute for Construction Engineering and Management at ETH Zurich, Swiss Federal Institute of Technology, Switzerland.

Mr. Eric Jenett's letter of appreciation is shown in Figure 4.4.

Professor Dr.-Ing. Gerhard Girmscheid's letter of appreciation is shown in Figure 4.5.

From: Eric Jenett, 105401,1210
To: Mr. Sherif Fouad Hashem, INTERNET: sherifh@link.nt
CC: Jim O'Brien, INTERNET:jimobriendd527@aol.com; Earl Glenwright, INTERNET:earl_csss@yahoo.com Stuart Ockman, INTERNET: oba@comcast.net; Jon Wickwire, INTERNET: jwickwire@wickwire.com; Russ Archibald, INTERNET: russell_archibald@yahoo.com
Date: 12/9/2005 1:58 PM
RE: Your Article in Design/Build November/December05

Mr. Hashem,

A brief note to do a couple things. First to thank you sincerely for preparing and then getting published in the Nov/Dec 2005 issue of Design/Build, your article on the concepts and application of the GERT scheduling approach. I find my experience closely matches the parameters you suggested and that your statement about the "conditions of appropriate application" is also strongly supported by my own experience. I would add one other comment based on my own experience: If (repeat "If") you encounter resistance of the technique in a case you feel needs or deserves its application, the cause is usually the stubborn and "fear-based" reluctance (even violent opposition) because the individual either wont/cant admit the fluidity inherent in the projects real status and ambient(s) or he understands fully but is "afraid" he'll be called on to provide input for the concepts to work—and he doesn't know what to say.
………………
Once again, sincere thanks for undertaking and then delivering thoughts and guidance on a technique I consider particularly effective in "portraying" a not-too-well defined project in its early/earliest stages and also, importantly, in presenting the impacts of decisions/actions AND/OR failures in actions and decisions in ways that "stakeholders" can more readily grasp the consequences.

Eric Jenett, Founder,
Fellow PMI, PMP (ret.) #1
713 887 5802, < ejenett@compuserve.com >
Clarewood House #802
7400 Clarewood Drive
HOUSTON, TX 77036-4340

Figure 4.4 Eric Jenett's appreciation of the SAFEDB-methodology

Apart from the underlying PhD dissertation itself, this book is the first published document that presents the SAFEDB-methodology to the construction industry, presented in practical and somewhat simplified terms for the ready use of the design–build academics and practitioners.

Zurich, 25 July 2007 GG/ca

Dr. Eng. Sherif Hashem
Your Doctoral Thesis

My dear friend,

Heartfelt congratulations! I just finished to thoroughly read your dissertation:

A Sound Approach to Formulation of planning for large civil engineering fast-track Design–Build projects SAFEDB-Methodology (Washington International University, PA/USA, February 2004 by Dr. Sherif Fouad Hashem).

You have written an absolutely interesting and scientifically substantial thesis with very high practical relevance. The results must by all means be applied in practice.

I am sure you will apply this latest knowledge in your every-day business for the success of the projects for which you are responsible, but the topic is also of the highest relevance for teaching in graduate engineering classes.

Kindest regards.

Prof. Dr.-Ing. Gerhard Girmscheid
Chair/head of the Institute for Construction Engineering and Management
ETH Zurich, Swiss Federal Institute of Technology, Switzerland.

Figure 4.5 Prof. Dr.-Ing Gerhard Girmscheid's appreciation of the SAFEDB-methodology

4.5 Summary

The SAFEDB-methodology is a scientific approach to managing design–build projects in a systematic manner and is based on a PhD dissertation developed by the author. It fills a gap in the current project management industry, which lacks a systematic approach to managing design–build projects. The methodology consists of three logical steps or components, namely, develop DB solutions, fast-track DB activities and control DB work progress. The SAFEDB-methodology introduces a bolt-on design–build-specific project management life cycle running in parallel to the standard project management life cycle applicable to all types of projects. The methodology has been praised by DBIA and significant individuals from the academia and the project management industry.

CHAPTER 5

The First SAFEDB-Methodology Component: Develop Design–Build Solutions

Preface

The first and most important step in the design–build process is to select the right and most time- and cost-effective design–build solutions. In design–build, this is the responsibility, choice, and decision of the design–build entity, which can make or break the project endeavor. Project success and profitability are directly linked to such decisions. The underlying assumption is that the early identification and selection of a simple design–build solution has a favorable effect that goes long way, and vice versa.

The design–build solution selection process starts early in the project life cycle during the precontract concept design phase, and extends throughout the project life cycle to cover the subsequent post-contract detailed design and construction phases. Therefore, the involved design–build teams should have the skill, ability, and tools to identify and select the best and most time- and cost-effective design–build solutions each step of the way.

This SAFEDB-methodology's first step is concerned with supporting decision making and assisting the project teams with developing, analyzing, and selecting the best design–build solutions through a practical and well-structured method. The methodology is based on the concepts and principles of the axiomatic design approach. This is achieved by examining and analyzing the candidate design–build solutions generated by the design–build project team and guides the process of ranking and selecting the best solution. It focuses on identifying and reducing complexity resulting in faster and cheaper project delivery and avoiding rework cycles and unintended consequences.

Axiomatic design is about working smarter and creating value through thinking and analysis.

5.1 Methodology Component Objective

The objective of this first and most important component is to examine the range of candidate design and construction solutions and to select the most effective solutions for implementation. The decisions taken at this early stage of the project can make or break project success.

There are always several ways to achieve a given objective or build a project. Not all that glitters is gold. Your ability to identify and select the best out of the possible solutions is what gives you an edge over competitors. Depending on expert judgment or past experience is essential but simply not enough in design–build. If all competitors use the same solution, winning a project will be down to who can build the project faster and with the lowest cost.

In design–build you get the opportunity to stand out of the crowd and win projects and make profit merely by your ability to identify what is the most effective way to satisfy Owner's requirements. Design–build is all about thinking out of the box and doing things differently and more efficiently. There is however a degree of risk associated with thinking out of the box and getting creative. That is the element of the unknown.

This methodology step will help you manage such risk. It digs behind the glitter to expose the actual substance of the options on the table. This is achieved through the application of the concepts and tools of the axiomatic design approach explained later in this chapter. The upfront successful selection of the most appropriate design and construction solutions will reduce project cost and time, smoothen project progress, and motivate project teams.

5.2 The Axiomatic Design–Build Theory

Axiomatic design is an innovative systems design theory developed by Professor Suh Nam Pyo at Massachusetts Institute of Technology, Department of Mechanical Engineering (Suh 1990).

Axiomatic design redefines the way the design process is perceived. It reveals that there are two particular design principles or design axioms that govern the analysis and decision-making process in developing high-quality products or system designs, namely:

1. Axiom 1: The Independence Axiom. Maintain the independence of the functional requirements (FRs).
2. Axiom 2: The Information Axiom. Minimize the information content of the design solution.

Axioms are defined as self-evident facts that cannot be derived or proven to be true, except that they have no counterexamples or exceptions. Axiomatic design sets the rules for the design process in a way similar to Newton's laws for engineering mechanics or Maxwell's equations for electrical engineering.

Axiomatic design is concerned with transferring the stipulated customer needs and end-product FRs into the most effective design solutions (design parameters [DPs]) and construction solutions (process variables [PVs]). In the axiomatic design, the best design or construction solutions are merely the simplest ones of the highest ability to satisfy customer needs and FRs.

In traditional design, design is produced using experience and iterations, and is evaluated at stages through independent reviews and subjective opinion. In the axiomatic design, design is produced by aligning design and construction solutions with customer needs and FRs, and is evaluated in real time through ensuring satisfaction of the two design axioms.

Axiomatic design ensures efficiency of the entire process with high focus on customer needs and FRs. Moreover, it enables the design–build team to know "why" the adopted design and construction solutions were selected, so that the team can better control, change, improve, and refine such solutions as and when needed in an educated manner.

The axiomatic design approach has gained great popularity in the manufacturing arena. The SAFEDB-methodology extends the application of the axiomatic design to the civil engineering arena with particular focus on design–build projects where the theory best applies. The application of the axiomatic design theory in design–build civil engineering projects is explained in detail in the following sections.

5.3 First Methodology Component—Step by Step

This section explains the use of the axiomatic design approach in developing the best design-build solutions in practical step-by-step fashion. While the process is presented in discrete progressive step by step, in reality, such steps may overlap and interact with each other in complex ways that cannot be completely explained in a document or with graphics. Figure 5.1 provides an overview of the title and purpose of the three logical steps of the first methodology component (FMC), namely FMC 1, 2, and 3.

This section is primarily concerned with explaining the theoretical background and underlying notions and objectives of the SAFEDB-methodology's FMC, supported by basic real-world examples to support the understanding of the presented concepts.

Full-scale practical application examples and case studies are provided in Chapters 8–11. However, some limited-scope practical examples shall be provided within the body of this chapter on when-and-as-necessary

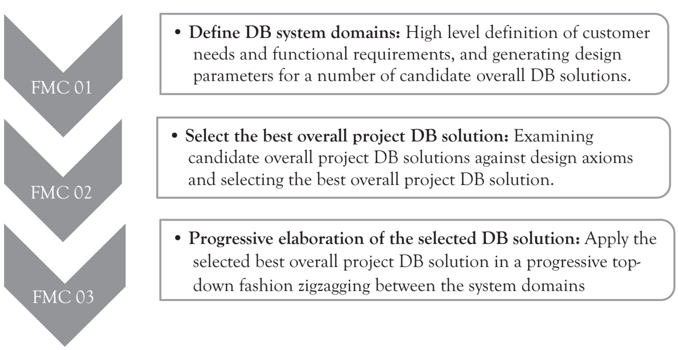


Figure 5.1 The SAFEDB-methodology—overview of the first methodology component
Note: DB, design–build.

basis aiming to support the information provided and make certain somewhat implicit concepts explicit to the reader.

5.3.1 First Methodology Component Step 1: Define the Design–Build System Domains

The purpose of this step is to render customer needs to a number of candidate DPs.

In more practical terms, transferring the project brief and Owner's vision of the end product as stated in the tender documents or request for proposal into an actionable project design and construction work plan. To this end, the axiomatic design approach assumes four logical system domains, namely, the customer domain (customer needs), the functional domain (FRs), the physical domain (DP), and the process domain (PVs).

Table 5.1 provides a high-level description of such process system domains.

Any design–build solution should go through such domain definition in the sequence presented in Table 5.1 in order to ensure the alignment of the project end product with the bottom-line customer needs, which is key to project success, as shown in Figure 5.2.

In practice, the process starts with defining the customer needs in the customer domain and the related FR in the functional domain. The design–build team then responds with generating DPs for a number of candidate design solutions (options) in the physical domain and PVs or construction parameters in the process domain.

The aforementioned terminology might be new to the reader or require further explanation. Table 5.2 provides an example for the

Table 5.1 High-level definition of system domains

System domain	Description	Purpose
Customer domain	CNs or customer needs	Customer-desired product attributes
Functional domain	FRs or functional requirements	What the design does
Physical domain	DPs or design parameters	How the design looks (design solution)
Process domain	PVs or process variables	How the design is built (construction solution)

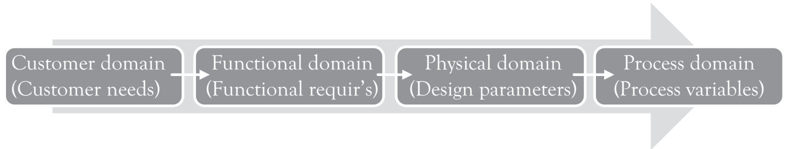


Figure 5.2 Mapping of system domains

practical application of system domains in civil engineering projects, which would help the practicing engineers have a clearer understanding of the used terms and concepts.

Example

The assumed project is the design and construction of a 150-m span three-lane dual carriageway bridge over a navigation pathway for an allocated budget of circa $100 million and within a maximum design–build time frame of 18 months. Table 5.2 illustrates how the above terms are interpreted.

In performing this exercise, it is very important for the design–build team to have a full understanding of the customer needs and to possess substantial experience in the application area. Candidate solutions are to be proposed by the design and construction teams collaboratively taking into consideration technical, commercial, and legal aspects. The candidate solutions or options are then to be examined in the next step, FMC 2, to determine and select the best project overall design–build solution.

5.3.2 First Methodology Component Step 2: Select the Best Overall Design–Build Solution

The purpose of this step is to select the best out of the candidate design–build solutions generated in Step 1.

This is accomplished by examining candidate solutions against the two axioms that govern the design process, namely, the Independence Axiom and the Information Axiom. Candidate solutions are first examined for satisfying the Independence Axiom, and then the successful ones carried over to the Information Axiom for further examination and selection of the best design–build solution (Figure 5.3).

Table 5.2 Example—the use of system domains in civil engineering projects

System domain > Project description	Customer domain *Customer needs* *(CNs)* Means >	Functional domain *Functional requirements* *(FRs)* What the design does	Physical domain *Design parameters* *(DPs)* How the design looks	Process domain *Process variables* *(PVs)* How design is built
	→	→	→	→
Design and construction of a 150-m span three-lane dual carriageway bridge over a navigation pathway in 18 months	CN1: Navigation pathway	FR1: Allow free span with no piers within the river profile	DP1 Option 1: Suspension bridge DP1 Option 2: Progressive cantilever	PV1: Construction means and methods
	CN2: 150-m span, three-lane dual carriageway	FR2: Bridge deck carrying six traffic lanes	DP2 Option 1: Single six-lane deck DP2 Option 2: Twin three-lane deck	PV2: Construction means and methods
	CN3: Project duration less than 18 months	FR3: Limited construction duration	DP3 Option 1: Precast solution DP3 Option 2: Cast-in-situ solution	PV3: Construction means and methods

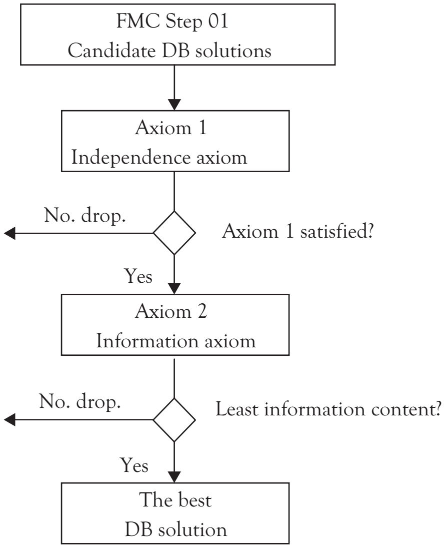


Figure 5.3 First methodology component Step 2—best Design–Build (DB) solution selection flowchart

5.3.2.1 Axiom 1: The Independence Axiom

The Independence Axiom examines the candidate design–build solutions to see how the FRs are satisfied by the DPs.

The process starts with mapping out the initial relationship between FRs and DPs for each candidate design–build solution in the form of a FR–DP dependency matrix equation as shown below, and then at a later stage try and influence such relationship to maintain (or maximize) the independence of FRs.

The following matrix equation illustrates the relationship between FRs and DPs:

$$\begin{Bmatrix} FR1 \\ to \\ FRn \end{Bmatrix} = [A] \begin{Bmatrix} DP1 \\ to \\ DPn \end{Bmatrix}$$

Matrix A is called the design matrix. The characteristics of matrix A determine if the Independence Axiom is satisfied. Suppose we have three FRs and DPs, the matrix equation will look as follows:

$$\begin{Bmatrix} FR\mathbf{1} \\ FR\mathbf{2} \\ FR\mathbf{3} \end{Bmatrix} = \begin{bmatrix} A1\mathbf{1} & A1\mathbf{2} & A1\mathbf{3} \\ A2\mathbf{1} & A2\mathbf{2} & A2\mathbf{3} \\ A3\mathbf{1} & A3\mathbf{2} & A3\mathbf{3} \end{bmatrix} \begin{Bmatrix} DP\mathbf{1} \\ DP\mathbf{2} \\ DP\mathbf{3} \end{Bmatrix}$$

The A matrix can be simplified to an X-0 fashion as shown below, where 0 indicates independence of FRs and an X indicates a nonzero value and hence a dependence between an FR and a DP. For example, if DP1 affects FR1, FR2, and FR3, then A11, A21, and A31 are all marked as X in the matrix. If DP1 affects FR1 and FR2 only, then only A11 and A31 are to be marked X and A21 is to be marked O, and so on.

The result will be an X-0 design matrix equation of one of the following three types:

Type 1: Uncoupled matrix (populated diagonally)

$$\begin{Bmatrix} FR1 \\ FR2 \\ FR3 \end{Bmatrix} = \begin{bmatrix} X & 0 & 0 \\ 0 & X & 0 \\ 0 & 0 & X \end{bmatrix} \begin{Bmatrix} DP1 \\ DP2 \\ DP3 \end{Bmatrix}$$

Type 2: Decoupled matrix (populated triangularly)

$$\begin{Bmatrix} FR1 \\ FR2 \\ FR3 \end{Bmatrix} = \begin{bmatrix} X & 0 & 0 \\ X & X & 0 \\ X & X & X \end{bmatrix} \begin{Bmatrix} DP1 \\ DP2 \\ DP3 \end{Bmatrix}$$

Type 3: Coupled matrix (populated fully or in any random pattern)

$$\begin{Bmatrix} FR1 \\ FR2 \\ FR3 \end{Bmatrix} = \begin{bmatrix} X & X & X \\ X & X & X \\ X & X & X \end{bmatrix} \begin{Bmatrix} DP1 \\ DP2 \\ DP3 \end{Bmatrix} \text{ or } \begin{Bmatrix} FR1 \\ FR2 \\ FR3 \end{Bmatrix} = \begin{bmatrix} X & 0 & X \\ X & X & X \\ 0 & X & X \end{bmatrix} \begin{Bmatrix} DP1 \\ DP2 \\ DP3 \end{Bmatrix}$$

Type 1 uncoupled matrix entirely satisfies the Independence Axiom and represents the ideal case scenario. Each FR is satisfied by a dedicated DP; thus, it is the simplest design process possible in which the various design tasks can proceed in parallel and independently to address the various listed FRs. Uncoupled design is of low risk, easy to perform, and requires the least amount of design coordination.

Type 2 decoupled matrix also satisfies the Independence Axiom if the design sequence is maintained. Each FR is satisfied independently by a dedicated DP, however, with input or assistance from previous higher-level DPs. FR1 is satisfied by DP1. FR2 is satisfied by the choice of DP2 and the fixed DP1. DP3 is determined in the same manner with the choice of DP3 and the fixed DP1 and DP2, and so on. The advantage of this scenario is reducing the risk of rework cycles and the low coordination effort required. The downside is the longer time required to complete the design as compared to that in the Type 1 uncoupled matrix where the design tasks can proceed in parallel.

Type 3 coupled matrix does not satisfy the Independence Axiom as FRs are not satisfied independently. In coupled design, some or all FRs are satisfied through more than one DP concurrently. This makes the design process a rather complicated exercise. It requires narrow information zigzagging between the concurrent DPs or design tasks that will have to progress dependent of each other. This entails a significant amount of design coordination and raises the risk of project delays and rework cycles.

Unfortunately, many of the common design concepts yield coupled design matrices, and this fact mostly goes unnoticed by the design teams leading to project complications. Uncovering the inherent status of design dependency early in the process through the indicated axiomatic design FR–DP dependency matrices can save the team the hassle of having to deal with coupled designs. Coupled matrices can always be improved by the team to become uncoupled or decoupled before proceeding with implementation. This can be done through a new choice of DPs, modification of work sequencings, or by simply dropping a candidate coupled solution in favor of another uncoupled or decoupled solution. This possibility of influencing the process and the obvious advantages of uncoupled and decoupled matrices over coupled matrices is what makes the Independence Axiom self-evident.

Examples

Example 1: Water Faucet Design

One of the popular examples of the application of the Independence Axiom is the design of water faucets paradigm. The desired FRs of water faucets are adjusting the water flow rate and adjusting water temperature. The classical faucet design used a "dual knob" solution having two knobs, one for cold water and the other for hot water, and both knobs were able to control the water flow. Such a design has generated many customer complaints over the years due to the difficulty in adjusting water flow and water temperature in the meantime without iterations and wastage of time and water. An axiomatic review of such a water faucet design revealed that it was indeed based on a "coupled matrix." As shown in the following decency matrix, each of the indicated DPs was able to address both of the stated FRs, resulting in a "coupled" matrix. While such design still works and is indeed addressing the stated FRs, it is not the "best" solution given the aforementioned customer complaints.

Initial design solution—dual knob faucet design matrix

	Design parameters	
Functional requirements	**Hot valve**	**Cold valve**
Control water flow	X	X
Control water temperature	X	X

To improve this coupled design scenario, a design improvement was introduced through the modern "lever arms" water faucet of the following "uncoupled" design matrix.

Improved design solution—lever arm faucet design matrix

	Design parameters	
Functional requirements	**Up–down**	**Side–side**
Control water flow	X	0
Control water temperature	0	X

In the lever arm design solution, DPs address FRs independently. The up–down move controls the water flow only, while as the side–side only and independently. This has resulted in a diagonal "uncoupled" axiomatic design independence matrix and thus the "best" design.

Example 2: Bridge over a Navigation River

Applying this concept once again but in civil engineering application, we can refer to the bridge design and construction example provided in

Section 5.3.1. A set of candidate DPs were developed for further assessment. The desired FRs addressing CNs are stated as follows:

1. Allow free span with no piers within the river profile
2. Bridge deck carrying six traffic lanes
3. Limited construction duration

If the DB team decides to use cable stayed bridge, single six-lane deck, and precast deck elements, the independence design matrix will be of a "coupled" type and will look as follows.

First potential combination—coupled matrix

FRs		DP1 Suspension bridge system	DP2 Single six-lane bridge deck	DP3 Precast bridge deck
FR1	Allow free span with within river profile	X	0	0
FR2	Bridge deck carrying six traffic lanes	0	X	0
FR3	Limited construction duration	X	0	X

DP, design parameter; FR, functional requirement.

As discussed above, a best design occurs when the design matrix is diagonal or "uncoupled," that is, each FR is addressed by only one DP, and no DP addresses more than one FR. In the above bridge design and construction DB combination example, while DP2 addresses the single six-lane deck requirement and DP3 addresses the limited construction duration, DP1 Option 1 suspension bridge solution is attempting to address and satisfy two FRs in the meantime, namely, FR1 free span and FR3 limited construction duration as the system implies. In this case however, finalizing the design of DP1 suspension bridge, including bridge towers and the long lead suspension cables, is coupled with and requires finalizing the design of DP2 single six-lane deck. If DP1 is changed from Option 1 suspension bridge to Option 2 progressive cantilever, and since Option 2 progressive cantilever is indeed just a construction concept aiming to satisfy FR1 free span, DP2 single six-lane deck can proceed independent of DP1, enabling an “uncoupled” matrix and thus a “best” design. The best solution would be then the one in which FR1 free span is satisfied by DP1 progressive cantilever, FR2 six traffic lanes is satisfied by DP2 single six-lane deck and FR3 limited construction duration is satisfied by DP3 utilizing a precast solution so that bridge foundations and piers can be designed and constructed in parallel with the design and construction of the precast system and precast segmental bridge via duct units.

Second (refined) potential combination—uncoupled matrix

		DP1	DP2	DP3
FRs		Progressive cantilever system	Single six-lane deck	Precast deck
FR1	Allow free span within river profile	X	0	0
FR2	Bridge deck carrying six traffic lanes	0	X	0
FR3	Limited construction duration	0	0	X

DP, design parameter; FR, functional requirement.

Hence, in summary, both of the above bridge design and construction solutions can be used; however, the second solution is better and more likely to be completed in a shorter design and construction time as it yields an uncoupled design independence matrix.

5.3.2.2 Axiom 2: The Information Axiom

The Information Axiom examines the candidate design–build solutions to identify and select the best solution. The best solution is defined as the one with the least information content.

From a design perspective, information content refers to complexity of the candidate designs. Simple designs of lesser information content are considered better than complex ones. Complexity is hard to measure and quantify; however, certain metrics can be used to get a feel of a candidate solution’s complexity and information content such as the expected design duration, number of design drawings, number of calculation sheets, size of specifications, or eventually through a catchall single figure representing the total man-hours required to develop and complete the design solution. This subjective measure however still must be verified and proven in more explicit business terms.

To that end, the ability of the candidate designs to satisfy the system constraints imposed by the Owner has been successfully used as an "index" of the information content. The information content index (ICI) is chiefly defined in terms of time and money, and is measured by comparing the "candidate solutions range" with the "Owner defined system range." This takes the matter to a whole new strategic level.

The ICI of a candidate design–build solution is calculated using the following equation:

$$\text{ICI} = \Sigma\ [\text{LOG2}\ (1/P_i)]\ \text{bits from}\ i = 1\ \text{to}\ i = n$$

where:

n = the number of DPs defining the proposed candidate solution

P_i = the probability of the proposed DPs to satisfy FRs and project constraints

(Note: The logarithm function is utilized to enhance additivity. The base of the logarithm 2 is utilized to express the ICI using the bit unit.)

The value of P in the above equation ranges from 0 to 1. In theory, a P value of zero means that the pertinent candidate solution is impossible, whereas a P value of 1 would mean that the proposed solution is absolutely perfect. A smaller ICI indicates a better solution.

The probability numeral P is derived in a way similar to the concept of the normal distribution (ND) curve, also known as the bell curve or Gaussian distribution. A perfect solution is one having a set of DPs that yield a ND that is congruent with that produced by the system of CNs and FRs defined by the Owner. Since such congruence is rarely possible, a comparison is made between the parameters of ND produced by the available candidate solutions and the same required by the Owner, and the candidate solution that best coincides with the Owner requirements is selected.

In practical terms, the value of the probability numeral P for a given candidate solution is calculated by comparing the "system range" and the "common range" of such solution. System range is the range of values required by the Owner. Any proposed candidate solution offers another range of values consisting of a target value defined by the Owner and a + or – range of deviation or tolerance. Common range is the overlapping stretch between the "system range" and the range provided by the proposed solution. In the axiomatic design, the probability of success of a given solution P_i is defined by the extent of overlap between the common range and the system range for such solution, namely:

$$P_i = \text{Common range } i/\text{System range } i$$

Figure 5.4 illustrates the relationship among the discussed system range, proposed candidate solution range, and the common range.

Example

In the bridge over a navigation pathway example explained under Section 5.3.1, the Owner identified a "system range" of circa $100 m cost and a maximum of 18 months for both design and construction of the bridge. Two candidate solutions were developed, namely, a suspension bridge

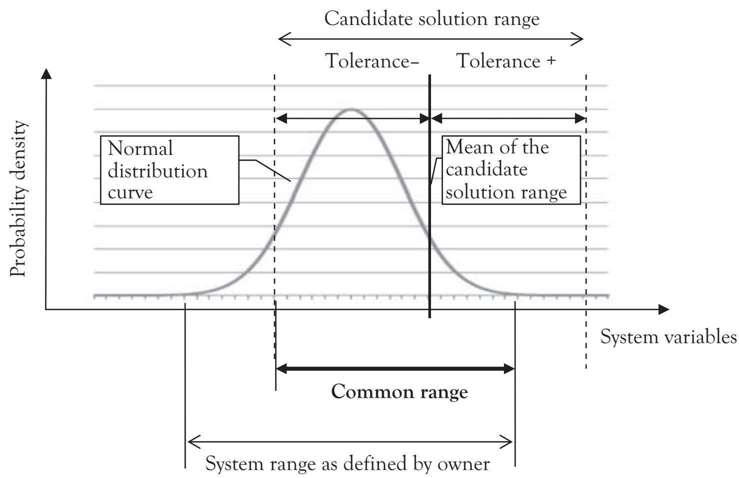


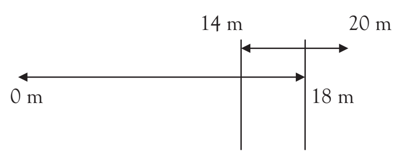
Figure 5.4 System range and common range relationship

system, and a progressive cantilever bridge system. The key DPs for these two solutions are:

1. Design and construction time
   The design and construction time was set by the Owner in the "system range" at a maximum of 18 months, that is a range from 0 months minimum to 18 months maximum (0,18). The design and construction time of the suspension bridge solution is expected to take 16 months; however, with a tolerance of +4 months to take account of the probable delay in procurement of the tailored suspension cables, and –2 months in case everything ran smoothly, that is, a candidate solution range of 14 months minimum and 20 months maximum (14,20). On the other hand, the design and construction time of the progressive cantilever solution is expected to take 16 months, with a tolerance of + or –3 months, that is, a candidate solution range of 13 months minimum and 19 months maximum (13,19).

Suspended bridge solution:

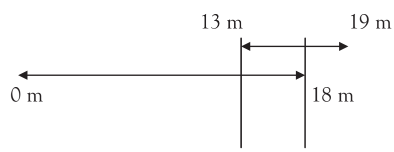
Candidate solution range	14 m	20 m
System range	0 m	18 m



Common range = 4 m
P-time = 4 m/18 m = 0.222
ICI-time = Log 2 (1/P-time) = 1.50 bits

Progressive cantilever bridge solution:

Candidate solution range	13 m	19 m
System range	0 m	18 m



Common range = 5 m

P-time = 5 m/18 m = 0.278

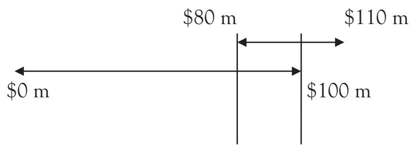
ICI-time = Log2 (1/P-time) = 1.28 bits

2. Design and construction cost

   The design and construction cost was set by the Owner in the "system range" at a maximum of $100 m, that is, a range from $ 0 m minimum to $100 m maximum (0,100). The design and construction time of the suspension bridge solution is expected to cost $90 m; however, with a tolerance of +$20 m to take account of the probable failed test and delay penalties, and –$10 m in case everything ran smoothly, that is, a candidate solution range of $80 m minimum and $110 m maximum (80,110). On the other hand, the design and construction cost of the progressive cantilever solution is expected to be $85 m, with a tolerance of +$20 m or –$10 m, that is, a candidate solution range of $75 m minimum and $105 m maximum (75,105).

Suspended bridge solution:

Candidate solution range	$80 m	$110 m
System range	$0 m	$100 m



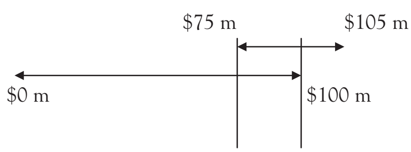
Common range = $20 m

P-cost = $20 m/$100 m = 0.20

ICI-cost = Log2 (1/P-time) = 1.61 bits

Progressive cantilever bridge solution:

Candidate solution range	$75 m	$105 m
System range	$0 m	$100 m



Common range = \$25 m
P-cost = \$25 m/\$100 m = 0.25
ICI-cost = Log2 (1/P-time) = 1.39 bits

Hence, the sum of the ICs for the two candidate solutions would be:

$$\text{ICI-suspension bridge} = \Sigma\,[\text{LOG2}\,(1/P_i)] = \text{ICI-time} + \text{ICI-cost} = 1.50 + 1.61 = 3.11 \text{ bits}$$

$$\text{ICI-progressive cantilever bridge} = \Sigma\,[\text{LOG2}\,(1/P_i)] = \text{ICI-time} + \text{ICI-cost} = 1.28 + 1.39 = 2.67 \text{ bits}$$

This means that the progressive cantilever bridge solution is the better and more robust solution to adopt as it has a lower ICI. It should be noted that such conclusion is based on the examined parameters and the estimated numerical values. More DPs or DP combinations or other numerical estimates could be examined by the project team in the same numerical and systematic manner shown above to further investigate the discussed or other proposed candidate solutions.

5.3.3 First Methodology Component Step 3: Progressive Elaboration of the Selected Design–Build Solution

After selecting the best overall global project design–build solution, the next step is to implement the selected solution in a progressive top-down fashion zigzagging between system domains. The process starts with decomposing (breaking down) the project into its components in a hierarchical style, then proceeding with the application of the axiomatic best solution examination and selection process in a top-down fashion, zigzagging down the design and build system hierarchy laterally then diagonally downwards among FRs, DPs, and PVs, as shown in Figure 5.5.

In Figure 5.5, the system hierarchy is illustrated in an indicative way without naming the elements of the various system hierarchy levels. In reality, project design and construction system hierarchy typically consists of a top-level total system, followed by system integrators, major assemblies, major components, subcomponents, and ending with materials. After selecting the overall design–build top-level total system in Section 5.3.2,

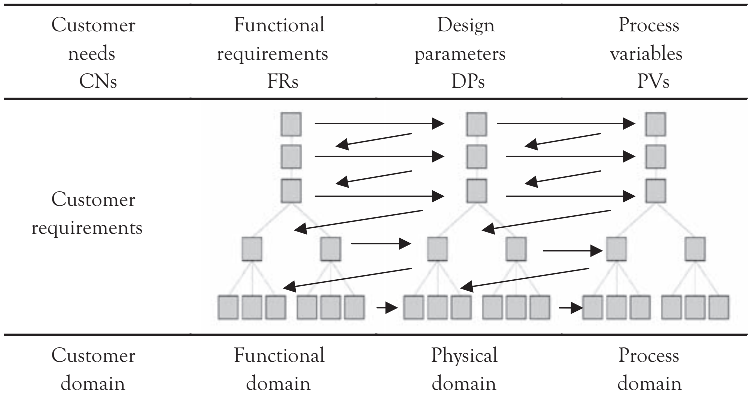


Figure 5.5 Axiomatic design–build hierarchies and zigzagging among FRs, DPs, and PVs

the axiomatic design process proceeds downwards to include other downstream hierarchy elements starting with system integrators, then major assemblies, and so on. At each level, the DP physical domain responds to pertinent FRs with several candidate DPs for examination and selection of the best design solution, and the PV process domain responds to the selected DPs with several candidate PVs for examination and selection of the best construction solution.

Figure 5.6 illustrates the typical axiomatic concepts of decomposition, system hierarchy, and top-down zigzagging between domains.

In a design–build environment, changes to a hierarchy upstream element, especially if one of the higher-level elements, can have a detrimental effect on project progress and success. The lateral and diagonal zigzagging among FRs–DPs–PVs in the shown manner mitigates such risk associated with the hierarchical nature of the process. It enhances confidence in the information released from higher- to lower-level system components and reduces the chances of costly and time-consuming rework cycles.

Example

In the context of civil engineering projects, and referring to the bridge over a navigation pathway example explained under Section 5.3.1, the indicated system hierarchy levels/elements (system integrators, major assemblies, etc.) would have the meanings as shown in Table 5.3 in

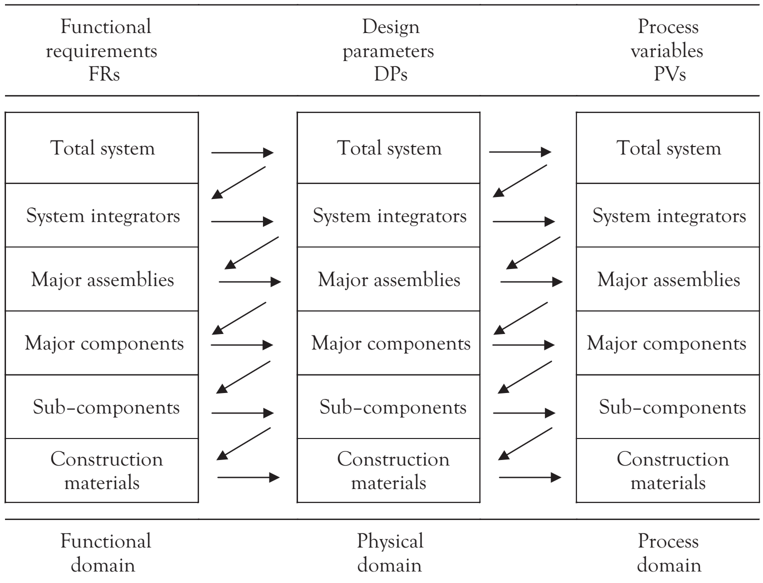


Figure 5.6 Axiomatic design–build decomposition and zigzagging among FRs, DPs, and PVs

Table 5.3 Definition and application of design–build system hierarchy elements

Hierarchy element	Definition	Application in the bridge example
Total system	A high-level description of the intended system	Progressive cantilever system
System integrators	Investigation and selection of the main features of the total system	Bridge system configuration
Major assemblies	Subsystems of the total systems	The combination of precast via duct elements and pre-stressing system
Major components	Primary system elements	Six-lane precast segments, launching girders, bridge piers, foundation
Subcomponents	Secondary system elements	Walkways, pavement, road marking, lighting, signage, landscape
Materials	Construction materials	Concrete, asphalt, reinforcing steel, pre-stressing tendons, etc.

absolute terms as well as in terms of the said bridge design and construction example.

5.4 Determining the Most Effective Design–Build Solution

According to the SAFEDB-methodology and its underlying principle of axiomatic design, the best and most effective design–build solution is one that has the maximum independence between DPs and FRs or PVs and DPs, combined with the minimum possible ICI. This ensures minimum complexity of the selected solution leading to faster design and construction, lower cost, and reduced risk of rework cycles and other unintended or unplanned consequences.

On the other hand, it should be noted that in practice, there might be other external factors that would affect the design–build solution selection decision such as organizational process assets and enterprise environmental factors. The presence of readily available specialist type or types of plant and equipment, or the design–build organization's specialism in specific engineered construction systems or any other justified bias factors can well affect the design–build solution-selection process.

The final decision on the selection of the most effective design–build therefore lies with the design–build organization's senior management. At any rate, the design–build team should exert utmost creative effort at this stage to generate the most effective candidate solutions leading to selection of the best of the best solutions. It is all about creating value by thinking, experience, and analysis.

5.5 Summary

Selecting the best design–build solution is key to project success. The axiomatic design approach examines and analyzes the candidate solutions proposed by the design–build team and helps identify the best design–build solutions by applying the Independence and Information Content axioms, leading to superior project results. This is achieved by identifying process domains that transfer the customer needs and FRs to DPs and construction PVs. Selecting the best design–build solutions starts with selecting the best overall global project solution, then decomposing the total system into its components and moving down the system hierarchy zigzagging laterally and downwards between the process domain hierarchy levels while applying the Independent and Information axioms each step of the way. Selecting the best design–build solution enables a faster and lower-cost project delivery and mitigates the risk of abortive work or rework cycles.

CHAPTER 6

The Second SAFEDB-Methodology Component: Fast-Track Design–Build Activities

Preface

In design–build, Owners' time-shortening expectations are usually very high and at times get close to the limit of impossible. This puts the onus on the design–builders to find ways to accelerate progress.

Deploying large teams and breaking down the job into discrete packages running in parallel are commonly used mechanisms to expedite projects. However, experience shows that such standard measures have practical boundaries beyond which they become ineffective. They lack inventiveness and cannot be considered trade secret differentiators. Standing out of the crowd, living up to the design–build unbeatable speed promise, and having a strategic market edge require thinking out of the box and applying innovative design–build project delivery tools and techniques not known to or used by competitors.

This chapter introduces a working procedure that can deliver design–build project faster. This is achieved by fast-tracking/overlapping the traditionally sequential design and construction activities. The procedure is based on the principles of the concurrent engineering approach. Overlapping of design and construction activities enables a level of schedule compression not available in going traditional. While waiting for the design task to finish before starting the related construction activity is the no-brainer way to go about the construction process, it is not necessarily a must if the design–build team was willing to take a bit of calculated risk. After all, no risk no gain. The concepts and mechanisms introduced in this chapter will help the design–build team to manage the risks associated with overlapping design and construction activities in a structured, informed, and controlled manner.

6.1 Methodology Component Objective

The objective of this methodology component is to shorten the overall design–build project execution duration by overlapping design and construction activities. This is achieved through the creative application of the theory of concurrent engineering. In practical terms, a component aims to accomplish a project schedule compression by allowing construction activities to start on site while the design process is still underway. The application of such daring schedule compression scenario permits an advanced level of additional schedule compression, which comes in addition to any other applied traditional schedule compression efforts. This concept is quite in line with the design–build basic idea of overlapping design and construction at the macro-level. The same concept is applied to lower project levels starting from project phases all the way down to project tasks and individual activities at the micro-level. As will be discussed later in this chapter, not all design and construction activities can or will be overlapped. The possibility and extent of overlapping will be decided on a case-by-case basis depending on the nature and fast-tracking characteristics of both the upstream design activity and its related downstream construction activity.

6.2 The Concurrent Engineering Approach

Concurrent engineering is essentially a systematic approach that is based on parallelizing engineering tasks.

In concurrent engineering, conducting the various engineering tasks related to the same product occurs at the same time, or concurrently. In doing that, the related engineering tasks overlap, interact, and progress concomitantly in a coordinated and incremental manner. Concurrent engineering is therefore a highly dynamic project management concept, which requires a fairly high degree of skill and project management maturity on the part of both the organization and the involved teams.

Concurrent engineering has roots in the manufacturing industry motivated by the need to develop new products faster so as to meet critical market deadlines. It revolves around two key concepts. The first is that functional requirements of the subject product are well defined early in the process, and the second concept is that engineering activities are conducted concurrently.

Concurrent engineering was originally concerned with overlapping engineering design activities. The SAFEDB-methodology expands on the current state of concurrent engineering application by moving forward to the design–build arena overlapping design and construction activities.

Before moving on to the next sections explaining the second methodology component, it is important to have a quick review of the overlapping process and the typical fast-tracking strategies.

Figure 6.1 illustrates the three typical overlapping relationships.

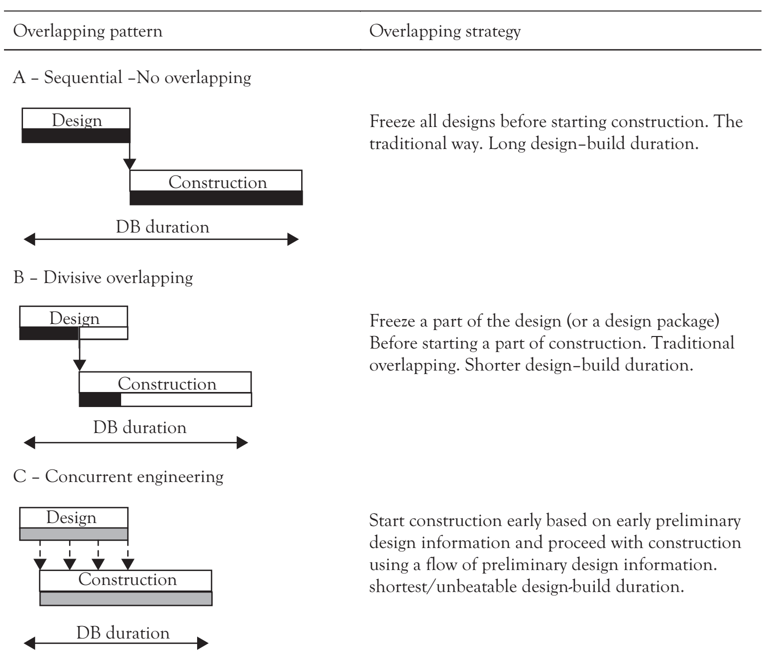


Figure 6.1 Common modes of overlapping strategies

Pattern A does not involve any degree of overlapping; so construction waits until the entire design is completed with a typical finish-to-start relationship. Pattern B presents a traditional overlapping pattern in which a part of construction starts based on a released part of the finalized design; further parts of construction may only proceed upon freezing further design. Pattern C presents the concurrent engineering overlapping strategy in which construction starts once a sufficient amount of preliminary design is available, and then construction proceeds to completion uninterrupted.

Like any innovative approach, concurrent engineering comes with risks and opportunities. The key source of risk to the project in concurrent engineering is communication. Alleviating such risk requires taking certain proactive actions including co-location of design and construction teams, deploying a modern project management information system (PMIS), performing multiple phase-gate governance reviews before releasing each and every design information pulse for construction, and creating a highly collaborative work environment. On the other hand, applying concurrent engineering introduces project opportunities and can be very rewarding in terms of shortening the overall design–build project duration, increasing productivity and enhancing the end-product quality.

6.3 Second Methodology Component (SMC)—Step by Step

This section explains the use of the concurrent engineering approach in developing and implementing design and construction overlapping strategies in a practical step-by-step fashion. While the process is presented in a discrete progressive step-by-step manner, in reality, such steps may overlap or interact with each other in complex ways that cannot be completely explained in a document or with graphics. Figure 6.2 provides an overview of the title and purpose of the three logical steps of the second methodology component, namely, SMC 01, 02, and 03.

This section is primarily concerned with explaining the theoretical background and underlying notions and objectives of the SAFEDB-methodology's second methodology component, supported by basic real-world examples to support the understanding of the presented concepts.

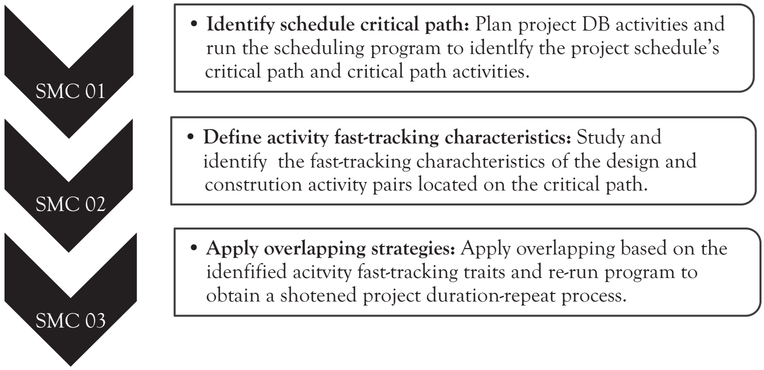


Figure 6.2 The SAFEDB-methodology—overview of the second methodology component

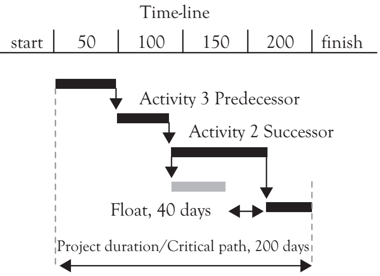
Full-scale practical application examples and case studies are provided in Chapter 9. However, some limited-scope practical examples shall be provided within the body of this chapter on when-and-as-necessary basis aiming to support the information provided and make certain somewhat implicit concepts explicit to the reader.

6.3.1 Second Methodology Component Step 01: Identify Schedule Critical Path

The SAFEDB-methodology adopts the critical path method (CPM) for planning and scheduling the design–build project design and construction activities. The CPM is a well-established project management technique widely used to plan and control civil engineering projects by focusing on the key critical activities that determine the shortest time to complete a project.

In CPM, all project activities are first listed down and each activity is assigned a duration that reflects an estimate of how long it will take to complete. In very simplistic terms, project scheduling starts with identifying the first and earliest project activity with no predecessor, and then proceeding with applying the logical successor–predecessor dependency connections between the remaining activities until the last project activity is reached. Activity dependencies take several typical modes including finish to start (the most common), start to start, start to finish, and finish

Activity Name	Duration	Predecessor
Activity 1	50 days	
Activity 2	40 days	Activity 1
Activity 3	80 days	Activity 2
Activity 4	40 days	Activity 2
Activity 5	30 days	Activity 3



Note: Activities 1, 2, 3 and 5 are on the critical path.

Figure 6.3 Critical path method

to finish sometimes with lag and/or lead periods. When all activities are logically connected, the longest path along the connected activities is called the critical path. The length of the critical path is the shortest time in which the project can be completed.

Figure 6.3 provides a simple example of the critical path concept.

During the course of the project, the critical path of a project can change for better or for worse. If an activity on the critical path takes longer to complete than the estimated duration, the critical path will take longer to complete, and so will the project. If the duration of an activity along the critical path can be shortened, by assigning more resources or working longer hours for example, the critical path will be shorter in duration and the project can be completed in less time. It should also be noted that if non–critical path activity slips (e.g., Activity 4 above) it can become a critical path activity.

In large civil engineering projects, the number of project activities is invariably a couple of thousands or more, making it practically impossible to assess the critical path manually. Project management scheduling software programs will calculate a CPM critical path for you. They can also examine various planning scenarios and enable activity relationships in a relatively easy way.

After identifying the critical path of the design–build schedule, the next step is to identify and set aside the construction activities located on the critical path for further assessment of their overlapping with their pertinent predecessor design activities, as discussed in detail in the following second methodology component Steps 2 and 3.

6.3.2 Second Methodology Component Step 02: Define Activity Fast-Tracking Characteristics

This step is a further elaboration on the interaction and the overlapping/fast-tracking of the design parameters (DPs) developed in the physical domain, and the construction activities or process variables (PVs) established in the process domain (see Section 5.3.3).

Overlapping design and construction activities means that construction will start while design is still being finalized. This involves the risk of rework cycles should the final design differ from that the construction was built based upon.

It is therefore key to have an in-depth understanding of the nature and characteristics of the associated design and construction activities, and to decide the extent of overlapping accordingly ensuring the least amount of rework risk. This area has been researched by various academics and practitioners in the industry, however, not at a large scale within an integrated design–build solution framework like that presented herein by the SAFEDB-methodology. Key research works in this regard include among others those by Pena-Mora (2001) and Krishnan (1996).

In the design–build context, overlapping invariably involves an activity pair consisting of an upstream design activity (UDA) and a downstream construction activity (DCA), as shown in Figure 6.4.

The extent of the safe amount of overlapping between the UDA and the DCA is a function of two key inherent parameters called the fast-tracking characteristics. These are the UDA speed of design evolution and reliability of the design information transferred to the downstream construction activity, and the DCA pattern and pace of construction production and sensitivity of the same to changes in the

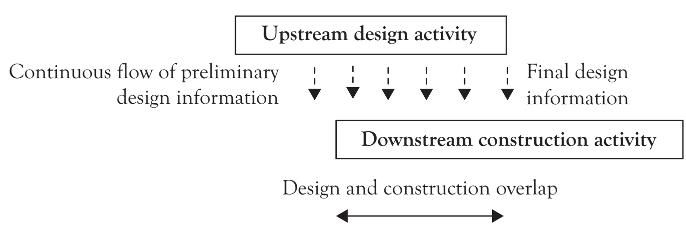


Figure 6.4 Typical design–build activity pair

design transferred from the UDA. These concepts are explained hereunder in greater detail.

6.3.2.1 Upstream Design Activity: Speed of Design Evolution and Reliability of Design Information

There are two key fast-tracking characteristics governing the design activity overlapping, namely, speed of design evolution and reliability of the early design information released from the design domain to the construction domain.

Speed of design evolution describes the rate at which the design information is generated by the UDA within the activity duration. Design evolution can be broadly classified as fast early evolution or slow early evolution. A fast early evolution design activity ramps up fast producing a significant amount of design information at an early stage, whereas a slow early evolution design activity produces a small amount of design information at its early stage and then ramps up gradually to produce the major part of its output at a later stage of its duration.

Figure 6.5 represents such design evolution scenarios and a numerical definition of each scenario. Evolution curves were sensibly considered to be congruent.

Another key fast-tracking characteristic related to the upstream design activity is the reliability of the design information released to the downstream construction activity. Reliability of the information developed in the upstream design activity is a key factor in determining the extent of the safe design–construction activity overlapping. In a design–build environment, reliable upstream design information can be readily passed along to feed the downstream construction activity with confidence, resulting in a speedier design–build process. On the other hand, low reliability design information should not be prematurely released to construction to avoid unwarranted abortive rework.

For the purposes of the SAFEDB-methodology, the fast-tracking characteristics of the design information generated from the UDA are to be classified as in Table 6.1.

The following basic practical examples aim to clarify the concept of design evolution and the related design information reliability.

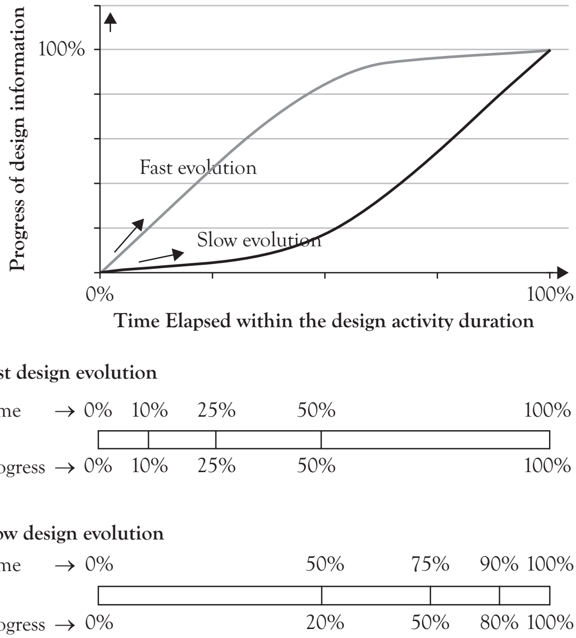


Figure 6.5 Upstream design activity evolution (indicative)

Table 6.1 Upstream design activities—design evolution and design reliability

Upstream design activity							
Fast evolution				Slow evolution			
Highly reliable	Fairly reliable	Fairly unreliable	Highly unreliable	Highly reliable	Fairly reliable	Fairly unreliable	Highly unreliable

Note: In practice, speed of design evolution and reliability of the design information transferred from the upstream design activity to the downstream construction activity vary according to the nature of the project itself, process maturity, and the level of experience of the organization with the very type of project under study. Therefore, it remains the design–build team's responsibility to determine the type and definition of such fast-tracking parameters using expert judgment and due diligence.

Examples

Example 1: Fast Design Evolution of Fairly Reliable Design Information

A basic example of fast design evolution would be the case of the design and construction of a reinforced concrete slab. Early in the process, in

25 percent of the design activity time, the structural designers can identify the slab thickness and dimensions with a reasonable level of certainty so that the design and construction of the related formwork system and its props and braces can proceed. This will provide for the design information required to cover 50 percent of the construction works and time required to design, fabricate, and install the slab formwork system. Slab structural modeling, analysis, and design of the size and spacing of the slab reinforcing steel can then proceed in parallel with the formwork design and construction. If the final slab design reveals that the slab should indeed be slightly thicker than originally anticipated, additional reinforcement could be added instead or additional props could be introduced to the formwork supporting system if necessary. Moreover, during the detailed design process, size and shapes of the reinforcing steel bars can be released in a second batch so that the rebar can be ordered, cut, and erected. If the final design reveals that additional rebar is required, the additional quantity can be fabricated and erected in a relatively very short time. The last and final batch of design information can then follow identifying the balance of the required final design information including concrete mix design and builder's work. The design evaluation curve in this example would look similar to the fast evolution curve shown in Figure 6.5. Another example would be the foundation design for a multistory building. Column loads can be calculated first, once the structural model is established and decisive load combinations are examined. Foundation design then can be finalized and released for construction while design of other structural elements (columns, slabs, beams) proceeds in parallel. The design evolution curve in this example will be looking similar to the fast evolution curve shown in the above figure.

Example 2: Slow Design Evolution of Highly Reliable Design Information

A basic example of slow design evolution would be the case of design and construction of a window system for a residential or a commercial building. This process usually involves selecting the window system to use from a range of potential proposed window systems. The process starts with the identification of the range of potential systems that appear to be in general compliance with the project requirements, then soliciting technical proposals and samples, followed by presentations and workshops, comparative analysis until the search is narrowed, and the window system is finally selected at the very end of the design activity duration. Given such strict and elaborative design process, only information on the window opening sizes and locations can be released at say 50 percent of the design activity time to initiate the related construction works with high reliability. This accounts for say 20 percent of the construction work and time. While completing the windows' final design, if the size of a few windows is deemed to require change or adjustment, this can be rectified with a nominal amount of effort. The design evolution curve in this example would look similar to the slow evolution curve shown in Figure 6.5.

6.3.2.2 Downstream Construction Activity: Evolution of Production and Sensitivity to Design Changes

There are two key fast-tracking characteristics governing the construction activity overlapping, namely, speed of construction evolution and sensitivity to changes in the design information released from the design domain.

The first fast-tracking characteristic related to the downstream construction activity is the pace and pattern of the construction progress or production. It is established that construction activities vary in their rate and pattern of production. This fact introduces a key fast-tracking characteristic that needs to be considered in identifying the design and construction activities overlapping strategy. As in design evolution, the construction production evolution can be classified as "fast early production" and "slow early production." A fast early production construction activity ramps up fast and produces a significant amount of physical work at an early stage, whereas a slow early production construction activity produces a small amount of physical work at its early stage and then ramps up gradually to produce a major part of the physical work at a later stage of its duration. Figure 6.6 represents such construction production evolution scenarios. Evolution curves were sensibly considered to be congruent.

For the purposes of the SAFEDB-methodology, the fast-tracking characteristics of the DCA will be classified as in Table 6.2.

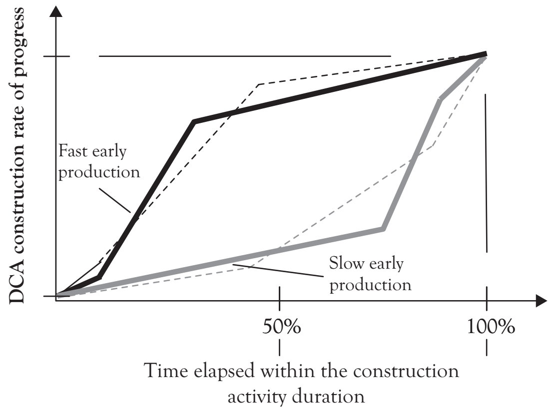


Figure 6.6 Downstream construction activity—production patterns and rate of progress (indicative)

Table 6.2 Downstream construction activities—sensitivity and production rate

Downstream construction activity					
Fast early production			**Slow early production**		
Insensitive	Sensitive	Highly sensitive	Insensitive	Sensitive	Highly sensitive

Note: In reality, the downstream construction activity's speed of early production and its sensitivity to changes in the design information transferred from the upstream design activity will vary according to the nature of the project, the type of the construction activity, and the technology used. Therefore, it remains the design–build team's duty and responsibility to determine the type and definition of such fast-tracking parameters using expert judgment and due diligence.

The other key element in determining the safe overlapping strategy is studying the sensitivity of the DCA to changes in the preliminary design information transferred from the UDA. Construction should not start until it is established that changes in the design information upon which the construction is based can only result in a nominal amount of rectification or abortive work. This determination requires a high level of experience and trust in the teams involved, and as discussed above, should be subject to a formal sign-off through an approved governance procedure.

In practice, certain construction activities are known to practitioners to be less sensitive to design changes; so a design change would only result in a small amount of rectification, abortive work, or physical rework. On the other hand, certain other types of construction activities are also known to practitioners to be sensitive to design changes; so a design

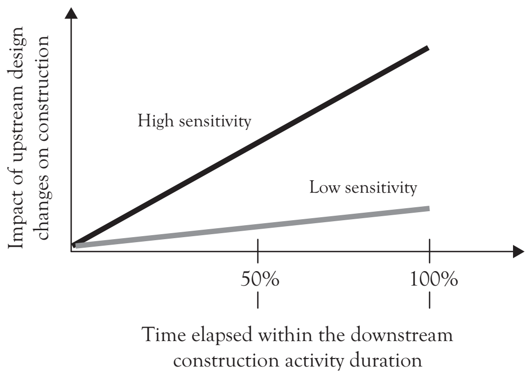


Figure 6.7 Downstream construction activity sensitivity (indicative)

change can well result in a considerable amount of rectification, abortive work, or physical rework.

Figure 6.7 represents the above two scenarios.

Construction activities have an inherent degree or another of sensitivity to changes in the design information released from the design domain. In broad terms, such degree of sensitivity can be classified anywhere between low and high. An assessment of the degree of sensitivity of the various types of construction activities should be performed by the design–build team on a case-by-case basis.

The following basic practical example aims to clarify the concept of sensitivity.

Example

A typical basic example of high sensitivity versus low sensitivity constructions is the precast versus the cast in place construction solutions, respectively. A precast solution for a reinforced concrete slab requires starting the fabrication of the numerous slab segments early in the process. The slab segments' full production including reinforcing steel and concreting proceeds until the time of panels' erection and assembly toward the end of the slab construction duration. Any change to the design information during the construction duration will render a part or all of the fabricated panels abortive. In contrast, in the cast in situ solution, design changes could eventually be relatively simply accommodated by providing additional reinforcing bars or even by changing the slab thickness. This assertion remains true until late in the slab construction duration when concreting starts toward the end of the slab construction duration.

After identifying the fast-tracking characteristics of the UDA design and DCA construction activity pairs located on the project schedule critical path, the next step is to select and apply a comprehensive fast-tracking strategy including the determination of the amount of overlapping between each activity pair as discussed in detail in the following SMC Step 03.

6.3.3 Second Methodology Component Step 03: Apply Design–Build Overlapping Strategies

Overlapping has obvious favorable impact on project schedule and leads to shortening project duration, but the question is how to do it in an effective and controlled manner. Too much overlapping of design and construction activities can cause work to stop until the design catches up, or even worse, leads to demolition of parts or the whole of the completed work. On the other hand, ignoring or applying an insufficient amount of overlapping undermines the benefits of the design–build approach. For effective and safe overlapping of design and construction activities, design–build project schedulers and planners need a system supported by academia (Hashem 2005, USA). This SAFEDB-methodology component provides such a system that is concerned with identifying and applying the maximum safe amount of overlapping between design and construction activity pairs located on the project's critical path, leading to shortening the project schedule.

The SAFEDB-methodology provides a well-defined overlapping strategy comprising all possible combinations of the upstream and downstream activity fast-tracking characteristics, as shown in Figure 6.8. The overlapping value (X) is defined as the percentage of the upstream design activity's time elapsed or work done at which the downstream construction activity may start. For planning and scheduling purposes, X is introduced to the project's schedule (Primavera P6 or similar) in a typical "start-to-start" relationship between the UDA and DCA, as shown in Figure 6.8.

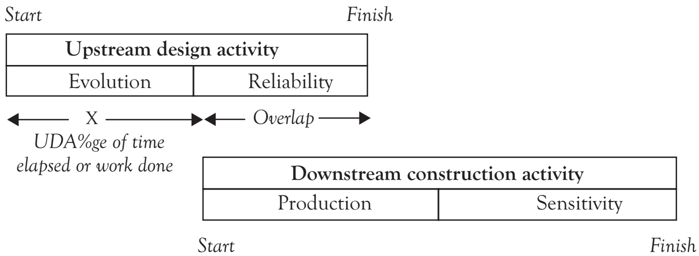


Figure 6.8 General illustration of the overlapping value (X)

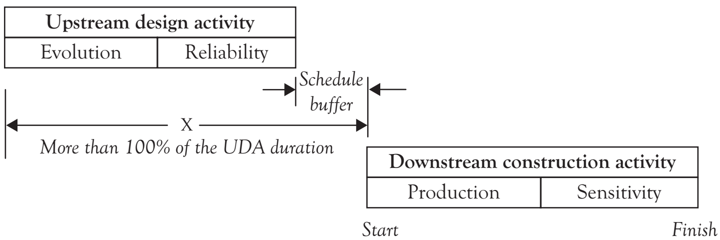


Figure 6.9 Illustration of the overlapping value (X) in the special case of a combination of unreliable design information with sensitive construction

The SAFEDB-methodology also aims to safeguard the project schedule against the risks associated with the combination of fast evolution design information of very low reliability (as is the case in highly innovative designs or those designs attempting to achieve a technological breakthrough) when combined with fast production construction of high sensitivity to changes in the design information. Such cases were provided with a schedule buffer, as shown in Figure 6.9.

The insertion of such a buffer is meant to allow some time after completing the upstream design activity for the design–build team to reevaluate and validate the design information and eventually discover and fix potential design errors, thereby avoiding the negative impact of potential design errors on the downstream construction activity. This case is particularly applicable to cases of innovative designs aiming to achieve a technological breakthrough or going beyond the state-of-the-art, which is anyway a malpractice that needs to be avoided in the design–build projects.

Table 6.3, which is pivotal, provides a numerical definition of the overlapping strategy covering the various UDA and DCA fast-tracking characteristic

Table 6.3 The SAFEDB-methodology—selection table for overlapping of design and construction activities based on their inherent fast-tracking characteristics

Overlapping strategy Guideline figures for various UDA and DCA overlapping combination scenarios			X (the start to start time between an UDA and a related DCA) Percentage of the Upstream design activity's time elapsed or work done at which the DCA may start Design X Construction							
			UDA							
Legend: 10% Time elapsed [20%] Work done			Fast evolution				Slow evolution			
			Highly reliable (%)	Fairly reliable (%)	Fairly unreliable (%)	Highly unreliable (%)	Highly reliable (%)	Fairly reliable (%)	Fairly unreliable (%)	Highly unreliable (%)
DCA	Slow production	Insensitive	10 [20]	25 [50]	50 [80]	100 [100]	50 [20]	75 [50]	90 [80]	100 [100]
		Sensitive	25 [50]	50 [80]	100 [100]	110 [100]	75 [50]	90 [80]	100 [100]	110 [100]
		Highly sensitive	50 [80]	100 [100]	110 [100]	120 [100]	90 [80]	100 [10]	110 [100]	120 [100]
	Fast production	Insensitive	25 [50]	50 [80]	100 [100]	110 [100]	75 [50]	90 [80]	100 [100]	110 [100]
		Sensitive	50 [80]	100 [100]	110 [100]	120 [100]	90 [80]	100 [100]	110 [100]	120 [100]
		Highly sensitive	100 [100]	110 [100]	120 [100]	130 [100]	100 [100]	110 [100]	120 [100]	130 [100]

DCA, downstream construction activity; UDA, upstream design activity.

combinations. The four segments of UDA fast and slow design evolution values indicated in Section 6.3.2 are first inserted in the table's top row, and then retracted gradually leftwards and downwards in the four quarters of the table to reflect the DCA fast-tracking characteristics. Values exceeding 100 percent are based on expert judgment and indicate a finish-to-start lag relationship between an UDA and its corresponding DCA. All shown values have been verified for suitability and alignment with the industry best practice. However, it remains the users' responsibility to verify the suitability of such values for the actual conditions of their own projects before use.

From the Table 6.3, it would be prudent for the design–build team to try and maximize the use of highly reliable designs and insensitive construction means and methods, and as much as possible avoid using highly unreliable designs or highly sensitive construction means and methods.

The following basic practical examples aim to clarify the manner of selecting an effective fast-track overlapping strategy based on activity fast-tracking characteristics and combinations thereof.

Examples

Example 1: Upstream Design Activities

A typical basic example for comparing and selecting an effective fast-track overlapping strategy based on UDA fast-tracking characteristics is the design of a reinforced concrete slab for a multistory office building. The key UDA design components in this example would include establishing the room (office space) layout and the structural design of the slab itself.

Choosing a traditional slab-beam system will require freezing the room layout so that beam locations can be determined (as they follow the location of the room partition walls), and the slab-beam system structural design can be completed. As freezing room layout is usually a prolonged exercise involving creating options for Owner approval and feasibility assessments, and given the fact that Owner requirements are likely invariably subject to change, the UDA in this case can be classified as one of a *Slow Evolution* (as the slab-beam structural design has to wait until room layout is fixed), and *Fairly Reliable* (as the room layout may still be changed by the Owner).

A flat slab (beamless) system can then be a better design–build solution. Flat slabs are not sensitive to room layout and their structural design can start independent of the room layout. Adopting a flat slab system changes the classification of the UDA to a favorable *Fast Production* (as the flat slab structural system can proceed regardless of the room layout), and *Highly Reliable* (as the flat slab is not affected by changes in the room layout).

Assuming that the DCA in both cases is *Slow Production* and is *Sensitive* with, and using the above overlapping strategy schedule, the recommended UPA–DCA overlapping information will be as follows:

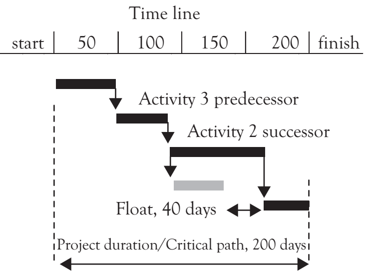
Option	X (%)	UDA–DCA overlap (100% – X)
Slab-beam system	90	10
Flat slab system	25	75

DCA, downstream construction activity; UDA, upstream design activity.

The flat slab system is therefore the better design–build solution as it allows a higher degree of UDA–DCA overlapping. Figure 6.10

The original project design–build schedule:

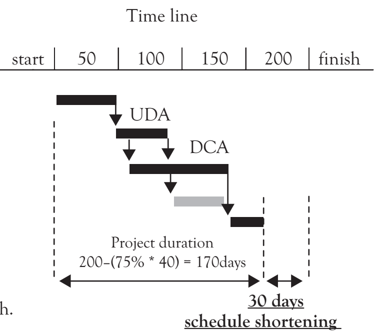
Activity name	Duration	Predecessor
Activity 1	50 days	
Activity 2 D	40 days	Activity 1
Activity 3 C	80 days	Activity 2
Activity 4	40 days	Activity 2
Activity 5	30 days	Activity 3



Note: Activities 1, 2, 3 and 5 are on the critical path.

The shortened project design–build schedule after applying the overlapping strategy:

Activity name	Duration	Predecessor
Activity 1	50 days	
Activity 2 D	40 days	Activity 1
Activity 3 C	80 days	Activity 2
Activity 4	40 days	Activity 2
Activity 5	30 days	Activity 3



Note: Activities 1, 2, 3 and 5 are on the critical path.

Figure 6.10 Upstream design activities—schedule-shortening example

illustrates the schedule-shortening effect of applying the overlapping strategy assuming that the UDA and DCA are Activity 2 and Activity 3, respectively.

Example 2: Downstream Construction Activities

A typical basic example for comparing and selecting an effective fast-track overlapping strategy based on DCA fast-tracking characteristics is the construction of a foundation system for a multistory office building. The key DCA construction components in this example would include foundation construction and installing column starter bars.

Choosing an isolated footing system will require freezing certain design information in the UDA including the column layout so that isolated footing locations can be determined (as they follow the column layout), in addition to determination of the column sizes and rebar requirements (so starter bars can be fixed). The DCA in this case can be classified as one of a *Fast Production* (as producing the first group of footings can start relatively fast), and *Highly Sensitive* (as any changes to column loads shall result in changing footing and column sizes thus abandoning the fabricated formwork boxes and rebar/starter bar cages).

A raft foundation (slab-on-grade) system can then be a better design–build solution. Adopting a raft foundation system changes the classification of the DCA to a favorable *Slow Production* (as the raft foundation construction will require some time to fix the vast amount of rebar for the entire slab), and relatively *Insensitive* (as additional rebar can be added and starter bars amended at a later stage if deemed required when the UDA raft foundation design is finalized and prior to casting concrete).

Assuming that the UDA in both cases is *Highly Reliable* with *Slow Evolution*, and using the overlapping strategy in Table 6.3 above, the recommended UDA–DCA overlapping information will be as follows:

Option	**X (%)**	**UDA–DCA overlap (100% – X)(%)**
Isolated footings	100	0
Raft foundation	50	50

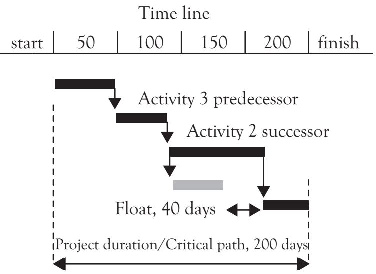
The raft foundation system is therefore the better design–build solution. Figure 6.11 illustrates the schedule-shortening effect of applying the overlapping strategy assuming that the UPA and DCA are Activity 2 and Activity 3, respectively.

6.4 Determining the Most Effective Design–Build Overlapping Strategy

The application of an effective fast-tracking strategy involves a relatively easy and systematic task; however, it requires a collaborative effort of the design–build team especially in the first applications until the team has gained adequate hands-on experience in applying it.

The original project design–build schedule:

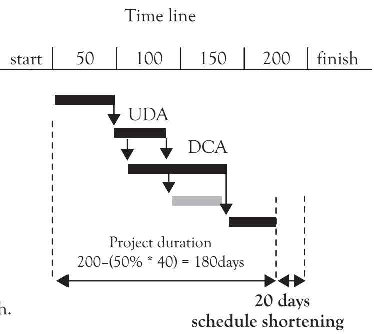
Activity name	Duration	Predecessor
Activity 1	50 days	
Activity 2 D	40 days	Activity 1
Activity 3 C	80 days	Activity 2
Activity 4	40 days	Activity 2
Activity 5	30 days	Activity 3



Note: Activities 1, 2, 3 and 5 are on the critical path.

The shortened project design–build schedule after applying the overlapping strategy:

Activity name	Duration	Predecessor
Activity 1	50 days	
Activity 2 D	40 days	Activity 1
Activity 3 C	80 days	Activity 2
Activity 4	40 days	Activity 2
Activity 5	30 days	Activity 3



Note: Activities 1, 2, 3 and 5 are on the critical path.

Figure 6.11 Downstream construction activities—schedule-shortening example

The following guidelines can be instrumental in this regard:

1. Overlapping of activities should be carried out only after careful consideration of the fast-tracking characteristics of the design and construction activity pairs as defined under SMC Step 02.
2. As much as possible, try and select UDA design solutions of fast evolution and high reliability, and DCA construction solutions of low sensitivity to changes in the design information and a slow early rate of production.
3. Promote UDA–DCA combinations that result in higher overlapping extents. For example if the DCA is sensitive to changes in the UDA design information, try and select a UDA design solution that can provide highly reliable design information.

4. Avoid UDA–DCA combinations that limit the overlapping extent or require schedule buffers. For example, if the UDA design is highly innovative, thus unreliable until adequately verified and validated, try and select a slow early production DCA construction solution of low sensitivity.
5. Releasing design information for construction should take place in accordance with a well-defined governance structure including a structured sign-off process. The process shall take the form of a quality assurance procedure including multiple reviews and a pre-construction meeting involving the concerned design and construction professionals. The sign-off shall be the only authority of the project manager or through a formal delegation of authority to a senior member of the team.

6.5 Summary

Aiming to shorten the design–build project delivery time, design–build organizations and professionals have the option of overlapping design and construction activities. Although schedule shortening can be achieved by increasing resources or working longer hours, overlapping of design and construction activities remains an advanced technique that comes in addition to any other traditional schedule compression concepts or techniques. Overlapping of design and construction activities however carries certain risks of rework or abortive work. The SAFEDB-methodology introduces a scientifically validated approach to effectively manage such risks in a structured and systematic manner. This approach is based on overlapping UDAs and DCAs based on their inherent fast-tracking characteristics. As demonstrated by examples, the application of this second methodology step can achieve overall project duration shortening by overlapping subsequent UDAs and DCAs located on the project's critical path. Such application however requires good understanding of the fast-tracking characteristics of both the UDAs and DCAs, and a governance process to ensure soundness of the decision of releasing design information for construction. The application of the overlapping strategy to schedule activities can be a laborious exercise.

Therefore, the design–build team should focus on major activities with maximum impact on schedule, until a computerized solution is available in the market in the future with a capability to read, understand, and implement overlapping based on their fact-tracking characteristics.

CHAPTER 7

The Third SAFEDB-Methodology Component: Control Design–Build Work Progress

Preface

The third SAFEDB-methodology component is concerned with addressing a key aspect of planning civil engineering projects, which is managing uncertainty in future project events and outcomes. To that end, the methodology component utilizes the axiomatic graphical evaluation and review technique (GERT) technique. It deals with uncertain activity outcomes probabilistically by assigning probability values to schedule branching and looping scenarios and adjusting original activities accordingly, something that the commonly used critical path method (CPM) and program evaluation and review technique (PERT) do not do. GERT can be utilized in both traditional and design–build projects. In traditional, and indeed all projects, GERT can be instrumental in dealing with the common uncertain project situations such as the outcome of testing completed work items, which would lead to schedule loops if tests fail. In a design–build environment, and in the context of the SAFEDB-methodology, GERT is utilized to mitigate the risk associated with uncertainty in the design information released to construction, which would lead to schedule loops if the design information is deemed inadequate. In both cases, GERT enables the probabilistic assessment of the potential branching and looping impact and absorbing such impact in the project schedule in a structured and proactive way. The theory and the application of GERT are explained later in this chapter in greater detail.

7.1 Methodology Component Objective

The objective of this SAFEDB-methodology component is to address the common real-world case of uncertainty in the outcome of the upstream design activity design information released to feed or initiate the related downstream construction activity. This is achieved through the application of the principles and concepts of the GERT.

The role of GERT in the SAFEDB-methodology is to account for and accommodate the potential network diagram branching and looping. The probable rework branches and loops shall first be identified, quantified, and then incorporated into the project's original schedule in the manner described later in this chapter. The SAFEDB-methodology assumes that the original project schedule is prepared using the CPM and its related PERT. The objective of the methodology is to replace some PERT diagram nodes with strategically located GERT smart nodes and then adjust the CPM schedule by incorporating additional durations to simulate the anticipated impact of the network diagram branching and looping effects in a probabilistic manner.

While doing this might appear to be prolonging the project schedule, in fact it does exactly the opposite by protecting the schedule from the potential delays resulting from unaccounted-for branches and loops. In order to absorb the durations of branches and loops, schedule activities should be adequately resourced to be completed in somewhat shorter durations. Should the impact of the planned loops and branches turn out to be less severe than expected, this would lead to schedule shortening; otherwise branches and loops are accounted for by embedding appropriate schedule buffers representing their potential occurrence in a proactive probabilistic manner. A GERT adjusted schedule is considered to be more reliable than a traditional CPM/PERT schedule as it duly takes into account the common schedule branching and rework looping scenarios.

7.2 The Graphical Evaluation and Review Technique

GERT is a network analysis technique used in project management to allow probabilistic treatment of both network logic and estimation of activity duration. The technique was first described in 1966 by Dr. Alan B. Pritsker in a memorandum prepared for the National Aeronautics and Space Administration (NASA) through The Rand Corporation (Pritsker 1966). It is considered a further advancement of the traditional PERT underlying the popular CPM project planning and scheduling method. The key difference between GERT and PERT is that the latter does not take into account uncertainty about the outcome of certain project activities and the resulting potential network branching and looping effects and rework cycles. GERT takes account of the case of the dependency of the downstream activities on the outcome of their pertinent upstream activities.

However, practically speaking, GERT is considered by many practitioners in the industry to be a rather complex technique that requires extensive effort to analyze and develop the activities network diagram. The reason for this might be that it involves a departure from standard planning and the lack of effective supporting planning software. This has led to a remarkable delay of the spread of application and use of the method despite its relevance and importance. This statement goes for both the design–build and the traditional construction projects. Therefore, and for the purposes of this book, GERT will be presented at a high level and then applied in a rather simplified and practical fashion aiming to facilitate its application and attract more practitioners to use it. In the SAFEDB-methodology, GERT will be incorporated in a modified manner that is user friendly with the objective of achieving the maximum benefit from the technique with the least possible amount of complexity and planning effort.

7.2.1 GERT Versus PERT

In traditional schedule networking diagrams, activities are generally modeled as a series of lines or arrows representing project activities, connected with a series of nodes signifying the transition from a project activity to another. Figure 7.1 illustrates a basic networking diagram with typical sequential "finish-to-start" logic for the sake of comparing and showing the difference between the PERT and GERT networking diagrams. The shown simple network diagram consists of three activities simulated by arrows A, B, and C, and four activity transitions simulated by nodes 1 through 4.

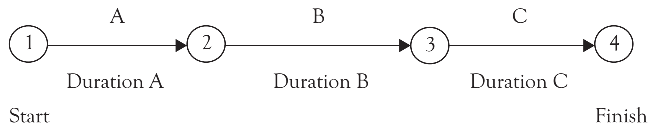


Figure 7.1 A simplistic basic schedule networking diagram

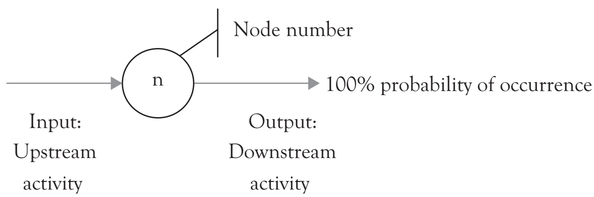


Figure 7.2 Simplified PERT network diagram node nomenclature

Note: PERT, program evaluation and review technique.

In PERT, the network diagram is structured based on the following assumptions:

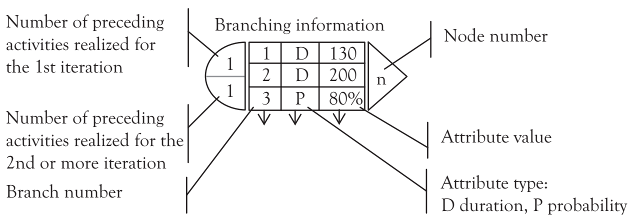
1. Upstream activities (i.e., A and B) will not require rework cycles.
2. Downstream activities (i.e., B and C) are certain, for example, one solution per activity.
3. No allowance for branching and rework loops.

PERT network diagram nodes are neutral and just serve to mark the completion of the upstream activity and the onwards start of the related upstream activity with 100 percent certainty or probability of occurrence (Figure 7.2). If any upstream activity fails to achieve its objectives, the related downstream activity cannot be initiated, resulting in a schedule interruption and getting back to the office for further planning and rescheduling. If the subject activities are on the project's critical path, such scenario will result in a schedule slippage and probably a project delay.

In GERT, the network diagram is structured based on the following assumptions:

1. Upstream activities (i.e., A and B) may require rework cycles.
2. Downstream activities (i.e., B and C) are dependent on the outcome of upstream activities.
3. Allowance made for branching and rework loops.

Table 7.1 GERT network diagram node nomenclature

Function	Symbol	Name	Explanation
Input		Inclusive	Any input branch causes the node to be realized
		All	All input branches must occur for the node to be realized
Output		Probabilistic	Only one output branch may occur when node is realized
		Deterministic	All output branches occur when the node is realized
Sample GERT Node in Action			

GERT network diagram nodes take account of the likely scenarios of the outcome of the upstream activities. This is achieved by utilizing smart nodes with the ability to define and accommodate the likely schedule branches and rework loops. The input side of the smart node is sensitive to whether the node is to be realized through the completion of one or all of the upstream activities leading into it. The output side of the node is also sensitive to whether on or all of the downstream activities generated out of it. Table 7.1 describes and illustrates the GERT smart node functions.

These workable functions and capabilities of the GERT smart node provide a better definition of actual project scenarios and a more effective simulation of project events. This is proven to lead to a higher level of control over operations, improved morale of the project team, and a significant enhancement of chances for project success.

7.2.1.1 The Adopted Graphical Evaluation and Review Technique Node

In practice, the GERT smart node can take the form of any combination of the above shown input and output functions. For the purposes of the

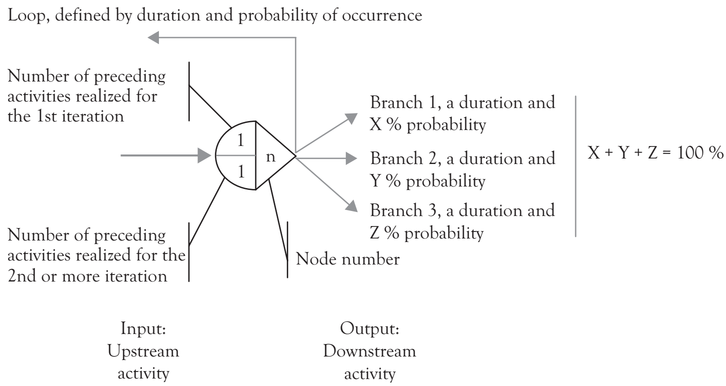


Figure 7.3 Simplified GERT network diagram node nomenclature

Note: GERT, graphical evaluation and review technique.

SAFEDB-methodology, which aims to take account of the probabilistic nature of the outcome upstream activities, focus will be on the following network node combination of the Input-All and the Output-Probabilistic node functions. Duration and probability of occurrence are assigned to each network rework loop and/or branch. Probabilities of occurrence are estimated by the design–build team using expert judgment and past experience with similar type of work.

Figure 7.3 illustrates such combination.

As will be discussed in detail in the following third methodology component (TMC) Step 3, the probability of schedule branches and/or rework loops will be identified while developing the PERT schedule networking diagram and inserted at selected strategic locations when branching and looping are expected. This will be followed by updating the project's CPM schedule to incorporate such anticipated branches and rework loops.

7.3 Third Methodology Component—Step by Step

This section explains the use of the GERT approach in simulating potential branching and rework loop scenarios. While the process is presented in discrete progressive step-by-step manner, in reality such steps may overlap or interact with each other in complex ways that cannot be

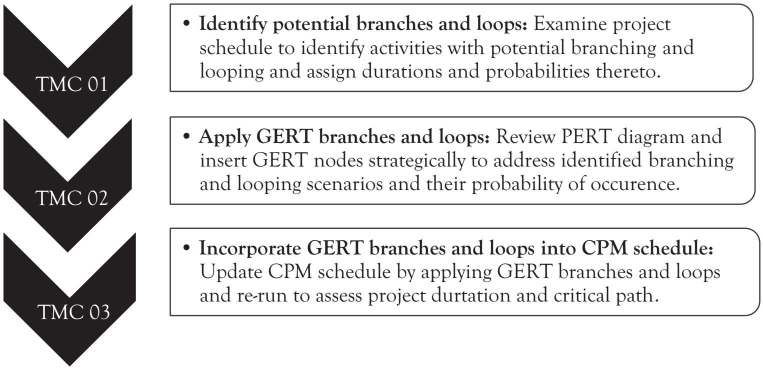


Figure 7.4 The SAFEDB-methodology—overview of the third methodology component

Notes: CPM, critical path method; GERT, graphical evaluation and review technique; PERT, program evaluation and review technique; TMC, third methodology component

completely explained in a document or with graphics. Figure 7.4 provides an overview of the title and purpose of the three logical steps of TMC 1, 2, and 3.

This section is primarily concerned with explaining the theoretical background and underlying notions and objectives of the SAFEDB-methodology's TMC, supported by basic real-world examples to support the understanding of the presented concepts.

Full-scale practical application examples and case studies are provided in Chapters 8 and 9. However, some limited-scope practical examples shall be provided within the body of this chapter on when-and-as-necessary basis aiming to support the information provided and make certain somewhat implicit concepts explicit to the reader.

7.3.1 Third Methodology Component Step 1: Identify Potential Branches and Loops

The purpose of this methodology component is to examine project activities and identify activities with probable branching and looping effects.

Such effort should first take place early in the process during the project planning phase and development of the project's baseline schedule, as well as at intervals during the course of the project to detect any newly developed branching and looping scenarios.

In design–build projects, the focus of the search for activities with potential branching or looping would be on critical or near-critical activities of doubtful design information (e.g., design activities classified in SMC above as highly unreliable), or suspicious construction means and methods (e.g., construction activities classified in SMC above as highly sensitive). Such activities are then to be short listed and set aside for further analysis under the subsequent TMC Step 2 to assess and evaluate their probability of occurrence.

Ideally, all activities should be examined for the likelihood of branching and looping. However, for practical purposes and given the fact that large civil engineering projects would invariably include thousands of activities, the design–build team may decide to focus only on critical activities, or better off as recommended in the SAFEDB-methodology to also include near-critical activities of significance.

The TMC Step 3 process would then include the following steps:

1. Prepare a list of project activities based on the project's CPM schedule.
2. Filter the list of activities for critical or near-critical activities (activities with limited total float).
3. Highlight design and construction activities with potential need for branching or looping.
4. Check the highlighted design and construction activities and finalize the selected activities list for taking over to TMC Step 2.

Table 7.2 would be useful to detect and capture significant candidate design and construction activities of high potential of branching and looping.

It will also serve as a basis for further analysis under TMC Step 2 where loops and branches are assigned to the network diagram using GERT smart nodes.

7.3.2 Third Methodology Component Step 2: Apply Graphical Evaluation and Review Technique Branches and Loops

The purpose of this methodology component is to assign the GERT smart nodes to strategic locations in the original project's PERT diagram.

Table 7.2 **TMC** ***Step 1—table of activities with likelihood for branching and looping***

Activities with likelihood for GERT branching and looping							
Critical or Near critical activities Activity information			GERT Branching or looping			Branches and loops information	
Activity ID	Activity description	Activity type D/C	Highly unreliable design	Highly sensitive construction	Other (Define)	Probability of occurrence	Duration
XYZ-001	…….	D	Branching			BR1 … %	… days
						BR2 … %	… days
						BR3 … %	… days
XYZ-002	…….	D		Looping		L … %	… days
XYZ-003	…….	D	Looping			L … %	… days
XYZ-004	…….	C			Branching	BR1 … %	… days
						BR2 … %	… days
						BR3 … %	… days
XYZ-n	…….					… %	… days

Notes: BR, branch, L, loop

These can be diagram loops indicating rework cycles, or diagram branches indicating a number of alternative solutions to the downstream activities pending the outcome of the adjacent upstream activity. When an activity is deemed suspicious for requiring a rework cycle to adjust or fix an erroneous or unsatisfactory output, a loop is to be assigned, carrying an estimated duration to complete the required rework (*x* days), and an estimated probability of occurrence (*y*%). Estimates are to be based on expert judgment and/or past experience with similar type of work.

Figure 7.5 illustrates this process.

In the probabilistic looping shown in Figure 7.5, only one loop is assumed to be required, and probabilistic looping will take any value above 0 percent and less than 100 percent. When a downstream activity is deemed to be dependent on the outcome of its upstream activity, a number of network diagram branches (*n* = 2 or more) are to be assigned at the GERT smart node. Branches shall represent downstream solutions to the likely outcomes of the upstream activity. Each branch is to be assigned an estimated duration to complete the required work (*xn* days), and an estimated probability of occurrence (*yn*%). Probabilities of occurrence are to be based on expert judgment and/or past experience with similar type of work.

Figure 7.6 illustrates this process.

In the probabilistic branching shown in Figure 7.6, only one branch will realize, and the sum of the probabilities for each branch leaving a probabilistic branching must be equal to 100 percent.

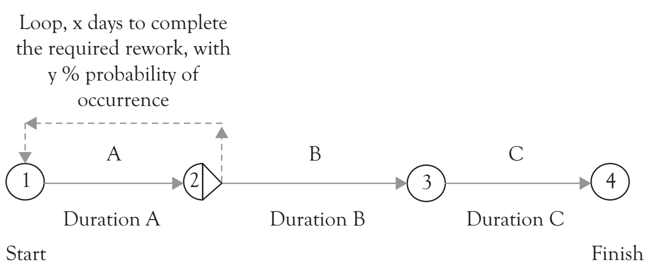


Figure 7.5 TMC Step 2—applying GERT smart node "loops"

Notes: GERT, graphical evaluation and review technique; TMC, third methodology component.

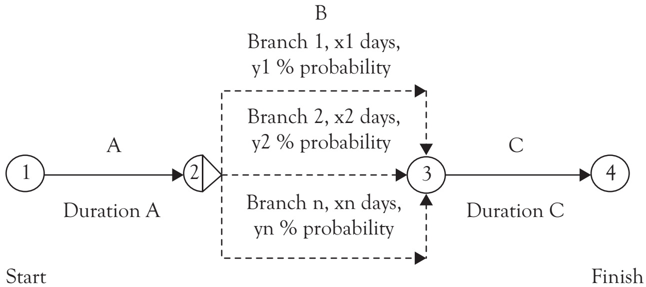


Figure 7.6 TMC Step 2—applying GERT smart node "branches"

Notes: GERT, graphical evaluation and review technique; TMC, third methodology component.

Examples

Example 1: Graphical Evaluation and Review Technique Network Diagram Smart Node "Loops"

A basic example of probabilistic looping would be the case of the design and construction of a reinforced concrete slab, with design and construction overlapping. The upstream design activity is classified as fairly reliable of slow evolution, whereas the downstream construction activity is classified as sensitive of slow production. According to the Overlapping Extent Selection Schedule provided in Section 6.3.3, the *X* value that should be applied is 75 percent, or an overlapping extent of 25 percent. However, the design–build team decided to increase the overlapping to 50 percent of the duration of the upstream design activity A, and to allow for a GERT loop of 20 percent probability.

Figure 7.7 illustrates how to incorporate such a probabilistic GERT loop in the project's network diagram.

In Figure 7.7, as all project activities fall on the project schedule's critical path, the overall project duration is calculated as the sum of the durations of such activities, namely, activities A, B, and C. Original project duration would have been A + B + C = 20 days + 30 days + 14 days = 64 days. Project duration with 25 percent overlapping of activities A and B would have been 64 days – 20 days × 25 percent = 64 days – 5 days = 59 days. Project duration with 50 percent overlapping of activities A and B and 10 days' loop around activity B of 20 percent probability would have been

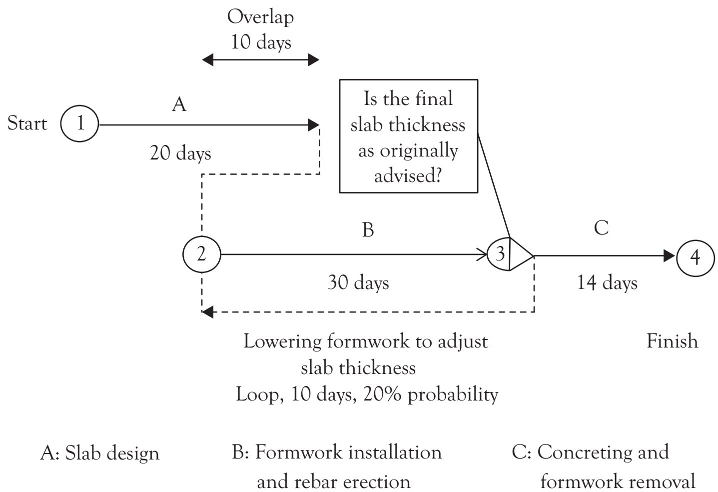


Figure 7.7 TMC Step 2—example of GERT probabilistic looping

Notes: GERT, graphical evaluation and review technique; TMC, third methodology component.

= 64 days − 20 days × 50 percent + 10 days × 20 percent = 64 days − 10 days + 2 days = 56 days. Should the loop not realize, the project duration would be further reduced to 54 days; however, if actually realized, the project duration can extend to become 64 days. A good judgment of the probability of occurrence of the rework loop and the duration associated therewith is therefore key to achieving the maximum benefit of the GERT approach.

Example 2: Graphical Evaluation and Review Technique Network Diagram Smart Node "Branches"

A basic example of probabilistic branching would be the case of performing inspection of a construction site for the presence of hazardous materials prior to excavation. The severity of the hazardous materials can only be determined at the end of construction site inspection. The time required to conducting the remedial action including countermeasures such as waste containment or waste removal will vary according to the hazardous material severity, which would be extensive, moderate, or light. Remedial action must be completed before excavation can proceed. If the severity of the hazardous materials is not properly accounted for, then the resulting

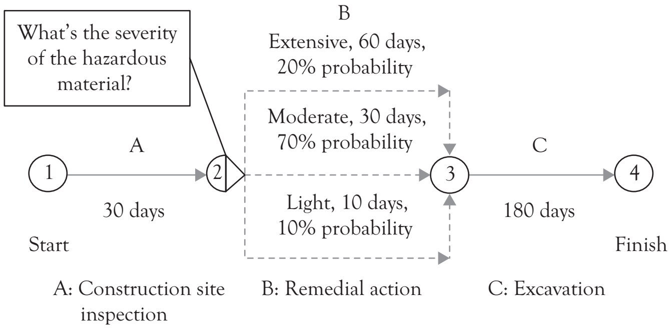


Figure 7.8 TMC Step 2—Example of GERT probabilistic branching

Notes: GERT, graphical evaluation and review technique; TMC, third methodology component.

schedule might be overly optimistic, or too conservative. The GERT approach helps define the appropriate amount of contingency probabilistically, so that the project planner can decide the final resource allocation and/or countermeasure technique that is suitable for the project.

Figure 7.8 illustrates how to account for the different scenarios and estimate the upstream construction site inspection activity probabilistically.

In Figure 7.8, as all project activities fall on the project schedule's critical path, the overall project duration is calculated as the sum of the durations of the three involved critical path activities, namely, A, B, and C. Duration of activities A and C can be estimated deterministically, namely, 30 days and 180 days, respectively. Duration of activity B will have to be calculated probabilistically as follows: duration of activity B = 60 days 20% + 30 days 70 percent + 10 days 10 percent = 12 days + 21 days + 1 day = 34 days. Hence, the overall project duration will be equal to 30 days + 34 days + 180 days = 244 days.

7.3.3 Third Methodology Component Step 3: Incorporate Graphical Evaluation and Review Technique Branches and Loops into Critical Path Method Schedule

The purpose of this methodology component is to update the project's CPM schedule by applying the GERT network diagram branching and looping scenarios developed in TMC Step 2. Unfortunately, the current state-of-the-art in project scheduling and programming software does not allow for incorporating probabilistic network diagram branching and looping. Until such software is developed, GERT loops and branches shall have to be simulated and manually incorporated in the CPM schedule in a creative work around manner.

7.3.3.1 Simulation of Graphical Evaluation and Review Technique Loops

As explained in TMC Step 2 above, GERT network diagram loops are defined in terms of both a time duration to implement the rework loop and a probability of its occurrence. As a work-around method, loops can be defined in the CPM schedule as a separate schedule activity attached to the parent activity suspect of rework looping with a finish-to-start relationship. The duration of such attached schedule activity representing the probable loop is calculated as the product of the rework loop estimated duration (*x* days) and its probability of occurrence (*y*%).

Figure 7.9 illustrates this GERT loop simulation method in CPM schedules.

As shown in Figure 7.9, activity A* acts a schedule buffer embedded within the schedule itself to be used if necessary in case a rework loop is deemed required. At the end of activity A, if the need for a rework cycle is established, activity A* accounting for the network diagram loop gets mobilized. If the rework loop is deemed not required, activity A* is skipped, thus making available its allocated duration for the use at other materialized rework loops along the critical path, or to achieve an overall project duration shortening.

7.3.3.2 Simulation of Graphical Evaluation and Review Technique Branches

As explained in TMC Step 2 earlier, GERT network diagram branches are defined in terms of both duration and a probability of occurrence for each of the likely downstream activity branches. As a work-around method, branches can be defined in the CPM schedule as a number (*n*, 2

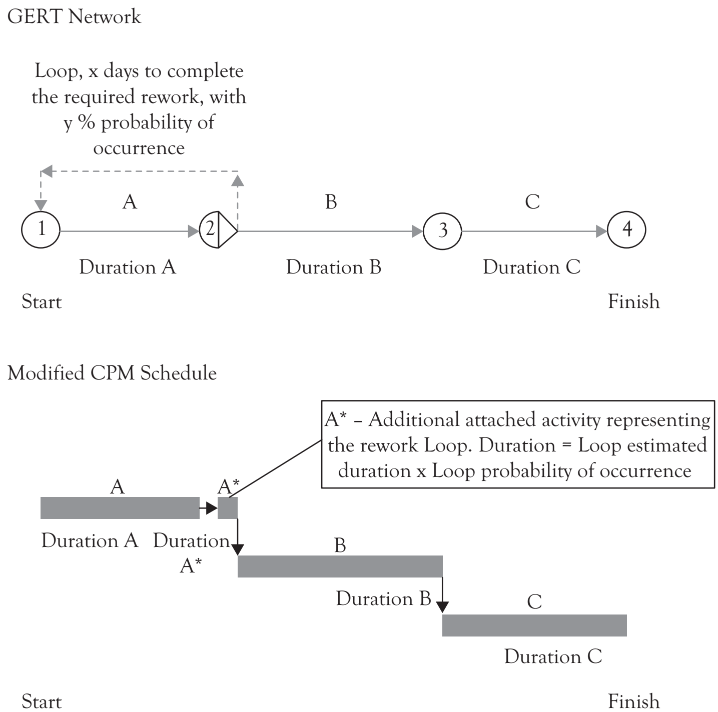


Figure 7.9 TMC Step 3—GERT loop simulation in CPM schedules

Notes: CPM, critical path method; GERT, graphical evaluation and review technique; TMC, third methodology component.

or more) of separate downstream schedule activities following the parent upstream activity expected to require downstream activity branching with a finish-to-start relationship. The duration of each of such downstream schedule activities representing the probable branches is calculated as the product of the estimated branch duration (Xn days) and its probability of occurrence (Yn%).

Figure 7.10 illustrates this GERT branches simulation method in CPM schedules.

As shown Figure 7.10, activity B* simulates the probable GERT branches. As discussed in TMC step 2 earlier, activity B* has a duration calculated as the sum of the product of the duration of each constituent branch and its estimated percentage of probability of occurrence as follows:

Activity B* duration in days = $\sum I = 1 \rightarrow n$ (BRi duration in days BRi probability in percentage)

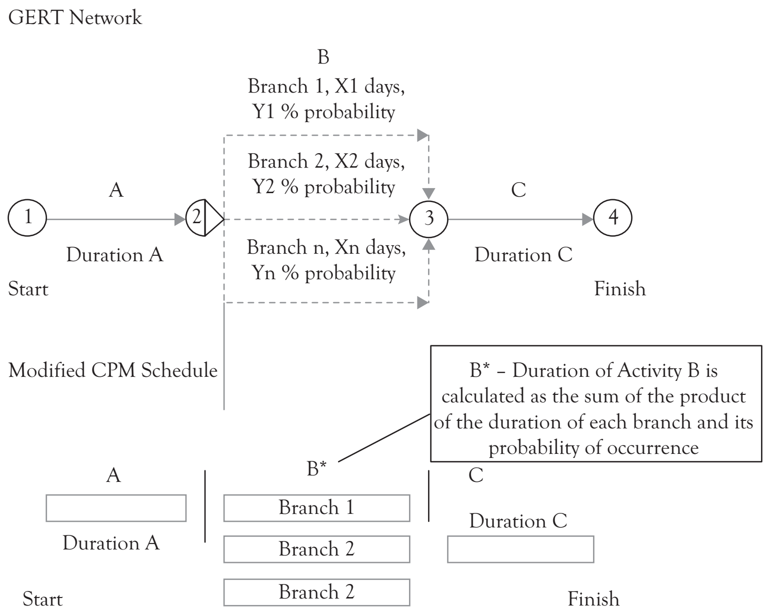


Figure 7.10 TMC step 3—GERT branches simulation in CPM schedules

Notes: CPM, critical path method; GERT, graphical evaluation and review technique; TMC, third methodology component.

where

n = number of GERT network diagram branches

BRi = any given constituent branch from a range of potential branches, where the sum of the individual branch probabilities BRi probability 1 -> n equals 100%.

Following this concept, the actual selected branch duration may in fact be longer or shorter than the probabilistically calculated duration of activity B*. At the end of activity A, and depending on its outcome, the appropriate GERT branch is mobilized. If the duration of such a selected branch is longer than the duration of activity B*, durations of all downstream activities along the critical path are then to be reviewed and slightly adjusted as necessary to absorb the difference. If the duration of the selected branch is indeed shorter than the duration of activity B*, the shorter branch duration is adopted in the schedule, making available additional time buffer to be used to support further downstream branches and loops, or to enable overall project duration shortening.

Finally and as also discussed earlier in this chapter, the incorporation of GERT network diagram branches and loops in the project's CPM schedule safeguards the project against potential schedule slippage. This is achieved by consciously and proactively incorporating calculated schedule buffers representing the potential branches and loops and their probability of occurrence in a scientific and structured manner. The impact of loops and branches on the project schedule is absorbed to maintain the original project duration. Should such impacts turn out to be less severe than originally anticipated, this would lead to additional floats within the schedule and eventually overall project schedule shortening. Otherwise, the advantage of accounting for such probable branches and loops remains there to avert significant schedule slippages during the course of the project implementation and to prevent overall project schedule overruns.

7.4 Determining the Most Effective Design–Build Schedule

The application of an effective design–build schedule requires taking into account the probable network diagram branches and rework loops generated by the inherent uncertainties in the outcome of certain project schedule upstream design or construction activities. This exercise requires the proactive identification of such activities, assessment and incorporation of probable GERT branches and loops, and the incorporation of the same in the project's CPM schedule as probabilistic activities forming favorable schedule buffers to absorb potential schedule delays as discussed earlier in this chapter.

The following guidelines can be instrumental in this regard:

1. As much as possible, choose well-established and tested design and construction solutions that have been previously applied successfully by the organization and the project team involved.
2. Review the organizational process assets and lessons learned database for similar design or construction solutions and analyze the same to have a better feel of work outcomes.
3. Use the design and construction activities overlapping strategy explained in Chapter 6; this will help reduce the chances for branches and rework cycles.

4. As in risk management, focus on GERT branches and loops of combined high probability and major impact, and ignore those of combined low probability and minor impact.
5. Update the project's CPM schedule frequently to ensure continuous validity of the schedule assumptions as well as to check the status or erosion of the availed schedule buffers.

Implementation of the above is the responsibility of the project team and can best be achieved through the collaborative efforts of experts from various disciplines including design and construction professionals. The ultimate responsibility of approving the project's design–build schedule stays with the project manager who should satisfy himself with the schedule efficiency and authorize the same for implementation and further monitoring and refinement at intervals during the course of the project.

7.5 Summary

This third SAFEDB-methodology component adopts the principles of the GERT method to control the design–build works. This is achieved by taking into account and simulating the probable schedule network diagram branches and rework loops. The process first estimates the time durations related to such branches and loops and their pertinent probability of occurrence. Branches and loops are then simulated as standard CPM activities and incorporated in the project CPM schedule, forming a proactive set of embedded schedule buffers. As the project progresses, the CPM schedule is monitored and updated frequently in a rolling-wave fashion. The application of this SAFEDB-methodology component safeguards the project schedule from the common unfavorable schedule cases of delay and slippage during implementation. This leads to schedule shortening and enables a better project control.

PART III

The SAFEDB-Methodology: Methodology Application Example and Case Study

CHAPTER 8

Application of the SAFEDB-Methodology

Preface

As discussed earlier, the SAFEDB-methodology adopts a number of rather complex concepts and theories that were indeed developed outside of the realm of the construction industry. Driving the application of such concepts and theories in the construction industry therefore requires exercising a fair amount of flexibility and common sense. After all, like every project management methodology, the SAFEDB-methodology, is merely a tool for project managers to deliver projects successfully and efficiently rather than a code or a standard that requires absolute compliance. This chapter discusses the practical application of the SAFEDB-methodology. It provides tips, hints, and guidelines regarding the application of the methodology in real-world organizations and projects, as well as the ways and manners in which the methodology may be applied in practice yet remain effective in achieving positive project results. The chapter also discusses the people, process, and technology impact on the effective use of the methodology and finally a review of the methodology use and limitations.

8.1 Methodology Application Guidelines

With the above preface in mind, the following tips and guidelines can be beneficial to the users in order to make the application of the SAFEDB-methodology a practical and effective exercise:

1. Read the presented methodology element descriptions and the provided simple inline examples more than one time and try and make

good sense of the presented concepts and techniques before starting to apply the methodology on other hypothetical or real projects.

2. Train your brain. Use paper, pencil, and eventually a calculator, and try and rewrite or redraw the provided tables and graphical aids until you get used to developing such tables and graphs on your own. That will help you train your brain on the use of the methodology and make it easy for you to develop similar tables and graphs for other project situations.
3. Methodology application may be completed by a single professional with adequate design and construction experience; however, best results are achieved by involving a team of design and construction professionals. In either case, the methodology application process must be well documented, checked, and signed off on before implementation.

The application of the SAFEDB-methodology is both art and science. It should be conducted both systematically and creatively, while taking into account the project context and the enterprise environmental factors. As experience on using the methodology is accumulated over time, acquired experiences should be recorded and added to the organizational process assets.

8.2 Methodology Modes of Application

This section looks into the methodology modes of application. The SAFEDB-methodology consists of three distinct yet complementary methodology components. Such three components are so far presented as one whole unit forming the methodology. However, in practice, the application of the SAFEDB-methodology can take several forms. Any single component can be used on its own or in combination with any other component and still achieve positive project results.

The application of the SAFEDB-methodology can take any of the following modes:

1. Mode 1—All three methodology components:
   This mode achieves maximum benefit of the methodology and is meant for global project solutions. The downside is that its application can be laborious and hence should be given adequate time and resources. Figure 8.1 illustrates this application mode.

2. Mode 2—A single methodology component only:
   This mode achieves partial benefit of the methodology; however, it is valid and can be effective in targeting a particular area of interest. The downside is that by its application you miss the benefits of the dropped methodology components. Figure 8.2 illustrates the three possible ways to use this application mode.

SAFEDB **component No. 1: Develop DB solutions**

SAFEDB **component No. 2: Fast-track DB activities**

SAFEDB **component No. 3: Control DB work progress**

Figure 8.1 The SAFEDB-methodology—application mode 1

Note: DB, design–build.

SAFEDB **Component No. 1: Develop DB solutions**

Mode 2.1 – Component 1 only

SAFEDB **Component No. 2: Fast-track DB activities**

Mode 2.2 – Component 2 only

SAFEDB **Component No. 3: Control DB work progress**

Mode 2.3 – Component 3 only

Figure 8.2 The SAFEDB-methodology—application mode 2

Note: DB, design–build.

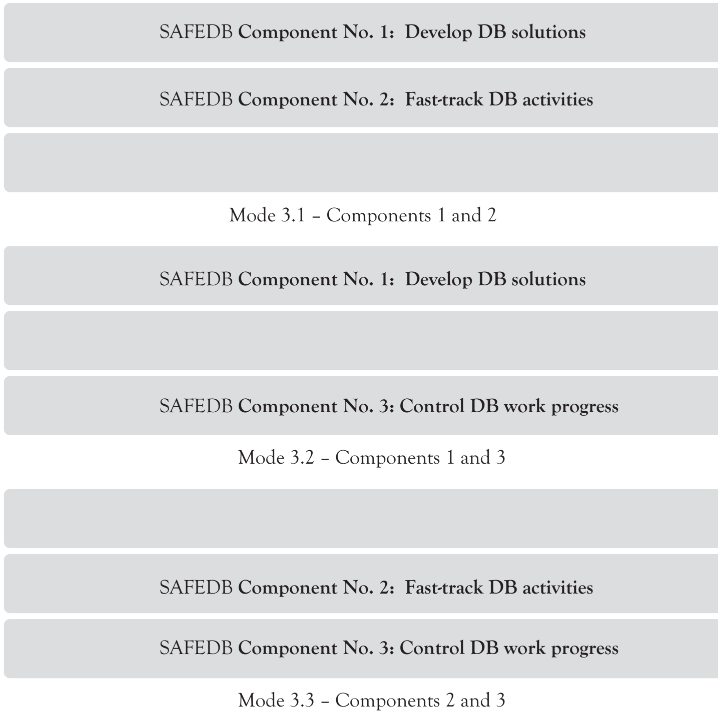


Figure 8.3 The SAFEDB-methodology—application mode 3
Note: DB, design–build; SAFEDB.

3. Mode 3—Any combination of two methodology components:
   This mode achieves partial benefit of the methodology; however, it is valid and can be effective in targeting particular areas of interest. The downside is that by its application you miss the benefits of the dropped methodology component. Figure 8.3 illustrates the three possible ways to use this application mode:

Hence, in summary, the SAFEDB-methodology can be used in whole or in part. The decision on the appropriate mode of application stays with the project team on a case-by-case basis.

8.3 People, Process, and Technology

The application of the SAFEDB-methodology is affected by three key elements, namely, people, process, and technology. This section provides a high-level review of the impact of each of such elements.

8.3.1 *People*

The application of the SAFDB-methodology does not require special skills or level of education; however, it requires exercising engineering sense and creative thinking on the part of the involved team. It also requires a blend of experiences within the team to ensure the soundness of the conclusions reached. Application can best be led and facilitated by a knowledgeable and experienced design–build coordinator whose duty would be to train the team on the concepts and use of the methodology, develop a design–build team or think tank, orchestrate the efforts exerted by the team of design and construction personnel involved, and document the process proceedings and outcomes.

8.3.2 *Process*

It is ultimately the project manager's responsibility to decide how much process to use on his project to best achieve project objectives. The complexity and extent of the methodology application can vary widely. It may be a comprehensive and detailed application covering all project activities or a limited high-level application only targeting a certain aspect of the project or a limited number of project activities. Both approaches are suitable and can enhance the chances of project success. The decision on the amount of process to use should take into account project size, nature, complexity, budget, duration, and the availability of experienced resources.

8.3.3 *Technology*

The application of the SAFEDB-methodology generally requires basic technological infrastructure such as MS-Office and a communication network to exchange information and correspondences. The only part of the methodology that requires somewhat advanced technology is the project scheduling. Current planning and scheduling software does not support concurrent engineering principles in terms of defining the activities fast-tracking characteristics to assess the appropriate extent overlapping automatically. At this stage, overlapping is assessed separately and then entered manually to the scheduling software. This is an area for further research and development in the industry.

8.4 Use and Limitations

The SAFEDB-methodology as presented in this book is meant to be a rather simple and user-friendly process. It is designed to strike a strategic balance between the time and effort invested by the team and the benefits attained from the project by the organization. As discussed earlier in this chapter, the use of the methodology is rather flexible; hence, the team can always decide how to apply the methodology, and to how much of the project activities to apply it. The methodology can be applied to virtually any type of design–build projects; however, it has certain limitations. These limitations include the fact that it requires prior training of the team on its concepts, tools, and techniques, in addition to the disadvantages in current scheduling software that do not allow defining activities in terms of their fast-tracking characteristics; so overlapping strategies will have to be entered manually.

8.5 Summary

The SAFEDB-methodology as introduced here is designed to be practical and user friendly. It does not require a high level of education or modern technology; however, it requires engineering sense and team effort. The methodology can be applied in full or in part, and still remains useful and effective in achieving superior project results.

CHAPTER 9

A Full Scale SAFEDB-Methodology Application Example

Preface

This chapter provides a practical application example of the SAFEDB-methodology on a hypothetical Ground Water Reservoir project. The example progresses in a logical step-by-step manner providing the reader with a real-world insight into how to apply the methodology, how design–build solutions are being developed in reality, and how design–build professionals think and take decisions. The embraced example represents one of many design–build situations encountered in the field of civil engineering. It is not meant to be inclusive of all design–build challenges and situations. The focus here is on the way of thinking and the factors surrounding the design–build decision-making process.

Figure 9.1 demonstrates the methodology components and their underlying concepts.

The full benefit of the SAFEDB-methodology is achieved by applying all of its above-presented three components. Nevertheless, the methodology can be applied in part, using one or two components.

9.1 Project Brief and Background

As part of its strategic nationwide water resources management program, a state authority, the Owner, decided to tender a design–build contract for the design and construction of a water collection and storage Ground Water

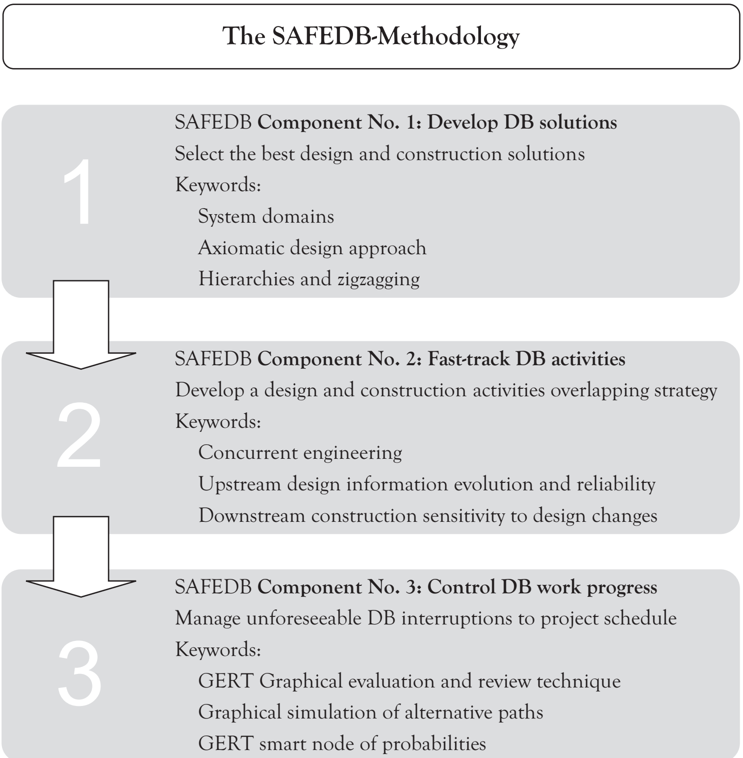


Figure 9.1 Overview of the SAFEDB-methodology components

Reservoir. The scope of work excludes dewatering works, which are to be carried out by a specialist dewatering contractor under an early enabling works package. The new Ground Water Reservoir is envisioned to utilize and enlarge the existing valley already acting as a natural Ground Water Reservoir by shaving off excess earth to increase its storage capacity. Along the sides of the new Ground Water Reservoir profile, a protective earth retaining reinforced concrete slab is to be provided forming an earth-stabilizing concrete liner connected tied down to earth using earth-stabilizing tie-back anchors. Site geotechnical conditions involve a top layer of soft clay underlain by strata of inconsistent hard clay and medium-grained to hard sandstone layers.

Figure 9.2 illustrates the above project brief.

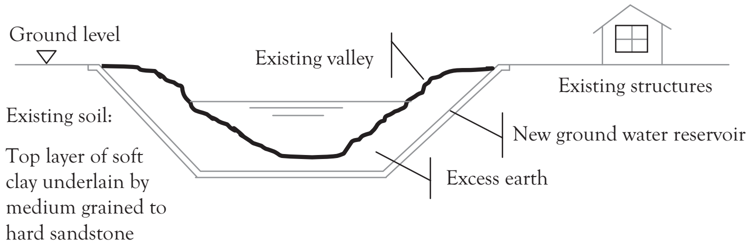


Figure 9.2 Cross-section view of the planned Ground Water Reservoir project

9.2 Constraints and Owner Functional Requirements

As the new Ground Water Reservoir is located in a populated area, the nearby inhabitants were to be able to continue to use their houses located along the valley embankment during the design and construction period. Project design and construction methods should therefore ensure full control over the new Ground Water Reservoir slope stability and the potential ground settlement and instability of the surrounding area resulting from the construction process. The project is required to be completed within two years from the date of contract award and at a design and construction budget of $100 million, with an expected deviation of + or –20 percent in both the targeted time and budget values.

9.3 First Methodology Component—Step by Step

Figure 9.3 provides an overview of the title and purpose of the three logical steps of the first methodology component, namely, FMC 01, 02, and 03.

Two potential design–build solutions were developed by the design–build team in the first instance for further analysis and examination using the SAFEDB-methodology first component aiming to identify and select the better and more effective solution.

The first potential design–build solution considered the use of the traditional scrape-and-excavate method (Figure 9.4). The scrape-and-excavate method utilizes traditional excavation means and methods to

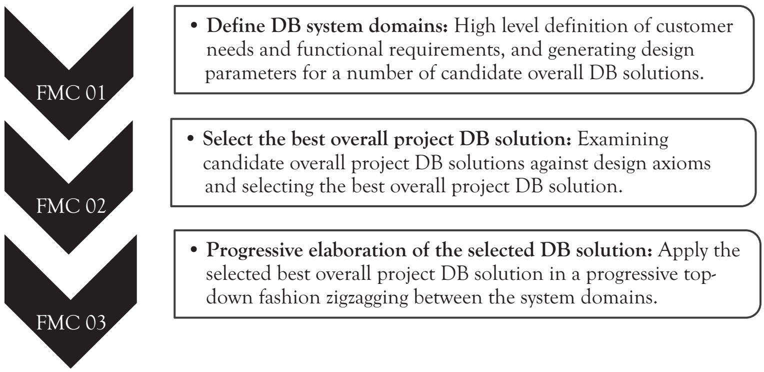


Figure 9.3 The SAFEDB-methodology—overview of the first methodology component

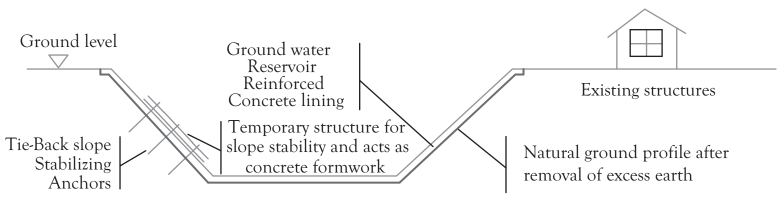


Figure 9.4 Scrape-and-excavate method

enlarge the existing valley profile by digging into the existing natural valley profile using excavators and bulldozers and removing the excess excavated material to the valley banks and then off-site using dump trucks. A temporary earth-retaining structure and tie-back anchors are deemed necessary to maintain slope stability during construction, as well as to make a formwork for casting the permanent earth-retaining reinforced concrete slab liner. This traditional work methodology is reliable and shaping of the sloped Ground Water Reservoir sides can be completed in a controlled and relatively accurate manner. The downside of the scrape-and-excavate method is that it can be significantly slowed down by the likely encountering of areas of exceptionally hard rocky soils that will require long time and intensive use of costly heavy equipment to complete. This could lead to cost and schedule overruns, leading to the risk of exceeding the stipulated time and construction cost limits.

The second design–build solution considered the use of explosives to slacken off the sandstone and then remove the loosened material using bulldozers and dump trucks (Figure 9.5). The application of explosion

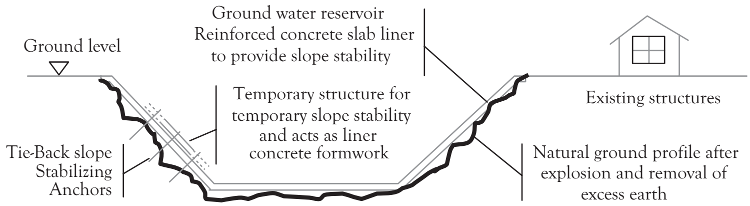


Figure 9.5 Use-of-explosives method

technique enables the weakening of a fairly large volume of earth, thus making the subsequent earth-removal task much faster and more cost effective. However, the downside of the explosion technique is that the outcome of the explosion process is hard to predict with a high degree of accuracy. The ground profile after explosion and removal of the excess loose material shall be irregular and can vary widely from the desired Ground Water Reservoir profile straight lines. This will affect the design of the earth-retaining temporary structure, which is provided to confirm slope stability during construction until the permanent reinforced concrete liner is constructed. The said irregular natural ground profile will also mean a variable thickness of the reinforced concrete-retaining slab, thus a variable fresh concrete pressure on the temporary structure, which is also intended to be used as a formwork for casting the permanent earth-retaining concrete slab liner. Finalizing the design and fabrication of the temporary structure shall therefore have to wait until the explosion operation is completed, excess loose earth is removed, the natural earth is exposed, and Ground Water Reservoir profile is measured. The design of use of explosives will also need to take account of the dynamic impact on the nearby structures.

9.3.1 First Methodology Component Step 01: Define the Design–Build System Domains

In the first step of the first SAFEDB-methodology component, system domains are defined. Table 9.1 illustrates how system domains are interpreted in the context of the subject Ground Water Reservoir project. All system domains remained the same for both of the proposed design–build options discussed above, except for the two years' time constraint defined in the first customer domain where two potential process variables (PVs)

Table 9.1 Ground Water Reservoir project—first methodology component step 01 definition of system domains

System domain > Project description	Customer domain Customer needs (CNs) Means >	Functional domain Functional requirements (FRs) What the design does	Physical domain Design parameters (DPs) How the design looks	Process domain Process variables (PVs) How design is built
	→	→	→	→
Design and construction of an underground reinforced concrete lined Ground Water Reservoir by enlarging the existing valley in two years, at a budget of $ 10 million, and without dislocating nearby structures	CN1 Project duration of two years	FR1 Enlarge the existing valley	DP1 Remove excess earth	PV1 Option 1: Scrape-and-excavate; Option 2: Use Explosives
	CN2 Budgeted cost of $ 10 million	FR2 Shave off excess earth to increase capacity	DP2 Maintain earth slope stability	PV2 Install temporary structure
	CN3 No dislocation to nearby structures	FR3 Provide a Ground Water Reservoir profile liner	DP3 Provide a retaining concrete slab	PV3 Pour reinforced concrete

were listed under the first process domain for further assessment, namely the scrape-and-excavate method and the use of explosives.

Customer need 1 (CN1) targeting project duration to two years was addressed by functional requirement 1 (FR1) through the time-effective enlargement of the existing valley. FR1 was addressed by design parameter 1 (DP1) through removing excess earth between the current valley profile and the desired new Ground Water Reservoir profile. DP1 is addressed by two options in PV1, the first is using the traditional scrape-and-excavate method and the second is the use-of-explosives method, which adopts the application of explosives to loosen hard earth layers and facilitate earth removal.

CN2 targeting project cost to \$100 million was addressed by FR2 through the economic shaving off of excess earth to increase Ground Water Reservoir capacity. FR2 was addressed by DP2 through maintaining slope stability to avoid the costly implications of slope volatility. DP2 is addressed in PV2 by installing a temporary structure to maintain slope stability and enable the construction of the reinforced concrete liner.

CN3 prohibiting dislocation to nearby structures was addressed by FR3 through providing a Ground Water Reservoir liner. FR2 was addressed by DP3 through building a retaining concrete slab. DP3 is addressed in PV3 by pouring the reinforced concrete slab Ground Water Reservoir liner.

9.3.2 First Methodology Component Step 02: Select the Best Overall Design–Build Solution

In the second step of the first SAFEDB-methodology component, the proposed DB solutions are examined against the Independence Axiom and the Information Axiom to select the best candidate DB solution. This is achieved as follows in the context of the subject Ground Water Reservoir project.

9.3.2.1 Axiom 1: The Independence Axiom

The independence axiom examines the proposed design–build solutions for their complexity. Complex design–build solutions are identified as those yielding a coupled independence matrix, which should be either decoupled or the solution abandoned all together. As the options in this project are related to PVs, the independence matrix will be constructed between DPs and PVs. Solutions yielding decoupled or uncoupled DP–PV matrices are considered acceptable, with the uncoupled DP–PV matrices remaining the ideal form of dependency matrix indicating the most effective design–build solution.

9.3.2.1.1 First Option: The Scrape-and-Excavate Method. The dependency matrix shown in Table 9.2 addresses the scrape-and-excavate option.

As shown in Table 9.2, the scrape-and-excavate method yields a favorable uncoupled DP–PV dependency matrix. Each PV satisfies and is linked to a single DP independent of other DPs. That is, PV1 satisfies and is linked to DP1, PV2 satisfies and is linked to DP2, and PV3 satisfies and is linked to DP3. Each PV (construction solution) requires design input information from a single DP (design parameter or requirement). This signifies a best axiomatic design–build scenario from an independence and solution complexity/simplicity standpoint. However, given the time and cost drawbacks of the method as explained above, the final decision on selecting the most effective way to go shall be postponed till the second option is studied.

Table 9.2 Ground Water Reservoir project—first methodology component step 2 scrape-and-excavate dependency matrix

		Process Variables		
	Design parameters	PV1 Scrape-and-excavate	PV2 Install temporary structure	PV3 Pour reinforced concrete
DP1	Remove excess earth	X	0	0
DP2	Maintain earth slope stability	0	X	0
DP3	Provide a retaining concrete slab	0	0	X

Table 9.3 Ground Water Reservoir project—first methodology component step 02 use-of-explosives dependency matrix

		Process variables		
	Design parameters	PV1 Use explosives	PV2 Install temporary structure	PV3 Pour reinforced concrete
DP1	Remove excess earth	X	X	0
DP2	Maintain earth slope stability	0	X	0
DP3	Provide a retaining concrete slab	0	0	X

9.3.2.1.2 Second Option: The Use-of-Explosives Method. The dependency matrix shown in Table 9.3 addresses the use-of-explosives option.

As shown in Table 9.3, the use-of-explosives method yields an unfavorable coupled DP–PV dependency matrix. As in option 1, each PV satisfies and is linked to a single DP; however, in this case with the exception of PV2, which satisfies DP2, however requires input from DP1. This input is the natural earth profile resulting after the use of explosives. This means that there is a coupled relationship between DP1 and DP2 and their related PV2. This signifies a complex solution and thus an undesirable axiomatic design–build scenario from an independence and solution complexity/simplicity standpoint. However, given the time and cost advantages of the method as explained above, a further look into the matter will be carried out to try and modify the work methodology with the aim of converting such unfavorable coupled matrix to a favorable uncoupled matrix.

Aiming to uncouple the dependency matrix shown in Table 9.3, the design–build team considered a refinement of the use-of-explosives work methodology, in which designing and sizing out of the temporary structure are to be finalized after completing the use of explosives and removing the loose excess earth. By doing so, the design of the temporary structure can proceed with confidence using confirmed earth profile irregularity information. This will make PV2 again independent of DP1, yielding a favorable uncoupled design–build dependency matrix.

Table 9.4 Ground Water Reservoir project—first methodology component step 02 modified use-of-explosives dependency matrix

		Process variables		
	Design parameters	PV1 Use explosives	PV2 Install temporary structure	PV3 Pour reinforced concrete
DP1	Remove excess earth	X	0	0
DP2	Maintain earth slope stability	0	X	0
DP3	Provide a retaining concrete slab	0	0	X

The dependency matrix shown in Table 9.4 addresses the modified use-of-explosives option.

The downside of this course of action is that it will attract some additional cost as the structural members and tie-back anchors of the temporary structure will have to be overdesigned to satisfy the somewhat conservative design assumptions, which in reality might turn out to be indeed worse than the actual case scenario found after explosions. However, the benefits to the project outweigh such nominal cost increase given the big advantage of having a design–build work methodology that yields an uncoupled dependency matrix. If the actual natural earth profile after explosions and removal of excess earth is still found to be even worse than the conservative assumptions made, a quick redesign can be conducted and some prearranged additional tie-back anchors and structural members can be added to the temporary structure to strengthen it in a fairly short time.

9.3.2.1.3 Conclusion. The scrape-and-excavate option had initially been considered superior to the use-of-explosives option as the first yielded a favorable uncoupled dependency matrix whereas the second option initially yielded an unfavorable coupled dependency matrix. A modification and refinement of the use-of-explosives method succeeded in converting its initial coupled matrix to a favorable uncoupled matrix. This was achieved by overdesigning the temporary structure to withstand a worst-case loading scenario. Given the perceived time and cost advantages of the use-of-explosives method, it is considered to be the preferred design–build solution at this stage and as the outcome of Axiom 1, the Independence Axiom.

9.3.2.2 Axiom 2: The Information Content Axiom

The Information Content axiom examines the various design–build options for their information content. According to the information content axiom, the preferred design–build solution is defined as that having the least information content. The Information Content axiom shall be used herein to evaluate and select the better out of the two proposed solutions under study, which were both accepted by the Independence Axiom; however, the use-of-explosives option was considered the better option given its perceived time and cost advantages. Evaluation and selection shall be based on the comparison of the information content index for each option. A quantitative and qualitative information content analysis shall be conducted to examine a number of inherent evaluation elements for each of the candidate design–build solutions, namely, budget, time, and slope stability.

The probability distribution shown in Figure 9.6 illustrates the relationship among the system range, the range of a given candidate solution, and the common range. The system range is defined by the Owner's requirements and project constraints, the candidate solution range is defined by the inherent parameters of such solution and its ability to align with or satisfy the system range, whereas the common range is the overlap between the two. A substantial common range or a full overlap between the system range and the candidate solution range will indicate a good solution that is able to satisfy the system range with the least or already inherent information content.

The information content index for the candidate design–build solutions is calculated using the below axiomatic information content equation: ICI = Σ [LOG2 (1 / Pi)] bits from i = 1 to i = n, where n is the number of evaluation elements under study and Pi = common range i/ system range i. The following paragraphs assess the information content for each of the candidate design–build options:

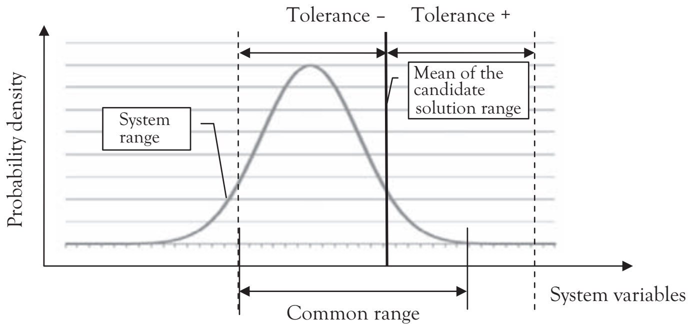


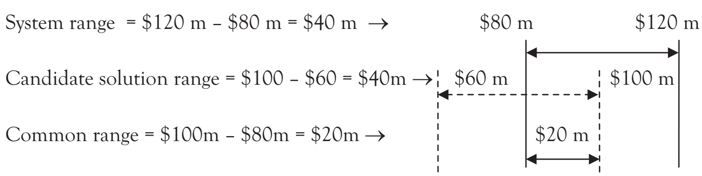
Figure 9.6 Relationship among system range, candidate solution range, and common range

1. Budget

   The design and construction budget was set by the Owner in the "system range" at \$100 m, with + or – 20% permissible deviation, that is, a range from \$80 m minimum to \$120 m maximum, or (\$80m, \$120m).

   Scrape-and-Excavate Method

   The cost of the scrape-and-excavate method has been estimated at \$80 m with a possible deviation of + or – \$20 m depending on the severity of soil conditions encountered during excavation. Hence, the cost range is from \$60 m minimum to \$100 m maximum, or (\$60 m, \$100 m).



Thus P-cost = \$20m / \$40m = 0.5, and ICI-cost = Log2 (1/P-cost) = 1.00 bits

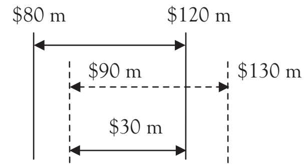
   Use-of-Explosives Method

   The cost of the use-of-explosives method has been estimated at \$110 m, however, with a possible deviation of + or – \$20 m depending on the severity of soil conditions encountered during excavation. Hence, the cost range is from \$90 m minimum to \$130 m maximum, or (\$90 m, \$130 m).

System range = \$120 m – \$80 m = \$40 m →

Candidate solution range = \$130 – \$90 = \$40 m →

Common range = \$120m - \$90m = \$30m →



Thus P-cost = \$30m / \$40m = 0.75, and ICI-cost = Log2 (1/P-cost) = 0.415 bits

The use-of-explosives-method is therefore the better option from a budget information standpoint. It has a larger common range with the system range, thus a higher probability to satisfy it.

2. Time

The design and construction time was set by the Owner in the "system range" at 24 months, with + or − 20 percent permissible deviation, that is, a range from 19.2 m minimum to 28.8 m maximum, or (19.2 m, 28.8 m).

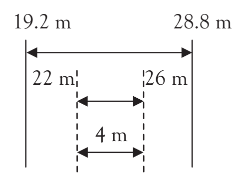
Scrape-and-Excavate Method

The time of the scrape-and-excavate method has been estimated at 24 months with a possible deviation of + or − 2 m depending on the severity of soil conditions encountered during excavation. Hence, the time range is from 22 m minimum to 26 m maximum, or (22 m, 26 m).

System range = 28.8 m – 19.2 m = 9.6 m →

Candidate solution range = 26 m – 22 m = 4 m →

Common range = 26m – 22m = 4m →



Thus P-time = 4m / 9.6m = 0.4167, and ICI-time = Log2 (1/P-time) = 1.263 bits

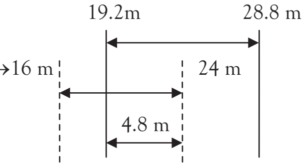
Use-of-Explosives Method

The time of the use-of-explosives method has been estimated at 20 months with a possible deviation of + or − 4 m depending on the severity of soil conditions encountered during excavation. So the time range is from 16 m minimum to 24 m maximum, or (16 m, 24 m).

System range = 28.8 m – 19.2 m = 9.6 m →

Candidate solution range = 24 m – 16 m = 8 m →

Common range = 24 m – 19.2 m = 4.8 m →



Thus P-time = 4.8 m / 9.6 m = 0.50, and ICI-time = Log2 (1/P-time) = 1.00 bits

The use-of-explosives-method is therefore the better option from a time information standpoint. It has a larger common range with the system range, thus a higher probability to satisfy it.

3. Slope stability

The design and construction constraints set by the Owner require no dislocation of the existing nearby structures. That would mean ensuring minimal ground settlement or upheave impact, which would be caused by slope stability issues during construction. Given the type and nature of the existing structures lying within the Ground Water Reservoir construction site influence zone, the allowable settlement of structures would be approximately 25 mm. However, for more safety, a nominal tolerance of + or –5 mm shall be adopted, that is, a system range of −5 mm settlement to +5 mm upheave, or (−5mm, +5mm). Moreover, in this particular case, since the candidate solution range for both of the solutions in hand are expected to exceed the system range, the candidate solution range will be used instead of the system range in the denominator of the P*i* equation so that the subject problem is appropriately simulated.

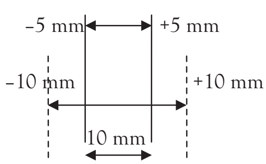
Scrape-and-Excavate Method

The scrape-and-excavate method, given its static nature, would cause a limited accidental ground movement of + or –10 mm, that is, a range from −10 mm settlement to +10 mm upheave, or (−10 mm, +10 mm).

System range = +5 mm – (–5 mm) = 10 mm →

Candidate solution range = +10 – (–10 mm) = 20 mm →

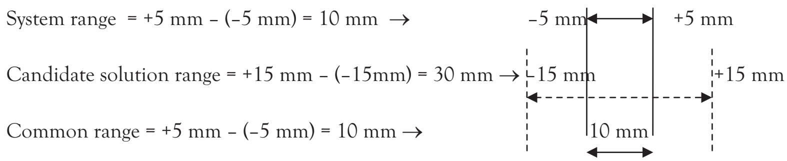
Common range = +5 mm – (–5 mm) = 10 mm



Thus P-stability = 10 mm / 10 mm = 1, and ICI-stability = Log2 (1/P-stability) = 0 bits

Use-of-Explosives Method

The use-of-explosives method, given its dynamic nature, would cause a somewhat substantial ground movement of + or –15 mm, that is, a range from −15 mm settlement to +15 mm upheave, or (−15 mm, +15 mm).



Thus P-stability= 10 mm / 10 mm = 1, and ICI-stability = Log2 (1/P-stability) = 0 bits

The scrape-and-excavate and the use-of-explosives methods are therefore of equal preference from a slope stability information content standpoint.

Conclusion and Summary of Findings

Table 9.5 summarizes the outcome of the above Information Axiom analysis and evaluation of both of the candidate design–build solutions for information content related to the key elements of budget, time, and slope stability.

Since the use-of-explosives method has an overall smaller *P* value than that calculated for the scrape-and-excavate method, it is the better design–build solution. The use-of-explosives method will be adopted and

Table 9.5 Ground Water Reservoir project—first methodology component step 02 P_i comparison

	P_i	
Evaluation element	**Scrape-and-excavate**	**Use-of-explosives**
Time	1.263	1.000
Budget	1.000	0.415
Slope stability	0.000	0.000
P-total	2.263	1.415

taken over for further SAFEDB-methodology progression, evaluation, and analysis.

9.3.3 First Methodology Component Step 03: Progressive elaboration of the selected DB solution

According to the SAFEDB-methodology, a design–build solution is described in terms of CNs and corresponding FRs. The project is then implemented through a set of related DPs and physical construction PVs.

For the subject Ground Water Reservoir project implemented using the use-of-explosives work methodology, the DPs and PVs are defined as follows:

DP1: Remove the excess earth
DP2: Maintain earth slope stability
DP3: Provide a retaining concrete stab
PV1: Use explosives
PV2: Install temporary structure
PV3: Pour concrete

The application of the selected best overall project DB solution is then progressed using a top-down manner zigzagging between the system domains as shown in Figure 9.7.

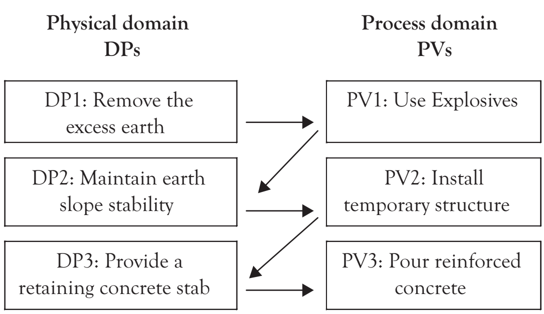


Figure 9.7 DPs and PVs hierarchy zigzagging process

Notes: DPs, design parameters; PVs, process variables.

The set of DPs provide the design information required to perform their corresponding PVs including calculations, specifications, and drawings. The PVs provide the physical construction of the project. Both DPs and PVs are to be developed collaboratively between the project's design and construction professionals. Progressing in the shown downward zigzagging fashion ensures the timely generation of design and construction information and reduces the chances for unwarranted rework cycles.

9.4 Second Methodology Component—Step by Step

This section explains the use of the concurrent engineering approach in developing and implementing design and construction overlapping strategies in a practical step-by-step fashion. Figure 9.8 provides an overview of the title and purpose of the three logical steps of the second methodology component (SMC) 01, 02, and 03.

In this section, the design and construction activities related to the use-of-explosives method are taken forward for design–build planning and scheduling. This will be carried out in three distinct steps, namely, conventional project planning using the critical path method (CPM), analyzing the various design and construction activities to determine their fast-tracking characteristics, and lastly applying the SAFEDB-methodology overlapping strategy to reduce the overall project duration.

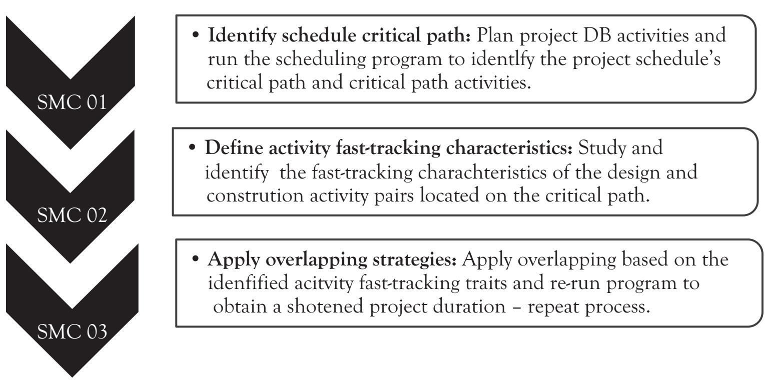
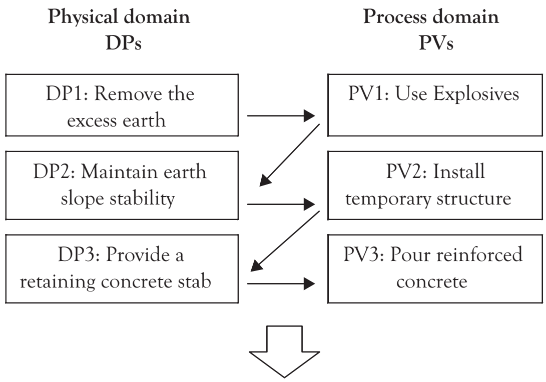


Figure 9.8 The SAFEDB-methodology—overview of the second methodology component



Activities for CPM planning and scheduling		
Activity ID	**Zigzagging domain**	**Activity description**
WD-D-01	DP1	Design explosion to remove excess earth
WD-C-02	PV1	Execute explosion to remove excess earth
WD-D-03	DP2	Design temporary structure to maintain slope stability
WD-C-04	PV2	Execute temporary structure to maintain slope stability
WD-D-05	DP3	Design retaining reinforced concrete stab
WD-C-06	PV3	Execute retaining reinforced concrete stab

Note: In Activity ID numbering, D denotes a design activity and C denotes a construction activity. CPM, critical path method; DPs, design parameters; PVs, process variables

Figure 9.9 Transferring DPs and PVs to the activity list for CPM scheduling

Figure 9.9 illustrates the key action of transferring the DP–PV zigzagging hierarchy into a practical list of design–build activities for CPM planning and scheduling.

9.4.1 Second Methodology Component Step 01: Identify Schedule Critical Path

For clarity, and to maintain the focus on the application of the SAFEDB-methodology, all activities are assumed to have a typical finish-to-start relationship. This results in all activities lying on the project's critical path. No activity overlapping is attempted at this stage as this

Table 9.6 Critical path method activity successor predecessor relationship

Activity ID	Activity description	Successor	Predecessor
WD-D-01	Design explosion to remove excess earth	2	None
WD-C-02	Implement explosion to remove excess earth	3	2
WD-D-03	Design temporary structure to maintain slope stability	4	3
WD-C-04	Implement temporary structure to maintain slope stability	5	4
WD-D-05	Design retaining reinforced concrete stab	6	5
WD-C-06	Implement retaining reinforced concrete stab	None	6

will be done separately in a scientifically validated manner in the subsequent SMC Steps 02 and 03.

Table 9.6 provides the CPM scheduling logic, sequencing, and activity dependencies.

In the scheduling logic shown in Table 9.6, the implementation of explosives is assumed to start after explosion design is completed to ensure optimization of the amount of applied explosives, implementation of the temporary structure is assumed to start after completing the temporary structure design based on actual site's measured earth slopes to ensure the temporary structure's capacity to withstand actual slope stability demands, and implementation of the permanent reinforced concrete slab liner is assumed to start after the temporary structure is installed to confirm design inputs and ensure that slab design is based on actual and final site conditions to avoid unwarranted rework cycles.

Table 9.7 provides an educated estimate of activity durations.

The Gantt chart in Figure 9.10 shows the project's chain of activities forming the project's critical path.

It is also noted that according to the activity duration estimates and schedule logic shown in Figure 9.10, the overall project duration amounts to 25 months, which exceeds the targeted 24-month project duration. This does not satisfy the Owner time requirements and puts the project at

Table 9.7 Critical path method activity duration estimates

Activity ID	Activity description	Activity duration
WD-D-01	Design explosion to remove excess earth	3 months
WD-C-02	Implement explosion to remove excess earth	6 months
WD-D-03	Design temporary structure to maintain slope stability	4 months
WD-C-04	Implement temporary structure to maintain slope stability	5 months
WD-D-05	Design retaining reinforced concrete stab	3 months
WD-C-06	Implement retaining reinforced concrete stab	4 months
	Total duration =	25 months

Note: The total duration exceeding the stipulated 24 months maximum Design–Build project duration.

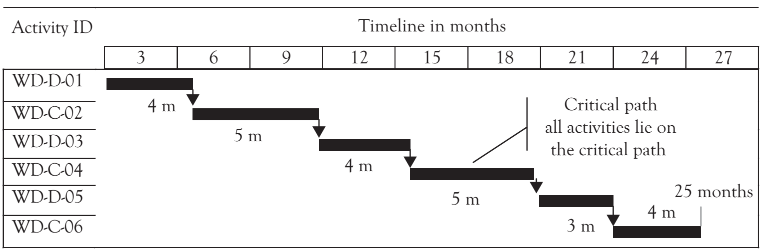


Figure 9.10 Critical path method Gantt chart

further risk should any of the project activities lying on the critical path gets delayed. This will be dealt with by overlapping design and construction activities as discussed in the following sections.

9.4.2 Second Methodology Component Step 02: Define Activity Fast-Tracking Characteristics

In this methodology step, each couple of upstream design and downstream construction activities is analyzed to investigate its fast-tracking characteristics, which will be used in the subsequent section to determine the project's activity overlapping strategy.

Table 9.8 represents the possible upstream design activity characteristics.

Table 9.9 represents the possible downstream construction activity characteristics.

Table 9.8 Upstream design activities—classification of design evolution and design reliability

Upstream design activity							
Fast evolution				Slow evolution			
Highly reliable	Fairly reliable	Fairly unreliable	Highly unreliable	Highly reliable	Fairly reliable	Fairly unreliable	Highly unreliable

Table 9.9 Downstream construction activities—sensitivity and production rate

Downstream construction activity					
Fast early production			Slow early production		
Insensitive	Sensitive	Highly sensitive	Insensitive	Sensitive	Highly sensitive

1. The first activity couple:

WD-D-01 Design explosion to remove excess earth
WD-C-02 Implement explosion to remove excess earth

WD-D-01: Design explosion to remove excess earth—It usually starts with conducting geotechnical investigation followed by conducting three-dimensional (3D) finite element method (FEM) computer modeling and vibration analysis to determine the optimum amount of explosives and sequence of operations. However, the outputs of the design task can start being released early in the process gradually and in increments to start up site works and keep the site going. The design information required to initiate field operations would include blasting grid, blast hole dimensions (diameter/depth), followed by confirming explosive amounts and application instructions. In concurrent engineering terms, the design process can be described as one of fast evolution and is highly reliable given the factual preengineering site studies and the sophisticated computer-aided design method used.

WD-C-02: Implement explosion to remove excess earth—It is a fairly complicated process that is implemented gradually upon receipt of validated design information packages. This slow and phased progressive process however remains sensitive to changes in the design information transferred from the design domain. Any change to the design information released to site would require some additional field work. In concurrent engineering terms, the construction process in this case can be described as one of slow production and is highly sensitive given the nature of the construction operation.

Summary of findings:

WD-D-01	Upstream design activity	Fast evolution	Highly reliable
WD-C-02	Downstream construction activity	Slow production	Highly sensitive

2. The second activity couple:

WD-D-03	Design temporary structure to maintain slope stability
WD-C-04	Implement temporary structure to maintain slope stability

WD-D-03: Design temporary structure to maintain slope stability—It is a rather complicated task. The temporary structure design utilizes a sophisticated structural system, specialist software, and various structural steel elements. Hence, the design domain can develop quite slowly and start releasing information to the construction domain only after soil information is available and the post-explosion natural soil profile is established and documented. In concurrent engineering terms, the design process in this case can be described as one of slow evolution and is highly reliable given the well-established design method used and the confirmed design input and accurate field information.

WD-C-04: Implement temporary structure to maintain slope stability—It starts with the installation of the tie-back anchors using special equipment and methodology, and all anchors must pass a quality assurance pull-out test before use. Once anchors are installed and tested, the installation of the temporary structure modular plate elements can start and proceed at a fairly high pace. Any change to the design information transferred from the design domain can interrupt construction. The remedial action will then comprise providing additional anchors, or strengthening the temporary structure with additional structure elements. In concurrent engineering terms, the construction process in this case can be described as one of slow production and is sensitive given the described sequence.

Summary of findings:

WD-D-03	Upstream design activity	Slow evolution	Highly reliable
WD-C-04	Downstream construction activity	Slow production	Sensitive

3. The third activity couple:

WD-D-05 Design retaining reinforced concrete slab
WD-C-06 Implement retaining reinforced concrete slab

WD-D-05: Design retaining reinforced concrete slab—for this, Ground Water Reservoir application is a rather rigorous design exercise. It requires FEM modeling and analysis to assess the combined effect of several design factors including soil properties, soil stiffness, subgrade reaction, actual natural soil state of slope stability, slab thickness, and slab stiffness. Such detailed FEM analysis will need quite some time to be developed and then tested, refined, validated, and finalized. Releasing early information to construction before finalizing the modeling and analysis exercise can be quite risky given the iterative nature of the process, which produces new refined results with the performance of each new iteration. In concurrent engineering terms, the design process in this case can be described as one of slow evolution and is fairly unreliable given the explained iterative nature of the modeling and analysis process.

WD-C-06: Implement retaining reinforced concrete slab—It can start early and slowly by conducting site preparation and cutting and erecting the reinforcing steel rebar based on the early design information transferred from the design domain. Later on, at any time before the concrete is poured, if such design information changes, reinforcement shall need to be rectified. This can be done by inserting additional reinforcement at strategic locations as required by the design. In concurrent engineering terms, the construction process in this case can be described as one of slow production and is somewhat sensitive given the described implementation sequence.

Summary of findings:

WD-D-05	Upstream design activity	Slow evolution	Fairly unreliable
WD-C-06	Downstream construction activity	Slow production	Sensitive

Having established the fast-tracking characteristics of all the design and construction activity couples in SMC Step 02, the next step would be to identify and apply the appropriate overlapping activity overlapping strategy and extent in each case. This is performed in the next SMC Step 03.

9.4.3 Second Methodology Component Step 03: Determine Overlapping Strategy

In this methodology step, the overlapping extent between each of the design and construction couples shall be determined based on their fast-tracking characteristics identified in SMC Step 02 above. That will be achieved by entering such fast-tracking characteristics into the SAFEDB-methodology overlapping strategy selection table.

1. The first activity couple:
   Upstream design activity (UDA) and downstream construction activity (DCA) fast-tracking characteristics:

WD-D-01	Upstream design activity	Fast evolution	Highly reliable
WD-C-02	Downstream construction activity	Slow production	Highly sensitive

   The application of such fast-tracking characteristics is highlighted in Table 9.10.

   Conclusion

   The recommended *X* value for this activity couple is 50 percent (80 percent), that is, the design–build team may transfer design information from the UDA to the DCA at 50 percent of the UDA time or 80 percent of the UDA design development. That would yield an overlap of 50 percent of the UDA duration.
2. The second activity couple:
   UDA and DCA fast-tracking characteristics:

WD-D-03	Upstream design activity	Slow evolution	Highly reliable
WD-C-04	Downstream construction activity	Slow production	Sensitive

   The application of such fast-tracking characteristics is highlighted in Table 9.11.

Table 9.10 The SAFEDB-methodology—selection table for overlapping of design and construction activities based on their inherent fast-tracking characteristics - the first activity couple

Overlapping Strategy Guideline figures for Various UDA and DCA overlapping Combination scenarios Legend: 10% Time Elapsed [20%] Work Done			X Percentage of the Upstream Design Activity's Time Elapsed or Work Done at which the DCA May Start Design X → Construction Upstream Design Activity (UDA)							
			Fast evolution				Slow evolution			
			Highly reliable (%)	Fairly reliable (%)	Fairly unreliable (%)	Highly unreliable (%)	Highly reliable (%)	Fairly reliable (%)	Fairly unreliable (%)	Highly unreliable (%)
Downstream Construction Activity (DCA)	Slow production	Insensitive	10 [20]	25 [50]	50 [80]	100 [100]	50 [20]	75 [50]	90 [80]	100 [100]
		Sensitive	25 [50]	50 [80]	100 [100]	110 [100]	75 [50]	90 [80]	100 [100]	110 [100]
		Highly sensitive	50 [80]	100 [100]	110 [100]	120 [100]	90 [80]	100 [10]	110 [100]	120 [100]
	Fast production	Insensitive	25 [50]	50 [80]	100 [100]	110 [100]	75 [50]	90 [80]	100 [100]	110 [100]
		Sensitive	50 [80]	100 [100]	110 [100]	120 [100]	90 [80]	100 [100]	110 [100]	120 [100]
		Highly sensitive	100 [100]	110 [100]	120 [100]	130 [100]	100 [100]	110 [100]	120 [100]	130 [100]

Table 9.11 The SAFEDB-methodology—selection table for overlapping of design and construction activities based on their inherent fast-tracking characteristics - the second activity couple

Overlapping Strategy Guideline figures for Various UDA and DCA overlapping Combination scenarios Legend: 10% Time Elapsed [20%] Work Done			X Percentage of the Upstream Design Activity's Time Elapsed or Work Done at which the DCA May Start Design X → Construction Upstream Design Activity (UDA)							
			Fast evolution				Slow evolution			
			Highly reliable (%)	Fairly reliable (%)	Fairly unreliable (%)	Highly unreliable (%)	Highly reliable (%)	Fairly reliable (%)	Fairly unreliable (%)	Highly unreliable (%)
Downstream Construction Activity (DCA)	Slow production	Insensitive	10 [20]	25 [50]	50 [80]	100 [100]	50 [20]	75 [50]	90 [80]	100 [100]
		Sensitive	25 [50]	50 [80]	100 [100]	110 [100]	75 [50]	90 [80]	100 [100]	110 [100]
		Highly sensitive	50 [80]	100 [100]	110 [100]	120 [100]	90 [80]	100 [10]	110 [100]	120 [100]
	Fast production	Insensitive	25 [50]	50 [80]	100 [100]	110 [100]	75 [50]	90 [80]	100 [100]	110 [100]
		Sensitive	50 [80]	100 [100]	110 [100]	120 [100]	90 [80]	100 [100]	110 [100]	120 [100]
		Highly sensitive	100 [100]	110 [100]	120 [100]	130 [100]	100 [100]	110 [100]	120 [100]	130 [100]

Conclusion

The recommended *X* value for this activity couple is 75 percent (50 percent), that is, the design–build team may transfer design information from the UDA to the DCA at 75 percent of the UDA time or 50 percent of the UDA design development. That would yield an overlap of 25 percent of the UDA duration.

3. The third activity couple:
   UDA and DCA fast-tracking characteristics:

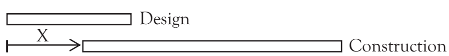
WD-D-05	Upstream design activity	Slow evolution	Fairly unreliable
WD-C-06	Downstream construction activity	Slow production	Sensitive

The application of such fast-tracking characteristics is highlighted in Table 9.12.

Conclusion

The recommended *X* value for this activity couple is 100 percent (100 percent), that is, overlapping of this activity couple is not recommended. Activity couple should therefore maintain their typical finish-to-start relationship.

Table 9.12 The SAFEDB-methodology—selection table for overlapping of design and construction activities based on their inherent fast-tracking characteristics - the third activity couple



Overlapping Strategy Guideline figures for Various UDA and DCA overlapping Combination scenarios			X Percentage of the Upstream Design Activity's Time Elapsed or Work Done at which the DCA May Start							
Legend: 10% Time Elapsed [20%] Work Done			Upstream Design Activity (UDA)							
			Fast evolution				Slow evolution			
			Highly reliable (%)	Fairly reliable (%)	Fairly unreliable (%)	Highly unreliable (%)	Highly reliable (%)	Fairly reliable (%)	Fairly unreliable (%)	Highly unreliable (%)
Downstream Construction Activity (DCA)	Slow production	Insensitive	10 [20]	25 [50]	50 [80]	100 [100]	50 [20]	75 [50]	90 [80]	100 [100]
		Sensitive	25 [50]	50 [80]	100 [100]	110 [100]	75 [50]	90 [80]	100 [100]	110 [100]
		Highly sensitive	50 [80]	100 [100]	110 [100]	120 [100]	90 [80]	100 [10]	110 [100]	120 [100]
	Fast production	Insensitive	25 [50]	50 [80]	100 [100]	110 [100]	75 [50]	90 [80]	100 [100]	110 [100]
		Sensitive	50 [80]	100 [100]	110 [100]	120 [100]	90 [80]	100 [100]	110 [100]	120 [100]
		Highly sensitive	100 [100]	110 [100]	120 [100]	130 [100]	100 [100]	110 [100]	120 [100]	130 [100]

Summary of Overlapping Results

Table 9.13 provides a summary of the concluded design and construction SAFEDB-methodology overlapping strategy for a later application to the project's CPM schedule.

The next step would be to apply the overlapping strategy to the original CPM schedule.

The Gantt chart in Figure 9.11 shows the original project's CPM time schedule.

And the Gantt chart in Figure 9.12 shows the compressed project's CPM time schedule after application of the overlapping periods presented in Figure 9.11.

As shown in Figure 9.12, using the SAFEDB-methodology SMC step 02 has enabled reduction of the overall project duration from the originally estimated 25 months down to 22 months, that is, a reduction

Table 9.13 Ground Water Reservoir—summary of overlapping strategy

Design–build activity couple	UDA duration	X		Overlap	
		%ge	Duration	%ge	Duration
WD-D-01 vs. WD-C-02	4 months	50%	2.0 months	50%	2.0 months
WD-D-03 vs. WD-C-04	4 months	75%	3.0 months	25%	1.0 months
WD-D-05 vs. WD-C-06	3 months	100%	3.0 months	00%	0.0 months
Total Project Schedule Shortening =					3.0 months

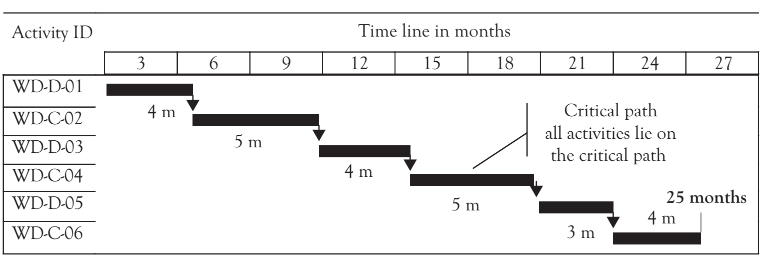


Figure 9.11 Critical path method Gantt chart—original schedule before compressing

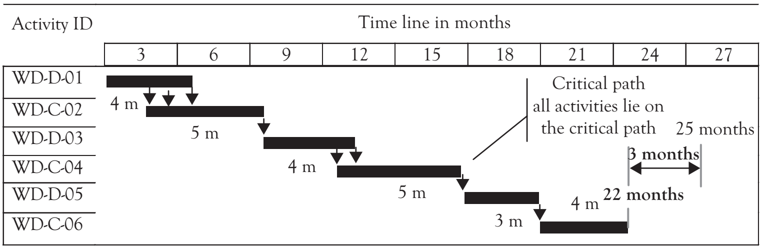


Figure 9.12 CPM Gantt chart—compressed as per the SAFEDB-methodology overlapping strategy

of three months, or 12 percent of the originally estimated project duration. This has also enabled completing the project within the stipulated 24 months targeted by the Owner.

9.5 Third Methodology Component—Step by Step

This section explains the use of the graphical evaluation and review technique (GERT) approach in simulating potential branching and rework loop scenarios. Figure 9.13 provides an overview of the title and purpose of the three logical steps of the third methodology component, namely, TMC 01, 02, and 03.

This section is primarily concerned with identifying the potential branching and looping scenarios of the DCA construction operations. This is realized in line with the GERT method and following the logical plan–do–check–act concept. Each DCA is discussed and analyzed for potential branching and looping, and then assigned an estimated duration and a probability of occurrence. Schedule buffers are then calculated as the product of DCAs' estimated durations and pertinent probabilities of occurrence.

Figure 9.14 illustrates the branching process.

And Figure 9.15 illustrates the looping process.

For planning purposes, each potential rework loop is assigned a duration *X* and a probability of occurrence *Y* estimates. Estimates are to be based on expert judgment and/or past experience with similar type of work.

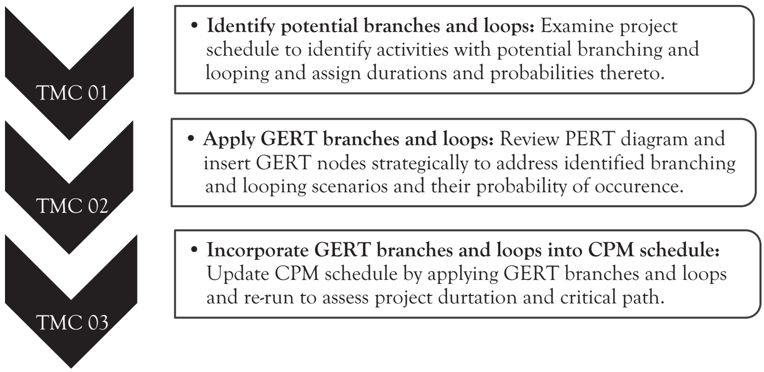


Figure 9.13 The SAFEDB-methodology—overview of the third methodology component

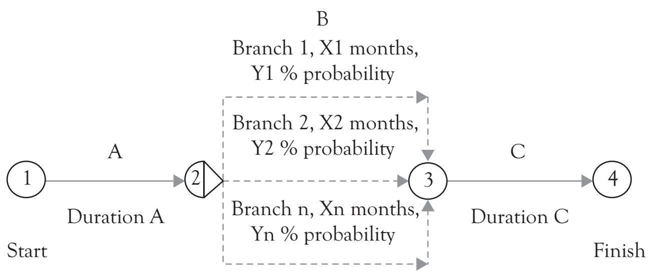


Figure 9.14 Third methodology component step 02—applying graphical evaluation and review technique smart node "branches"

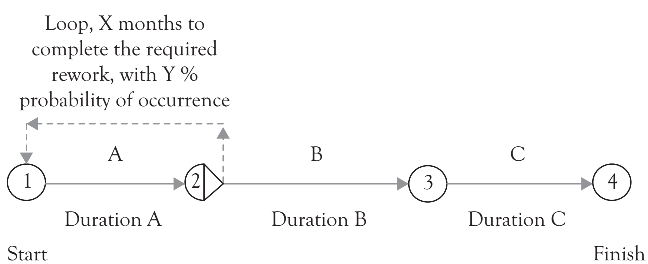


Figure 9.15 Third methodology component step 02—applying graphical evaluation and review technique smart node "loops"

9.5.1 Third Methodology Component Step 01: Identify Potential Branches and Loops

The subject Ground Water Reservoir project has a fairly clear scope and construction methodology, leaving little or no chance for branching as the work methods are very well defined. However, rework looping effects are to be expected for WD-C-02: Implement explosion to remove excess earth and WD-C-04: Implement temporary structure to maintain slope stability given the degree of uncertainty associated with the outcome of the explosion operation. This will be discussed in detail in the following paragraphs.

WD-C-02: Implement explosion to remove excess earth

The implementation of the explosion operation is carried out based on the design information transferred from the upstream design activity WD-D-01: Design explosion to remove excess earth. Despite the duty of care exercised in such design activity, including soil investigation and computer modeling, deviation from the plan is still to be expected. Deviation would include over- or underestimation of the required amount of explosives. Overestimation leads to over-excavation, which can be accounted for and dealt with in the subsequent steps while designing the temporary structure, whereas underestimation will require conducting additional explosions, thus leading to a partial rework loop. The estimated duration of rework loop in this case is set at two months, and the probability of occurrence at 25 percent.

WD-C-04: Implement temporary structure to maintain slope stability

The implementation of the temporary structure is carried out based on the design information transferred from the upstream design activity WD-D-03: Design temporary structure to maintain slope stability. Design information includes locations and capacity of the tie-back anchors, which should all be proof-tested for load capacity, anchor by anchor, before validation and adoption for use. Despite the duty of care exercised in such design activity, including soil investigation and computer modeling, deviation from the plan is still to be expected. Deviation would include failure of some anchors to pass the proof load test due to design and/or installation causes. This will entail a partial rework loop including developing a remedial action and installation of replacement or additional anchors. The estimated duration of rework loop in this case is set at one month, and the probability of occurrence at 50 percent.

9.5.2 Third Methodology Component Step 02: Apply Graphical Evaluation and Review Technique Branches and Loops

In this section, the project's PERT diagram is first developed, and then modified by inserting GERT nodes where applicable and applying the probable branches and loops identified in TMC Step 01, along with their estimated durations and probability of occurrence.

Figure 9.16 illustrates this process.

Table 9.14 would be useful in detecting and capturing significant candidate design and construction activities of high potential of branching and looping.

Table 9.14 will serve as the basis for further update and development of the project's CPM schedule as discussed under TMC Step 03.

9.5.3 Third Methodology Component Step 03: Incorporate GERT Branches and Loops into CPM Schedule

In this section, the project's initially compressed CPM schedule is further impacted to accommodate the additional schedule buffer durations assessed and developed under TMC Step 02 to account for the probabilistic

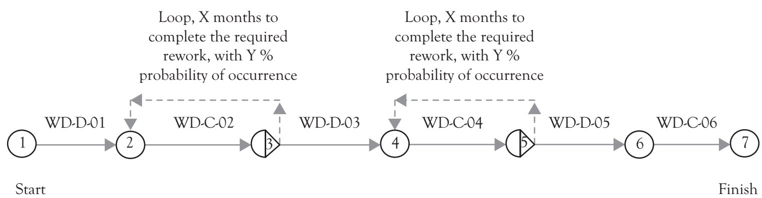


Figure 9.16 Third methodology component step 02—Ground Water Reservoir project—applying graphical evaluation and review technique smart node "loops"

Table 9.14 Third methodology component step 1—Ground Water Reservoir project—table of activities with likelihood for looping

Activities with likelihood for GERT branching and looping						
Critical or Near critical activities Activity information			GERT Branching or looping	Branches and loops information		
Activity ID	Activity description	Activity type D/C	Sensitive construction	Probability Y	Duration X	Probability * Duration Y * X
WD-C-02	Implement explosion to remove excess earth	C	Looping	L 25 %	2 months	0.5 month
WD-C-04	Implement temporary structure to maintain slope stability	C	Looping	L 50 %	1 month	0.5 month

Notes: D, design, C, construction, L, loop schedule branches and rework loops. For further clarity, the original CPM schedule is also shown to demonstrate the cumulative impacts of applying the SAFEDB-methodology.

The Gantt chart in Figure 9.17 shows the original project's CPM time schedule.

The Gantt chart in Figure 9.18 shows the compressed project's CPM time schedule after application of the design and construction activity overlapping and before the incorporation of the probabilistic schedule buffer durations.

Finally, Figure 9.19 represents the final SAFEDB-methodology baseline schedule, which takes account of the original CPM schedule, the schedule compression through the overlapping of design and construction schedule, and the additional schedule buffer durations, namely, 0.50 month for WD-C-02 and 0.50 month for WD-C-04.

As can be seen in Figure 9.19, the incorporation of the probabilistic schedule buffer durations has resulted in reducing the schedule shortening from three months to two months, and increasing the estimated

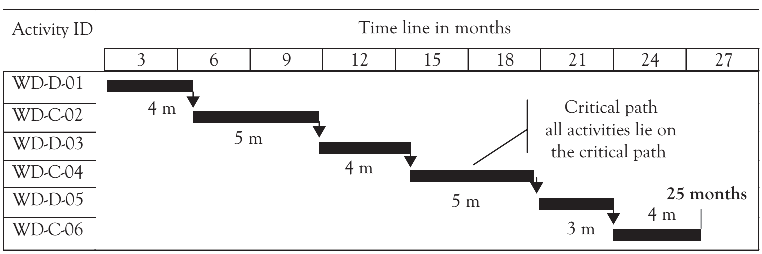


Figure 9.17 Critical path method Gantt chart—original schedule before compressing

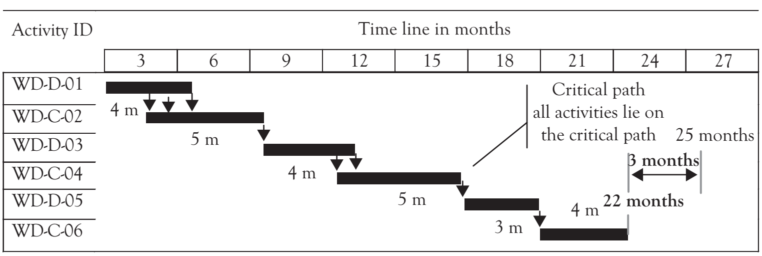


Figure 9.18 Critical path method Gantt chart—compressed as per the SAFEDB-methodology overlapping strategy

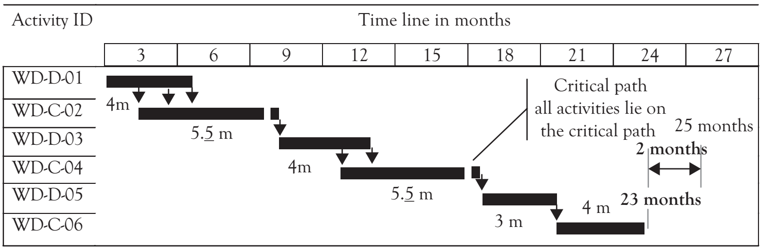


Figure 9.19 Critical path method Gantt chart—finally compressed and buffered as per the SAFEDB-methodology

project duration from 22 months to 23 months. The newly estimated project duration however remained less than the originally estimated 25 months, as well as the 24 months targeted by the Owner.

9.6 The Power and Benefits of the Methodology Application

As demonstrated in the subject Ground Water Reservoir design–build project, the SAFEDB-methodology has been instrumental in dealing with three key aspects of the project, selection of the most effective design–build solution, safe and educated schedule compression, and mitigating the risks associated with the probable schedule branching and rework loops. This was achieved through the application of the SAFEDB-methodology first, second, and third methodology components, respectively.

9.6.1 First Methodology Component

The design–build solution-selection process took place under the FMC. Without looking deep into and uncovering the inherent parameters of the candidate solutions, selecting the right method would have been a dilemma for the design–build team. The scrape-and-excavate method would have been selected as it is more traditional despite its time- and cost-efficiency drawbacks, leading to project time and cost overruns. The use-of-explosives method would have been dropped due to the complexity related to the coupled relationship between the design and installation of the temporary structure on one side and the competing needs of the removal of excess earth and maintaining slope stability on the other side. The axiomatic design detected such coupled relationship and allowed its uncoupling leading to bringing about simplicity, thus enabling the adoption of the time- and cost-effective method.

9.6.2 Second Methodology Component

The design–build schedule compression process took place under the SMC. Without the application of SMC, the CPM schedule would have exceeded the Owner's targeted project duration. Overlapping was conducted in a controlled an educated manner and overlapping extents were assessed based on the fast-tracking characteristics of the design and construction activity couples. Arbitrary overlapping would have led to schedule interruptions or abortive work. The application of the principles of concurrent engineering in SMC has allowed conducting overlapping in a safe manner to safeguard the project schedule. SMC has enabled compressing the project schedule from the originally estimated 25 months down to 22 months, that is, a schedule shortening of 3 months or 12 percent. Such schedule shortening has enabled completing the project within the 24 months' time frame targeted by the Owner.

9.6.3 Third Methodology Component

The mitigation of design–build schedule risks associated with the probable schedule branches and rework loops took place under the TMC. Without taking into account such probable branches and rework loops, the schedule would have been exposed to the risk of delays in case the actual outcome of certain operations differed from the planned outcome. The impact of the potential schedule branches and rework loops was assessed using the principles of GERT and accommodated into the CPM schedule in the form of schedule buffer durations applied to the concerned activities. Such buffers embed provisional durations in the schedule body to be used if and as necessary. Some buffers will realize in the amounts estimated, but some others will exceed or be less than the buffer duration estimates. Overall schedule remains protected and the end state will likely be an actual project duration that is very close to the planned duration.

The incorporation of such buffers has increased the design–build project duration from 22 months up to 23 months, that is, a schedule shortening of two months or 8 percent of the originally estimated 25-month project duration. Despite such slight project duration increase, the schedule remained well within the 24 months' time frame targeted by the Owner. So TMC enabled creating a shorter and more reliable design–build CPM schedule.

9.7 Summary

The Owner decided to award a design–build contract to upgrade and enlarge the capacity of an existing valley to create a Ground Water Reservoir within certain specified time and budget constraints. The design–build team decided to use the SAFEDB-methodology to plan and implement the project. Two design–build solutions were initially developed by the design–build team. The SAFEDB-methodology FMC was used to select the superior design–build solution of a lower cost and a higher probability of success and meeting project time and cost constraints. SMC was used to develop the design and construction activities overlapping strategy, thus enabling a schedule shortening of 12 percent and completing the project within the required project duration. TMC was then used to safeguard the schedule against potential rework loops by calculating and inserting certain probabilistic schedule buffer durations amounting to 4 percent of the project time, thus reducing schedule shortening to 8 percent. It is noted that the indicated schedule-shortening percentages are those achieved during such schedule shortening percentage is the sole outcome of the application of the SAFEDB-methodology, and comes on top of any other published or measured schedule shortening percentages resulting from the application of the Design-Build process at large. The use of the SAFEDB-methodology to deliver the design–build project has enabled reducing project cost and shortening project duration, while proactively taking account of events that might cause project delays.

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The Power of Design–Build

A Guide to Effective Design–Build Project Delivery Using the SAFEDB-Methodology

Sherif Hashem

Design-build is a powerful project delivery approach. But how to actuate such power and deliver the design-build promise? This is what this book is all about. It provides the reader with cutting-edge knowledge, know-how, techniques, trade secrets, and best practices to deliver design-build projects in a safe and controlled manner. It covers the entire design-build process—from building the design-build team and winning the design-build tender competition, to project management, selecting the best design-build solution, and the sound planning of design-build activities. To this end, the book introduces a totally new and innovative design-build planning methodology, namely, the SAFEDB-methodology.

The SAFEDB-methodology consists of three key components: develop design-build solutions, fast-tack design-build activities, and control design-build work progress. The first component is concerned with evaluating candidate design-build options and selecting the most effective design-build solution. The second component looks deep into overlapping design and construction activities and introduces an effective overlapping strategy enabling maximum safe schedule compression. The last methodology component focuses on enhancing the design-build schedule reliability by taking into account potential schedule branching and rework loops in a structured and proactive manner. A range of real-world practical examples of the methodology application are provided for clarity and immediate use by the readers.

The book is meant for the design-build contractors, designers, and owners; for the professionals and the academics, those new to the design-build arena or the seasoned design-builders.

Sherif Hashem is a formal co-author of PMI's Project, Program and Portfolio Management global standards. He is a graduate of Alexandria University and holder of a BSc, MSc, and PhD in Civil Engineering. Dr. Hashem has authored numerous papers and articles on design-build and project management published in the United States, Brazil, and the Middle East.

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