DESIGN REVIEW

# Constructing Quality

## 5 key steps for building an effective design review

by Akhilesh Manchanda

## Just the Facts

- Insufficient information, poorly managed inputs and lack of resolution of conflicting requirements in designs could lead to disasters. That's why one of the most important activities to realize a reliable and sustainable asset is an effective engineering design review.
- An effective design review process enhances a project's probability of succeeding and ensures a reliable asset that meets applicable requirements.

Industrial disasters deteriorate public confidence in the assets that are built to serve communities. Commercial buildings, pipelines, bridges, production facilities and nuclear reactors, for example, must be safe and reliable.

Large and complex capital projects generally contain many potential failure modes. The success of these projects relies on the desired outcome of a combination of resources that include the competency of personnel, application of specifications and standards, or material used.

In the construction industry, increased public scrutiny and a greater project presence from regulators are becoming the new norm. The goal of a construction organization should be to not only reassure the public, but also revive its overall confidence in the organization's asset. This is accomplished by becoming a high-reliability organization and actively managing any associated financial and reputational risks.

The overall success of a capital construction project greatly depends on the engineering designs provided to the construction team. As cited by Randell Goodden, "Engineering design reviews are vital, probably the most important first step in a construction project's life cycle and the least expensive stage to incorporate a change."[1]

Post-failure investigations highlight where a process control or barrier was missing or failed at detecting or preventing the contributing factors. When a problem arises, the issue often is tracked back to the design or ineffective design review processes that might have contributed to field failures.

It's essential to perform design reviews at various stages of a construction project's life cycle or phases. An effective review reduces work effort while minimizing the gap between bidding and construction drawings and requiring fewer requests for information and project change orders. It also could save the organization significant time and money.

The ultimate onus for designers is to not just engineer the asset as specified by the client, but also develop a design that ensures reliability and sustainability for the life of the asset. In many circumstances, it makes sense to perform reliability and safety analyses during design review activities.

This article provides an overview of the design review definition, method, planning, design review stages, team selection and facilitation, and five key steps for an effective design review.

## Definition

A few definitions of "design review" can be found online, but I prefer this one:

A process of performing systematic, comprehensive design critique activities that determine design capability in meeting client and regulatory requirements.

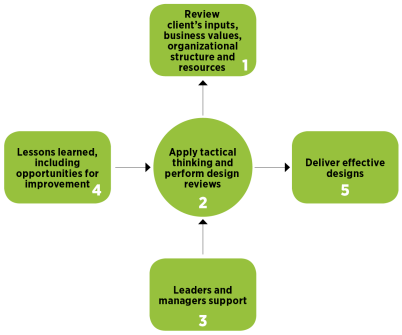
This includes analyzing the specified material and associated processes, which allows you to construct reliable assets while operating them safely and maintaining them economically.

## Method

As shown in Online Figure 1, leaders must emphasize constancy of purpose by establishing and communicating a clear method for planning and performing design reviews that include:

ONLINE FIGURE 1

**Method**




Online Figure 1

1. **Client inputs:** An upfront clear understanding of client values and needs, and their classification—such as safety, stated, real, perceived and cultural needs, and needs traceable to unintended use—is necessary.[2] After values and needs have been identified, consolidate the requirements, including values, structure and resources, and establish a focused approach to accomplishing targeted results.

2. **Tactical thinking:** While maintaining alignment with the overall strategic direction, tactical thinking establishes meaningful plans and design review methods. For example, a design review plan serves the stakeholders and establishes the mode of communication for disseminating information to the design team and other stakeholders. It emphasizes design review creativity and innovation.

3. **Management support:** Demonstrated commitment from leaders and ongoing managerial support are vital.

4. **Lessons learned:** Validating the existing design by deploying lessons learned and leveraging strengths and opportunities for improvement is the foundation for this exercise. Optimize results by collecting a maximum number of inputs and sharing them with the design review team early in the process.

5. **Effective designs:** An effective and optimized design that meets specified requirements and facilitates methods to realize a reliable asset is the design review team's primary goal.

A systematic, structured approach with a focus on applying the plan-do-study-act or plan-do-check-act cycle at every stage of the design review process enhances the consistency of reliable designs.

## Planning

A design review plan should include a brief description of the project's scope and objectives, the design review process steps and a list of applicable specifications and standards, subject to the scope of work.

It also should include a proposed agenda and an overview of the process while highlighting the expectations of participants, including the facilitator, managers and leaders, and the client representative's roles and responsibilities.

The guideline must be established to ensure a systematic, structured and effective design review.

The design review shouldn't focus just on the associated risks and hazards of the asset. It also should be considered an opportunity to ensure several key factors that contribute to a robust design. These factors are depicted in Figure 1. Formalizing a checklist with assigned responsibilities and control barriers for each contributing factor facilitates an effective design review process.

FIGURE 1

**Contributing factors to realize an effective design**

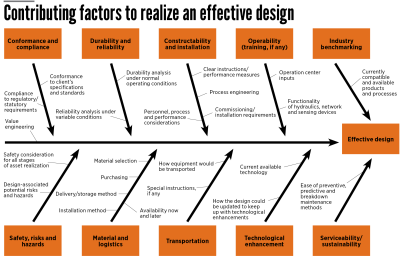



Figure 1

A thought process based on the overall function of an asset and how it will be constructed, operated and maintained could help simplify requirements. Along with a typical review, this functional analysis provides exceptional benefits to the outcome—the design.

While developing the iPhone, for example, Steve Jobs obsessed about what could mess up the phones.[3] Like Jobs, designers should be passionate and obsessed with visualizing potential failure modes and working toward subsequent prevention and mitigation activities.

Identifying potential risks and eliminating or mitigating them in the formalized design review process must be part of the design team's core responsibilities.

## Design review stages

Based on the complexity, magnitude and timeframe of the project, design review stages can be planned and performed during the project's life cycle while considering that cost of quality increases at subsequent stages. It is essential to consider potential failure modes and respective proactive actions to mitigate the risk of failure at every design review stage. The information can be compiled, as shown in Table 1.

TABLE 1

**Design review focus areas**

| Design review focus area | Potential failure modes | Recommended proactive action |
|---|---|---|
| Conceptual design | • Scope and criteria are not clearly defined.<br>• Constraints or challenges are not foreseen. | • Engage stakeholders, understand background and drive maximum clarity upfront.<br>• Simulate challenging conditions/scenarios, develop a plan to address them. |
| FEED review | • Unclear concept—lack of specific details. | • Collect specific details within the scope and review them with designers prior to starting the work. |
| Detailed design work | • Lack of workforce competency. | • Define and ensure required competency for each position. |
| Interdisciplinary review | • Reviews are done in silos.<br>• Lack of external subject matter experts (SME) where the organization has limitation in competency. | • Conduct cross-functional review sessions and ensure conformance to client's requirements.<br>• Identify internal competency gaps, prequalify external SMEs to fill the gaps and ensure their availability at the time of the review. |
| Drawing/design approval | • Approved without verification. | • Verify design based on inputs and required outcome prior to approving the drawing/design. |
| Post-construction review | • Concerned personnel were not engaged.<br>• Lack of traction and interest as the construction team is ready to move on to different projects. | • For an effective review, ensure availability of construction crew members that worked on the project.<br>• Formalize this requirement as a mandatory deliverable for project closeout documentation. |
| All of the above | • Lack of consideration of past lessons learned. | • Compile a list of relevant lessons learned to close the loop with upstream processes. |

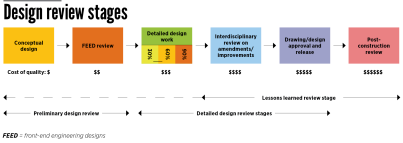
*FEED – front-end engineering designs*

Table 1

There are three primary design review stages (see Online Figure 2):

ONLINE FIGURE 2

**Design review stages**




*FEED – front-end engineering designs*

Online Figure 2

1. **Preliminary design review.** This stage of the design review covers conceptual designs and front-end engineering designs. Typically, the objective is to frame needs, resources, proposed design capability, and regulatory, statutory and asset realization requirements.

   Analyzing the design review results identifies areas of concern regarding design reliability, material, quality, specification compliance, the environment and any other vital points that could adversely affect the asset's integrity.

   This type of design review is conducted primarily by project sponsors, managers, client representatives and any other concerned personnel who could provide insight to enhance the design.

2. **Detailed design review.** This stage starts with developing detailed engineering drawings with planned design reviews usually scheduled at intervals of 30%, 60% and 90% design completion.

   A focused checklist for each review is developed in conjunction with design stakeholders and used to minimize changes at subsequent stages. Some projects may evaluate the risks and combine 30% and 60% design completion reviews.

   An effective interdisciplinary peer review or squad check process ensures that, based on design review inputs, all the required amendments are incorporated and such amendments do not adversely affect the design—that is, they conform with all applicable requirements.

3. **Lessons learned review.** Each effective design review provides significant lessons learned, which are fed back into the design review process with an ongoing mechanism to incorporate improvements. They also can be used to facilitate the enhancement of checklists used in the detailed design review.

Lessons learned typically are collected during and after interdisciplinary reviews, design approvals and construction phases. However, it's prudent to establish a mechanism that starts collecting lessons from the conceptual design forward. Engineering personnel, in consultation with respective client representatives, consider such improvement points for possible implementation in other in-progress projects.

It's important to collect lessons learned when the experience is still fresh in the participants' minds. This is an opportunity to evaluate applied efforts and accomplishments against planned activities.

Based on lessons learned during the project, an assigned action list must be developed and used to repeat optimized successful results and improve for the next time. A decision based on insufficient information is counter-productive at any stage of the design review process.

## Team selection

Team size varies based on the complexity and magnitude of the project. For an effective design review process, it's important to form a competitive team with defined roles, responsibilities and objectives.

Typically, engineering design reviews are performed among the design team lead, management, subject matter experts (SME) and client representatives.[4] Occasionally, SMEs also are part of the client's review team. Team members are chosen based on their technical competency, but understanding and visualizing the asset in action, interpretation and communication skills, and understanding regulatory requirements are equally important.

The team must be comprised of members who possess the required experience and skills of the various related departments, functions and disciplines. A typical roster includes representatives from numerous groups and functions, as shown in Figure 2. Others are involved based on required expertise that could add value to the design being reviewed, such as a project quality representative, material/equipment supplier representative and nondestructive testing representative.

FIGURE 2
**Team roster**


Figure 2

The design review plan establishes the team formalization process and, more importantly, the expected contribution from each team member, required outcomes and performance standards.

Design review participants must be competitive, innovative and firm when conducting design improvements. If functional representation isn't feasible at the time of the design review, provisions and necessary controls are established to involve concerned personnel prior to design approval and release. Compromising on any required design aspect may be costly at a later stage of the project or asset life cycle.

To realize timely reviews and collaborative contributions from the client's personnel, design reviews can be completed in sequential steps based on the availability of design deliverables, such as civil, structural, mechanical, electrical, instrumentation and process engineering design packages.

The design review facilitator, assigned by management, plays an active role in ensuring the successful completion of the process and is responsible for key activities, such as:

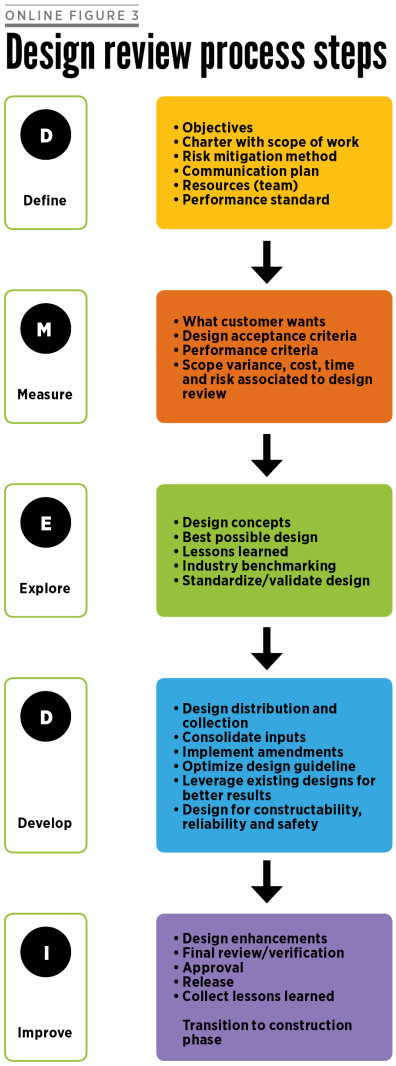
- Determining the scope, objectives and unique ID for each design review.
- Establishing a design review plan, agenda and schedule in consultation with team members.
- Informing or explaining to team members the process.
- Ensuring team member availability and communicating expectations to stakeholders.
- Sending formal design review packages to reviewers and participants with clearly defined expectations.
- Collecting and compiling off-site preliminary reviewed design packages. (A web-based data distribution and collection system is an efficient way to achieve this.)

- Arranging the facility with required audio/video, phone, Skype, telepresence and network connection support, and in an efficient and logical layout.
- Preparing participants' attendance (sign-in) and post-review feedback sheets.
- Ensuring availability of required specifications, standards and software.
- Keeping participants informed about timelines and deliverables.
- Compiling input points and engaging personnel for design amendments.
- Preparing and distributing meeting minutes and following up on any action items.[5]

## Steps for successful design review

For an effective design review, follow this five-step design review process (see Online Figure 3):

ONLINE FIGURE 3




Online Figure 3

1. **Define:**
   - Objectives—What are you trying to accomplish?
   - A design review charter—A high-level description of the process, including what will be reviewed and where.
   - A risk mitigation method or strategy that will be applied to identified concerns.
   - The plan for conducting the review.
   - Any required resources, including team members, and who should be engaged, including their roles and responsibilities.
   - The performance standard, such as zero errors on regulatory requirements.

2. **Measure** the design by determining performance acceptance criteria. How will performance be evaluated? Also determine what the client wants—deliverables using applicable codes, specifications, standards or specific

requirements. Prioritize the client wants to evaluate associated risk during the design review and determine the provisions to measure scope variance, cost, time and associated risk for conducting the design review.

3. **Explore** design concepts and solutions. Copy and paste is becoming a common practice, but sometimes a better design can be instilled by challenging orthodoxies. Explore other possible avenues. Be creative and aim for the best possible or most robust design. Identify lessons learned using past projects as input. Is there industrial benchmarking available for the scope of work? Is it prudent to incorporate the same or similar practices in the design being reviewed? Check the avail-ability of standardized and validated designs for the specific scope of work. Is there a need to amend a standardized or validated design?

4. **Develop** web-based data, design distribution and a comments collection system. Develop a method for performing the design review and consolidate the amendments required for enhancing the design. Develop a suggested improvement implementation tracking mechanism. Establish a plan and guidelines for an optimized design. Leverage previous designs for better results using lessons learned from existing asset performance, including maintenance data, and incorporate them into current assets. Focus on designs for reliability, safety and constructability while reducing complexities. Remember: A robust design won't serve its purpose if it can't be constructed or commissioned.

5. **Implement and improve** reviewed designs. Ensure they are amended or improved to meet requirements. Establish a final review and design verification process to ensure all required amendments are incorporated. An appropriate design approval and release function should be a line of defense against design errors. Finally, establish a mechanism for regularly collecting and implementing lessons learned for continual improvement.

Establishing key performance indicators and metrics with respect to subject areas, such as civil, mechanical and electrical, will further improve the process's efficiency and effectiveness.

## Compiling comments

A cohesive, collaborative approach helps accomplish design review objectives. Design reviews may be supplemented with technology, such as a computerized simulation or tracking system.

An expected outcome of the design review process is a set of required amendments to enhance the effectiveness of the design, as shown in Table 2. However, it is not uncommon for there to be conflicting improvement points. Consolidating and analyzing such inputs prior to implementation is vital to ensuring regulatory or statutory requirements aren't compromised, and that any potential or high-lighted risks are evaluated with a subsequent mitigation plan developed and applied accordingly.

TABLE 2

**Required amendments and action plan**

| ID | Identified gap | Risk ranking | Planned action to mitigate/eliminate risk | Discipline (level 1) | Classification (level 2) | Responsibility (title/name) | Target completion date |
|---|---|---|---|---|---|---|---|
| E1 | Drawing No. 541, Rev. 1, does not meet CSA CEC 2018 C22.1-18 | High | Revise main and associated drawings to meet code requirements | Electrical | Cable trays | Electrical department head | 01/01/20 |
| C1 | Concrete design parameters are not referenced on drawing No. 786, Rev. 2.2 | Low | Review and update respective drawings with reference to applied concrete design specifications | Civil | Concrete design | Civil engineer | 02/25/20 |
| C2 | Cantilever length (CL3) is longer 2 cm in drawing No. 2354, Rev. 01 | Medium | Verify client's requirements and correct the required length | Civil | Dimensional Error | Civil engineer | 02/21/20 |

*CSA* = Canadian Standards Association *CEC* = Canadian Electrical Code

Table 2

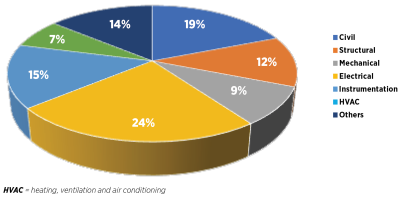
A clear decision-making process is needed, and a competent individual must hold the authority to approve and release the design, especially if fiscal or schedule impacts are foreseen. An integration task force determines the relevancy and appropriateness of prioritized conflicting inputs that must be addressed.

A formal approach to establishing a comprehensive list of required amendments, issue resolutions, identified risks, responsible parties, target dates and verification methods significantly contributes to a successful design review. Effective design review is a prevention cost and may help significantly reduce failure costs at the construction, commissioning and operation phases. The process also can be objective evidence for design verifications, as required by ISO 9001:2015, clause 8.3.4.[6]

## Performance metrics

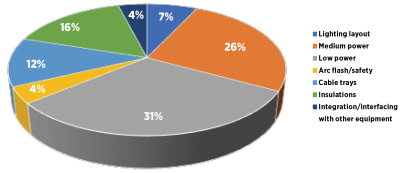
After collecting required inputs, the facilitator—in conjunction with the design team—summarizes improvement points and prepares a report for management. The report should include a discipline (Online Figure 4) and classification (Online Figure 5) of highlighted improve points.

ONLINE FIGURE 4




Online Figure 4

ONLINE FIGURE 5




Online Figure 5

A radar diagram showing the status of post-design review information based on survey feedback from participants provides considerable inputs to enhance the process. For example, the diagram in Figure 3 shows the following:

FIGURE 3

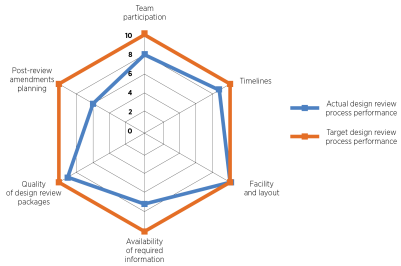



Figure 3

- Team participation was at 80%.
- Half of the participants were dissatisfied with post-review amendments planning.
- Facility and layout secured a perfect score.
- Quality of design review packages and availability of required information must be improved.

To add value, improvements can be made to the selection of performance indicators for the design review process, as well as the appropriate tool to reflect associated results.

## Ensuring success

Formal, documented design reviews ensure a conforming and compliant design that will be used to develop an asset.

An effective design review process enhances a project's probability of succeeding, as well as realizing significant benefits and becoming a reliable asset that meets all of the applicable requirements as it becomes available for service.

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## References

1. Randall Goodden, presentation, ASQ World Conference on Quality and Improvement, Pittsburgh, May 16, 2011.
2. Joseph M. Juran, *Juran on Quality by Design: The New Steps for Planning Quality Into Goods and Services*, Free Press, 1992, pp. 71-78.
3. Walter Isaacson, *Steve Jobs*, Simon & Schuster, 2011, p. 465.
4. Tom Gilb, "Talking Points: Rule-Based Design Reviews," *Software Quality Professional*, Vol. 7, No. 1, 2004, pp. 4-13.
5. "Design Reviews," https://tinyurl.com/y244zrvr.

6. International Organization for Standardization (ISO), *ISO 9001:2015—Quality management systems—Requirements*, clause 8.3.4.

## Bibliograpohy

Bliley Technologies, "5 Simple Steps for Truly Effective Design Reviews," https://blog.bliley.com/5-simple-steps-for-truly-effective-design-reviews, June 20, 2016.

Drewien, Celeste A., Georgia Artery, Ken Eras, William Ballard and John F. Nagel Jr., "Effective System Engineering Peer Reviews," conference paper, Sandia National Laboratories, www.osti.gov/servlets/purl/1331669, 2014.

Gopalaswamy, Smita and Venky Gopalaswami, *Combination Products: Regulatory Challenges and Successful Product Development*, CRC Press, 2008.

International Organization for Standardization (ISO), *ISO 9001:2015—Quality management systems—Requirements*.

ISO and International Accreditation Forum, "ISO 9001 Auditing Practices Group Guidance on: Design and Development Process," https://tinyurl.com/y244xk5e.

NCC Group, "Technical Design Review," https://tinyurl.com/y44fnbow, March 2015.

Parham, Derek, "Strengthening Products and Teams With Technical Design Reviews," *Medium*, https://medium.com/git-out-the-vote/strengthening-products-and-teams-with-technical-design-reviews-ae6a1bec5216, Oct. 8, 2016.

Ploeg, Heidi-Lynn, "Engineering Design Review Guidelines," University of Wisconsin-Madison.

Spillinger, Ralph S., and the Federal Facilities Council, *Adding Value to the Facility Acquisition Process: Best Practices for Reviewing Facility Designs*, National Academy Press, 2000.

Tang, Kwei, and Jen Tang, "Design of Screening Procedures: A Review," *Journal of Quality Technology*, Vol. 26, No. 3, 1994, pp. 209-226.

UCAR Software Engineering Assembly, "Design Reviews," https://sea.ucar.edu/best-practices/design-review.

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