

Quality Assurance in Construction as a Sustainability Approach

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ABSTRACT

The purpose of Quality management is to provide a common focus for all employees, so that individuals with different tasks, abilities and priorities are able to communicate in pursuit of a common organizational goal (Wilkinson, 1992). Typically, this focus is upon providing quality management. Environmentally sustainable building construction has experienced significant growth during the past 10 years. In today's world, the definition of quality has been extended to more comprehensive level, which also comprises sustainable performance. The paper systematically builds an integrated model that includes quality as well as sustainable performance of the built environment and accompanying construction processes. This model for the "Quality Assurance in Construction as a Sustainability Approach" presents a three-level arrangement, namely: the structure, process/ project, and construction product, the built environment's impact on greenhouse gas emissions and natural resource consumption. Other factors, including higher energy prices, increased costs of building materials, and regulatory incentives, are also pushing the green building market to grow and expand. The management philosophy of Edwards Deming is teaching managers to look more closely at how they affect all of the outcomes that their workers produce systems thinking, the concept of variation, psychology and the theory of knowledge. However, barriers to green building continue to exist, including the ability to deliver a green project within acceptable cost constraints. In order for project managers to deliver sustainable construction according to clients' cost expectations, modifications must be made to traditional project management processes and practices. The objective of this paper is to suggest specific modifications to conventional building practices to optimize the delivery of cost-efficient green building projects. This paper presents an overview of research related to the costs and trends of green building and uses these research findings to make recommendations for greening project management practices for the construction industry. Our research results show that greening project management practices can add significant value to a sustainable construction project while delivering it within acceptable cost constraints.

Keywords: Construction Management, Quality Assurance, Energy Savings

INTRODUCTION

The design and construction of a building differs significantly in many ways from the design and manufacture of products. It is important to appreciate some essential differences with regard to quality in building (Griffith, 1990). Almost all construction projects are 'unique' with the building process representing a single production run. The construction site is "individual" in terms of its temporary environment the life cycle of a construction project, from inception to completion, extends beyond the manufacturing cycle and also tends to evolve and develop through time.

Considerable mobility of design and construction staff precludes the development of long-term production teams and each construction site is likely to have different team members.

Today's most widely accepted definition of quality proposed by Crosby (1979) as "conformance to requirements" is also incorporated into the present standard dealing with quality ISO 9001 (2008). However, the concept of quality in construction is rather involved, because it demands the fulfillment of both explicit and implicit requirements/needs, and it needs to be assessed from the viewpoint of the product (structure) or the process (construction project). In addition, one should be aware that quality has a multidisciplinary nature; therefore, different approaches may be required for its analysis and treatment.

To assess quality for the whole structure, the basic requirements defined already by (function, structure/durability, and aesthetics) (O' Gorman 1998) have to be fulfilled. In addition to these requirements, various stakeholders may have additional ones. Here, it should be kept in mind that a structure is used for a longer period of time, and that there is a great probability that these requirements may be changed over time, especially during the operation and maintenance stage. Conformance to the specified requirements for the structure is ensured by

- designing the structure in accordance to appropriate rules (*EN Eurocodes 2010*);
- using construction products (that are permanently built in the structure during the construction process) that conform to the relevant specifications (*Council Directive 89/106 1989*);
- Proper execution of construction work conforming to relevant standards.

The growing awareness of sustainable construction's potential to positively impact environmental issues is pushing green building to the forefront. As a result, more local governments are adopting green building standards and regulations or providing permitting and financial incentives for sustainable development. Research data show dramatic increases in the number of development projects seeking environmental certification, indicating that the demand for green construction is also on the rise (*U.S. Green Building Council 2006a,b*),

After presenting an overview of green building construction, we provide an extensive review of literature, case studies, and research to prove that cost is the most significant constraint when building green. We then analyze how modifying traditional project management practices can contain the risk of inflated costs associated with green building. These results are summarized in a matrix showing where in the project management life cycle adjustments must be made in order to deliver a successful green building project. Further, we highlight specific green management practices, with detailed information for implementation.

Extending the concept of quality to sustainability performance

In the contemporary world, the awareness of the importance of sustainable development is increasing ever since a global framework for environmental activities was provided first by the so-called Brundtland report (*Our common future ... 1987*). Consequently, the implementation of principles of sustainable development is today one of the fundamental goals of EU policies. Since 1987, the concept of sustainable development has been extended from purely environmental concerns to also include those related to social and economic issues. Today, these three pillars - environmental, social and economic, are considered to have equal importance.

This is especially valid for the construction sector, where the built environment is its generalized product, and which has large impacts in all three areas of sustainability. Worldwide, estimates indicate that approximately 40% of the total energy consumed, 40% of all the waste produced, and 40% of all virgin raw materials consumed are associated with the construction sector. In today's world, only the total production of petrous materials has larger consumption of water than that of construction (*Šelih 2007*). In addition, built environment provides infrastructure for humans and substantially contributes to the quality of human life.

The environmental and social effects of the built environment are clearly large. Economics influences construction by demanding for cost efficient buildings and other structures, where cost efficacy is required in construction as well as in the operation and maintenance stages. In construction, it is apparent that in addition to achieving conformity to the requirements related to the quality of the built environment, sustainable development should be a primary goal; and in this regard, the scope of quality should encompass sustainability. Therefore, a sustainable component needs to complement the goals of the traditional construction project.

Establishing awareness

Quality Assurance becomes understood within the construction industry, the requirements for independent recognition and certification of quality assurance systems will increase (*Griffith, 1990*). Quality assurance must be introduced with the understanding, enthusiasm and commitment of top management, starting with the chief executive. There can really be no other way (*Thorpe, Sumner & Duncan, 1996*).

Commitment by management is an essential step without it; there is no need to go further. The chief executive officer (CEO) may not yet be ready to make a personal commitment to change. Equating change without allowing others to make decisions so long as they are the same as the ones the chief executive officer (CEO) would make does not equal to a commitment to change. Another common symptom of lack of personal commitment is when the chief executive officer proclaims commitment to quality assurance.

The discerning executive will be aware that pressure for quality assurance is building up because those who are placing contracts for work are realizing more and more that the prospects of getting things done properly, to program and costs, are greater when the contractor or supplier operates sound management and control systems recognizing quality standards such as ISO 9000. In other words, the main incentive to adopt quality assurance is the improvement of business performance (*Thorpe, 1996*).

Quality assessment in construction

In what concerns the structure, all parties must ensure that quality is satisfied in all stages of its life cycle: inception, design, execution, operation and maintenance, and end-of-life. If the life cycle approach is not used, the structure does not meet the requirements of all stakeholders involved, and consequently the perception, rightly or not, is that structure fails in what quality is concerned (*Leonovič, Kaševskaja 2007*); under these circumstances, and on an environmental perspective, it is possible the occurrence of burdens, which may shift from one stage to another, when deciding on different options (*Braune et al. 2007*).

Quality of the structure depends first on the successful identification of the requirements provided by various stakeholders: clients, developers, owners, users, tenants, public (represented in various ways, e.g. NGOs), and (finally yet importantly) governmental bodies. In addition, these governmental bodies provide additional requirements and grant permissions for the planned structure at various stages of the construction project, from the conceptual design to the final approval for the structure. The project brief, as the first document where the basic requirements of the client are collected, should be prepared with great care, and it should deal with the planned structure from different perspectives. All stakeholders should receive this document, and they should express clearly and unambiguously the additional requirements and changes that may have. In the pre-tendering stage, the client (or his agent) should ensure the requirements (scope, quality level, timeframe, and costs) are fully understood by the potential tenderers (*Hellard 1993*).

Green Building

A variety of terms are used to mean “green” in the construction industry, including green building, sustainable design, high performance building, whole building design, sustainable building, and integrated design. Theoretically, this collection of industry terms represents a movement taking place over the past 40 years to change the way we understand building architecture, design, construction, use, and decommission. As Kibert *_2005_* stated, “buildings are predominant artifacts of modern society . . . important cultural symbols” that impact vast populations based on their “design, materials, color, location, and function.” With the environmental progress of the 1970s and the green building movement of the 1990s, sustainable building practices can be characterized as a broad and far-reaching cultural evolution of society’s relationship to the built environment.

There is no single, widely accepted definition for green building, but a survey of definitions reveals many common threads. Table 1 presents an abbreviated comparison of green building definitions from a variety of sources.

Using the culmination of these resources, we define green building - also referred to as sustainable design, sustainable construction, and other terms previously listed - as a philosophy and associated project and construction management practices that seek to:

- Minimize or eliminate impacts on the environment, natural resources, and nonrenewable energy sources to promote the sustainability of the built environment;
- Enhance the health, wellbeing and productivity of occupants and whole communities;
- Cultivate economic development and financial returns for developers and whole communities;
- Apply life cycle approaches to community planning and development.

Quality management

Quality management is a key element of project management. It involves carrying out a project through its four phases (concept, development, execution, and finish) with zero deviations from the project specifications. The environment necessary to support this effort must focus on quality policies, plans, procedures, programs, and specifications.

The quality management function is the process of ensuring that all aspects of project and its results fully meet the needs and expectations of the project’s client, participants and shareholders-both internally (relating to the project’s systems of development), and externally (relating to the project’s performance or service). A quality management System is defined in BS 4778 as: The organization structure, responsibilities, activities, resources and events that together provide organized procedures and methods of implementation to ensure the capability of the firm to meet quality requirements (*Griffith, 1990*). Quality management, in simple terms is “that aspect of the overall management function that determines and implements the Quality Policy” (*Hellard, 1993*). Quality Management Systems and Quality Assurance should be instinctive aspect of the building process. During the 1950’s, Deming introduced his ideas about Deming’s “system” view of quality management to develop a framework for a detailed assessment of the organization (*Deming, 1986*). Deming introduced his ideas to Japanese industrialists using a graphic illustration of a delivery system commonly referred to as the Deming Flow Diagram shown in Figure (1-1). Deming’s flow diagram represented his view of the processes and interactions associated with the design and production of a product.

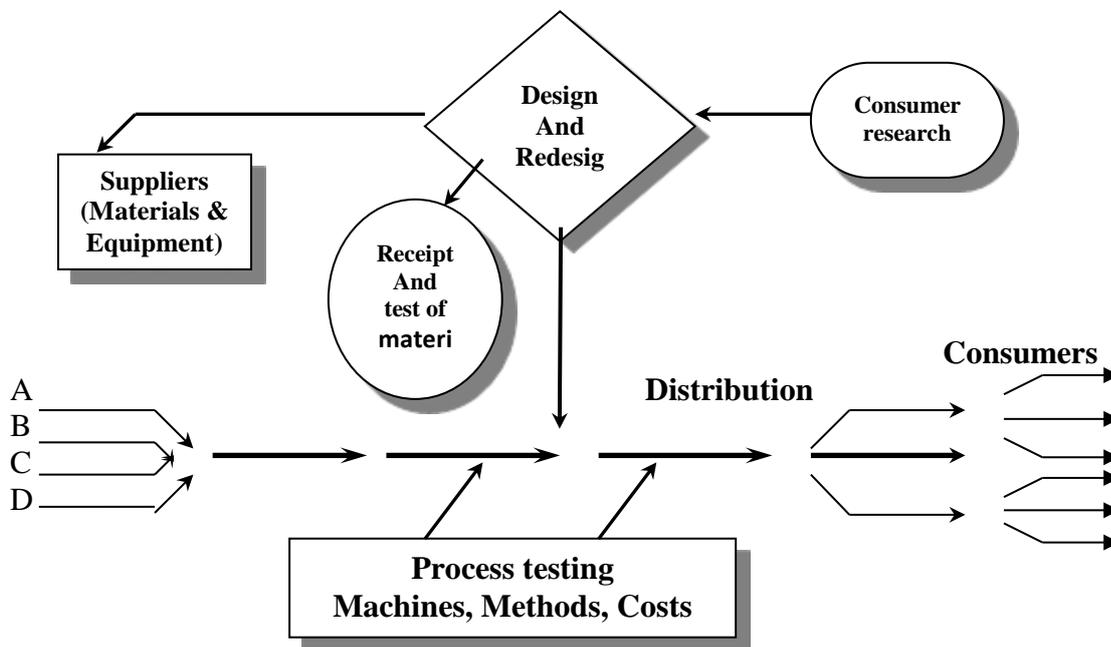


Figure (1-1) Edward Deming’s Flow Diagram Supporting a System’s View of Quality Management.

On the left, multiple suppliers provide “input” that is, the raw materials necessary to manufacture of the product. The mainline processes shown along the spine of the diagram include production, assembly, and inspection. The system tracks the distribution of the product or output to the consumer, the ultimate “consumer” of the manufacturing process. Consumer research provides constructive feedback to improve the processes and the product through design and redesign efforts.

Total Quality Management (TQM)

Total Quality Management (TQM) evolved as a flexible, comprehensive Management philosophy suitable for a wide range of applications in many different setting, whether

overseas or in the United States, organizations in manufacturing, service, and construction have successfully adopted TQM principles and concepts.

Table (1-1).The Evaluation of Quality Management (Main Differences)

Identify characteristics	Inspection	Quality Control	Quality Assurance	Total Quality Management
Primary concern	Detection	Control	Coordination	Strategic impact
View of quality	A problem to be solved	A problem to be solved	A problem to be solved, but one that is attacked proactively	A competitive opportunity
Emphasis	Product uniformity	Product uniformity with reduced inspection	The entire production chain, from design to market, and the contribution of all functional groups especially designers, to preventing quality failures.	The market and consumer needs.
Methods	Gauging and measurement.	Statistical tools and techniques.	Programs and systems.	Strategic planning, and mobilizing the organization.
Role of quality professionals.	Inspection, sorting counting, and grading.	Troubleshooting and the application of statistical methods	Quality measurement, quality planning, and program design.	Education and training, consultative work with other departments, and program design.
Who has responsibility for quality?	The inspection department.	The manufacturing and engineering departments.	All departments, although top management is only peripherally involved in designing, planning, and Executing quality policies.	Everyone in the organization, with top management exercising strong leadership.
Orientation and approach	Inspects in quality	Controls in quality	Builds in quality	Manages in quality

Today, construction firms feel quite welcome to adjust TQM; redefining and shaping its application to capture the uniqueness of their organizational needs and wants. Current definitions range from the conciseness of the Federal Quality Institute that defines TQM as a strategic, integrated management system for achieving customer satisfaction (*How to, 1990*).

Total Quality Management (TQM) is both a philosophy and a set of guiding principles that represent the foundation of a continuously improving organization. TQM is the application of quantitative methods and human resources to improve the material and services supplied to an organization, all the processes within an organization, and the degree to which the needs of the customer are met, now and in the future. TQM integrates fundamental management

techniques, existing improvement efforts, and technical tools under a disciplined approach focused on continued improvement (*Volume 1, 1991*).

Successful TQM implementation results from an integrated, collective effort among all levels of a company to increase customer satisfaction by continuously improving current performance. Acceptance of TQM principles from job site workers to senior executives creates an organizational perspective that focuses on process improvement, customer and supplier involvement, participate leadership, teamwork, and training and education in a deliberate effort to achieve customer satisfaction, cost effectiveness, and defect free work (*Matthews, and Burati, 1989*).

There have been four levels in the evolution of quality management. The four levels are inspection, quality control (QC), quality assurance (QA), and total quality management (TQM) (*Dale, B.G., and Plunkett, J.L.1990*).

The four levels in the evolution of quality management as given by B.G.Dale are shown in figure (1-1) (Edward Deming's flow Diagram supporting a system's view of Quality Management). Table (1-1) shows the main differences between the four levels in the evolution of quality management.

Quality standards:

Since 1979, mainly due initially to the requirements, the construction industry has gradually adopted ISO 9000 for use by its main construction contractors, subcontractors and suppliers. It is interesting to look at the three parts of ISO 9000 and see how they are applicable to the construction industry.

ISO 9001: is the most onerous of the quality assurance standards, it covers "design", therefore any organization involved in conceptual design which was setting up a quality assurance system would set up its management system to meet ISO 9001 (*Brian, Peter, and John, 1996*). This specification would apply to large building and civil companies carrying out their own design, to design consultants, architects and so on.

ISO 9002: this is the standard applicable to manufacturing or installation organization, ISO 9002 demands process control and therefore would apply to many construction contractors where evidence of inter stage inspections and tests has to be given to the client, for instance (*Brian, Peter and John, 1996*):

- Construction of form work and false work
- Placing concrete
- Manufacturing of precast concrete blocks
- Laying damp – proof membranes
- Building structures where there are hold points for inspections and checks at vary stages.

In ISO 9003 the nature of the product or service does not require a documented system to cover in process controls but ISO 9003 could typically apply to the product areas (*Brian, Peter and John, 1996*):

- manufacturing of machined components
- manufacturing of galvanized duct work
- building of a non-load bearing brick wall
- laying of roofing tiles

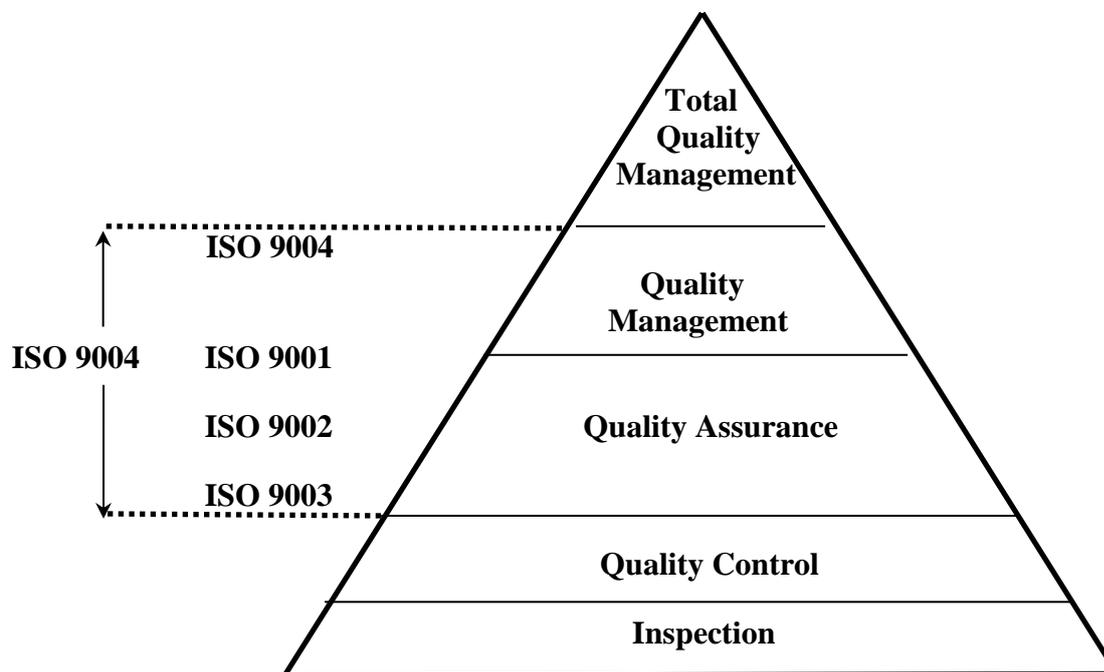


Figure 1-2 Level of Quality Commitment.(Paul, 1996)

Interpretation of ISO 9000 because ISO 9000 is a standard which can equally be applied to the manufacturing industry, it can be interpreted in different ways by different sectors. There is a family of quality standards working in unison that enables an organization to develop a quality management/quality assurance system. Figure 2-3 illustrates the levels of an organization's quality commitment and demonstrates the levels where the ISO 9000 standards apply within this framework.

Management Responsibility

The responsibility for establishing and formally defining the quality policy and objectives is placed clearly with management (with executive responsibility). This further requires management to ensure that the policy and objectives are understood all levels. Management can ensure that the system is being applied continually and effectively in several ways.

There is a quality loop in management responsibility that addresses customer expectations and organizational needs. It starts with the quality policy that addresses the goals and objectives of the organization, which leads the organization responsibility and authority to carry out these quality policy goals. Resources and trained personnel are essential to the implementation and continued success of the quality system. A management representative is essential to act as liaison between executive management and the quality system. A documented quality system is the foundation on which the organization operates. The quality system is measured by internal quality audits and customer feedback. Corrective and preventive actions are implemented to correct and improve the quality system. Scheduled

reviews by executive management ensure the measurement of the quality system for suitability and effectiveness and make sure that the goals and objectives of the quality policy are being addressed (Nee, 1996).

Design Phase

The design phase is the most comprehensively addressed portion of the life cycle in most sustainable building guidelines and evaluation methods. The areas of the design phase that will be compared relate to energy efficiency, water efficiency, indoor environment, site location, material usage, and atmospheric considerations. Each of these will be considered in turn. Energy efficiency is easily and intuitively related to sustainable design and is covered by most guidelines and recommendations. All regions have their own standards relating to building energy efficiency. Many sustainable building guides and measurement programs deem a sustainable building as one that provides additional energy savings over minimum local requirements. Our comparison is based on the stringency of different energy usage guidelines, and how these recommendations were determined.

Another area related to the energy efficiency portion of the design process is the implementation and use of renewable or “green” energy sources for sustainable buildings. The types of renewable energy recommended by the various international guidelines vary based on the regional availability of renewable energy sources. Recommendations concerning renewable energy sources will be evaluated based on region, as well as applicable financial incentives or subsidies. Water usage and efficiency guidelines define specific targets and describe various methods and means by which these targets can be achieved.

Our review compares the amounts of water reduction recommended for sustainable buildings, and what each guideline uses as a basis for its water reduction recommendations. Thermal comfort and health aspects of indoor air quality are addressed in the design phase recommendations of different guidelines. This comparison highlights what constitutes an acceptable indoor environment for sustainable buildings. Sustainable site location and selection considerations are evaluated in a number of sustainable building guidelines and methodologies. The various areas concerning sustainable sites include urban sprawl, Brownfield redevelopment, effects on local ecosystems, and interaction with the surrounding built environment. Potential financial incentives available for the development of sustainable sites are also compared and evaluated for various regions.

Material usage includes the selection of materials with recyclable properties, reusable products, and the implementation of recycling procedures throughout building operation. Recommendations for the amount of materials with recycled content are provided in various sustainable guidelines as well as the amount of products that are being functionally reused in a building. The basis for determining the appropriate amount of recyclable material in a product is evaluated, as well as the appropriate amount of reused products recommended for use in sustainable buildings. The recommended amount of recycling recommended during building occupancy is also evaluated for the various standards. Atmospheric considerations are primarily related to the use of ozone-depleting substances during the design of a sustainable building. The emission of greenhouse gases is also considered in the comparison of programs.

Building Construction

The building construction phase of the sustainable building life cycle process encompasses the sustainable practices that are employed during the actual construction process of a building. The sustainable practices that will be evaluated and compared for the construction process are waste management during the construction process, transportation of building construction materials, and the impact of the construction process on the site and surrounding disturbances.

Waste management during the construction process relates to the amount of recyclable material generated during the construction process. Measures should be implemented and work should be sequenced to control the emission of volatile organic compounds and particulates during the construction process, similar to Leadership in Energy and Environmental Design _LEED_ Indoor Environmental Quality credits 3.1 and 3.2. The transportation of building materials relates to maximum recommended travel distances between the construction site and the material supplier. The impact of the construction process on the surrounding environment includes recommendations for the control of storm water runoff and plans for minimal impact on ecological systems in adjacent areas.

Building Operation

Building operation in the life cycle of a sustainable building involves the operation, maintenance, and control of the building systems to maintain the sustainable levels for which they were originally designed. Various international sustainable guidelines and methodologies provide recommendations for the ongoing monitoring of building systems, and also recommend the establishment of commissioning procedures to ensure initial and ongoing performance.

Building Demolition

The final phase in the life cycle of a building is demolition. Sustainable design in this area focuses on recycling and waste management procedures to handle the material waste generated during demolition activities, and on the design of building assemblies and systems to facilitate removal during demolition.

LEED

The LEED rating system was established by the United States Green Building Council as a voluntary rating system to evaluate the environmental performance of a building over the entire life cycle. The building is evaluated over five environmental categories: sustainable sites, water efficiency, energy and atmosphere, indoor environmental quality, and materials and resources. Credits are awarded for satisfying various criteria in the five environmental categories, and different levels of certification can be obtained based on the number of points earned from each credit. The levels of certification a building can receive based on number of points acquired are [United States Green Building Council (USGBC) LEED Reference Package Version 2.0 (USGBC 2001)]:

- Certified=26–32 points;
- Silver=33–38 points;
- Gold=39–51 points; and

- Platinum=52 or more points.

The LEED-NC program for new construction and major renovation building projects is evaluated based on the various building life cycle processes described in the methodology. The LEED program currently has pilot certification programs for existing building operations, commercial interiors or tenant fit-out projects, and building core and shell projects. The development of a LEED home certification program is also underway.

Conclusions

Due to the complexity of the construction project, introducing sustainability assessment into construction practice presents even a bigger challenge as in manufacturing. Each stakeholder, client, designer, contractor and the user, interpret sustainability within a different context and level. The whole construction supply chain can therefore profit from a model that provides systematic guidance on different fields and levels to be tackled. Integration of quality and sustainability performance assessment into a single model, as proposed in this paper, can lead to a more sustainable as well as cost efficient management of the construction project while meeting all project goals.

The commonalities in recommendations identified between programs should be taken into consideration during the planning of sustainable design work regardless of the region of construction. The referenced program materials can be researched further to determine the specific requirements of the region. Designing sustainable buildings depends on consideration of the entire life cycle when implementing sustainable features into designs. Designing for the life cycle of a building will help designers meet the needs of today, without adversely affecting future generations. In addition, the following guidelines should be adopted when pursuing a green construction project:

1. Begin with the end in mind: set specific sustainability goals and project priorities for green building features before initiating design and construction.
2. Integrate the project team: hire the project manager and the key members of the project team early in the project's feasibility stage to ensure collaboration.
3. Design with the whole team approach: all members of the project team should continue to participate in the formal design phase, initial price estimating, and construction document development.
4. Use bonuses and rewards in project contracting: use cost plus- fee arrangement with special clauses to promote efficiency and incorporate incentives and bonuses for implementing sustainable practices and exceeding sustainability goals.
5. Provide for training and communications throughout construction: conduct kickoff and monthly meetings with the entire site workforce, including a sustainable education component in sessions.

The benefits of the integrated design process are essential for the successful delivery of a cost-efficient green construction project. The integrated approach is successful in overcoming a challenge that has impacted development and construction for many years. It can therefore serve as a useful tool for the main targeted audience, the construction clients. The successful implementation of the model requires various measures on all specified levels (construction products, processes/project, and building). The green procurement is receiving high priority today, and the proposed model can constitute an important part of green procurement

schemes, for both public and private clients. In addition, national policies on sustainable development should promote the legislation and accompanying measures that enable full implementation of the integrated quality and sustainability assessment in construction. The developed model is in its present stage limited to buildings; however, there is no particular difficulty in extending it to other construction works.

Finally, the paper has summarized the principal emerging technologies that could assist in achieving a radical step-change in energy performance, identified the need for construction industry up skilling to ensure effective installations, and under- lined the need for better public engagement in energy performance issues.

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