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OPTIMIZING CONSTRUCTION PROJECT LIFESPAN VALUE USING TOTAL QUALITY MANAGEMENT PRINCIPLES

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An effective strategy aligning costs and quality is pivotal for augmenting project value in the construction industry. This study develops and applies a model to evaluate the impact of Total Quality Management (TQM) principles on Egyptian construction projects. Objectives include identifying key TQM principles, quantifying their value, and validating outcomes through a case study. Methodologically, a TQM evaluation model, utilizing the Relative Importance Index (RII) method and validated via Cronbach's alpha, is formulated. A value formula estimates the financial impact of top TQM principles compared to construction project life cycle costs. Applied to a 2023 Egyptian construction project case study, the formula demonstrates cost savings surpassing the required investment. Specifically, project value improved 2.77 times using the created Value Engineering Business Approach (VEBA) formula, translating to an estimated 12.8% reduction in total life cycle costs. This research advocates a data-driven approach to prioritize TQM principles, showcasing positive financial returns for firms and endorsing TQM as an effective framework for the Egyptian construction sector.

Keywords: life cycle cost analysis, quality evaluation, total quality management, value analysis, value engineering, value engineering business approach

1 INTRODUCTION

Success is the ultimate goal of every project and the primary goal for project owners. Studies show that cost, scope, time, quality, and stakeholder satisfaction are the key factors that typically determine a project's success [1]. The quality goal of a construction project is to fulfill the owner's or user's demands while adhering to the defined scope of work, within the confines of a cost-effective plan and a rigorous timeline.

Since 2021, the Egyptian construction industry has witnessed a notable deterioration, evidenced by various key ratios and rates. The sector experienced a decline in new project starts, with the construction start rate reducing by approximately 15% compared to the previous year. Additionally, there was a marked increase in project delays, with on-time delivery rates decreasing by 20%. Moreover, the industry saw a surge in material costs, contributing to a 25% spike in overall project expenses. These adverse trends underscore the Egyptian construction market's challenges, highlighting the need for strategic interventions to improve the industry [2]. Cost, time, quality, and safety are all important project values. Projects must be effectively led by strategic management strategies and procedures to succeed. Several studies have debated how to gauge project success from the perspectives of the participating parties [3].

Intent on contributing by extracting Total Quality Management (TQM) items from the studies, a stratified sample of different construction professionals received a total of 500 questionnaires. Of these, 300 surveys were duly filled out and re-submitted. Regression analysis and mean weighted value were used to determine the weight of the TQM items, utilizing a flexible method that can calculate a percentage for the TQM-weighted items.

Instead of the standard numerator in the VE formula, which is the function (extracted from the Functional Analysis Systems Technique (FAST) diagram), the output value will be the Value Engineering Business Approach (VEBA) as an alternative method. Study every project component from the life cycle cost perspective to determine the true cost, including both construction and actual costs from construction to depreciation. Accordingly, the traditional value formula V=Function/Cost will be developed into VEBA= TQM Business Aspect/(LCCA/construction cost).

2 LITERATURE REVIEW

Since its inception in the industrial sector, the TQM concept has been explored for application in construction projects. However, the diverse nature of each project, the variability in the labor force, the multitude of stakeholders involved, and the impact of various factors such as climatic conditions and legal constraints make implementing this theory in the construction industry exceptionally challenging [4].

A significant change in the systems utilized in the American construction sector was seen in the 1950s, with the construction of towers that included both commercial spaces and residential flats. Due to the rapid growth of the building industry, large quantities of materials were needed to integrate utility distribution linkages. From this point on, there was a need to develop a method known as Value Engineering to be implemented in the process [5].

2.1 Total Quality Management TQM

Total Quality Management (TQM) can be defined as a management approach that relies on employee engagement, is client-centered, and employs effective management techniques. A well-known industry leader who places a high value on quality understands that merely sustaining the current level of perfection is insufficient in today's competitive world [6]. Implementing TQM is a strategic goal. Numerous TQM principles have been effectively applied in various operations. However, the core of TQM lies in individual employee involvement committed to controlling and enhancing performance quality at every level. Consequently, wherever TQM is implemented, numerous benefits will be realized [7].

Eight fundamental principles of comprehensive quality management essential for Egypt's construction sector can be identified. This set of guidelines provides a framework for Egyptian construction businesses to focus their quality control efforts. These principles include the following, as shown in Figure 1.

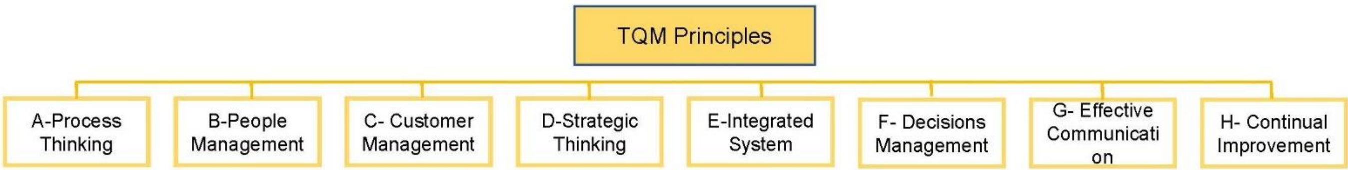

Fig 1. TQM principles [8]

Process Thinking; is a set of actions that converts inputs from project parties (internal or external) into outputs delivered to the project [9]. People Management (Commitment); The project members are eager to acquire new practical and analytical skills. Staff are expected to believe in their capabilities to succeed, receive discipline and direction, and be given time to learn and develop new abilities logically and gradually [10]. TQM Customer Management; Customer satisfaction needs to be evaluated in light of performance objectives. Construction project parameters should be measured and analyzed against the customer's main objectives before the project kicks-off [11]. Strategic and Systematic Thinking; This procedure involves developing a strategic plan with quality as a fundamental element [12]. Integrated System; Establish a work attitude that prioritizes quality above all else, and uses diagrams, graphs, and other visual aids to explain to staff how their duties contribute to the organization's larger goals [13].

Decision-Management; Make informed judgments by consulting reliable historical data and safeguarding prior decisions. Modify past decisions based on data analysis, ensuring the dependability and quality of the data by thoroughly examining and verifying it. Provide relevant information to investors and utilize effective tools to gather and analyze data [14]. Communications management; This process involves actions such as commitment, willingness to change organizational culture, adequate planning, connecting individuals and departments with a compatible organizational structure, effective measurement techniques, and acknowledgement, attention to internal and external clients, teamwork, and empowerment [15]. Continuous Improvement; Implement measures to set quantifiable objectives for individuals, teams, and departments to improve processes and systems. Encourage innovation to enhance development and processes, and motivate staff members to take advantage of available training opportunities [12].

2.2 Life Cycle Cost Analysis LCCA

LCCA can be defined as a system that objectively measures and manages the lifetime costs of any project or asset. It allows for comparing design variants over their entire lifespan in construction, which lowers total costs and enhances depreciation management [16].

In project management, it is essential to distinguish between various types of costs. Investment costs encompass the financial outlay required to evaluate a project's profitability, including expenses associated with implementing the project's financial plan and aligning it with market demands relative to the product's value. Additionally, opportunity costs, which represent the foregone profits from utilizing funds for the project instead of alternative purposes such as servicing bank loan interest, may also be factored into investment-related expenses [17].

Construction costs: are the most economically significant category, constituting over 50% of the total project expenditure. They encompass expenditures on materials, labor, and machinery essential for project initiation or completion. Additionally, construction costs cover management fees, the contractor's profit, and any additional modifications that may arise during the construction process [18].

Operational Costs; These are costs incurred after construction. Examples include energy costs, salaries, maintenance expenses, and replacement expenses. Additionally, operational costs encompass expenses throughout the project's lifecycle, relating to the building's performance and utilization efficiency [19]. Maintenance Costs; refer to both annual and one-time expenses associated with building upkeep, including planned refurbishment or ongoing replacements [20]. Depreciation Costs; These refer to expenses incurred when replacing any component of the project, often related to activities such as painting, equipment replacement, and minor maintenance. Replacements may occur multiple times during the project [21].

2.3 Value Engineering Business Approach VEBA

Value Engineering (VE) can be defined as a systematic approach to optimize the cost and function of a project or product, aiming to increase its overall value. VE assists in achieving improved performance, faster delivery, cost reduction, and enhanced quality [22]. VE passes through five phases, beginning with the Informative Phase, during which the group evaluates and specifies the project's existing situation. Additionally, active verbs and measurable nouns are used to describe the functions of the project. The process involves assessing and studying these functionalities to determine which ones need to be changed, eliminated, or invented to meet the project's goals [23]. The speculative (Creative) Phase is where the team explores additional methods to carry out the function(s) of the project using creative techniques. It also generates alternative options that fulfil project requirements [24].

The Analytical (Evaluation) Phase involves the team employing a systematic evaluation process to identify ideas that could be valuable additions to the project's functions. This phase also considers performance standards and resource restrictions [25]. The Development Phase, involves the group creating alternatives to the chosen ideas, allowing decision-makers to determine whether to proceed with their execution [26]. Final Report (Presentation) Phase; The team leader develops a report and/or presentation that describes and conveys the applicability of the team's alternative(s) and the associated opportunity for value growth [27].

3 MATERIALS AND METHODS

In the quantitative segment of this descriptive-based research, employing the inductive method, the study investigates cases related to Total Quality Management (TQM), Life Cycle Costing (LCC), and Value Engineering (VE) from a business standpoint. In the qualitative segment, insights from the literature review are combined with the Relative Importance Index (RII) technique and Life Cycle Cost Analysis (LCCA) equations. This approach culminates in the formulation of a Value Engineering equation within a business framework to evaluate project value.

3.1 Calculating the TQM evaluation model

To assess the importance of each principle, 300 quality management experts from local and international construction firms operating in Egypt participated, drawing on their professional experience to identify effective indicators, as shown in Table 1. This approach enabled the identification of the most critical Total Quality Management (TQM) concepts for Egypt's construction sector. These findings provide an empirical foundation for prioritizing concepts to enhance quality management in Egyptian construction firms.

Table 1. TQM extracted items

Principle	Main Enhancing Category	Indicator		Reference
A- Process thinking	Defining the Project scope	A1	Defining Project Program	[28]
		A2	Defining Project Goals	[9]
		A3	Defining the scope of work	[29]
		A4	Defining Quality SWOT	[30]
		A5	Defining Quality Goals	[9]
	Check work criteria	A6	Project Match Company Size	[31]
B- People management	Establishment of organizational staff to achieve the specified quality goals	B1	managerial background	[32]
		B2	staff qualifications	[32]
		B3	staff training and development	[33]
	outsourcing	B4	Needs new hiring and outsourcing	[28]
		B5	outsource qualifications vs need	[31]
C- Customer management	Customer focus	C1	check customer need	[34]
		C2	check if the criteria of the end product	[35]
		C3	Manage customer relationships	[34]
		C4	balance for satisfying customers and	[26]
	Check	C5	Check with the Expert Consultation	[27]
		C6	Check with the Permanent Expert	[27]
		C7	Periodically	[27]
	Measure satisfaction	C8	Direct client satisfaction	[24]
		C9	End-user satisfaction	[23]

Principle	Main Enhancing Category	Indicator		Reference
D- Strategic thinking	References	D1	References use	[21]
		D2	References update	[21]
	Establishment of performance measures for:	D3	Owner	[27]
		D4	Consultant	[27]
		D5	Contractor	[27]
E- Integrated system	Participants of all project team members in the quality improvement process	E1	all parties are participating in the	[18]
		E2	Value Engineering team participation	[28]
		E3	Risk Management team participation	[29]
	clarify the methodologies and policies	E4	Promote a work culture focused on	[23]
		E5	illustrating the function flow chart	[19]
F. Decisions management	data collection and analysis	F1	market survey	[19]
		F2	similar projects Analysis	[18]
		F3	Analyze collected data	[20]
		F4	Data availability to stakeholders	[27]
	Decision making	F5	Decisions based on the facts	[30]
		F6	Decisions based on a specialized team	[30]
		F7	Make decisions based on voting	[30]
G. Effective communications	Communicate with customers (external communication)	G1	Official agreed channel	[30]
		G2	Documented channel	[31]
		G3	Nominated contact persons	[33]
	Inhouse communication (internal communication)	G4	Using emails (external or internal)	[31]
		G5	WhatsApp in internal communication	[31]
		G6	Document the communication	[31]
		G7	A responsible person from each team	[31]
	Data Control	G8	Document control	[35]
		G9	Project documents	[29]
		G10	Project documents cycle	[28]
H. Continual improvement	Generate a dramatic technology and economic development	H1	Using innovative systems	[22]
		H2	Using innovative technology	[26]
		H3	Policies that establish project	[28]
		H4	Encouraging employees to participate	[28]
	Feedback on the results from	H5	Owner	[30]
		H6	Consultants	[34]
		H7	Constructors	[18]

The following steps were taken to calculate the relative weights using the Relative Importance Index (RII) method:

Survey respondents were asked to rate the importance of each Total Quality Management (TQM) principle on a 5-point Likert scale, ranging from 1 (not important) to 5 (extremely important). This allowed for the assessment of the perceived importance of each principle within the context of the study [36].

The RII was calculated for each principle using the formula (1):

$$RII = \frac{\sum W}{A \times N} \quad (1)$$

Where:

- W = weighting given to each principle by the respondents (ranging from 1 to 5)
- A = highest weight (5 in this case)
- N = total number of respondents

RII values range from 0 to 1, with higher values indicating greater importance.

The relative weight (RW) of each principle was computed by dividing its RII value by the total of all RII values (2) [37]:

$$RW = \frac{RII_i}{\sum RII} \quad (2)$$

Where:

RW = relative weight of the ith principle

= RII value of the ith principle

Σ RII = sum of all RII values

The calculated RWs represent the relative weights of the TQM principles based on their perceived importance in the survey. These weights sum to 1 and allow the principles to be ranked by significance. The RII method provided a straightforward technique for quantifying the relative importance of the identified TQM principles from the expert survey. The resulting weights can inform quality management strategies and initiatives for the construction sector in Egypt as shown in Table 2.

Table 2. RII Analysis Relative weights results

Indicator		RW	Indicator		RW
A1	Defining Project Program	0.018	E3	Risk Management team participation	0.019
A2	Defining Project Goals	0.018	E4	Promote a work culture focused on quality with ratio	0.019
A3	Defining the scope of work	0.018	E5	illustrating the function flow chart and visual aids	0.018
A4	Defining Quality SWOT	0.016	F1	market survey	0.017
A5	Defining Quality Goals	0.017	F2	similar projects	0.017
A6	PMCS	0.018	F3	analyze collected data	0.018
B1	managerial background	0.018	F4	data availability to stakeholders	0.019
B2	staff qualifications	0.018	F5	decisions based on the facts	0.019
B3	staff training and development	0.018	F6	decisions based on a specialized team	0.018
B4	Needs new hiring and outsourcing	0.017	F7	make decisions based on voting	0.017
B5	outsource qualifications vs need	0.018	G1	Official agreed channel	0.019
C1	check customer need	0.019	G2	Documented channel	0.019
C2	check if the criteria of the end product match the customer or not	0.019	G3	Nominated contact persons	0.019
C3	Manage customer relationships	0.018	G4	using emails (external or internal)	0.019
C4	balance for satisfying customers and other involved parties	0.019	G5	WhatsApp in internal communication	0.019
C5	Check with the Expert Consultation Team	0.018	G6	Document the communication	0.019
C6	Permanent Expert Consultation Team	0.019	G7	A responsible person from each team	0.019
C7	Monthly Check	0.018	G8	Document control	0.018
C8	Direct client satisfaction	0.019	G9	Project documents	0.018
C9	End-user satisfaction	0.018	G10	Project documents cycle	0.018
D1	References use	0.019	H1	Using innovative systems	0.018
D2	References update	0.018	H2	Using innovative technology	0.018
D3	Owner	0.017	H3	Policies that establish project	0.019
D4	Consultant	0.017	H4	Encouraging employees to participate in available training	0.018

Indicator		RW	Indicator		RW
D5	Contractor	0.018	H5	Owner	0.018
E1	all parties are participating in the project with their weights	0.018	H6	Consultants	0.018
E2	VE team participants	0.017	H7	Constructors	0.018

Cronbach's alpha analysis was conducted to validate the reliability of the RII method results. Cronbach's alpha measures the internal consistency and reliability of a measurement instrument with multiple items or principles. It ensures that the principles are closely related and measure the same underlying construct, which in this case is TQM effectiveness. The Cronbach's alpha value was calculated using the survey response data and RII weights for the TQM principles indicators. The resulting alpha coefficient was 0.89, indicating a high level of internal reliability. A value of 0.70 or higher is generally considered acceptable [38].

This high Cronbach's alpha confirms that the identified TQM principles are considered important. It statistically validates the capability of the RII method and survey to reliably distinguish the critical TQM principles for the Egyptian construction industry. The principles of higher RII-based weights consistently contributed more to the overall scale reliability.

3.2 Life Cycle Cost Analysis LCCA formulas

To estimate future expenses based on the present value (PV) of the same processes, the following cost formulas were utilized (3), (4), (5), (6) [39]:

To conclude the future costs are equal to:

$$(f+1)^n = \left[\frac{cost_n}{cost_0}\right] \tag{3}$$

While is the estimated cost of a good or a service, that has a cost of in the present time and an inflation rate that is equal to to n period.

$$cost_n = (f+1)^n \times cost_0 \tag{4}$$

Future value Fv, of a sum Pv, invested to the n periods, compounded at interests.

$$Fv = Pv[1 + i^n] \tag{5}$$

Where An annuity value, a payment per period, compounded at interests, $\boldsymbol{n}$ number of years:

$$A = a * [1 - \frac{(1+i)^n - 1}{i*(1+i)^n}] \tag{6}$$

By considering a compound banking interest rate as an investment alternative; the present value can be calculated by the following formula (7): While is Present Value, is Future Value, interests, and n periods.

$$Pv = \frac{\text{Fv}}{(1+i)^n} \tag{7}$$

3.3 Value Engineering Business Approach VEBA

The relationship between function and cost determines the very traditional formula (8) for measuring value:

$$Value = \frac{Function}{Cost}$$ (8) [40]

When evaluating an option, it's critical to consider how it will function in the future, how it will adjust to shifting customer demands, and how much money it will cost in the future. To account for the differences between typical products and buildings as products, the concept of life cycle value should be introduced to the value index calculation. Therefore, for calculating the lifespan value of the project according to the Total Quality Management approach, we can use the following formula (9):

$$Value\ Engineering\ Business\ Approach\ (VEBA) = \frac{Performance}{Life\ Cycle\ Cost\ (LCC)} \tag{9}$$

$$= \frac{TQM\ Evaluation\ (\text{Business Approach})}{Life\ Cycle\ Cost\ (LCC)}$$

4 RESULTS AND DISCUSSION

To streamline the auditing process for each category, a TQM model was created using Excel software. This model incorporates both primary and secondary TQM elements and features a dropdown menu instead of the traditional

FAST diagram. Each item within the sub-lists is rated on a scale of 1 to 10 based on its influence on the quality process. Green flags indicate items that passed with minimal or no adjustments required, while red flags indicate items that have significantly impeded the process and necessitated immediate revision.

4.1 Quantitative study results

The simplification of the review process and project cost calculation can be achieved through the implementation of an Excel model. This model utilizes LCCA equations (3), (4), (5), (6), and (7). The resulting output from the model will serve as the updated cost value and will be utilized as the denominator in the value calculation. The new formula involves taking the TQM output as the numerator and dividing it by the LCCA execution cost as the denominator. This approach ensures a standardized measure for comparison, facilitating optimal decision-making processes as shown in formula (10):

$$V\alpha\ (VEBA) = \frac{TQM\ output\ (Bussinees\ Approach)}{new\ lcca/_{Executed\ cost}} \tag{10}$$

4.2 Results tracing

To verify the validity of the VEBA formula, a case study was conducted on a water treatment plant (WTP) project with a capacity of 8600 m³/day, located in Bani-Sweif, Egypt. The contractor scope included turn-key services, including design work. The project's work order was issued in April 2022, with the project commencing in May 2022 and scheduled for completion in April 2023, inclusive of imported equipment. The contractual cost was 60,000,000 EGP (equivalent to 2,000,000 USD). According to the TQM Model's analysis of the project case, it was determined that the project should not be awarded to the hired contractor. The analysis revealed that the contractor scored 33.93%, accumulating a total of 187 points out of 550. This score fell short of the minimum safe target score of 70%, as shown in Table 3 (1st Run).

Table 3. TQM model runs before and after correction actions

		Before (1st run)				After (2nd run)			
TQM principles	Items	given	F	R.W	Grade	given	F	R.W	Grade
A. Process thinking	A1	4		0.18	0.72	7		0.18	1.27
	A2	10		0.18	1.83	10		0.18	1.83
	A3	10		0.18	1.81	10		0.18	1.81
	A4	0		0.16	0.00	7		0.16	1.14
	A5	1		0.17	0.17	7		0.17	1.18
	A6	4		0.18	0.71	8		0.18	1.42
B. People management	B1	4		0.18	0.73	8		0.18	1.45
	B2	4		0.18	0.73	8		0.18	1.46
		4		0.18	0.73	8		0.18	1.46
	B3	4		0.17	0.70	7		0.17	1.22
	B4	1		0.18	0.18	8		0.18	1.43
	B5	8		0.19	1.48	8		0.19	1.48
C. Customer management	C1	7		0.19	1.31	7		0.19	1.31
	C2	2		0.18	0.37	8		0.18	1.48
	C3	0		0.19	0.00	10		0.19	1.88
	C4	2		0.18	0.36	8		0.18	1.45
	C5	10		0.19	1.88	10		0.19	1.88
	C6	10		0.18	1.81	10		0.18	1.81
	C7	6		0.19	1.12	8		0.19	1.49
	C8	1		0.18	0.18	8		0.18	1.43
	C9	4		0.19	0.76	8		0.19	1.53
D. Strategic thinking	D1	3		0.18	0.54	10		0.18	1.81
	D2	0		0.17	0.00	6		0.17	1.03
	D3	10		0.17	1.68	10		0.17	1.68
	D4	8		0.18	1.47	8		0.18	1.47
	D5	2		0.18	0.36	8		0.18	1.44

		Before (1st run)				After (2nd run)			
TQM principles	Items	given	F	R.W	Grade	given	F	R.W	Grade
E. Integrated system	E1	4		0.17	0.69	8		0.17	1.38
	E2	1		0.19	0.19	8		0.19	1.49
	E3	0		0.19	0.00	8		0.19	1.51
	E4	0		0.19	0.00	8		0.19	1.51
	E5	0		0.18	0.00	8		0.18	1.47
F. Decisions management	F1	2		0.17	0.34	10		0.17	1.71
	F2	2		0.17	0.34	8		0.17	1.37
	F3	10		0.18	1.79	10		0.18	1.79
	F4	2		0.19	0.38	8		0.19	1.52
	F5	0		0.19	0.00	10		0.19	1.92
	F6	2		0.18	0.35	8		0.18	1.40
	F7	0		0.17	0.00	6		0.17	1.03
G. Effective communications	G1	0		0.19	0.00	10		0.19	1.92
	G2	5		0.19	0.96	10		0.19	1.92
	G3	0		0.19	0.00	8		0.19	1.53
	G4	5		0.19	0.94	10		0.19	1.87
	G5	0		0.19	0.00	8		0.19	1.50
	G6	5		0.19	0.94	10		0.19	1.87
	G7	0		0.19	0.00	10		0.19	1.87
	G8	0		0.18	0.00	10		0.18	1.85
	G9	5		0.18	0.89	10		0.18	1.78
	G10	5		0.18	0.91	10		0.18	1.82
H. Continual improvement	H1	0		0.18	0.00	8		0.18	1.47
	H2	0		0.18	0.00	6		0.18	1.10
	H3	0		0.19	0.00	8		0.19	1.50
	H4	0		0.18	0.00	8		0.18	1.42
	H5	8		0.18	1.44	8		0.18	1.44
	H6	8		0.18	1.42	8		0.18	1.42
	H7	4		0.18	0.73	8		0.18	1.46
	Fail	187			33.93%	465			84.68%
	pass	total		TRW	Ratio	total		TRW	Ratio

The VEBA formula will be used to determine the project value, taking into account that the LCC is the same as the execution cost, dividing the result by one:

$$V\alpha = \frac{TQM\ output}{new\ lcca / Executed\ cost} \qquad V\alpha = \frac{33.93}{1} = 33.93\%$$

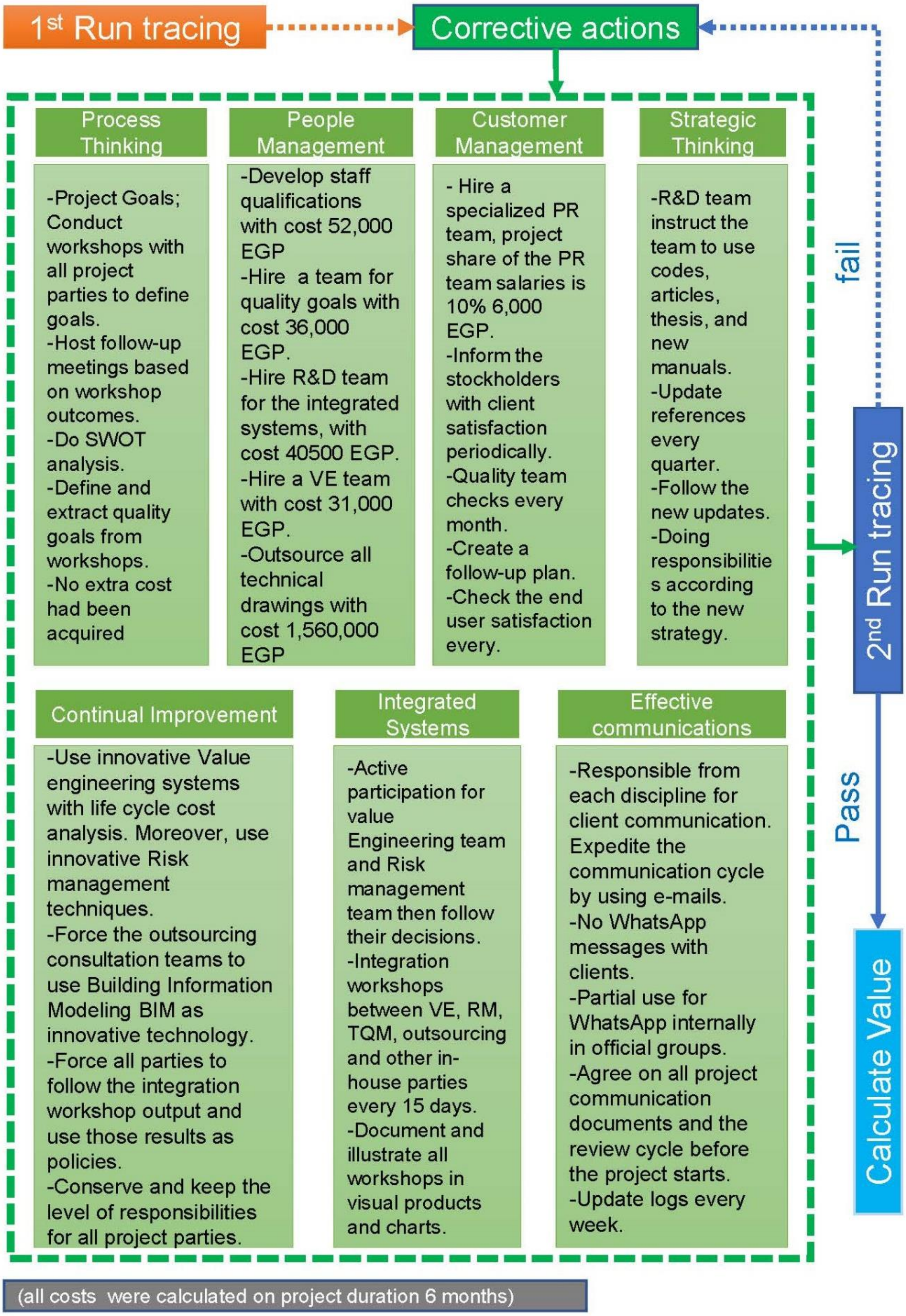

Fig. 2. Framework and correction actions

To evolve the business from the TQM aspect with cost considerations, corrective actions were extracted from the TQM model results shown in Table 3 (1st Run). Accordingly, corrective actions were taken as illustrated in Figure 2. Following these actions, a second evaluation was processed, as shown in Table 3 (2nd Run). A re-evaluation was conducted, revealing that the organization's score improved significantly. The score increased from 187 points (33.93%) to 465 points (84.68%), as shown in Table 3. This improvement is also illustrated in comparison with the first run in Figure 3.

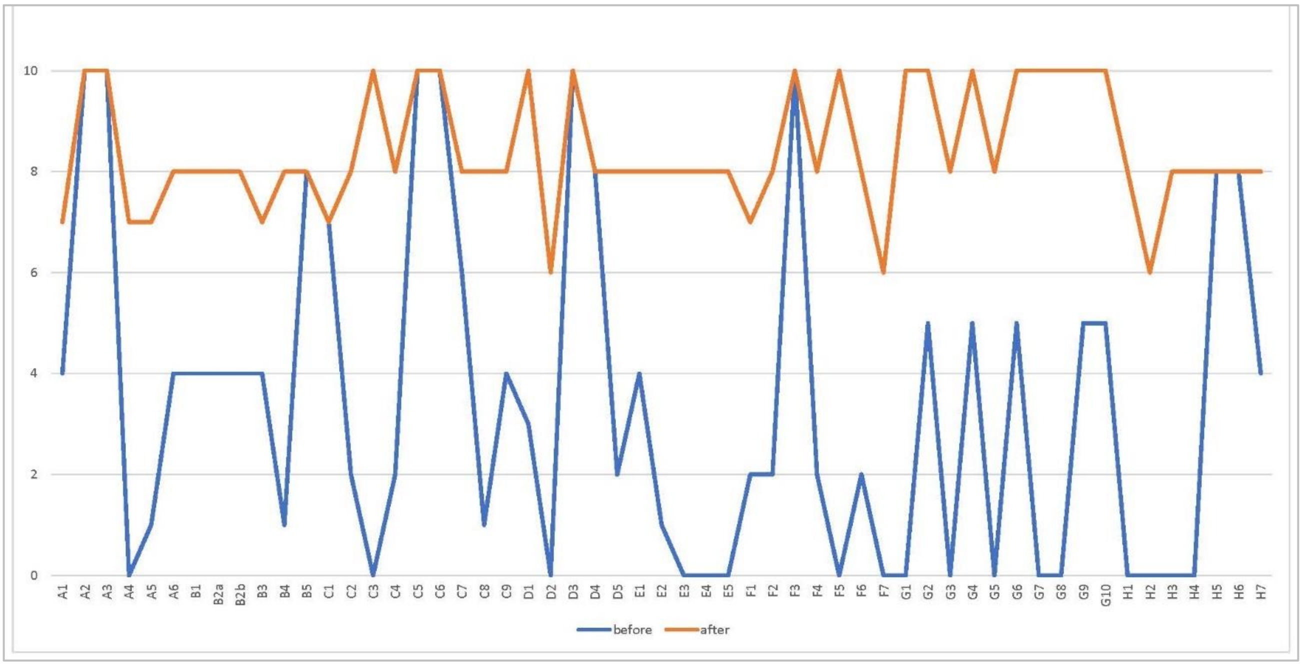

Fig. 3. The difference in TQM items before and after corrective actions

After applying the LCCA model to the examined items, the original tender's construction cost of 25,440,505 EGP was reduced by 12.8% to 17,729,050 EGP, as shown in Figure 4.

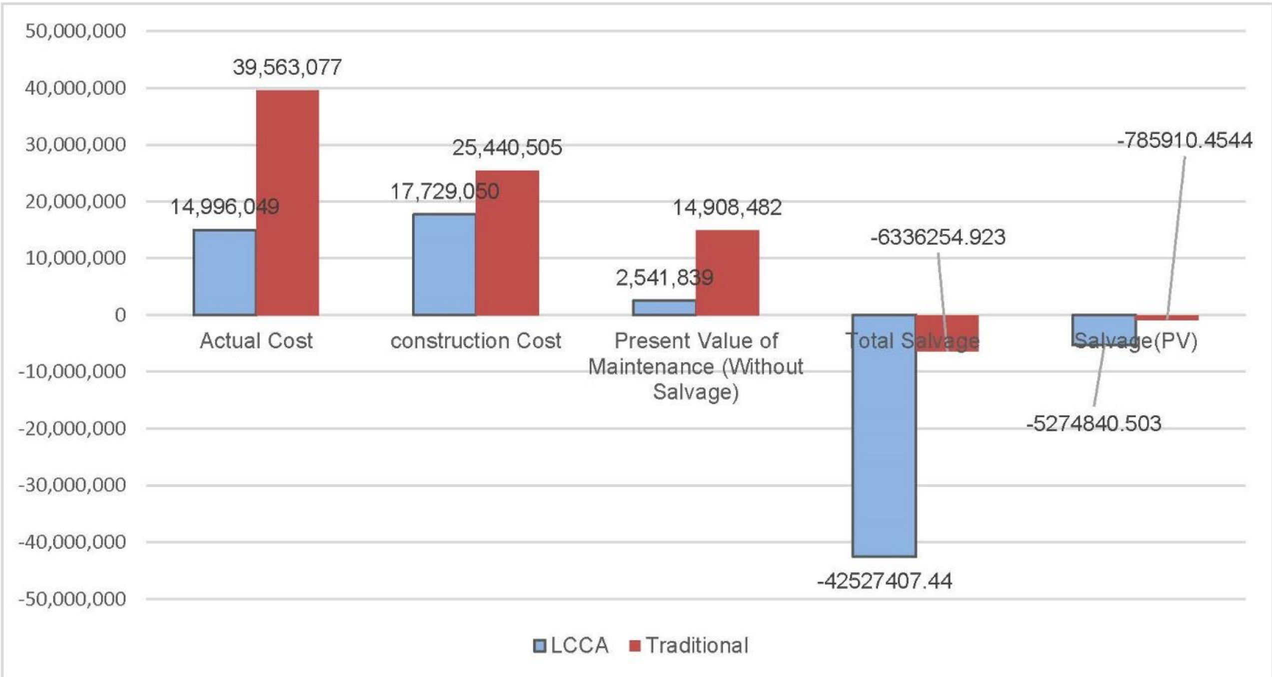

Fig. 4. Project Cost Before and after LCCA

After implementing the integrated value approach (VEBA) with its corrective and preventive actions, the quality discipline results improved to 84.68%. This approach reduced the project cost by 5,985,955 EGP. After accounting for the additive cost of 1,725,500 EGP from TQM corrective actions, the total project cost was reduced to 54,014,045 EGP. The following formula will be used to determine the project's value:

$$V\alpha = \frac{TQM\ output}{new\ lcca / Executed\ cost} \qquad V\alpha = \frac{84.68}{54{,}014{,}045 / 60{,}000{,}000} = 94.06\%$$

The project value improved significantly, increasing from 33.93% to 94.06%, which represents a 60.14% enhancement in quality without affecting the project timeline.

5 CONCLUSIONS

The study aimed to integrate Total Quality Management (TQM) principles into construction project evaluation. Based on eight key principles, TQM involves measurable activities prioritized by their anticipated impact. These principles were translated into quantifiable metrics that can be assessed by various organizational components. Life Cycle Cost Analysis (LCCA) was used to assess facility ownership costs, comparing project alternatives to achieve optimal savings while meeting performance standards.

A new value-evaluating approach formula combining TQM and LCCA was proposed to evaluate project value, demonstrating significant potential for construction cost reduction and increased project value. According to the case study, this integrated approach offers a comprehensive methodology for tracking, projecting, and evaluating project components, resulting in a substantial value increase of approximately 60%.

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