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RESEARCH ARTICLE

Assessment of awareness of life cycle cost analysis in Qatar's construction industry

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Abstract

Life cycle cost analysis (LCCA) methodology is based on principles that provide a reliable means for determining the total cost of a project, facility, or process from its initial stages to the end of its life or salvage period. The LCCA objective for the construction industry is to establish or calculate the optimum solution for investment in a project that would meet the long-term's lowest cost estimate. This, in turn, allows selecting the best investment option for selected project(s). The contribution of this study is to identify and quantify the factors which relate and assist in gaining new knowledge, insight and understanding of life cycle cost analysis practice in Qatar's construction industry. A survey was designed and distributed to different construction contractors, subcontractors, and consultants to evaluate their expectations and perceptions in the construction industry regarding LCCA application in the construction industry. A data sample of 101 working professionals was analyzed using statistical data. The data obtained were analyzed using statistical analysis techniques using the relative importance index to determine the ranking between different groups of LCCA factors. According to the research and data analysis findings, 27.7% of employees had an average exposure to LCCA during their work training and/or studies, while 72.3 % lacked exposure to LCCA. 32.7% of respondents had LCCA implemented during their tenure or work stay in the organization or project, and 36.6 % of respondents informed that their organization/companies advocate the use of LCCA during the planning stages of the project. 14.9% of respondents said their respective companies had any policies for LCCA implementation in their respective departments. An extensive look into LCCA knowledge, awareness, implementation, and variables that can improve LCCA implementation in Qatar is given by this research study.

1. Introduction

Life cycle analysis is an economic analysis process [1] that is based on economic evaluations of alternatives for cost efficiency based on predictive tools of Net Present Value (NPV), Cost-benefit Analysis (CBA), Payback Period (PP) and Internal Rate of Return (IRR) to obtain optimum life cycle costs of projects, process or services. LCCA is based on data obtained and is the sum of all project costs over its entire operations life. It has been implemented in several countries by relevant

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agencies who have identified its benefits noticeably in the infrastructure and transportation sector and have saved significant sums of money. Application of LCCA is present much more in the private sector due to the requirements of financial investment needs and protecting investments. LCCA provides an analytical technique to the owners for several options of using their available funds to the best optimum cost scenario. LCCA application on projects provides fund allocation strategies and generation of appropriate plans for meeting the required performance objective [2].

By modifying performance prediction models, LCCA makes it possible to forecast the project's or process's future state and schedule maintenance appropriately. Among the many advantages of LCCA are the necessary maintenance methods and supplies, the overall expense of allocating and investing funds appropriately, and network priority setting. Above important, by analyzing the total cost as a similar entity, the LCCA technique provides a logical means of comparing plans and alternatives. Project options can be evaluated and chosen to find the best cost solution by using an appropriate LCCA method. The core processes of LCCA are comprised of the following steps, as given below in Fig. 1.

With this research, how LCCA is used and applied in Qatar's construction sector was studied. This study contributes to the understanding of life cycle cost analysis practice in Qatar's construction industry by identifying and quantifying the aspects that are related to it. To ascertain the expectations and perspectives of various construction contractors, subcontractors, and consultants regarding the implementation of LCCA in the construction sector, a survey was developed and disseminated to these parties. Utilizing statistical data, a sample of 101 working professionals was examined. In order to rank the various groupings of LCCA components, the data were studied using statistical analytic techniques and the relative relevance index.

2. Literature Review

LCCA is an effective tool to ascertain the economic viability of a project, process, or service. LCCA is applied in fields as varied as transportation, aerospace, mechanical engineering, and biogenetics. In order to fully understand the impact of LCCA and its impact in so many industries, the literature review is compiled to emphasize the application of LCCA in different industries while also mentioning the application of LCCA in Qatar's infrastructure industry.

Using the LCCA approach, Altaf et al. [3] examined economic sustainability in the Malaysian construction sector. This study investigated the exposure to and knowledge of life cycle cost accounting (LCCA) among professionals employed in Malaysia's construction sector.

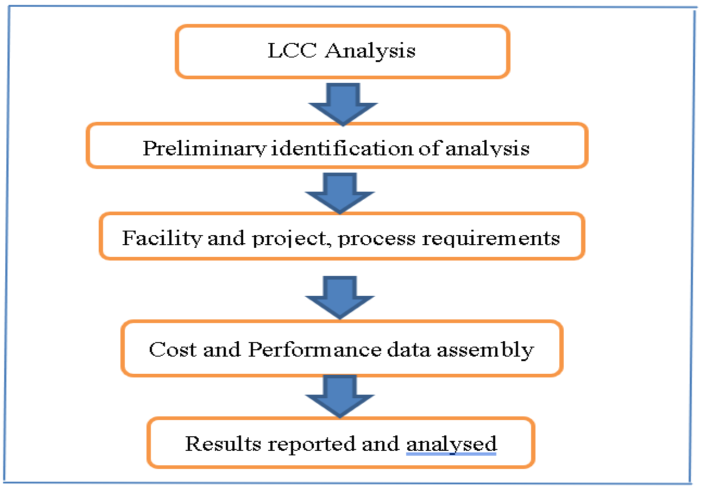

Fig. 1. Core processes of LCCA

The majority of professionals were discovered to be ignorant about and unaccustomed to using LCCA for their organizations. It was discovered that just 4% of respondents had substantial experience in the relevant subject of construction and a high degree of awareness. According to the authors, Malaysia's construction industry is still lagging behind industrialized nations like Australia, Singapore, and the United Kingdom when it comes to the use of LCCA. Value Engineering (VE) was applied by Fathoni et al. [4] to the construction sector in Malaysia, where LCCA is utilized to obtain the most value over a predetermined amount of time. The results of the exercise showed that 33% of participants were not familiar with the term LCCA or its significance in value engineering, and a sizable portion of candidates had no idea how to put LCCA into practice.

Assaf and Abdo [5] discuss their research of life cycle assessment including economic and environmental results for including recycled materials in the design phase of pavement material. A wide variety of recycled materials have been investigated and researched for their use in pavement construction. A large percentage of recycled materials studied for this purpose consist of reclaimed asphalt pavement (RAP) and recycled plastic materials. This research methodology involves conducting a life cycle assessment study for environmental and economic results due to the mixing of reclaimed asphalt pavement (RAP) with recycled plastic in pavement. The results obtained indicated that including recycled plastic materials yielded better results for pavement as compared with reclaimed asphalt pavement material. Recycled plastic used in pavement material resulted in lower energy consumption, and also reduced smog generation and air acidification. Reclaimed asphalt pavement (RAP) material increased the consumption of energy and also resulted in the emission of harmful gases, acidification of air, and generation of smog. However, it was found that using both reclaimed asphalt pavement and recycled plastic largely reduced costs, since use of recycled materials lessen the use of virgin materials and avoided the transport cost of moving the recycled materials to landfills. The costs were calculated as Net Present Value (NPV), and it was found that usage of recycled plastic and RAP caused a reduction in cost by 30% which is quite substantial. This study is quite beneficial, since it imparts valuable knowledge for a range of recycled materials impact in economic and environmental design when used in pavement materials in different proportions.

Reducing energy consumption in buildings also can be referred to it as increasing the energy efficiency in a building [6]. Using materials for minimizing the energy consumption in the buildings for example using insulation materials in the construction of a building will reduce the consumption of energy for cooling and heating.

Settanni [7] discusses LCCA for maintaining motorway pavement using recycled asphalt. It mentions LCM Life Cycle management of a product being affected by streamlining decision-making at an organizational level. Business analysis with a life cycle perspective projects the financial effect of an organization. It was discovered that aggregates used in road construction pavement were becoming scarcer. Therefore it opted to use recycled aggregates to conserve costs for new pavement structures.

Khodabocus and Seyis [8] aimed to portray the integrated usage of Building Information Modelling (BIM) and lean construction methods throughout the lifecycle of modular construction projects. This research considered the whole lifecycle, and the methodology integrates hands-on experiences from qualified industry experts.

Guerrero-Ibanez et al. [9], conducted research for reducing traffic congestion and environmental costs by numerically analyzing the cost-and-benefit ratio of intelligent transportation systems. The relationship between intelligent transport systems and environmental cost is analyzed.

Rahman and Vanier [10] discuss the application of life cycle cost analysis as a decision support tool for infrastructure management. The research paper explains that life cycle cost analysis works by computing and evaluating the cost over the complete life of an asset which is inclusive of initial design and construction costs, and future computed costs which have been discounted to a certain rate. According to a survey conducted among infrastructure managers in the Canadian industry, 91% of managers want assistance in managing their infrastructure assets through decision support tools. Additionally, 24% of managers said that life cycle cost analysis (LCCA) can be used as a decision support tool, and 70% of managers believe that LCCA can significantly reduce deferred maintenance. In summary, the paper advocates for the application of life cycle cost analysis as a tool for infrastructure decision support, given the availability of precise data, pertinent and comprehensive computer modeling, and logically applied processes.

The use of LCCA in Malaysian industry's economic sustainability was examined by Altaf et al. [3]. This study looked at the exposure to and awareness of LCCA in the Malaysian construction industry. It was found that a majority of professionals were unaware and unaccustomed to using LCCA for determining final costs for their respective projects. A survey revealed that only 4.4% of respondents had substantial experience in the relevant construction field along with a high level of awareness.

Mikolaj and Remek [2] concluded that LCCA could effectively calculate and assess the economic feasibility of Maintenance Repair and Rehabilitation (MR&R) for specific road or highway sections that had earlier deteriorated and are required to be put into serviceable condition. LCCA, in this case, can enable the agency or organization to devise a strategy to effectively distribute funds for Maintenance, Repair, and Rehabilitation regarding section road or highway sections required for repair.

In Ding et al. [11], they describe how pavement preventive maintenance (PPM), which is increasingly being recognized at the professional level by highway managers, has been improved by the idea of LCCA. The study conducted for the LCCA and optimal strategy decision of pavement preventive maintenance over the course of the road's whole life cycle is discussed in the paper. A specific road section was taken as a life cycle study incorporating parameters of pavement performance climatic conditions and economic variables, which were integrated into the model of PPM for the LCCA study. The results of the study confirm that Preventive pavement maintenance (PPM) using LCCA techniques and methodology incorporated shows a huge advantage in both cost and benefit during the project cycle.

Santos and Ferreira [12] discuss a software design based on the LCCA system called OptiPav, which assists pavement designers in choosing the optimum pavement structure for roads or highways. The software Optipav allows LCCA to be developed for pavements/roads for 20 years of service and 40 years design period. Allowing LCCA design between the ranges of 20 to 40 years allows the professionals to make a comparative study to select the final pavement structure with an optimum cost which includes construction cost, maintenance, 20 costs, user costs, and the residual estimates of the pavement structure. Using OptiPAV software allows us to consider LCCA while using any combination of expenses related to construction, maintenance, user, and residual values.

The life cycle costs for carbon emissions of energy technologies, such as offshore wind, are covered by Thomson et al. [13]. The paper discusses that wind power is composed of zero emissions as gases are formed during the process of installation, maintenance, and decommissioning. The life cycle cost of producing energy from conventional sources is compared with onshore wind. Carbon emissions over the wind farm lifecycle are addressed and compared with other technologies.

The paper questions whether the onshore wind farms achieve carbon emissions savings over their operational life. The life cycle cost associated with technologies for electricity generation is in 3 main categories.

1. Capex – capital expenditure costs
2. Opex – operations and decommissioning
3. Dismantling and decommissioning

In conclusion, it is summarized that life cycle costs for CO_2 emissions savings were much more optimistic for wind power generation as compared to conventional sources of producing energy and emitting carbon emissions.

Shanmugam et al. [14] discussed the application of 3R (reduce, reuse, and recycle) principles for a wastewater treatment plant (WWTP) and using LCCA for quantitative evaluation of the value of WWTPs by using LCCA. A wastewater plant reduces sewage and its affiliated pollution while at the same time generating by-products of effluent, biogas, and sludge which can be used as fuel, end products, or chemicals. The sustainable value of WWTP can be calculated by combining its environmental and cost performance using LCCA tools. This includes calculating the total costs of WWTP Operations and Total Revenues generated by by-products for external use like biogas, effluent, and sludge.

Heracleous et al. [15] discuss using LCCA analysis by suggesting a new design and retrofitting approach, which will meet the energy demand of some old educational buildings in Cyprus. This paper discussion includes the improvement of knowledge and contribution of novel knowledge on energy utilization of old buildings in the Mediterranean region in parallel with LCCA. The new knowledge will be used more effectively to develop a framework that can be used extensively for supporting retrofitting buildings to provide resilience against climate change. This study also identified key factors, e.g., discount rate, energy cost, and hours of operation. The findings are as follows:

a. Installation of mechanical ventilation to increase energy efficiency with an energy conversion of 49%.

b. Installation of roof insulation with an energy usage reduction of 18%.

c. Wall insulation installation with an energy reduction of 8%.

The LCCA of Reclaimed Asphalt Pavement (RAP) and Hot Mix Asphalt (HMA) is compared by Rafiq et al. [16]. Reclaimed asphalt pavement is currently utilized as a preferred, less expensive substitute for standard hot mix asphalt, according to the authors. On the other hand, after asphalt is applied to the surface, HMA shows negative effects when used with a high RAP content. Therefore, it is crucial to ascertain whether RAP is practical and cost-effective in the infrastructure sector. In order to complete the case study for this paper, RAP at 20% was computed using resources pertaining to cost analysis. When the results were compared to conventional materials, employing RAP resulted in a roughly 14% cost reduction. Apart from the cost mentioned above difference due to using RAP, no other cost reduction was noted while considering manpower, construction materials, operations, and transport of materials from plant to site. The plant, transport, and operations machinery were considered while considering the impact of carbon dioxide.

In Dunmade [17], the industrial use of Lifecycle tools in West Africa is discussed. It makes reference to instruments created by academics and engineers to optimize resource utilization and reduce waste production. The tools listed are life cycle techniques that help engineers and designers create products that give them a competitive advantage over rivals. The procurement staff is also provided a platform for making choices of selecting products that are eco-friendly and which are not. The study encompasses trends in implementing lifecycle tools in West Africa. The industries included in the study were building and road construction, energy industries, waste management, and food industries. Very few industries reported implementing LCCA methods due to a lack of awareness or keeping the information confidential. It was also speculated that educational and research facilities lack the required resources for lifecycle-based research, including training for teaching/training personnel on lifecycle concepts and applications in industry.

3. Research Methodology

The research methodology involved the stages from designing the questionnaire survey, distributing the questionnaire to potential respondents, obtaining responses, gathering and evaluating data, and presenting data in different forms to present the status of the LCCA study, as given below in Fig. 2.

3.1. Design of the questionnaire

A questionnaire was designed and distributed online to potential candidates in the construction industry to evaluate the factors affecting LCCA awareness. Data was collected based on the perception of respondents on the LCCA awareness factors practiced in Qatar's construction industry. The questionnaire was composed of 6 sections as follows:

1. *Life Cycle Cost Analysis*: A general explanation of LCCA to potential respondents.
2. *General Sections Questions*: This section of the questionnaire comprises general questions related to the respondent's occupation, qualifications, industry, and experience working in that particular industry.
3. *LCCA Implementation in Qatar*: This section comprises questions regarding implementing LCCA practice in Qatar companies and industries.
4. *Educating on Life Cycle Cost Analysis (LCCA) in Qatar Industries and Companies*: This section of the questionnaire addresses the training and education of LCCA professionals in the construction industry.
5. *Optimizing Project Costs Using LCCA*: This section of the questionnaire addresses the major factors of cost optimization considered for LCCA.
6. *Advantages and Benefits of Life Cycle Cost Analysis*: This questionnaire section assesses whether the respondent agrees or disagrees with the benefits of the LCCA application.

The LCCA questionnaire was sent to potential respondents working in the construction industry with designations ranging from junior engineers to project managers. Since the entire questionnaire would be too lengthy to include in the study, a sample is provided in the Appendix.

In order to check the consistency of questionnaire responses, the following mathematical technique comprising quantitative and qualitative tools were used.

4. Data Collection

The data was collected from the online questionnaire distribution, and the results obtained were used for graphical representation and data analysis. The questionnaire was developed on Google Forms and distributed accordingly using links to construction professionals, including engineers, construction managers and project managers in the construction industry.

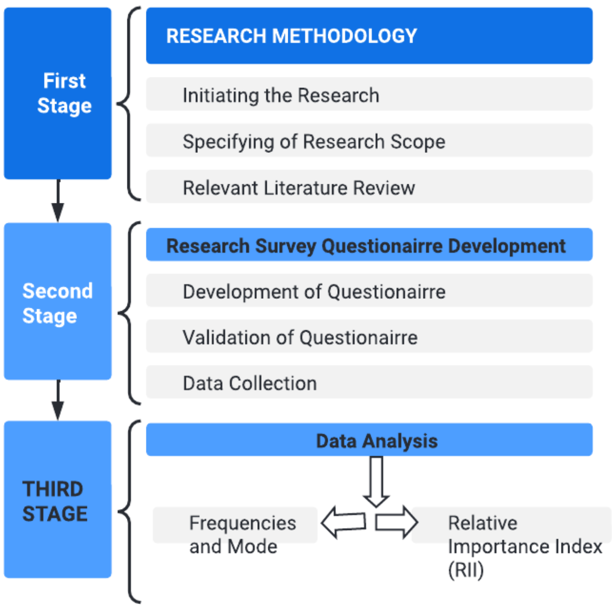

Fig. 2. Research methodology

This section provides information gathered from the questionnaire, including a summary of the respondents' profiles and a thorough analysis of the findings. The Google survey website was used to create and administer the questionnaire. The online tool was used to gather and analyze a total of 101 responses.

4.1. Respondents profile

Figures 3 to 8 present the respondent's profile details based on location, type of organization, job title, construction industry, and total amount of experience in the field of construction.

4.1.1. Respondents' educational qualifications

As shown in Fig. 3, the respondents with bachelor's degrees represented the largest portion of professionals who participated in this study, with 69 respondents, which accounted for (68.3%) out of 101 participants. Respondents with master's come in 2nd place with 19 respondents (18.8%). Respondents from the other remaining educational backgrounds accounted for 12.9%.

4.1.2. Respondents' professional department designations

The respondents in the engineering department represented the largest portions of professionals belonging to their respective departments, with 36 respondents (35.6%) out of 101 participants, as shown in Fig. 4. Respondents from the other remaining departments accounted for 64.35%, which includes 24 respondents with project management departments.

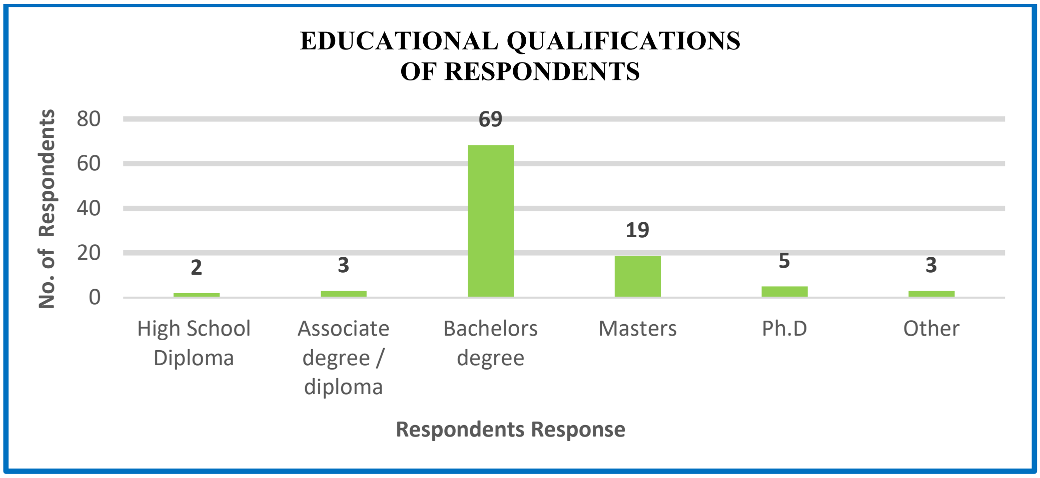

Fig. 3. Respondents' educational qualifications

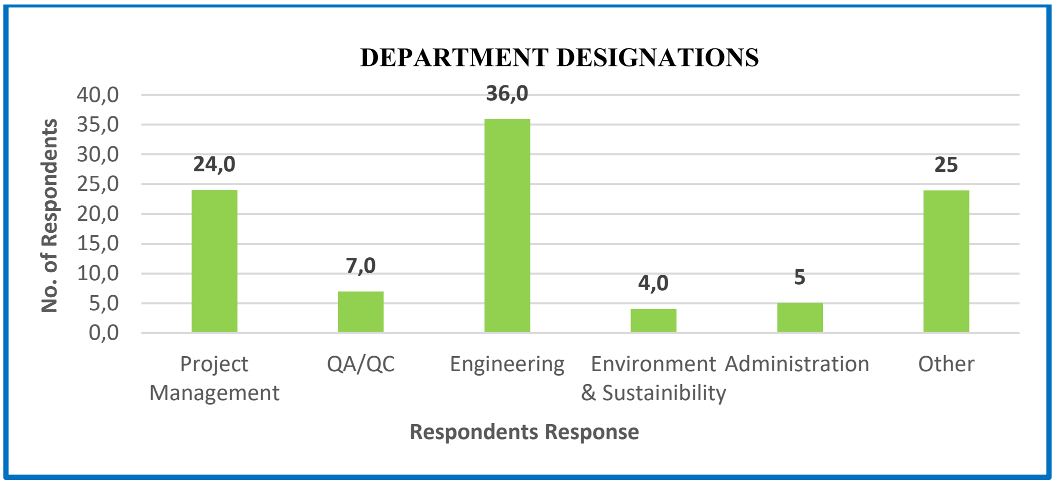

Fig. 4. Respondents' department designations

4.1.3. Respondents' work experience

As shown in Fig. 5, the respondents with 11-15 years of work experience represented the largest portions of professionals in their respective departments, with 26 respondents (25.7%) out of 101 participants. 19 nos. respondents with 16-20 years of work experience accounted for 18.8%.

4.1.4. Respondents' professional occupations

The respondents with project management-related positions represented the largest portion of professionals in their respective departments, with 26 respondents (25.7%) out of 101 participants, as shown in Fig. 6. Respondents from other professional occupations accounted for 74.3%.

4.1.5. Respondents' professional designation

The respondents with managerial positions represented the largest portion of professionals in their respective departments, with 31 nos. respondents (30.69%) out of 101 participants, as shown in Fig. 7. Respondents from the other remaining departments accounted for 69.3%.

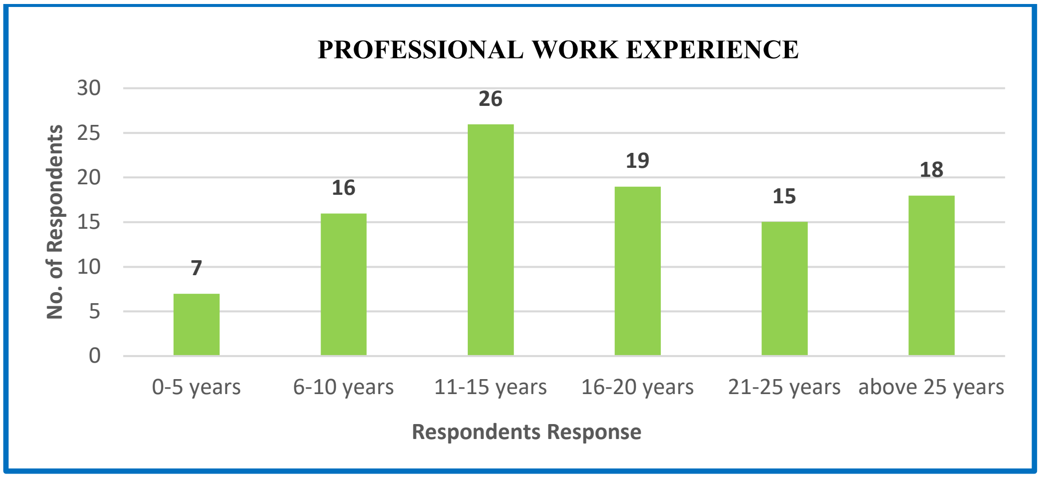

Fig. 5. Respondents' professional work experience

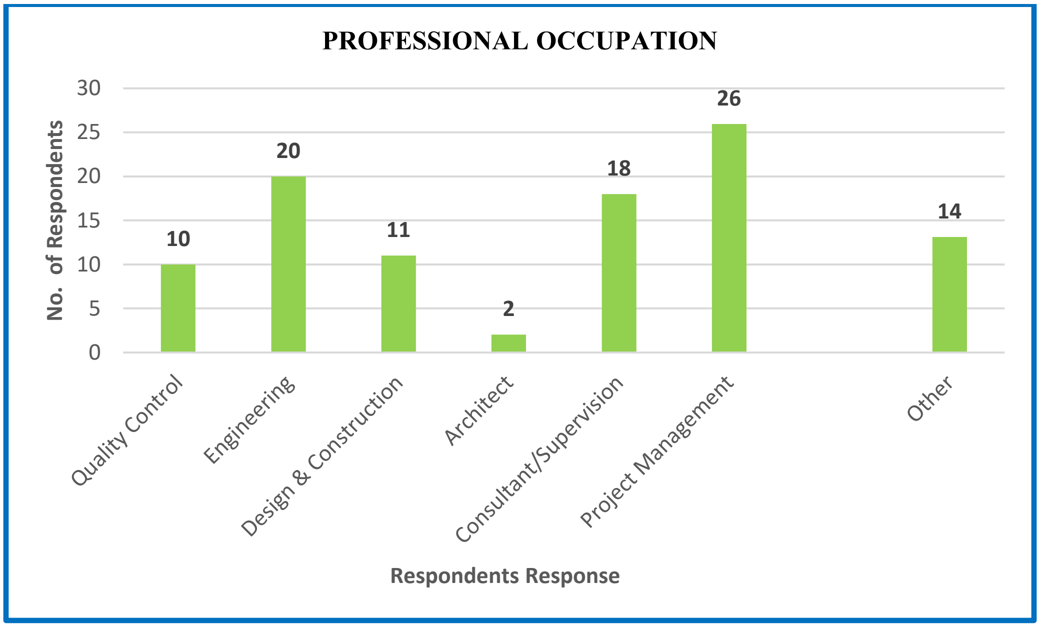

Fig. 6. Respondents' professional occupation

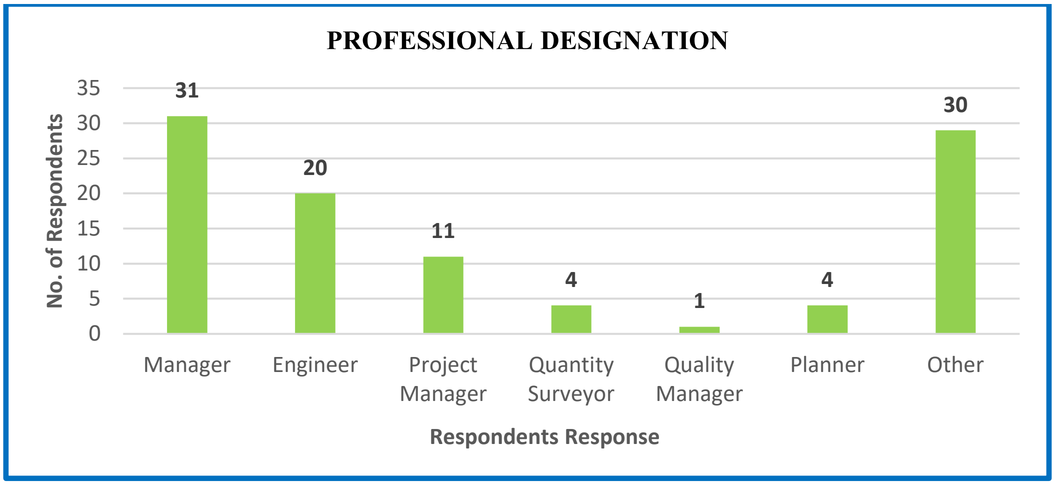

Fig. 7. Respondents' professional designation

4.1.6. Respondents' projects type

As per Fig.8, the respondents with infrastructure projects, including roads, bridges, railways, etc., represented the largest portion of professionals in their respective departments, with 56 respondents (55.4%) out of 101 participants. Respondents from the other remaining departments accounted for 44.6%.

4.1.7. Respondents to LCCA college education

The respondents agreeing with implementing LCCA for college education represented the largest portion of professionals with 51 nos. respondents (50.5%) out of 101 participants, as shown in Fig. 9. 28.7% of respondents chose to remain neutral, while other remaining departments accounted for 21.0% approx.

4.1.8. LCCA for management of project expenses

The respondents agreeing with the management of project expenses accounted for the largest portions of professionals belonging to their respective departments, with 53 respondents (52.5%) out of 101 participants, as shown in Fig. 10. Respondents from the other remaining departments accounted for 47.5%.

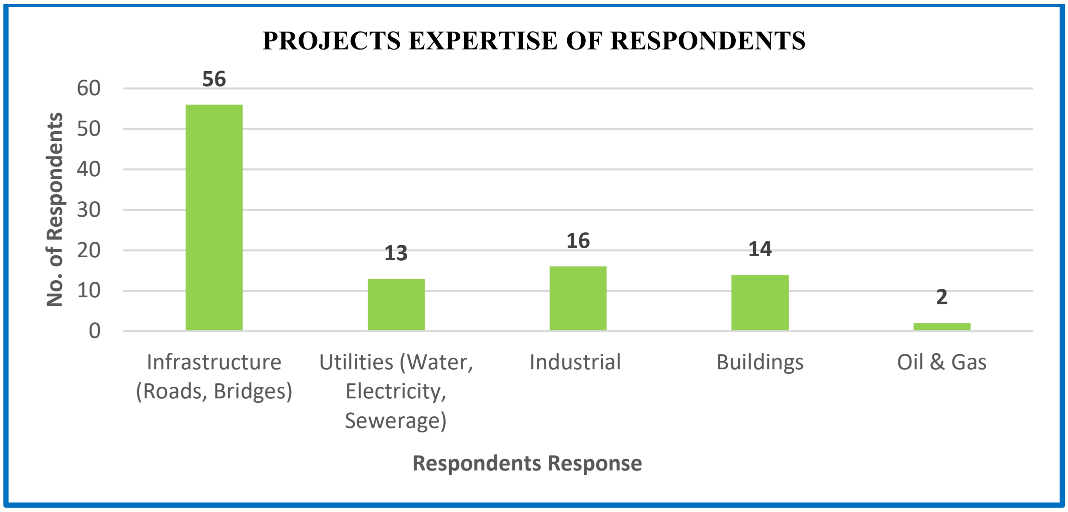

Fig. 8. Respondents' project expertise

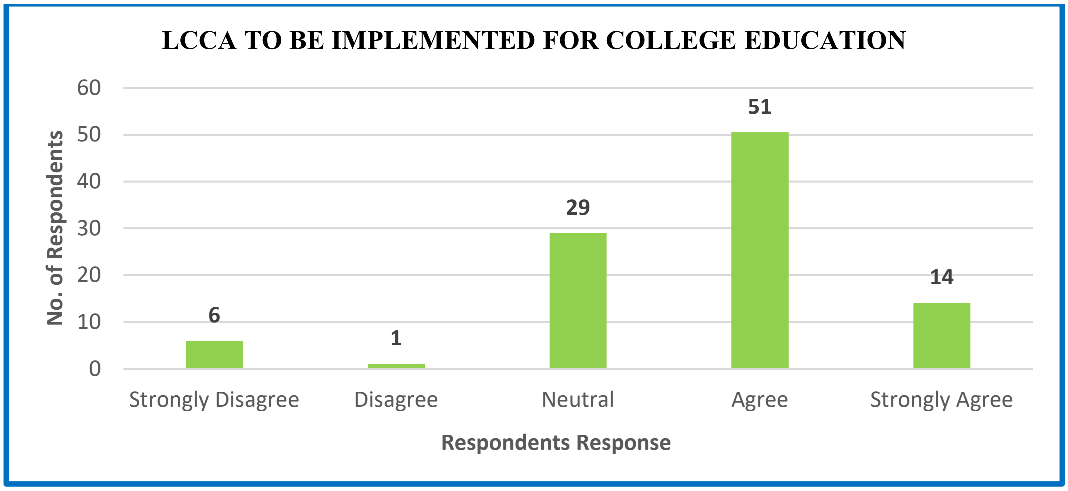

Fig. 9. LCCA implementation in college education

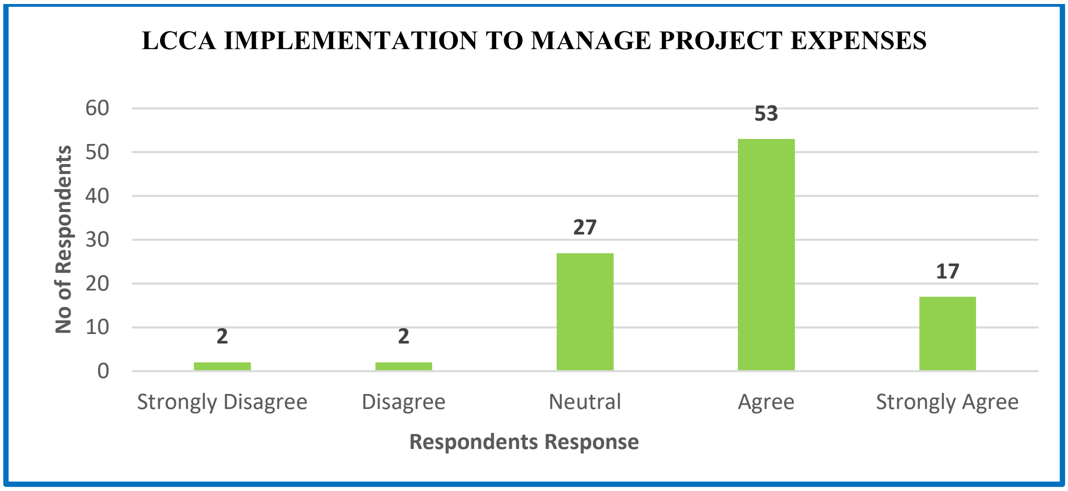

Fig. 10. LCCA managing project expenses

4.1.9. LCCA and eco-friendly technologies

As shown in Fig. 11, the respondents agreeing that LCCA can enhance eco-friendly technologies represented the largest portion of professionals in their respective departments with 54 respondents (53.5%) out of 101 participants. Respondents who prefer to stay neutral accounted for 35 respondents (35.64%).

4.1.10. LCCA for management of facilities maintenance programs

The respondents agreeing that LCCA enables facilities management to develop maintenance programs that improve efficiency represented the largest portion of professionals in their respective departments, with 54 respondents (53.5%) out of 101 participants, as shown in Fig. 12. 27 respondents choose to remain neutral.

4.1.11. LCCA life cycle cost calculations

The respondents agreeing to perform the project's LCCA cost calculations represented the largest portion of professionals in their respective departments, with 55 respondents (54.5%) out of 101 participants. Respondents choosing to remain neutral accounted for 27.7% or 28 respondents (Fig. 13).

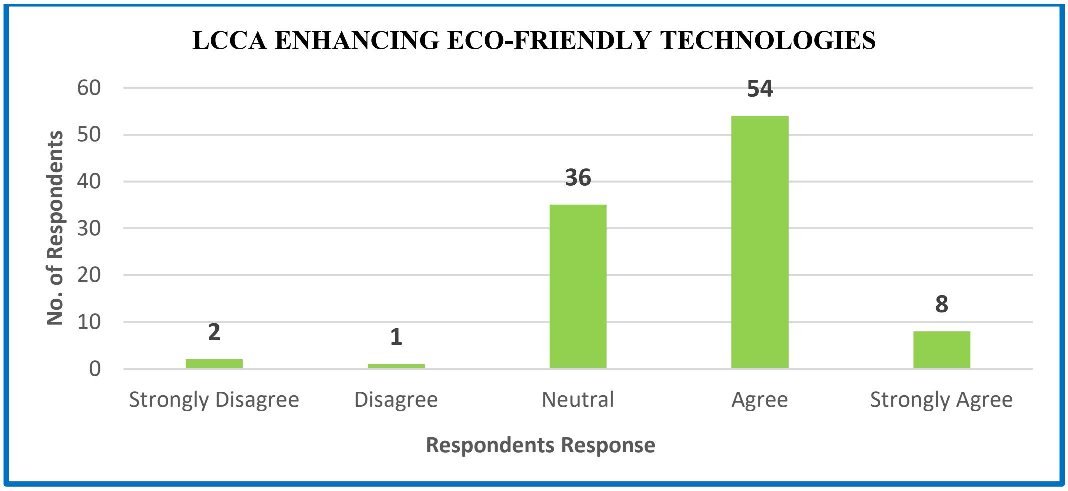

Fig. 11. LCCA and eco-friendly technologies

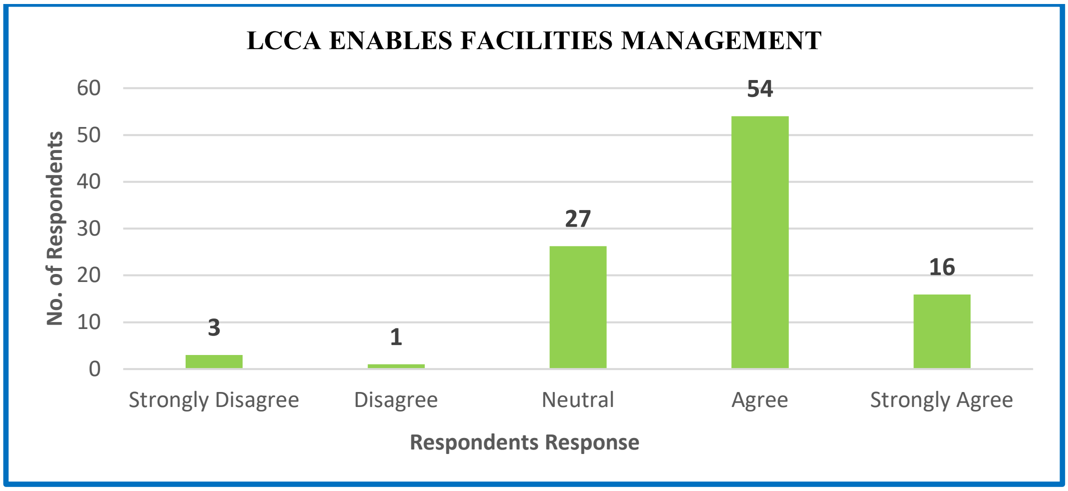

Fig. 12. LCCA assisting facilities management maintenance programs

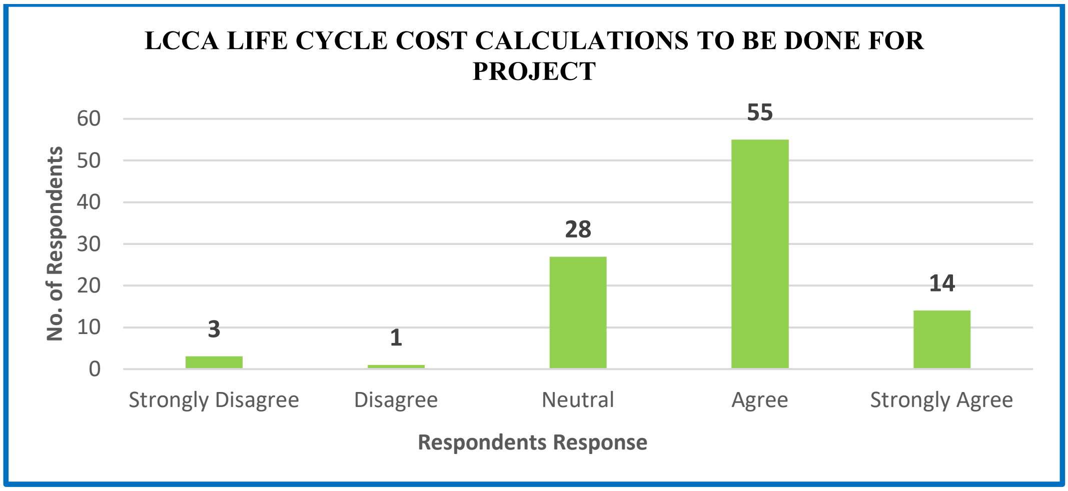

Fig. 13. LCCA life cycle cost calculations

4.1.12. LCCA and cost-optimized design for clients

The respondents represented the largest portion of professionals in their respective departments, with 54 respondents (54.1%) out of 101 participants. Respondents neutral for this response accounted for 29.7% or 30 nos. respondents (Fig. 14).

4.1.13. LCCA safety improvements

The respondents agreeing with LCCA improving safety, process, project, and service security represented the largest portion of professionals in their respective departments, with 54 nos. respondents (53.4%) out of 101 participants. Respondents neutral for this response accounted for 29.7% or 30 respondents, and 10.9% or 11 nos. respondents strongly agreed (Fig. 15).

4.1.14. Training of LCCA during studies or project work

The number of respondents who had any type of LCCA training during their project work was 28 respondents (27.7%), and the number of respondents who did not go through any training of LCCA during either their training or studies were 72.3% or 73 respondents (Fig. 16).

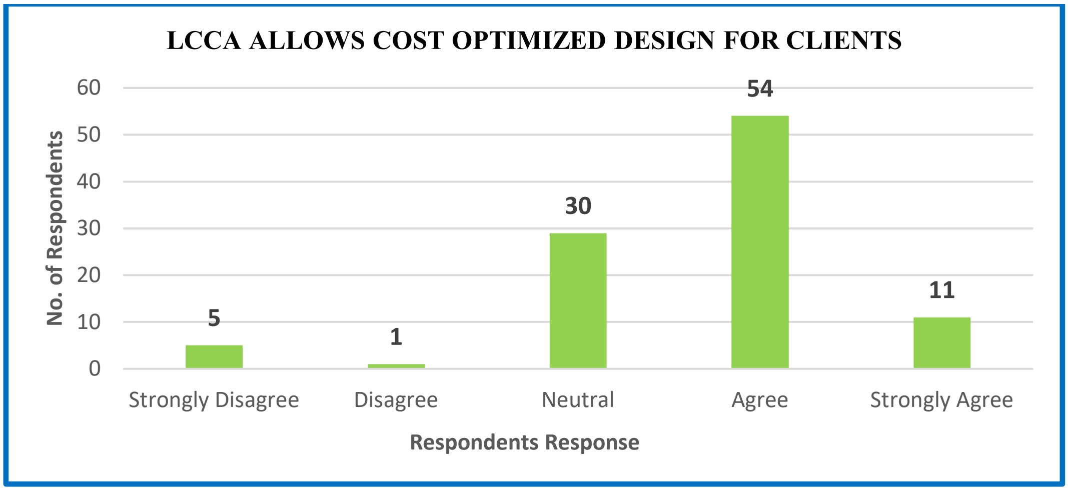

Fig. 14. LCCA allows cost optimized design

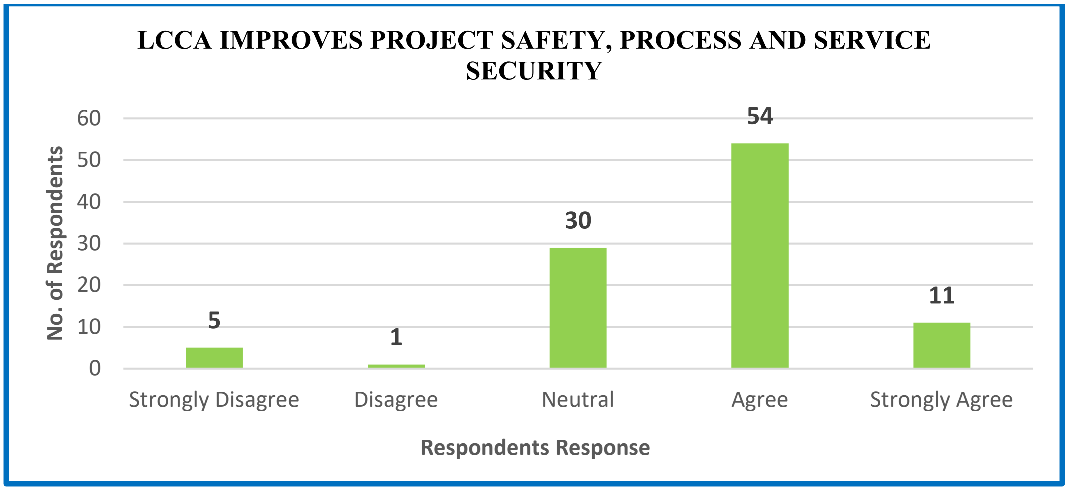

Fig. 15. LCCA improves project safety, process, and service security

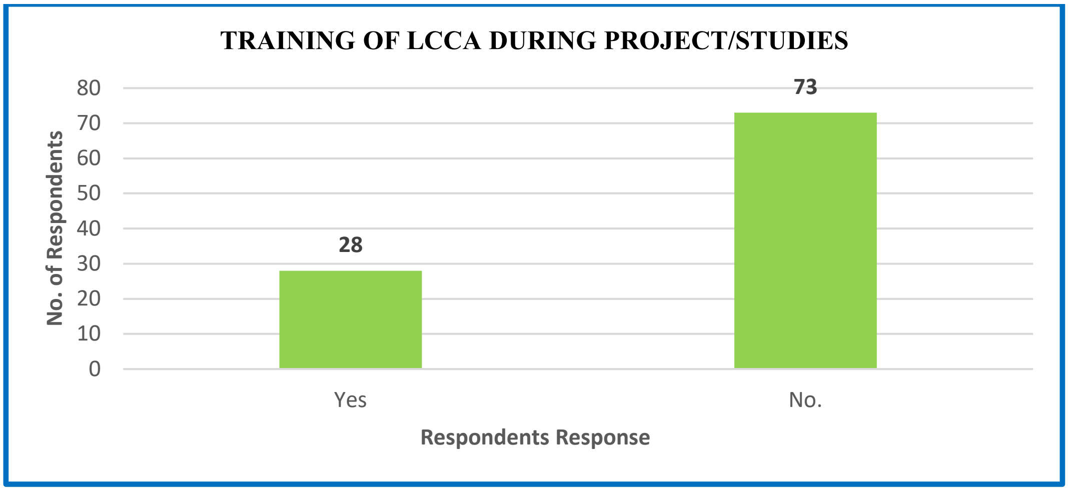

Fig. 16. Training of LCCA during project/studies

4.1.15. Using LCCA during the planning stages of a project or a product development

The number of respondents advised by their respective organizations to use LCCA techniques was 36.6% or 37 respondents. The number of respondents without advice from their respective organizations to use LCCA during the planning stages was 63.4% or 64 respondents (Fig. 17).

4.1.16. LCCA strategies resulting in cost-savings for project/product development

The number of respondents who agreed that adopting LCCA strategies would result in cost savings was 49.5% or 50 respondents. The number of respondents who disagreed with this proposal for LCCA was 12.9% or 13 respondents. The number of respondents unsure about implementing LCCA was 37.6% or 38 respondents (Fig. 18).

4.1.17. Arranging seminars with LCCA experts

The percentage of respondents who agreed to have LCCA training seminars was 85.1%. The percentage of respondents who disagreed with this proposal for LCCA was 14.9% (Fig. 19).

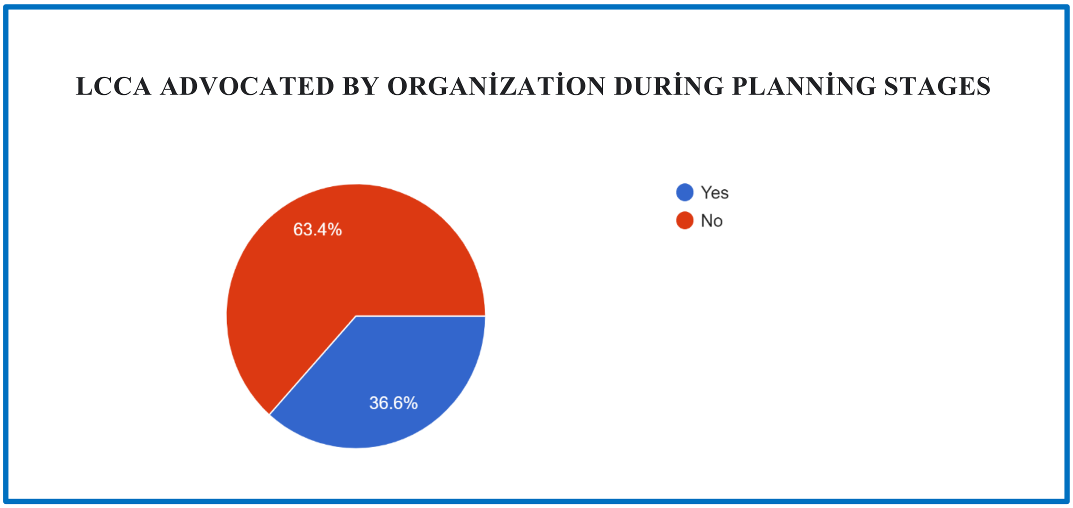

Fig. 17. LCCA to be used in planning stages advocated by the organization

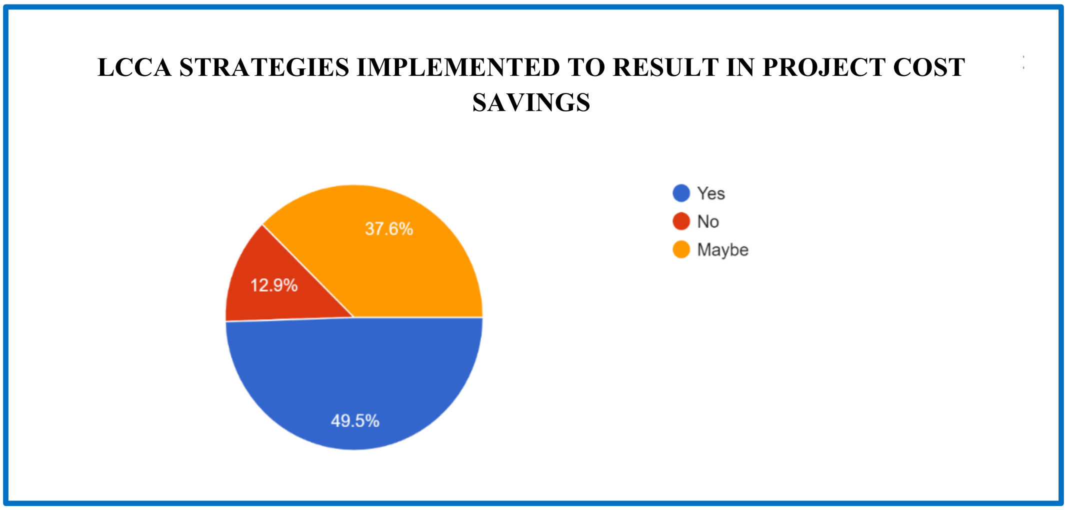

Fig. 18. LCCA strategies implemented to result in project cost savings

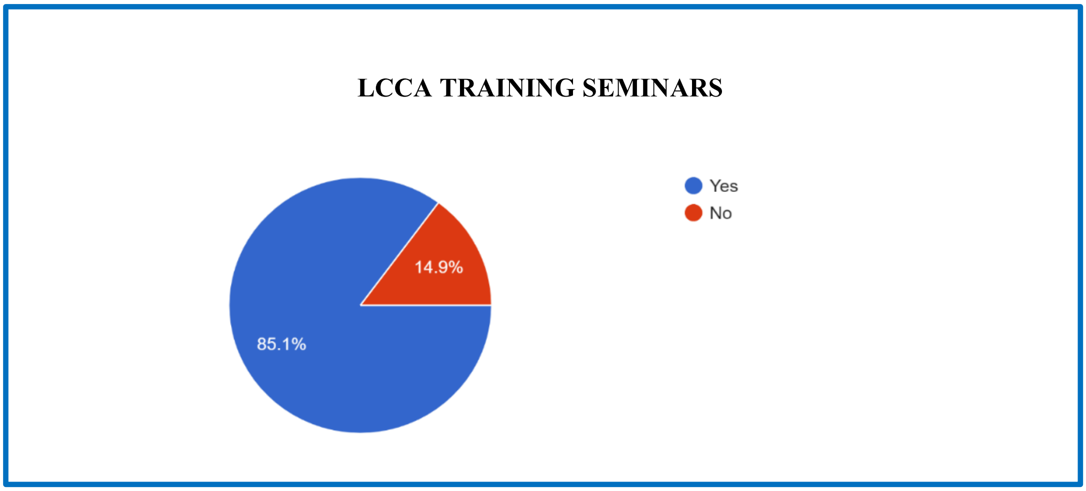

Fig. 19. LCCA training seminars

4.1.18. BIM training to improve efficiency for calculating LCCA

The number of respondents who agreed that including BIM training to decrease time and improve efficiency for LCCA analysis was 49.5% or 50 respondents. The number of respondents who chose to remain neutral due to lack of information or being unsure about LCCA analysis was 32.7% or 33 respondents (Fig. 20).

4.1.19. LCCA allows the development of energy-efficient systems

The number of respondents who agreed that LCCA analysis allows facility designers to develop energy-efficient systems was 58.4% or 59 respondents. The number of respondents who strongly agreed with this proposal for LCCA was 6.9% or 7 respondents. 31.7% or 32 respondents chose to remain neutral due to lack of information or being unsure about LCCA analysis (Fig. 21).

4.1.20. Calculating life cycle costs introduces novel concepts and knowledge to project clients and management

The number of respondents who agreed that life cycle costs introduce novel concepts and knowledge to project clients and management was 53.5% or 54 respondents.

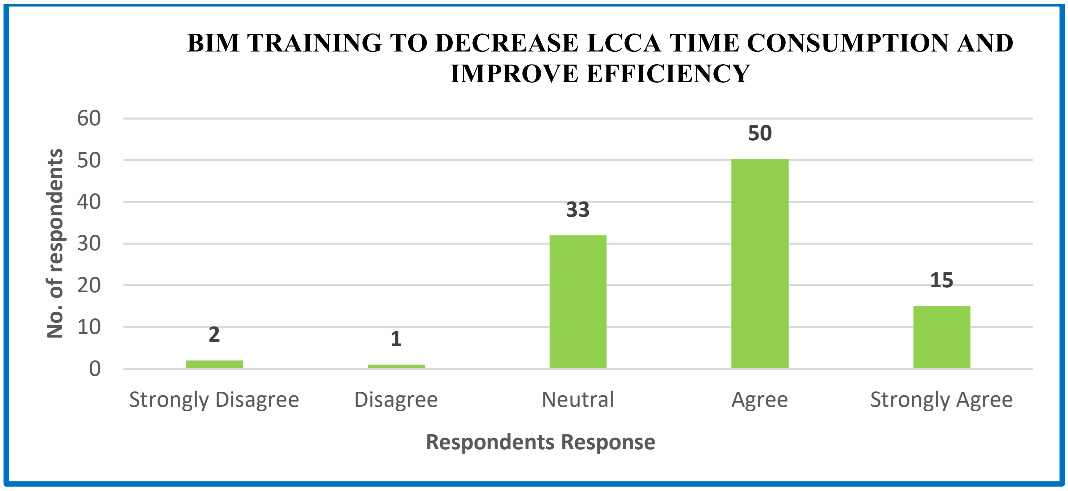

Fig. 20. BIM training to decrease LCCA time consumption and improve efficiency

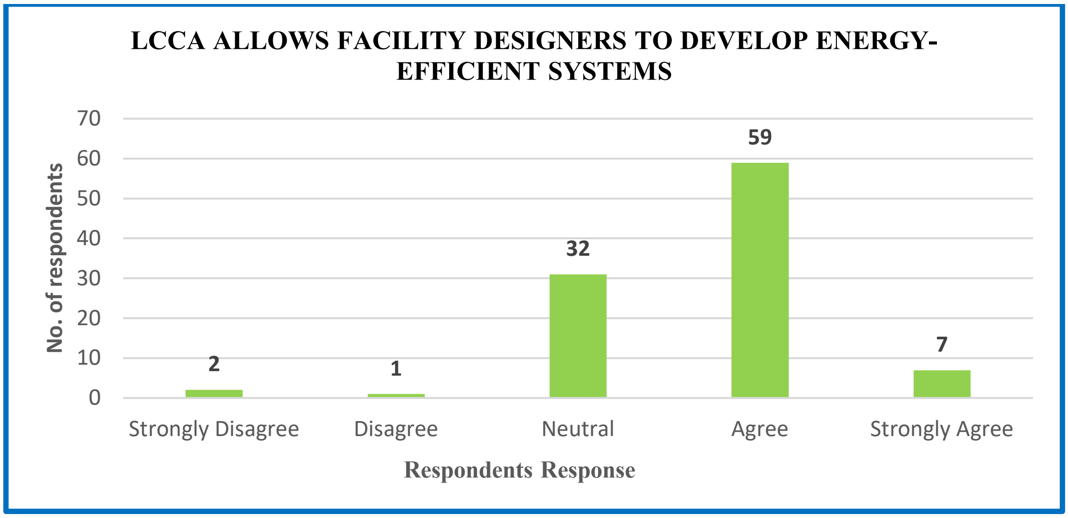

Fig. 21. LCCA allows facility designers to develop energy-efficient systems

34.7% or 35 respondents chose to remain neutral due to lack of information or being unsure about LCCA analysis (Fig. 22).

4.1.21. LCCA enables facilities management to develop maintenance programs that improve efficiency and effectiveness

The number of respondents who agreed that life cycle costs introduce novel concepts and knowledge to project clients and management was 53.5% or 54 respondents. The number of respondents who strongly agreed with this proposal for LCCA was 16.8% or 17 respondents. 27.7% or 28 respondents chose to remain neutral due to lack of information or being unsure about LCCA analysis (Fig. 23).

4.1.22. Public authorities to encourage LCCA education to save energy wastage

The number of respondents who agreed that life cycle costs education should be encouraged was 58.4% or 59 respondents. The number of respondents who strongly agreed with this proposal for LCCA was 15.8% or 16 respondents. 21.8% or 22 respondents choose to remain neutral due to lack of information or being unsure about LCCA analysis (Fig. 24).

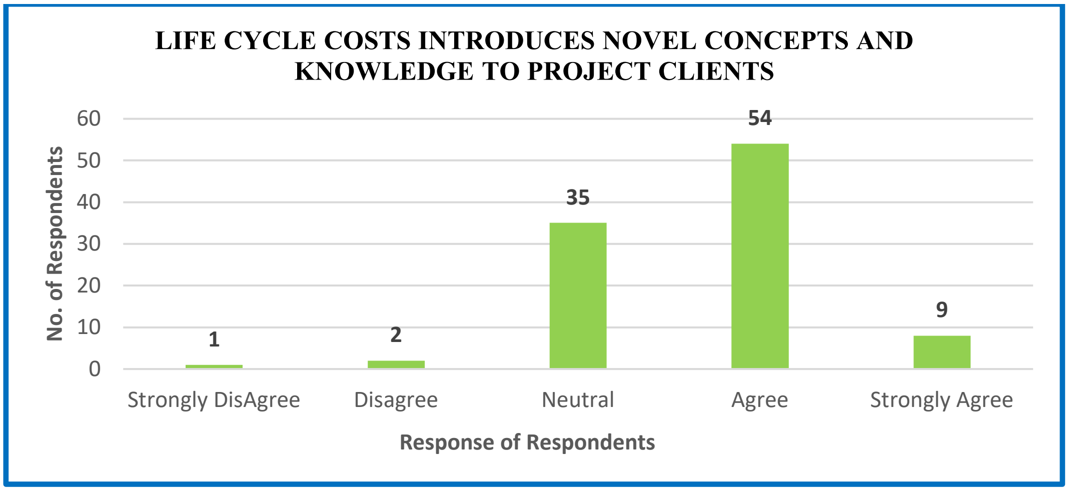

Fig. 22. Life cycle costs introduce novel concepts and knowledge to project clients

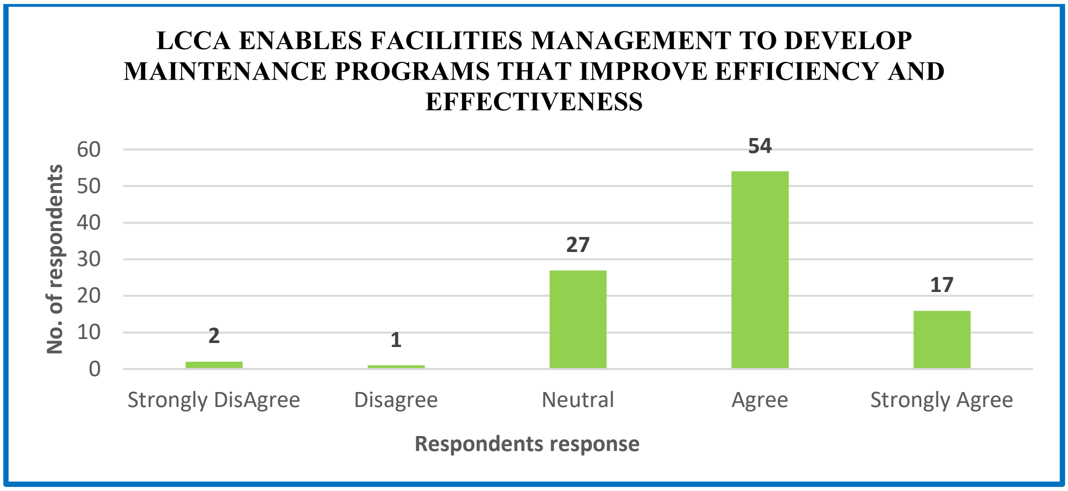

Fig. 23. LCCA enables facilities management to develop maintenance programs

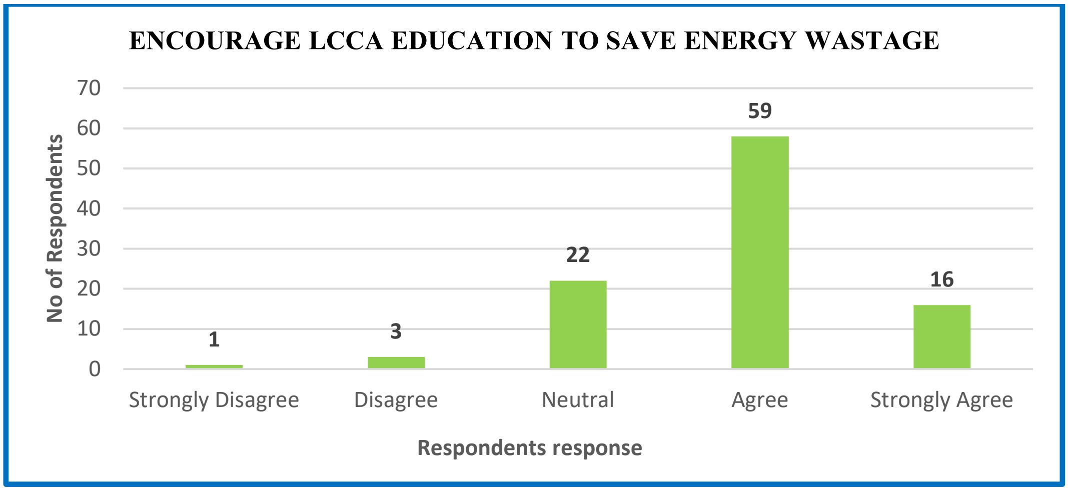

Fig. 24. Encourage LCCA education to save energy wastage

4.1.23. LCCA to enhance increasing green concept learning

The number of respondents who agreed that life cycle costs would enhance the green concept was 60.4% or 61 respondents. The number of respondents who strongly agree with this proposal for LCCA was 11.9% or 12 respondents. 23.8% or 24 respondents chose to remain neutral due to lack of information or being unsure about LCCA analysis (Fig. 25).

5. Data Analysis

5.1. Relative Importance Index (RII)

Based on the scores obtained for each questionnaire response, RII is used to assess the significance of each LCCA response. The importance of the various factors in this research study is rated on a 5-point scale. Eq. 1 represents the equation that determines the value of the Relative Importance Index (RII):

$$RII = \sum W/(A \times N) \quad (1)$$

Where;

W= weight given to each attribute by the respondent (1 to 5)

A= the highest weight (in this case is 5)

N= total number of respondents (101)

The RII values range from 0 to 1, in which the value of higher ranking indicates the more important attribute, which respondents consider (Table 1).

6. Discussions

The purpose of this research study was to determine the key variables influencing the application of LCCA in Qatar's construction sector. Respondents were given a survey questionnaire called LCCA, which took 38 factors into consideration. A survey questionnaire that could be accessed online was created to make it easier to distribute and gather information from respondents. The survey that was created was distributed to architects, project managers, designers, engineers, and quantity surveyors who are employed in the construction industry. A total of 101 participants assessed the significance of the direct influence of the LCCA methodology on the construction projects' performance factors.

The survey participants regarded the following LCCA-related criteria as the most significant, based on their assessment of the respondents. The most important variables in the questionnaire were addressed as use of LCCA methodologies for projects in managing project expenses and LCCA education factors to reduce energy waste.

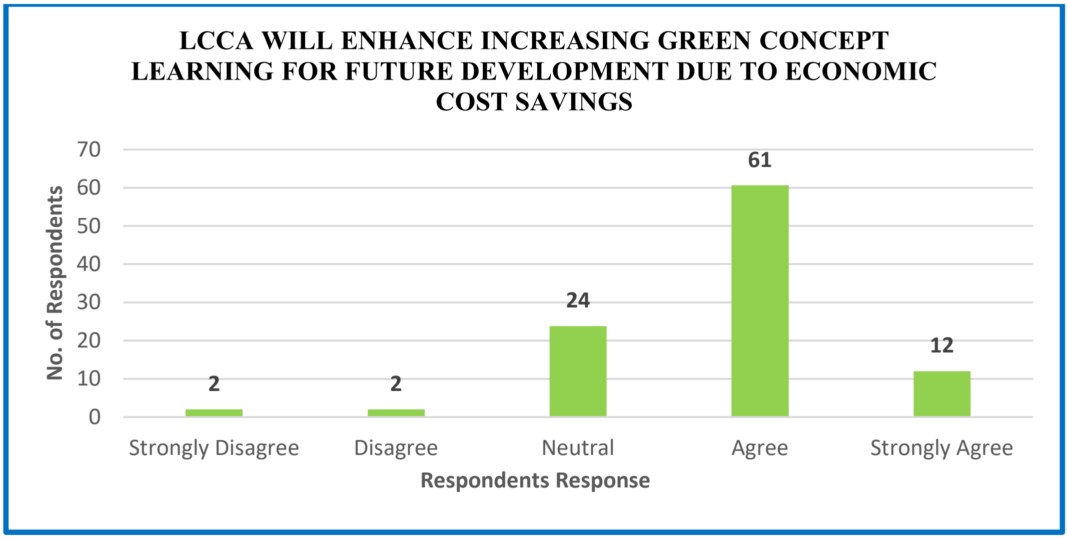

Fig. 25. LCCA will enhance increasing green concept learning for future development

Table 1. Relative Importance Index RII

S. No	Statements on subject	RII
1	LCCA education to project teams to save energy wastage	0.77
2	Utilizing LCCA can aid in managing project expenses	0.77
3	Life cycle cost calculations of a project or facility make it possible for clients and management to clearly understand the expenditure to purchase, operations, and maintenance of a structure or infrastructure system.	0.76
4	LCCA to enhance green learning concept	0.76
5	Include BIM training to increase the efficiency of LCCA	0.76
6	LCCA enables facilities management to develop maintenance programs that improve efficiency and effectiveness.	0.76
7	Clients seek designs that yield long-term economic benefits, and LCCA enables the selection of cost-optimized alternate designs in the long run.	0.76
8	LCCA will enhance increasing green concept learning for future development due to economic cost savings.	0.76
9	The accuracy and precision of maintenance cost calculations will be enhanced by utilizing LCCA, which provides a detailed cost breakdown.	0.74
10	Due to LCCA, managers of projects and facilities can calculate and keep replacement parts in storage, thus saving time and cost.	0.74
11	LCCA can enhance in development of eco-friendly technologies by having detailed economic studies of their product and feasibility.	0.74
12	LCCA incorporates energy cost calculations allowing facility designers to develop energy-efficient systems.	0.74
13	Integrating LCCA methodology into a project improves its safety, as the benefits of life cycle cost analysis extend to process, project, and service security.	0.74
14	The accuracy and precision of maintenance cost calculations will be enhanced by utilizing LCCA, which provides a detailed cost breakdown.	0.74
15	LCCA enables project and facility managers to estimate and stock replacement parts, resulting in time and cost savings.	0.73
16	Calculating life cycle costs introduces novel concepts and knowledge to project clients and management.	0.73
17	Training in NPV, IRR, and CBA will assist professionals in calculations for LCCA	0.72
18	Do you think incorporating LCCA cost-related benchmarks as a primary specification within a project would yield economic benefits in terms of cost?	0.72
19	LCCA to be included in College Education	0.72
20	LCCA Methodology is better than normal cost calculations for a project	0.70

One noteworthy component that was thought to boost the efficiency of LCCA was BIM training. The notion of green learning was deemed significant by participants in the LCCA survey, indicating the growing significance of green learning, implementation, and sustainability within the construction industry.

The participants ranked the following LCCA-related factors as the most significant, based on their perception of the respondents. The following factors were ranked by participants from all over

Qatar as the most important top five influencing factors for LCCA:

(1a) Utilization of LCCA methods in managing project expenses.

(1b) LCCA education and awareness to facilitate in preventing energy wastage of projects or processes.

(2a) BIM training to increase the efficiency and effectiveness of LCCA.

(2b) Green learning concept to be enhanced while using LCCA.

(2c) Life cycle cost calculations to ensure that the client/management understands the expenditure of project expenses.

(2d) LCCA enables facilities management to develop maintenance programs that improve efficiency and effectiveness.

The participants listed the least significant factors as follows:

1. Consideration of LCCA Methodology to be better than normal cost calculations for a project.
2. Incorporating LCCA cost-related benchmarks as a primary specification within a project.

The 38 factors mentioned in the study are all considered significant for LCCA implementation in Qatar's construction industry. However, the first five factors in Relative Importance Index show that LCCA training and education during work to save energy wastage, utilization of LCCA for project expenses, consideration of green learning and BIM training concepts from increasing the efficiency and effectiveness of LCCA implementation play the most important role in respondents' perception.

It is to be noted that LCCA techniques and principles, once correctly implemented within an organization, project, or process, will assist in determining optimum solutions for investment decisions that involve consideration of long-term benefits in terms of cost-effectiveness and maintenance. LCCA also facilitates top management in making strategic decisions regarding selecting the most cost-effective projects and processes.

Considering the above factors, it can be concluded that LCCA not only improves the long-term economic outlook and costs for a facility or project but is also a main factor in improving its maintenance programs, promotion of energy conservation, optimized design of facility and processes, eco-friendliness, public safety, and project's security.

7. Conclusions

The goal of this study was to identify the key variables influencing the application of life cycle cost analysis (LCCA) in Qatar's construction sector. The LCCA survey form that was given to respondents took 38 criteria into account.

Google Forms was used to develop a web-based survey questionnaire that would make it easier to distribute and gather data from responders. The survey that was developed was shared with experts in the construction industry. A total of 101 participants assessed the significance of the Life Cycle Cost Analysis methodology's direct influence on the performance elements in construction projects.

The authors recommend that contractors, sub-contractors, and consultants readily accept and incorporate the techniques and methodology of LCCA. This will benefit their respective projects and processes in managing project expenses and optimizing energy costs by imparting proper LCCA education and training addressing the wastage of energy during their project or process life cycles. The above-implemented measures will, in turn, allow them to have proper control of the operating and maintenance costs of the facility, project, or system and hence minimize any type of economic losses to the process or project.

The green learning concept for LCCA is recommended to be enhanced in the construction industry in order to reduce greenhouse gases through the application of renewable energy-related technologies for improvement in processes which will also improve their efficiency of energy usage.

In current LCCA practice, it is recommended to use LCCA software in different construction industries, and several organizations have already started to design their own LCCA software to suit their specific needs for incorporating LCCA practice in their industry.

Utilizing Building Information Modelling (BIM) in LCCA is recommended, which can facilitate the transformation of facilities or projects, especially for their operations and maintenance departments (O&M). BIM technology can improve the efficiency and effectiveness of maintenance and repairs required for facilities/projects, planning and implementation of energy management systems, and improvements for emergency management systems.

Since life cycle cost calculations provide maintenance and operating costs of facility, project, or process, it is recommended for future work incorporating LCCA to design a maintenance program of the facility or project that is consistent and does not conflict during normal and peak operation stages. LCCA also allows pinpointing specific areas/phases of the project with the highest requirement for improvements and where the resources are required to be allocated. Hence in this manner, the financial resources are used effectively without any wastage of funds and allow clients, stakeholders, and management to understand the expenditure of expenses clearly.

LCCA analysis has shown, over time, improvement of investment decisions that can benefit the project, processes, related stakeholders, and the public. The submitted survey questionnaire poses questions to respondents which relate to improved forecasting capabilities to energy conservation, which provides short and long-term advantages from the viewpoint of operating a facility, property, or process.

It is recommended by the authors to have LCCA performed as soon as possible during the lifespan of the process or project, especially during the design stage of the project, so that it can easily be included/integrated within the design process.

Due to the systematic approach of LCCA, the processes, and activities of subcontractors and contractors are optimized, saving cost and resources and consequently benefiting the organization or project. LCCA education to save energy wastage is one of the main factors to be considered by the respondents during the survey.

It is recommended to encompass LCCA within the regulatory framework of the facility and project, which will also improve public safety and project security. LCCA benefits include compliance with regulations, conservation of energy, and proper staff training, which, in the long run, make facilities, projects, and processes safer to be used by the public.

The work presented in this research paper can be improved further by:

- Arranging and conducting interviews of respondents at their workplace in person and having detailed discussions with them regarding LCCA applications practiced in their respective professional fields.
- Providing an LCCA survey questionnaire to all professionals in the construction industry working in the MENA region to increase the number of respondents, their experience, and their expertise.
- Investigate more factors of LCCA that can improve efficiency and cost savings of a project, by conducting interviews with more professionals practicing and specializing in LCCA and concurrently conducting a more extensive and advanced literature review of research and progress being made in the fields of LCCA.
- Exploring and reviewing the different software being designed and developed for LCCA and checking their consistency, effectiveness, and accuracy in the prediction of life cycle costs of projects.
- Since LCCA includes optimization of energy costs in its process, it gives future incentives to engineers and architects to design and develop facilities, projects, and processes that are energy efficient and environmentally friendly.
- LCCA can accurately forecast the expenses related to the repair and maintenance of the facility or project. In addition, water and utility costs can be forecasted with improved accuracy and precision, providing a realistic breakdown of maintenance costs over a longer period saving money for public facilities or projects.
- It would be beneficial to study the difference between the perception of owners and FM vs other groups on the paper's topic.

Declaration

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Author Contributions

M. Gunduz: Conceptualization, Methodology, Investigation, Visualization, Resources, Validation, Writing- Review & Editing, Supervision, Project administration; O. Sirin: Conceptualization, Methodology, Investigation, Visualization; Resources, Validation, Writing- Review & Editing, Supervision, Project administration; N. Ahmed: Conceptualization, Methodology, Investigation, Writing- Original Draft, Visualization; Resources, Validation, Writing- Review & Editing.

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Not applicable.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

Ethics Committee Permission

The authors declared that all participants were fully informed consent for inclusion before they participated in the study, and the study meets national and international guidelines.

Conflict of Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Appendix A

Sample questionnaire

Life Cycle Cost Analysis Questionnaire

Life cycle cost analysis (LCCA) is a methodology for calculating the cost-related economic parameters of a process, product, or service. The LCCA is determined by adding all costs in the lifecycle and allowing the user to look at financial results from a long-term perspective. Some of the leading predictive tools used in calculating Life Cycle Cost Analysis are Net Present Value, (NPV), Cost Benefit Analysis (CBA), Payback Period (PP) and Internal Rate of Return (IRR) which are effective for calculating LCCA. LCCA allows the user to develop a predictive model for representing the cost of ownership for the entire life cycle of an asset which may be infrastructure, plant, project, or a process.
The below questionnaire will assist in gaining new knowledge, insight and understanding regarding awareness of life cycle cost analysis practice in Qatar's construction industry.

General Questions Section

This section of the questionnaire comprises general questions related to the respondent's occupation, qualifications, industry, and experience they have for working in that industry.

1. Please select your educational qualification

Mark only one oval.

- High School diploma or Equivalent
- equivalent Associate degree or
- diploma Bachelors degree
- Masters degree
- Ph. D
- Other

28. Do you think that utilizing LCCA can aid in managing project expenses?

Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly Agree
- Other: ______________

29. Do you think LCCA methodology is much better than typical cost calculations for a project?

Mark only one oval.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

30. Do you think incorporating LCCA cost-related benchmarks as a primary specification within a project would yield economic benefits in terms of cost?

Mark only one oval.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly agree