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A Framework of Integrated Sustainability and Value Engineering Concepts for Roads Projects

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ABSTRACT

This research addressed the critical intersection of sustainability and road maintenance, "Major Arterial System," explicitly focusing on applying Value Engineering (VE) principles. In the face of mounting challenges posed by urbanization, climate change, and resource scarcity, optimizing the life-cycle performance of road infrastructure has become a pressing imperative. Infrastructure projects are a country's economic development locomotive, yet they negatively impact environmental and social concerns. As a result, these initiatives should be reviewed and developed based on their expected sustainability performance to overcome the three obstacles you encounter in an integrated manner (Economical- Environmental-Social). Previous research in sustainable engineering has employed various strategies and approaches to solve this challenge. Value Engineering (VE) is a critical strategy that systematically assists managers in this field. Thus, integrating sustainability and Value Engineering (VE) will increase the value of an infrastructure project. This study aims to provide a framework incorporating VE and sustainability ideas for road repair in Egypt to improve project values. According to the findings, both VE and sustainability are in road maintenance. As a result, the relationship between the two was determined, and a framework for integrating sustainability and VE was developed.

Keywords: Sustainability; Value Engineering; Embodied Co2; Carbon Capture Use and Storage (CCS).

1- INTRODUCTION:

The world now depends on infrastructure. Without it, it would be difficult to transport food, goods, and services, with no possibility of power to our homes or access to clean water, and would not be able to travel or move around [1]. It is infrastructure projects that sustain vital tasks in life. There are different types of infrastructure projects, including (Roads, and Streets, Bridges, Railways, Mass Transit, Airports, and Airways, Water Supply and Resources, Waste Management, and Wastewater Management, Power Generation and Transmission Telecommunications Hazardous Waste Removal and Storage). The importance of infrastructure projects has increased dramatically in recent years with the increase in the world's population and its concentration in cities [2]. Road maintenance pays excellent attention to the deep belief that road maintenance and preservation are no less essential than their implementation with the aim of maintaining the level of road performance and ensuring safety for its users, as more than (60,000) km of asphalt roads are subject to regular and preventive maintenance in Egypt. The development of these projects is the driving force for economic growth, and it is an integral part of social and environmental development. One of the most critical challenges facing developing infrastructure projects is achieving sustainability [3]; the emergence of the concept of sustainability has been motivated by natural catastrophes, environmental contamination, depletion of natural resources, and other incidents. By 2050, over 66% of the world's population is estimated to live in cities. 75% of greenhouse gas emissions occur by the people, either directly or indirectly, due to this significant influence. Similarly, there are various obstacles to overcome when implementing sustainable infrastructure.

Sustainable development has gained significant importance in various disciplines, including infrastructure. Infrastructure projects demand more complex engineering, financial, and planning work and unique resources than ordinary buildings to achieve sustainable development requirements. Infrastructure projects must adhere to the principles of sustainable development, and the strategy for developing infrastructure projects must meet the three sustainability requirements (economic, environmental, and social) [4]. At the same time, The term "VE" refers to a methodical, organized, and function-oriented strategic tool that enables a variety of specialists to work together to enhance the quality and performance of their systems or offerings at the lowest possible overall cost. [5]. Therefore, VE improves function safety, functional performance, sustainability, and design while giving cost-effective solutions, reduced work time, enhancements in quality, and overall cost reductions. [6]; [7] ; [8]; [9].

Using VE, decision-makers can evaluate, rank, and prioritize projects based on their anticipated sustainability performance and then select the options that result in the highest overall sustainability achieved within specified parameters. This paper aims to develop a comprehensive sustainability optimization method for infrastructure projects in Egypt. The sustainability measurement system in previous studies includes standardized measurement methods such as life cycle assessment (LCA) to determine environmental impacts and life cycle cost analysis (LCCA) to determine economic impacts by using the Analytical Hierarchy Process (AHP). In the end, a set of weights is given that is difficult to understand for many people. Therefore, progress towards sustainable development required measuring a limited number of indicators to give sustainability standards for highway designs, setting a mark that recognizes sustainability achievements, and transforming the three sustainability elements into a single element through which it is easy to make a decision whether this alternative achieves the best sustainability or not, and this is what was achieved in this research, the sustainability elements were integrated and expressed as costs for easy comparison using value engineering. Where the factors influencing the three pillars of sustainability were identified and evaluated, the project life cycle cost for the maintenance process was calculated. Then, the most influencing factors on the environment were determined, as the concentration of carbon dioxide in the atmosphere, which is the primary driver of global warming, so the carbon emitted was calculated for each of the different maintenance methods, and the cost of disposing by using carbon dioxide capture and storage technology CCS, to convert all the pillars of sustainability into one factor, which is the cost, to facilitate the process of comparison between alternatives. Finally, an application was developed to facilitate the work of these accounts on stakeholders, and a case study was applied to ensure its effectiveness and document the importance of using value engineering to achieve sustainability in road maintenance projects.

2- LITERATURE REVIEW:

2.1 Road Maintenance

Roads are defined as corridors (engineering structures) above the ground to pass vehicles, pedestrians, and animals and transport goods from one place to another. Roads may be divided in terms of the nature of the paving into a) paved - asphalt, b) paved - concrete, c) gravel, and d) dirt, such as unpaved roads; their nature is dirt. Roads are classified into main roads, collector roads, and local secondary roads in function [10].

Roads in Egypt may also be classified according to traffic: dual roads, first-class roads, second-class roads, and third-class roads. The responsibility for the environmental deterioration of roads falls on the following bodies: the Ministry of Transport and Communications and the Ministry of Housing and Construction - Localities. Researchers believe that environmental deterioration of roads falls primarily on the state and then on society. Among the causes of roads' environmental deterioration is the road network's insufficiency in meeting the and increasing [11]. The number of licensed vehicles of all types and the scarcity of parking spaces. Researchers believe that the damage caused by environmental deterioration of roads can be classified into material damage or loss, loss of time, loss of effort or health, psychological loss, and human loss. There are several methods to determine the methods of measuring these damages: 1- The monetary measurement method, 2- The quantitative measurement method, and 3- The descriptive measurement method [12].

Manifestations of environmental deterioration of roads: crack, numerous potholes, speed bumps, traffic congestion, air pollution, lack of afforestation, poor lighting, neglect of cleanliness, and noise. Road maintenance is required to reduce the environmental deterioration of roads. The word “maintenance” is metaphorically applied to all work that aims to preserve the road. Maintenance means maintaining the performance of the road and is divided into 1- Preventive maintenance, 2- Remedial maintenance, and 3- Repair and restoration qualifying. The road maintenance process consists of several stages to calculate costs: 1- Identifying the road sections that need maintenance work. 2- Defining and specifying the types and quantities of maintenance work required for each section. 3- Estimating the cost of maintenance activities for each road section. 4- Calculate the total cumulative cost of maintenance activities. Maintenance costs can be classified into fixed maintenance costs and variable maintenance costs. It can also be divided into direct and indirect costs [13].

This study aims to create a model for highway maintenance in Egypt (repair and rehabilitation) to restore balance to the environmental system, leading to the protection of resources, economic prosperity, and social justice in what is known as sustainability, which achieves the least possible damage to the environment while increasing development rates, through technology Value Engineering.

2.2 Sustainability

Earlier human societies, like the Bushmen of South Africa, pioneered the concept of sustainability [14]. Global environmental degradation, the loss of natural resources, and related societal issues have intensified concern about sustainability[15]. Many companies have adopted sustainability, pushing society to embrace it to improve the world. [16]. The construction industry is notable in this sense, as sustainability has resulted in a complete and noticeable change. [17]. As a result, sustainability principles are now linked with building processes to lessen physical assets' total environmental effect throughout their life cycles [18]; [19]; [20]. As a result, in building projects, value and risk can be balanced with the help of sustainability [21].

Sustainability will be essential if the building industry wishes to fulfill the 17 SDGs for sustainable development listed in the UN Agenda 2030 [22]. This is due to the direct connections between the industry's indirect influence on the goals of "poverty, education, health, hunger, gender equality, energy, and climate change," as well as the two objectives of "sustainability and resilience in infrastructure" and "cities." [23]. Because sustainability is a method for enhancing human well-being so that people may coexist with their surroundings without hurting the eco-systems accomplished [24]; [25]; [26][27]. Consequently, a decrease in the built environment's energy consumption and natural resource protection, which will benefit future generations, have emerged as the main factors in the definition of sustainable performance ([28]; [29]; [30].

Sustainability adoption involves a cradle-to-grave strategy. After a product has been designed and built, it is demolished [31]; [20]. It begins with extracting essential elements and concludes with the product's annihilation. As a result, sustainability must adhere to organizational criteria such as building, facilities management, and design work practices; also, there are technological needs (technologies to boost energy performance). Environmental, economic, and social sustainability consequences have been roughly categorized by [32] into three groups.

Although there are sustainability advantages, the general assumption is that green construction requires a more significant amount of money and time to execute [27]; [33]. Additionally, financial risk is associated with implementing sustainability because project costs may exceed the allotted sum [34]. Additionally, inadequate policy enactments and the client's lack of awareness and expertise hinder the implementation of sustainability [32]; [16]. Additionally, investigations have found that while practitioners are aware of sustainability, its implementation has been limited thus far [35]; [36]; [37]. The combination of sustainability and VE has been highlighted as a practical solution to address the obstacles encountered during the execution of sustainability [38]. It will boost the long-term value of construction while enhancing its economic profitability.

The sustainability measurement system in previous studies includes standardized measurement methods such as life cycle assessment (LCA) to determine environmental impacts and life cycle cost analysis (LCCA) to determine economic impacts by using the Analytical Hierarchy Process (AHP). In the end, a set of weights is given that is difficult to determine. Numerous individuals understand What is meant by that. Therefore, progress towards sustainable development required measuring a limited number of indicators to give sustainability standards for highway designs, setting a mark that recognizes sustainability achievements, and transforming the three sustainability elements into a single element through which it is easy to make a decision whether this alternative achieves the best sustainability or not, and this is what was achieved. In this research, the sustainability elements were integrated and expressed as costs for easy comparison using value engineering.

2.3 Value Engineering (VE):

Value management strategies aim to identify, optimize, and obtain value for money, focusing on overall In other words, it is a broad phrase that incorporates value strategies such as value planning (during the project idea stage), VE (during the design and construction phases), and value analysis (to quantify efficacy at any point in the life cycle) [39]; [40]. VE is a methodical, organized, and function-oriented strategic tool that enables a multidisciplinary team of professionals to work to improve the quality and performance of their systems or services at the lowest overall cost [5]. As a result, VE allows cost-effective solutions, time savings, quality enhancements, and total cost savings, all while boosting function safety, functional performance, and maintaining ability [6]; [7]; [8] ; [9]. As a result, VE is more than just a cost-cutting strategy; it is additionally a tool for enhancing value [38]. To reap the advantages of VE, a project must be either costly or complex [7].

Although VE has many benefits, professionals are hesitant to use it for a variety of causes, including an absence of knowledge, choices based on erroneous beliefs, habitual thinking, not desirable views, a refusal to ask for advice, a lack of time, technological advancements, and inadequate interpersonal connections [41];[42]. Researchers developed the VE Job Plan, Functional Analysis Systems Technique (FAST), and Delphi Method to address these issues, encouraging creative thinking [43]. These solutions consider the numerous needs for VE deployment [44].

SAVE (Society of American Value Engineers), which proposed a six-stage task plan, was used in this study. The phases of the job plan are as follows:

1. Information: information, background, purpose, and demand information are gathered for the project's many components [45]; [46] ; [47].

2. Function: function analysis involves identifying and examining the function [48]. Each function is weighed against the performance to determine its importance [49].

3. Creative: the creative phase involves developing alternative techniques according to functional analysis [49]. To create a list of alternatives, brainstorming and accommodating creative suggestions are strategies [45]; [8].

4. Evaluation: unworkable or unworthy of further investigation alternatives are eliminated [49]. Using idea comparison, feasibility rating, and analysis matrices, options are sorted and structured to choose workable alternatives [46]; [44].

5. Development: the selected solutions or concepts are transformed into proposals for submission to the owners of the idea [50]. Extensive scientific and economical testing is performed to provide final suggestions on the possibility of the proposals being effectively implemented [51].

6. Presentation: the project owner is presented with a proposal for approval together with information on cost reductions and additional materials [49]; [26].

2.4 Using Value Engineering (VE), Sustainability:

Combining VE and sustainability is used to maintain a project's excellence, dependability, and longevity while improving its performance across its life cycle [47]. As stated by [26], VE can be utilized to achieve these objectives. Sustainability concepts are developed to increase the value of projects. According to recent studies [52], [53], VE makes choosing the system that would deliver the best sustainable solutions easier. To produce sustainable projects and increase the value of construction, experts have frequently suggested integrating VE with sustainability [54], [38].

Additionally, this combination will make it easier to create a platform that supports and includes environmentally friendly and cost-effective designs and development during the life of the projects.[55]. Therefore, it is clear that integrating environmental ideas with VE will make them more valuable and effective. The anticipated benefits will give the client a greater return on their investment, and other stakeholders will also benefit in terms of the sustainability of the environment, the economy, and society [56].

According to earlier research, there are several obstacles to integrating sustainability with VE, including time constraints, an absence of sustainability standards guidelines, a loss of understanding and awareness of sustainability, and contradictory sustainability perspectives [57]. [58] contrasting the conventional three-way equilibrium model of cost, time, and quality with a Pentagon model incorporating social and environmental factors is necessary to include environmental and social aspects in design and construction projects, as shown in Figure 1. However, as [33] stated, a rigorous VM Job Plan can successfully integrate environmental concerns throughout a project's life cycle. The study created a research approach to give a framework to combine VE with sustainability to maximize project value in the construction business.

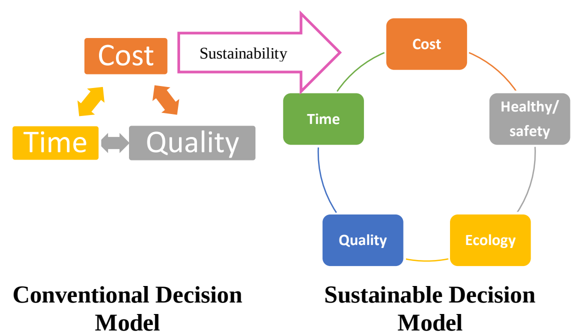


Figure: 1 Decision-making frameworks for construction projects that are conventional and sustainable [58]

3- METHODOLOGY:

To support the road maintenance process, the study aimed to connect the state-of-the-art expertise in sustainability and value engineering, which has recently been shown to positively impact costs, environmental results, and the global trend toward green construction [59].

The study's methodology was centered on using value engineering to assess alternatives to environmentally friendly maintenance techniques and demonstrate their viability as a replacement for conventional techniques. Instead of employing traditional maintenance when there are flaws in the road base layer, the Full-Depth Reclamation FDR approach was utilized as an example of environmentally friendly maintenance. Each of the two methods' costs and, thus, their relative worth has been calculated. To compare the alternatives in terms of the environmental aspect, criteria have been chosen to make the results more understandable; an integrated model that facilitates the process of combining value engineering and sustainability has been used to calculate the carbon emission of the alternatives and the cost of disposing of them, as they are the primary cause of the process warming that leads to the climate change that the world is currently experiencing.

By using VE as a technology for problem-solving that generates the ideal and unorthodox answer, a perfect balance between functionality, performance, quality, and cost can be accomplished by adhering to the six-step "VE Action Plan" of the SAVE technique[60] , as shown in Figure 2. Is a simplified figure to illustrate the stages of value engineering and what happens during each stage. As a result, the following research techniques are included: The problem and its existing, appropriate solutions are recognized during the VE information phase, paired with the introduction and problem statement. The open choices are then examined. The VE study starts with a job analysis, then moves on to the VE creativity phase, where it explains how the alternatives perform concerning comparison criteria; the VE evaluation phase, which establishes the values and costs of the other options; and the VE development phase, where the results are compared and evaluated. The presenting stage corresponds to the conclusion and covers the research findings and recommendations.

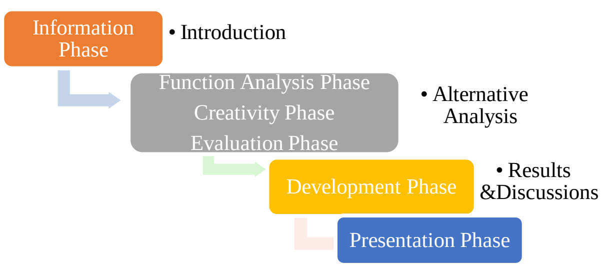


Figure 2: Structure of the research using the Value Engineering approach

As a summary of the model for fusing sustainability with value engineering, the Sustainable Road Maintenance Model Using Value Engineering (SRMVE) is presented in Figure 3.

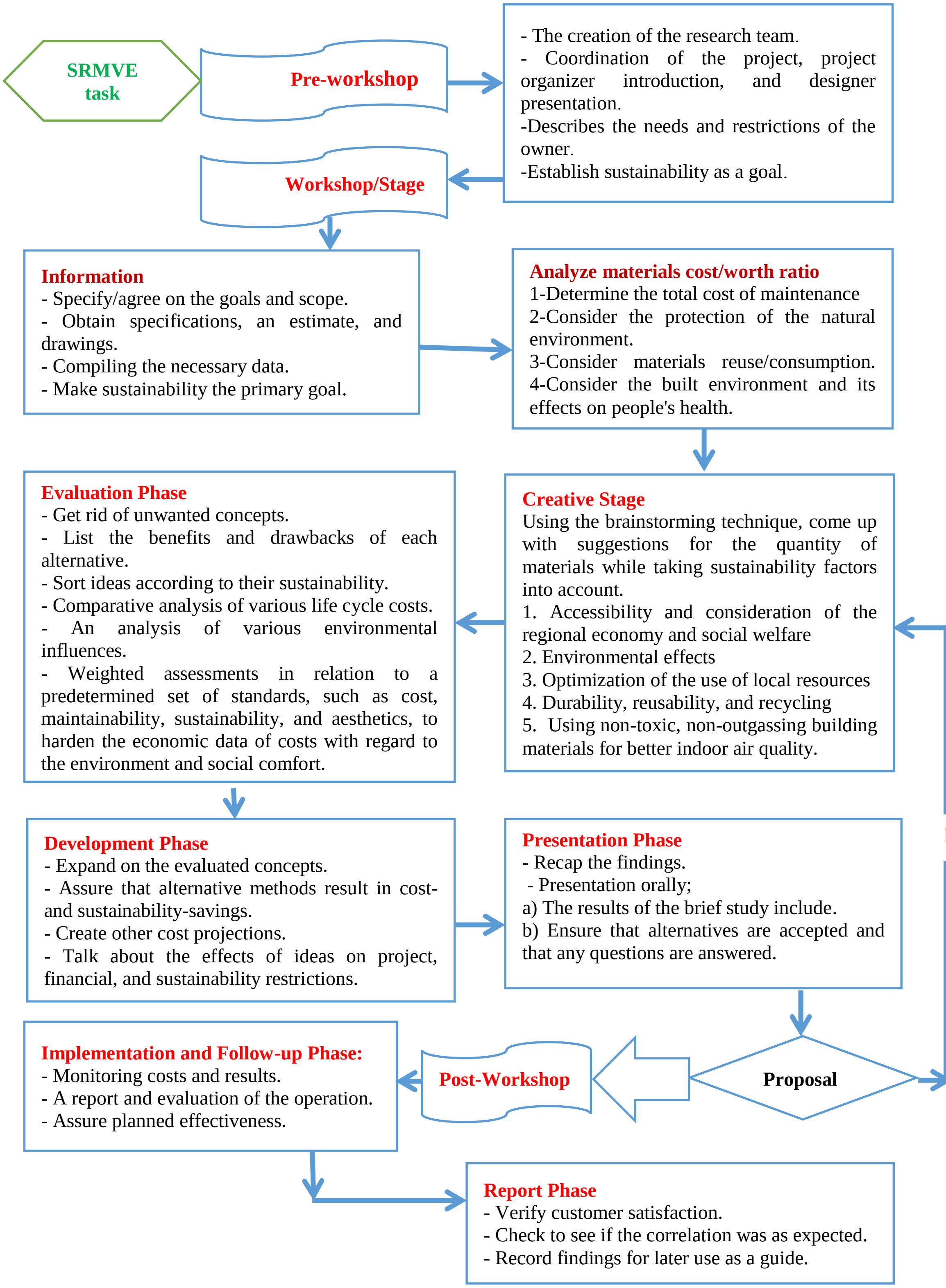


Figure: 3 SRMVE task

3.1 Function Phase:

Function Phase is the stage that includes collecting information and analyzing. At this point, a questionnaire was created to gather information regarding value engineering, sustainability and connecting the two to develop the perfect road maintenance service model. The factors affecting sustainability were limited to its three main aspects, as they are the most critical factors identified and impact sustainability in Egypt according to previous studies, as shown in Table 1. For this reason, the following three questions were the most important in the survey. They will help to identify the most critical factors to consider to achieve sustainability in Egypt.

Table 1. Key Variables Influencing Each of the Three Sustainability Pillars [14].

Economic factors	Environmental factors	Social factors
{EF1}Determine the project's financing sources and its scheduling plan. **{EF2}**The project manager's competency is the number of years of experience. **{EF3}**Creating a capital budget for planning and reducing overall costs **{EF4}** thoroughly examines the project's scope, design, feasibility studies, drawings, and bid preparation. **{EF5}**The competence of the main contractor, the sum of his years of experience, and administrative and organizational skills. **{EF6}**The ability to troubleshoot errors quickly and make decisions promptly. **{EF7}**The dedication of all project parties to their responsibilities and their understanding of the role and obligation. **{EF8}** Efficiency of on-site supervision and availability of technical skills. **{EF9}**The availability of raw supplies, facilities, and human and financial resources. **{EF10}**Preparing appropriate designs, drawings, comprehensive, and specifications. **{EF11}**Enhancing the processes for awarding contracts and choosing the contractor by giving less weight to price and more weight to the contractor's aptitude, financial standing, and prior performance. **{EF12}**Reflection of the project's positive economic impact on the neighbourhood.	**{EnF1}**The project's effects on public health. **{EnF2}** chemical waste and organic contaminants are treated before being dumped into the sewers. **{EnF3}**Examining how much water the planned project would use and any potential water pollution it might cause. **{EnF4}**Special treatment of radioactive compounds, heavy metals, and poisonous substances released during maintenance and replacement. **{EnF5}**The project's operation had no adverse effects on the ecosystem, vegetation, or animals. **{EnF6}**Use non-toxic alternatives and make efforts to lessen solid infractions. **{EnF7}**Examining possible air pollution from the proposed project and how it would affect the local climate. **{EnF8}**Applying adherence to all environmental standards during project conception, execution, operation, deconstruction, recycling, and disposal. **{EnF9}**Adopting project maintenance techniques and increasing waste reuse and recycling.	**{SF1}**The design must consider the Touareg cases, such as fire, earthquakes, floods, radiation, environmental accidents, and the installation of safety alarms and screens. **{SF2}**The design considers the needs of people with disabilities. **{SF3}** Considering the regulations about the dangers to workers and the public's safety during the project's demolition from explosions, dismantling, poisonous, and radioactive materials. **{SF4}** Implement safety, facilities, and insurance procedures for project employees. **{SF5}** impact on historically significant sites and cultural heritage conservation. **{SF6}**The expected impact on local development.

(Q1)This inquiry demonstrates that EF3, which 37% of respondents agreed is the most significant component impacting the economic side of the sustainability process, is followed by the other variables in various amounts, as shown in Figure 4.

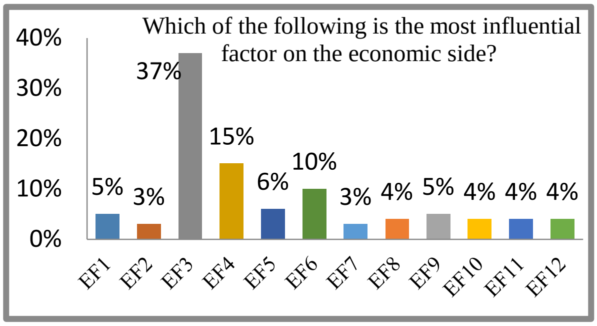


Figure 4: Ranking the factors that have the most effects on the economic side of the sustainability process

(Q2)Knowing the primary factor that influences the environmental aspect of sustainability was an important question. After completing the survey and learning the respondents' opinions, it was discovered that EnF1 and EnF4 shared the same level of importance as they had the highest percentage, 27%. It may be seen in Figure 5.

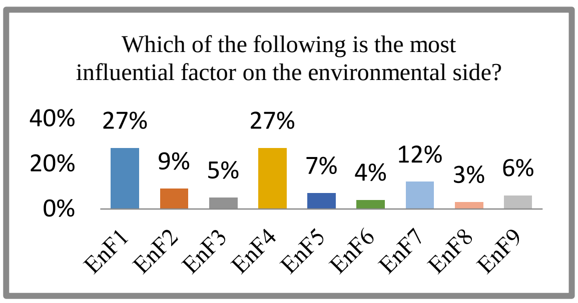


Figure 5: Ranking the factors that have the most effects on the environmental side of the sustainability process

(Q3)The SF5 factor, which 47% of respondents agreed is the most critical factor affecting the social aspect of the sustainability process that all societies are now working to achieve, is the factor that has the most significant impact on society, as shown in Figure 6.

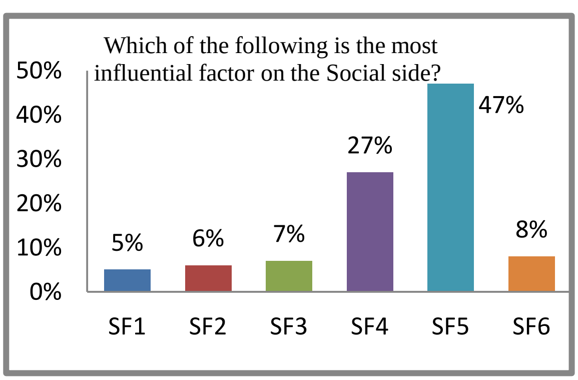


Figure 6: Ranking the factors that have the most effects on the Social side of the sustainability process

It stated that the most significant factors affecting the economy are creating a capital budget for planning and reducing overall costs (EF3). In contrast, the two most significant influences on the environmental side are the project's effects on public health (EnF1) and the special treatment of radioactive compounds, heavy metals, and poisonous substances released during maintenance and replacement (EnF4) in equal measure, followed by the factor impact on historically significant sites and cultural heritage conservation (SF5) that affects the social side. These elements will be emphasized when comparing the alternatives to apply value engineering.

3.2 Creative Phase:

The highest amount of alternatives that could be utilized for road maintenance was collected at this point, and value engineering was used in this situation by looking for alternatives to the maintenance process as a whole rather than just for materials. For instance, the traditional maintenance technology for the base layer and the surface layer, the Full-Depth Reclamation (FDR) method, and the Cold in-Place Recycling (CIR) approach were the possibilities employed to obtain the model of road maintenance by combining value engineering and sustainability.

3.3 Evaluation Phase:

The environmental aspect was concerned with both (the EnF1 project's effects on public health and the EnF4 special treatment of radioactive compounds, heavy metals, and poisonous substances released during maintenance and replacement). Studying what affects public health and the toxic substances emitted was essential. It was found that carbon emission is one of the most dangerous substances that affect them because it leads to global warming, which in turn works on climate change, and this is the main reason that made the world turn to sustainability. Therefore, at this stage, the percentage of carbon emitted was calculated for each method of maintaining the methods used in the alternatives; a method was reached to estimate the amount of carbon emitted using Equation 1.

$$Embodied\ Co2 = CCF \times Q \times D \quad (1)$$

[61]

Q › Is the quantity of the substance.
D › The material's density is denoted.
CCF › Is the carbon coefficient factor.

One of the essential procedures that will take place at this stage is the conversion of environmental and social factors into financial factors, after figuring out how much carbon is embodied in the projects for which value engineering is used. Choosing a uniform component for comparison is necessary to compare the options. The purpose of the cost is highlighted in this essay, and a cost comparison is provided. Therefore, the carbonized quantities estimate needs to be converted to a cost. It is done by Carbon Capture Use and Storage (CCS)[63], [64], [65]. As shown in Figure 7, carbon is gathered using contemporary technologies, transported to appropriate storage locations, and stored in deep underground areas where it cannot leak and be transferred to the atmosphere, preventing it from contributing to climate change.

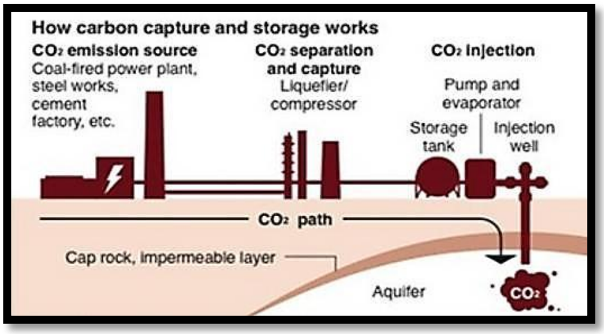


Figure 7: How carbon capture and storage works [63]

According to estimates from [66], (ICS 2012), 58$/ton of embedded CO2 represents the total allocated for capturing one ton of CO2 emissions. Thus, the cost of carbon is determined. As a result, the project's direct cost might increase the cost of reducing carbon emissions. The best option in terms of cost is then selected after comparing the detected options.

$$\text{Cost CCS} = \text{Embodied Co2(ton)} * 58 * PD \quad (2)$$
[65]

PD › *The price of the dollar in pounds*

$$\text{Current Cost} = T\,C * (1 + i)^{n} \quad (3)$$
[66]

T C › Total Cost of activities project
i › Inflation Coefficient
n › Number of years

To facilitate all the previous stages, an integrated model was created using the computer to integrate value engineering in the road maintenance process by utilizing both Flutter and Visual Studio code, and it can also be used as a mobile application to facilitate its use and benefit from it at maximum speed. It was called SRMVE, an acronym for the model for integrating sustainability with value engineering. It shows how to use it in Figure 8.

SRMVE			
Input	**Processing**	**Output**	
✓ digit of interest years ✓ inflation coefficient ✓ dollar price ✓ Project name ✓ Road length ✓ Road width	Select the alternatives to compare, and the model will determine their total cost using the prices saved in the application. It will then calculate the amount of carbon emitted from each alternative, convert it into a cost using CCS, and collect both the cost of the activities and the cost of disposing of the emitted carbon. Then, compare the alternatives using the graph at the procedure's end.	❖ Table	A table for each alternative details the project's activities, overall costs, the quantity of carbon emitted, and the disposal cost.
		❖ Graphs	Graph The vertical axis represents the cost, while the horizontal axis represents the alternatives.

Figure 8: A diagram of the SRMVE model

4- CASE STUDY:

Egypt is currently undergoing a change that will make it a regional industrial center and an energy exporter. Since 2015, the infrastructure market has boomed across various industries, including energy, transportation, roadways, and other sectors. The National Roads Project was crucial in ensuring that inhabitants were close by and well-connected and that goods were transported effectively. The use of sustainable solutions with favorable effects on the environment and entire life cycle costs is a goal of Egypt Vision 2030. Consequently, a plausible case study was provided to support the optimization concept. To test this model, a width of 9 meters and a 10 km long approach route from Mansoura (Sandub) to the eastern entrance of the new Talkha Bridge in Egypt was selected; it shows how to use it in Fig(9). The General Authority for Roads, Bridges, and Land Transport will carry out this project (GARBLT).

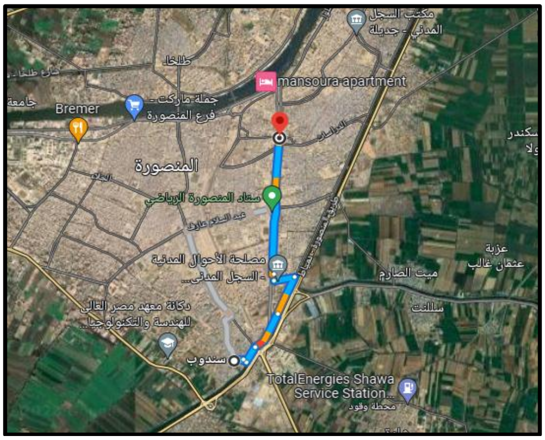


Figure 9: Sandub to the eastern entrance of the new Talkha Bridge in Egypt (Google Earth)

The General Authority for Roads, Bridges, and Land Transport improved this project's efficiency by following customary procedures because the road had much rutting. This project was specifically picked to ensure the model's effectiveness since the cost it extracts is matched. On the other hand, it is essential to guarantee that integrating value engineering and sustainability into road maintenance will benefit society economically and environmentally. The project activities for the first alternative, the original method implemented by (GARBLT), appear in Table 2, while Table 3 shows the activities for the second alternative (FDR).

Table 2: Sandub – eastern entrance of the new Talkha bridge project activities

Activities	Description	unit
Cracking works	The work of crushing and removing the collapsed, creeping, and undulating surfaces with the current pavement includes the operation and compaction of the crushing bottom layer and the transportation of the crushing product outside the site to the overheating dumps without the family's income in that, following the conditions and specifications, and the category includes everything necessary to complete the work.	M^3
Scraping works	Scraping and removing collapsed, creeping, and wavy surfaces in the current pavement using an automatic cold asphalt scraping machine with a unique mechanical car to transport the materials resulting from the abrasion and for use in completing the linings, shoulders and side inclinations. The category includes all necessary to finish the work according to the conditions and specifications.	M^3
Basis	The works of supplying and operating a foundation layer using graded hard stones whose tolerance percentage is less than the product of crushing crushers so that the thickness of the layer exceeds 8% with brushing and compaction on layers so that one is more than 15 cm after compaction according to the conditions, specifications, instructions of the supervising engineer and the concerned area, and engineering accounting after compaction.	M^3
Impregnation layer (M.C.O)	The construction of an impregnating layer (prime) using medium-volatile liquid asphalt (M.C.O.) at a rate of 1.5kg/m^2, according to the conditions and specifications, provided that the surface of the base layer is cleaned of any extra pebbles or fine materials before spraying and that the asphalt is sprayed at regular rates using mechanical spraying equipment and the category inclusive of everything needed to complete.	M^2
Hot bonding layer of asphalt concrete	The work of constructing a bonding layer of hot asphalt concrete graded (3) with a thickness of 6 cm after compaction using hard, graded stones with good adhesion to the asphalt, and using hard asphalt 60/70 that conforms to the conditions and specifications, and the category includes everything necessary to complete the work. The category consists of brushes with a spreader Equipped with a laser device to adjust the levels.	M^2
Paste layer R3000	The work of constructing an adhesive layer of fast-volatile liquid asphalt (R.C .3000) or with asphalt emulsions that comply with the conditions and specifications at a rate of not less than 4 kg / m^2 below the paving layers. It was spraying the area of the asphalt layer being spread during one work shift according to the conditions, specifications, and category, including everything necessary to complete the work.	M^2
Surface layer of hot asphalt concrete	Construction of a surface layer of hot asphalt concrete graded (4) with a thickness of 5 cm after compaction using hard-graded stones. The product of crushing cracks with good adhesion to the asphalt and the use of hard asphalt 60/70 conforms to the conditions and specifications, and the category includes everything necessary to finish the work.	M^2
Restoration (replacem	Restoration works with hot mixed asphalt (3) in places of abrasion and leveling and in places determined	M^3

ent of elements)	by the supervising engineer using hard stones. Layers and the thickness of one layer does not exceed 6 cm. The category includes laying an adhesive layer of fast-volatile liquid asphalt (R. C. 3000). Or with asphalt emulsions that comply with the conditions and specifications at a rate of not less than (4.0 kg/ m^2) below the restoration layers. The category includes everything necessary to complete the work.	

Table 3: Sandub – eastern entrance of the new Talkha bridge project activities of alternative 2 (FDR)

Activities	Description	unit
The base layer spreads by recycling asphalt and primer	It supplies and lays a stabilized base layer by recycling layers of asphalt and the existing foundation with a thickness of 25 cm in the existing road using the FDR machine. The category includes cleaning the current asphalt surface and everything necessary to complete the work following the principles of the industry, the approved detailed drawings, and the item with all its components following the specifications of the General Authority for Roads and Bridges.	M^2
Cement recycling and brushing	Supplying cement brushes for recycling the existing road following the design mix and everything necessary to complete the work following industry principles and approved detailed drawings and the item with all its contents following the specifications of the General Authority for Roads and Bridges.	ton
MC 30 impregnation layer	The work of supplying and spraying an impregnation layer of medium-volatility liquid bitumen MC30 at a rate of 1.5 kg /m2, which is sprayed over the base layer after it, has been wholly compacted and cleaned well. It is implemented following the typical cross-sections and approved detailed drawings. The item with all its components follows industry principles and specifications of the General Authority for Roads and Bridges.	M^2
Paste film R C 3000	The work of supplying and spraying an adhesive layer of quick-volatile liquid bitumen RC3000 at a rate of 0.5 kg /m2, which is sprayed over the asphalt layer after it, has been wholly compacted and cleaned well. The implementation follows the typical cross-sections and approved detailed drawings. The item with all its components follows the specifications of the General Authority for Roads and Bridges.	M^2
Link layer brushes asphalt	The work of supplying and spreading a bond layer of asphalt concrete with a thickness of 6 cm after compaction using hard stones, the product of crushing crushers, and solid bitumen 60/70 supplied by Al-Nasr Company in Suez or similar. The category includes conducting laboratory and field experiments on the mixture and the materials used, and implementation is carried out according to the typical cross-sections and drawings. The approved details and the item with all its contents follow industry principles and specifications of the General Authority for Roads and Bridges	M^2
Surface brushing asphalt	The work is to supply and lay a surface layer of asphalt concrete with a thickness of 5 cm after compaction using hard stones, the product of crushing crushers, and solid bitumen 60/70 imported from Al-Nasr Company in Suez or similar. The category includes conducting laboratory and field experiments on the mixture and the materials used, and the implementation is carried out according to typical cross-	M^2

	sections. The approved detailed drawings and the item with all its components follow industry principles and specifications of the General Authority for Roads and Bridges.	

The length and width of the road were entered, and the alternatives that will be studied were determined on the model. The alternatives used were the traditional and FDR methods, as shown in Figure 10, as Flutter and Visual Studio codes were used to make this model.

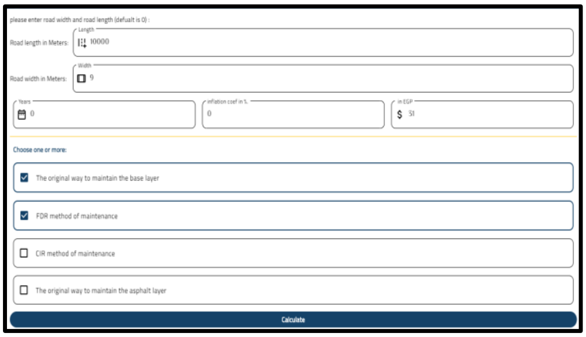


Figure: 10 User Interface Input Screen

Figure 11 shows the cost of project maintenance using the first alternative, which is the traditional method, and also shows the effectiveness of the SRMVE model that was made, as the cost that was calculated is identical to the cost of maintenance carried out by (GARBLT), and also shows the amount of carbon emitted from this method and calculating the cost of disposing of it by CCS Road.

1- The original way to maintain the base layer:

Activity name	unit	Quantity (Q)	Price/unit (LE)	Cost (LE) Quantity* price/unit	$ECO_2 = CCF*D*Q$	$CCS = ECO_2*58$ dollar
Cracking works	M^3	8000.01	90.00	720000.90	22353750.00	1296517500.00
scraping works	M^3	4000.00	300.00	1200001.50	22353750.00	1296517500.00
Basis	M^3	35000.00	324.00	11340000.32	4331250.12	251212507.18
impregnation layer (M.C.O)	M^2	90000.00	20.00	1800000.00	9900000.00	574200000.00
Hot bonding layer of asphalt concrete	M^2	90000.00	102.50	9225000.00	12453750.00	722317500.00
Paste layer R 3000	M^2	90000.00	6.00	540000.00	9900000.00	574200000.00
Surface layer of hot asphalt concrete	M^2	90000.00	100.00	9000000.00	12453750.00	722317500.00
restoration	M^3	1000.00	1750.00	1750000.00	138375.00	8025750.01

Cost of activity : 35575002.73.
Total Cost of CCS : 168804555.97.
Current Cost : 35575002.73.
Total Cost of Project : 204379558.70.

Figure: 11 Analysis of Alternative No. 1

Figure 12 shows the cost of project maintenance using the second alternative, FDR, which is an alternative method to the traditional method, in which pre-existing materials are reused in the paving layers; project cost calculation, as well as the amount of carbon emitted from this method, and calculating the cost of disposing of it through CCS.

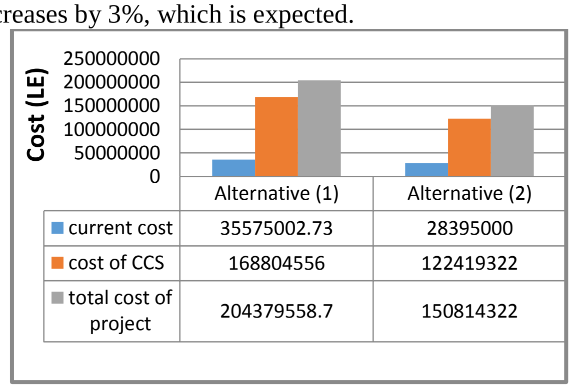
2- FDR method of maintenance:

Activity name	unit	Quantity (Q)	Price/unit (LE)	Cost (LE) Quantity* price/unit	$ECO_2 = CCF*D*Q$	$CCS = ECO_2 * 58$ dollar
Base layer spreads by recycling asphalt and primer	M^2	90000.00	55.00	4950000.00	22353750.00	1296517500.00
Cement recycling and brushing	M^3	3150.00	900.00	2835000.00	1025136.00	59457888.00
MC 30 impregnation layer	M^2	90000.00	20.00	1800000.00	9900000.00	574200000.00
Paste film R C 3000	M^2	90000.00	6.00	540000.00	9900000.00	574200000.00
Link layer brushes asphalt	M^2	90000.00	103.00	9270000.00	12453750.00	722317500.00
Surface brushing asphalt	M^2	90000.00	100.00	9000000.00	12453750.00	722317500.00

Cost of activity : 28395000.00.
Total Cost of CCS : 122419322.03.
Current Cost : 28395000.00.
Total Cost of Project : 150814322.03.

Figure: 12 Analysis of Alternative No. 2

Figure 13 shows the cost of the maintenance process, the cost of disposing of the carbon emitted, and the project's total cost. It indicates that the second alternative is the best, as the maintenance cost, when using the second alternative, saves 21% of the project cost if done using the traditional method. Thus, the use of value engineering has an economic benefit, and by integrating value engineering with sustainability to preserve the environment, the second alternative provides 26% when compared with the first alternative. However, by applying sustainability to the project and choosing the second alternative, the cost of the maintenance process increases by 3%, which is expected.



	Alternative (1)	Alternative (2)
current cost	35575002.73	28395000
cost of CCS	168804556	122419322
total cost of project	204379558.7	150814322

Figure 13: Alternatives total cost

5- CONCLUSION:

Creating an integrated framework to predict the sustainability of proposed road maintenance using value engineering (VE) technology and transforming the three sustainability elements into one element embodied in the cost to make it easier for decision makers to compare the alternatives proposed by value engineering and choose the preferred alternative that achieves sustainability.

The fundamental contribution of this work is creating an integrated sustainability optimization tool for Egyptian road maintenance projects. SRMVE is a technology that allows these projects' alternatives to be evaluated and chosen for execution based on their predicted sustainability performance. The proposed tool will enable decision-makers to select the best option for the proposed Road Maintenance projects.

Through road maintenance sustainability prediction development, A literature review was used to identify some of the sustainability evaluation criteria. These criteria were carefully chosen to encompass the three pillars of sustainability: environmental, economic, and social. The suggested road maintenance sustainability forecast model used value engineering (VE). As a result, a sustainability optimization model was created, using carbon emission accounting as a technique to improve sustainability, especially for the environmental side. CCS technology was used to convert all the data obtained into one factor (cost) to facilitate comparison between the alternatives for decision-makers.

Finally, a program SRMVE was employed to make it easier to use the suggested model. A practical case study was also explored for usage to confirm the model's efficacy. This model was used in the case study, and the following is evident:

1- When using value engineering technology alone, when employing the alternative, the cost of the life cycle of the maintenance process is reduced

2- When considering the sustainability process only, the maintenance cost for the traditional method increases three times the cost of the maintenance life cycle.

3- When value engineering is combined to achieve sustainability, the total cost of the maintenance process increases, but at a lower value by one-third when using sustainability alone.

4- When using the model of integrating value engineering with sustainability, the total cost of the maintenance process is reduced by 26% of the total cost when using the traditional method.

5-Despite the increase in cost when it comes to the cost of the project’s life cycle, it is an economical method in the long term because it will achieve in terms of preserving the environment, climate change, and reducing the spread of diseases.

6- FUTURE RECOMMENDATIONS:

The inclusion of the sustainability aspect in this model results in increased costs. Therefore, research is required to find out whether owners are interested in implementing this strategy for their projects. The SRMVE model might not be of interest for projects that were designed with sustainability in mind, despite the fact that this kind of model will have a noticeable effect on them. However, there is still a need for procedure research on road maintenance methods in developed and developing nations is still necessary in order to assess value engineering's effects on sustainability more accurately.

It is also recommended to apply the SRMVE model to more projects with different quantities in order to find out whether the size of the project affects the results or not.

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