

A MATURITY MODEL FOR A SUSTAINABLE CONSTRUCTION INDUSTRY

by

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A Thesis Presented to the Faculty of the  
American University of Sharjah  
College of Engineering  
in Partial Fulfillment  
of the Requirements  
for the Degree of

Master of Science in  
Engineering Systems Management

Sharjah, United Arab Emirates  
January 2014



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## **Acknowledgments**

I would like to extend my profound thanks and gratitude to Allah for enabling me to complete this work in spite of my various commitments. I want to extend my special thanks to my advisor Professor Adil Al Tamimi for his guidance since the outset. I would like also to thank my committee members Dr. Salwa M. Beheiry, Dr. Md. Maruf Mortula, and Dr. Zied Bahroun for their valuable comments, reviews, and suggestions that greatly helped shape this work. Finally, I wish to express my great love and sincere appreciation to my beloved parents, wife, and all my family for their endless support and extraordinary patience and understanding throughout this research study.

## **Dedication**

This thesis is dedicated to my father, role model, and best friend Mohamad Taha Dahabra, to my mother Fawzie Dahabra, and my wife Nadia Azzam. This work would not have been completed without their sacrifice, encouragement, and limitless belief in me. Dad, Mom, and my beloved wife, I will be in your debt forever. May Allah bless you all.

## **Abstract**

Although the construction industry has provided societies with facilities and infrastructure projects that meet their needs and fulfill their requirements, created up to 7% of the world's job opportunities, accounted for around one-tenth of the world's gross domestic product, and stimulated the growth of other industries; it also, on the other hand, proven to have a negative impact on the environment [1]. The construction industry accounts for 40% of CO<sub>2</sub> emissions worldwide, 30% of raw material usage, 40% of energy consumption, and 20% of fresh water consumption [2]. The world's countries have achieved varying levels of success in implementing sustainability in their local construction industries. However, it is still difficult to rank them based on their achievements due to the absence of a clearly defined scale that all countries can be compared to. This thesis introduces a new concept called mature sustainability in the construction industry. It also introduces a maturity model that can be used as a scale to evaluate how mature a country is doing in regard to its sustainability adoption in the local construction industry. The model is created by studying different maturity models from other industries and understanding how they define maturity. Furthermore, the thesis develops a rating system that can determine a country's sustainability level using mathematical equations, and it includes a case study in which the United Arab Emirates (UAE) is rated to show how the rating system works. The input data of the rating system was obtained by conducting a survey on different construction companies and the local public of the UAE. The rating example found that the UAE falls into level 2, which is the “satisfactory” level, and deviated from the ideal mature level of 2.427.

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# Abbreviations

IML: Ideal maturity level

DIML: Distance to the ideal maturity level

PC: Performance coefficient

BREEAM: Building Research Establishment for Environmental Assessment Method

CO<sub>2</sub>: Carbon dioxide

O<sub>3</sub>: Ozone

GHG: Greenhouse gas

GDP: Gross domestic product

HVAC: Heating, ventilation, and air-conditioning

LEED: Leadership in Energy & Environmental Design

UAE: United Arab Emirates

UNCED: United Nations Commission on Economic Development

DEWA: Dubai Electricity and Water Authority

ISO: International Standards Organization

CE: Collaboration engineering

PM: Project management

EEG: Emirates Environmental Group

MTPA: Million tons per annum

GCC: Gulf Cooperation Council

# Chapter 1: Introduction

By the middle of the last century, one out of every three people lived in an urban setting. Today, a majority of the world's population resides in urban places, and it is forecasted that, by 2015, there will be 23 "mega cities," with 19 of them located in developing countries [3]. This rapid population growth and urban expansion has led to a furious competition for resources. One of the main characteristics of urban regions is their excessive consumption of natural resources, leading to large amount of waste. This affects not only the surrounding environment but also distant environments over time. Civic authorities strive to ensure the provision of adequate quality of life, sanitation, access to clean water, public transportation, and waste management in all urban programs and policies. This too leads to wasted resources and pollution.

Unfortunately, we have realized the extent of this environmental crisis only recently. Our rapid consumption of non-renewable natural resources will only result in forcing the coming generations to face a more deprived situation. Therefore, it is essential to become aware of the concepts of sustainability and its ideals to turn the wheel of environmental depression. Awareness on its own is not enough. We need to apply our awareness through fruitful actions that will control our consumption of natural resources and scale it to match our actual needs. Such behavior will not hinder human development but, on the contrary, will sustain human resources for longer periods. This can be translated into further development with no risks. According to UN Secretary General Ban Ki-moon, "sustainability is the most promising path forward" [4].

Several countries have adopted environmental policies to reduce environmental degradation. However, environmental policies are often accompanied by many question marks in regard to economic growth. As environmental concerns are growing, many countries are striving to achieve a balance between their environmental policies and economic growth.

"Environment" is defined as the aggregate of surrounding things, conditions, or influences. The surroundings include the air, water, minerals, organisms, and all other external factors surrounding and affecting a given organism, as well as social and cultural forces [5]. "Ecology," in turn, is characterized as the branch of biology

that deals with the relationships and interactions between organisms and their natural environment [5]. Both the environment and ecology have the potential to change according to external–internal and natural–manmade forces, such as severe air and water pollution, drought, floods, deforestation, and land degradation due to natural disasters, wars, or political and social transformations.

The natural world started as an agricultural environment and became an urbanized world, where natural ecosystems around the world were transformed into anthropogenic ecosystems. These anthropogenic ecosystems yield food and products for billions of people [6]. Modern societies cannot live from nature alone, but they cannot survive without nature, either. However, our future does not depend on maintaining nature in its original state but upon maintaining ecosystems. Having an intact and productive environment is an indispensable condition for human existence and culture. If the environment degenerates, modern society's existential basis disintegrates. The ecosystem requires a continual input of energy and preventive intervention to prevent it from breaking down. Social forces must intervene continually to correct environmental conditions. This is why knowledge about the ecological basis of our life is so important.

Mankind operated with an attitude of inadvertent sustainability until the time of the Industrial Revolution. This attitude was a result of a limited population using simple techniques for farming, industry, and general human activity. Nature was therefore able to cope with all the pollution caused by humans. However, to meet the increasing demand for resources, industrial activities have grown without taking the resulting environmental degradation seriously, and the enterprises that produced these negative effects have not been held accountable [6].

In the mid-20th century, environmental movements created awareness regarding the long-term cost of the material benefits that were being enjoyed as a serious environmental cost. Later in the century, environmental problems expanded to a global scale. Global community demand became highly dependent on non-renewable energy resources, which was clearly demonstrated by the 1973 and 1979 energy crises [7].

Environmental conditions worldwide are at a critical stage, with water and air pollutants increasing significantly alongside higher temperature levels detected worldwide. Most importantly, many ecosystems have been adversely affected.

With such a chain of negative health and environmental effects, the global community's attention is now directed toward the issues of unsustainable human practices.

## **1.1. Health Problems**

Studies conducted around the globe have revealed that humans everywhere are carrying a number of synthetic chemicals (wood preservatives, industrial solvents, pesticides, fire retardants, etc.) in their blood and even breast milk. These compounds lead to potential birth as well as reproductive defects. Many indigenous people in remote arctic regions possess high levels of pesticides and consequently have been advised to abstain from breastfeeding their babies [7].

## **1.2. Increasing Population and Scarcity of Natural Resources**

Natural resources are now a limiting factor. At the beginning of the Industrial Revolution, we had a seemingly endless supply of natural resources and a scarcity of skilled labor to work in our factories. Today, the situation is reversed. The global population is roughly seven billion, with unemployment becoming a widespread bane. According to the best estimates of the U.N., we should expect our population to increase by another three billion by 2050 [8].

Simultaneously, many of our natural resources are dwindling. According to the U.N. Food and Agriculture Organization, the world lost 94 million hectares of forestland in the 1990s alone, about 64,000 acres a day. Eleven of the 15 major fishing grounds in the world are already at or exceeding the maximum sustainable yield, while others have collapsed completely. Concurrently, soil erosion, desertification, urban sprawl, salinization, and aquifer depletion are further compromising our crop yields [8].

The world's population is increasing rapidly, and the demand for resources is increasing as a result. Researchers claim that the only solution for the current environmental crises must be innovative. For example, we must try to improve the productivity of the environment by finding alternative green resources that are renewable [8].

### 1.3. Global Warming

Global warming has become another major economic and political issue. In late October 2006, British Foreign Secretary Margaret Beckett sought to redefine climate change as a global security issue. Up to a fifth of the world's wealth could disappear and the lives of billions of people put at risk within this century unless we invest now in creating a global low-carbon economy [9].

Global warming results from many factors; the linkage between pollution and global warming is very complex, and expectations of gradual increases in understanding the consequences in terms of local climate and its instability are expected [9]. There are many examples, such as forestation, the adoption of a worldwide measure of energy saving, pollution control, and carbon fixing. Carbon dioxide and various atmospheric gases called "greenhouse gases" transmit incoming sunlight but absorb outgoing infrared radiation, thus raising the average temperature of the earth's surface.

Carbon dioxide, a major byproduct of fossil fuel combustion is clearly the most influential greenhouse gas. Methane gas is actually twenty times more powerful than carbon dioxide with respect to volume, but its presence in the atmosphere is in smaller amounts and short-lived when added to the atmosphere [10]. The earth's temperature has closely followed the greenhouse gas concentration. The possible consequences of global warming include:

- Sea level rise, endangering millions of people. The National Aeronautics and Space Administration (NASA) climate scientist Jim Hansen has suggested that this rise could significantly exceed the Intergovernmental Panel on Climate Change (IPCC) upper estimate of about one meter rise by 2100.
- Earlier spring runoffs in many areas.
- Worsening drought conditions in Africa, where millions face famine.
- Storm severity will increase for low-lying areas.
- Mountain glaciers, serving as a water supply for millions of people, are shrinking as they melt, and their disappearance will result in severe water shortages.
- Increases in diseases, heat waves, landslides, wildfires, and famine.

## 1.4. Environmental Impact of Fossil Fuel Usage

Since the Western Industrial Revolution in the 18th and 19th centuries, people have relied predominantly on fossil fuels to generate energy. Since then, the usage of the fossil fuels has been increasing dramatically, resulting in huge CO<sub>2</sub> emissions [11]. The below graph demonstrates the increasing global level of emissions from fossil fuel burning and the CO<sub>2</sub> concentration level in the atmosphere for the last 162 years:

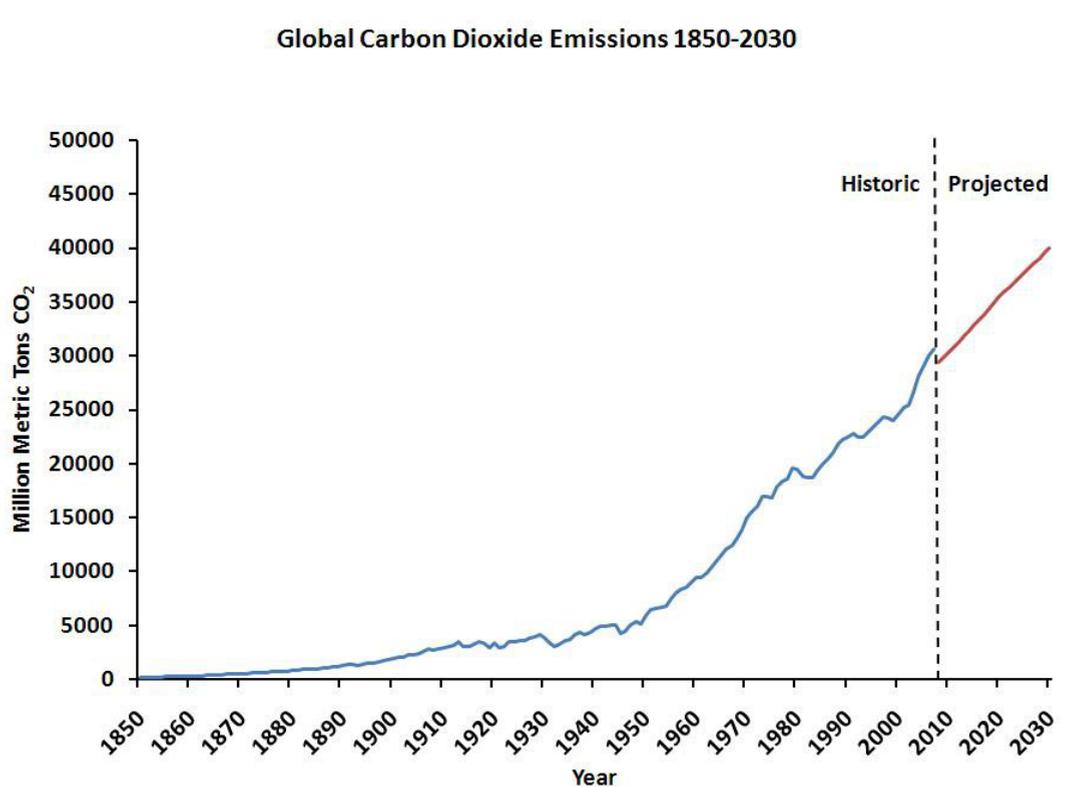


Figure 1: Global carbon dioxide emissions from fossil fuel burning [12].

In 2009, the United Nations Department of Social and Environmental Affairs revealed that, over the past 420,000 years, the CO<sub>2</sub> content in the atmosphere has varied cyclically with a period of 100,000 years, ranging between 180 ppm and 290 ppm in volume. Today, the CO<sub>2</sub> level has reached 380 ppm and is rising at the incredible rate of about two ppm per year. Scientists now know that an increase in temperature in the earth's surface can release CO<sub>2</sub> from the ground and seawater and thus an increase in greenhouse gases that will cause a further rise in the atmospheric temperature.



## **1.5. Ozone Depletion (O<sub>3</sub>)**

Ozone depletion occurs in the atmosphere in separate locations and presents a different concern for each region. Ozone is located in the surrounding air 10 km above the earth's surface, and the troposphere shields the earth from harmful ultraviolet light [13]. The increase in ozone near ground level, especially in urban areas, is a significant health and environmental concern. Furthermore, this concern includes the decrease in ozone in the upper atmosphere, which is 10 to 30 km higher than the ground surface. A layer of relatively high ozone concentration, about 300 parts per billion, is responsible for protecting life on our planet, as it absorbs much of the sun's dangerous ultraviolet radiation. NASA's study concluded that increased ozone levels can cause skin cancer and may damage crops and destroy the beginning of the marine food chain [13].

Moreover, chlorofluorocarbons (CFCs) were found to rise to the stratosphere, attacking the ozone. Chlorofluorocarbons (CFCs) are inert and can remain in the atmosphere for 100 years. The Environmental Protection Agency has estimated that, for every 1% decrease in ultraviolet radiation absorbed in the atmosphere, there will be a 2% increase in skin cancer incidence. Ultraviolet light also damages the immune system and seems to affect marine life. Many developing countries do not share a sense of urgency with respect to this problem. There are wide differences among nations concerning the appropriate balance between economic development and the protection of the global environment [14].

## **1.6. Acid Rain**

Another result of the unsustainable practices of the human beings is acid rain, which can damage forest, crops, and other vegetation in several ways. The combination of acid rain and high ozone levels can harm tree foliage by degrading compounds contained in leaf cells. Acid rain can cause soil to release toxic materials such as aluminum, which can damage the roots of plants.

Additionally, acid rain and other pollutants are believed to be a major or contributory factor in the decline and death of forests in many parts of Europe, North America, and South America. It is important to know that declining PH levels increase the activity of acid rain and that acidic runoff has killed or threatened fish and other aquatic organisms in thousands of lakes and streams in many industrialized countries

[15].

Moreover, the combination of acid rain and ground-level ozone has significantly reduced crop yields. Statistics published by the United States Environmental Protection Agency and the Institute for Plant Research at Cornell University estimated that high ozone levels might reduce crop yields by 12%–30%. Similarly, a high concentration of acid rain and ozone can corrode metals and cause the deterioration of building materials, paint, papers, plasters, and textiles. It can also destroy works of art, architectural work, limestone, marble, and monuments [15].

## **1.7. Thermal Pollution**

Thermal pollution is defined as the addition of unwanted heat to air and water. The greatest source of heated water is nuclear power plants and steam electricity generation stations; lake, river, or ocean water is mainly employed to cool the condensers and improve efficiency. This water is taken from the source and discharged to the same source, adding heat to it. For an estimated 1,000 Mw power plant, a flow of about 10,000 gallons per second of water at a water temperature of 8 °C is required. Water demand for electricity generation plants accounts for about 80% of current water usage [16].

# **Chapter 2: Literature Review**

## **2.1. The Need for Sustainability**

Researchers have realized that human beings must apply the principles of sustainability to all aspects of their lives to ensure that the needs of current and future generations will continue to be met. Sustainability is the minimum condition that the planet requires to continue to maintain all life and systems in the future. It is important because all of the choices we make today will affect the future.

Humanity depends on nonrenewable energy sources for over 80% of its energy needs. Even if the speed of innovation cannot keep up with the growth of humanity's desire to get more out of its environment, a national economy's innovative potential is still important. We must reduce the demand for consumption of the environment; however, some researchers have argued that it is too late to go back; the situation will no longer allow it [17]. The need to define and pursue sustainability has become increasingly evident as the ecological crisis has been further linked to human activities, and similarly, the environmental crisis is clearly correlated with economic, social, political, and cultural crises.

## **2.2. Definition of Sustainability**

Having a broad scope, sustainability has been defined in several ways. Some define sustainability as the ability to preserve and maintain natural resources by avoiding their overuse, while others define sustainability in relation to policymaking. Barton [18] and Du Plessis [19] presented a conceptual model in which sustainability is defined as the interconnection between three sectors: the environment, the economy, and society. According to Barton and Du Plessis, sustainability happens when a reasonable balance of interactions between these three sectors is achieved.

Environmental sustainability has been also defined, according to BusinessDictionary.com, as the ability to preserve the factors contributing to the well-being of the environment on a long-term basis. In 1992, the "Earth summit" took place in Rio de Janeiro, during which sustainable development was able to penetrate the global stage. The goal of the summit was to raise awareness of a complex problem: achieving a balance between the need to consume natural resources and the compelling urge to preserve them. Because of the thoughtless consumption of some

affluent populations of their natural resources and potential, others are suffering from increasing poverty and environmental degradation [20].

Before the 1992 Earth summit, several debates took place between activists who supported more economic growth and others who strongly called for a sustainable environment. According to the activists, if sustainability were to be followed, this would mean drastically reducing the consumption of resources, which will hinder the progress of economic growth.

However, sustainability has a much wider scope than the activists think. It could be said that sustainability is a pot in which all aspects of the economy, the environment, society, and culture are combined and considered equally. It strives to achieve a balance among all aspects of life and allows us to see potential threats and opportunities that might have been missed before.

### **2.2.1. Economic Dimension of Sustainability**

According to the common understanding, there has always been an inverse correlation between economic growth and environmental conditions. Whenever there is a rise in the economic state, it is believed that environmental degradation will accompany it due to the unsustainable use of resources. Such a relation is found when comparing the population count and economic growth with environmental indicators. Similar to cancer, unsustainable economic growth is able to rapidly spread and harm the balance of the environment, destroying life-supporting systems.

However, the term “decoupling” has recently appeared in the economic and environmental fields. The term refers to the ability to maintain economic growth without causing environmental depression as a result. Ecological economics studies societal metabolism, which includes studying the amount of resources entering and exiting from the economic system in relation to their effect on the environmental quality. Therefore, a community that is able to achieve GDP growth without compromising its environmental quality is said to be a decoupled one [21].

The importance of nature to the economy is indicated in the use of ecosystem services, which highlights the relevance of scarce natural resources to the market. However, these resources can no longer be considered unlimited or free. The natural resources are often treated as economic externalities, so they are easily consumed and overused. This behavior leads to the generation of short-term profits at the expense of

the environment, and degrades the quality of life over time.

### **2.2.2. Social Dimension of Sustainability**

Besides benefitting the environment and the economy, sustainability provides equal consideration to the social aspect of life. The social dimension of sustainability is largely intangible, as it relates to the common beliefs and social norms maintained in each society, such as language, education, work attitudes, and other beliefs that will most likely influence social life.

Social sustainability relates to adhering to the social norms and values within a community. It concerns the extent to which an individual contributes to improving his society and how much the society as a whole contributes to the individual's growth and improvement as well [22]. Moreover, social sustainability aims at satisfying the basic needs of human beings, such as food and shelter, though it does not end there, as it improves quality of life and enhances welfare, including health and safety by, for example, reducing noise and dirt, which would be inconvenient to the local residents [22].

In addition, the social dimension combines urban design and planning of the physical built environment with a focus on how the community that uses it is connected and functions. Social sustainability has a huge influence on the city, and achieving it involves many requirements, such as improving social skills and health care, achieving equity across neighborhoods, giving all members of society the opportunity to get involved in building the society, and always thinking about the coming generations [22].

It is a fact that how the built environment is developed has always had either a positive or a negative influence on society. For instance, the construction of wide roads for high-volume traffic with fewer pedestrian facilities threatens people's safety and security. On the other hand, providing a neighborhood with all the required basic services and facilities (such as a grocery store, a park, a bank, a restaurant, etc.) encourages social interaction between community members [23] [24]. The built environment will have the greatest value and sense when people feel that they belong to it and believe that it reflects their culture and thoughts [25].

### **2.2.3. Cultural Dimension of Sustainability**

Within a short period, globalization has led to worldwide developments that threaten cultural diversity and identity. Cultural sustainability was developed recently, as an interdisciplinary approach, with the goal of maintaining cultural values when applying sustainability in local, regional and global scales. For cultural sustainability, culture plays an important role in achieving sustainability, as it reflects our understanding of each other and our appreciation of our natural resources and the surrounding environment [26].

In academic research, culture has been considered in a variety of frameworks, such as indigenous cultures, developing countries, regional development, nature preservation, primary production, and tourism. Such research suggests that cultural sustainability addresses the cultural values, the definition of equal rights, and the cultural logic associated with decision making and policy planning within different communities. In this sense, cultural sustainability supports approaches based on community and participation [26].

Cultural sustainability also deals with art, creativity, and cultural activities, which contribute to community planning, enhancement, and revitalization. The promotion of cultural diversity while preserving cultural heritage in its tangible and intangible forms is one of the main aspects of sustainable development, according to many studies [26]. This position is built on the idea that sustainable development exists only when harmony and alignment are achieved between the objectives of environmental responsibility, economic viability, social equity, and cultural diversity.

## **2.3. Sustainability in the Construction Industry**

Sustainable construction is viewed as an application of the concept of “sustainable development” on the construction project life cycle. Construction can be said to be sustainable when sustainability aspects are implemented throughout the project life cycle from the project inception to the project demolition and disposal. The phases of a traditional construction project are usually divided into separate independent phases that are not integrated, and there is no interaction and communication between their participants. This frequently leads to numerous reworks and changes during the construction, reducing sustainability [8].

Sustainability in construction must also address the project operations, waste management for the project's infrastructure and elements, transportation, and utility transmission systems [27]. An integrated design approach that integrates all the systems used in the project together in a way that saves energy and reduces the emission footprint is essential to achieve a sustainable construction project [28]. Furthermore, sustainable construction promotes the conducting of comprehensive social and feasibility studies prior to launching the project and encourages the involvement of all the project stakeholders from the pre-design phase to obtain better transparency in communications and to achieve the maximum input from all parties involved [29].

Applying sustainability as a practice in the construction industry achieves many benefits that can be categorized as environmental, economic, social, and cultural aspects. Among these benefits are improved compliance requirements, fewer maintenance requirements, a reduction in risk and liability, improved health and safety by reducing illnesses associated with released emissions, the prevention of harmful effects on the environment, such as pollution and waste, increased reliability from customers and peers, and enhanced relationships with stakeholders, such as clients, government agencies, and community groups [30].

Moreover, sustainability is particularly important to construction companies for ensuring their long-term survival. As sustainability in construction promotes the effective selection and usage of equipment, waste reduction, efficient design, and enhanced quality in construction, it results in winning more projects, gaining marketability, and increasing profitability. In addition, reducing environmental effects ensures less use of resources, which increases the competitiveness of the company [30]. Therefore, it is crucial for a construction company to implement sustainable practices to ensure its survival in the market and increase its market share. Knowing this, it can be concluded that sustainable construction results in many benefits, some of which are tangible and others that are not, as listed below:

### Tangible benefits:

- Cost savings from improved energy management.
- Cost savings from efficient operations.
- Increased profits and more markets due to the introduction of low-carbon products and services.

### Intangible benefits:

- Gaining a competitive position in the market.
- Improved relations with the stakeholders.
- Employee-related benefits.

The three major areas of the construction industry that are associated with CO<sub>2</sub> emissions are materials manufacturing, construction, and operation [31]. CO<sub>2</sub> emissions in construction industry can be categorized as direct emissions from the burning of fuel or indirect emissions from the use of electricity from the grid supply, the use of company vehicles, and business travel and waste. Figure 2 shows an estimate of the global and industrial CO<sub>2</sub> emissions.

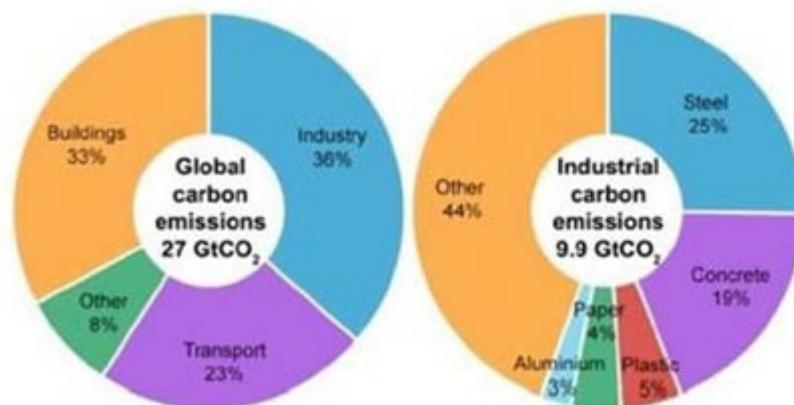


Figure 2: Global and industrial CO<sub>2</sub> emissions [31].

Material usage in the construction industry has been the most significant factor since 1900. The construction industry's material use has risen to an alarming level [32]. Figure 3 shows the material flow (in tons) in various industries beginning in 1900.



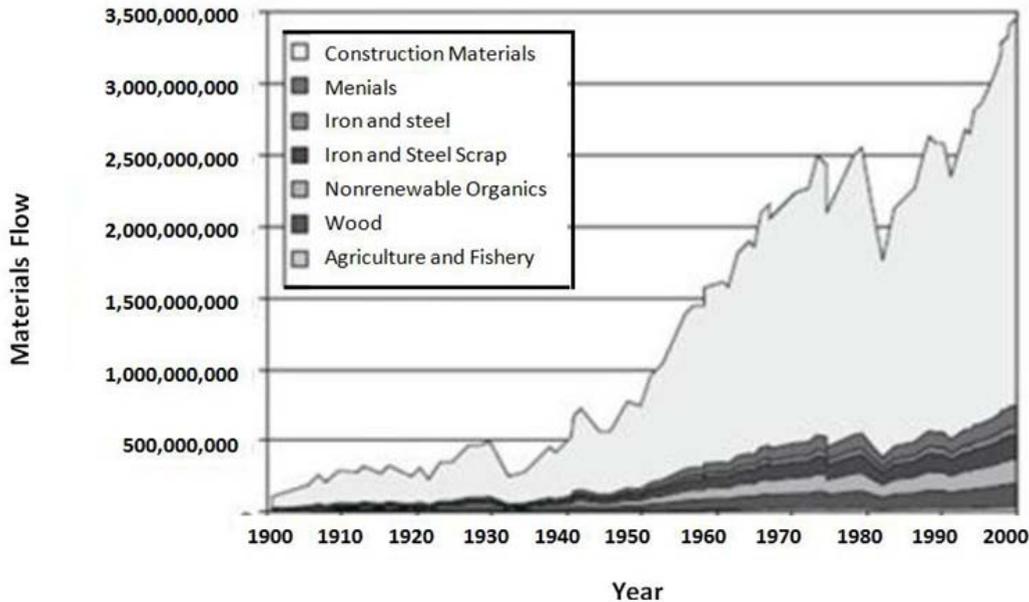


Figure 3: Materials flow in various industries [32].

Examples of effective ways to reduce CO<sub>2</sub> emissions in the construction industry are the use of modern construction technologies that lead to a reduction in the quantity of building materials and the use of alternate low energy-consuming materials [33]. Human activities such as fossil fuel burning in cars, power plants, industrial farms, and many other activities result in increasing the emissions of greenhouse gases such as carbon dioxide into the atmosphere. These activities create significant imbalances in the ecological cycle, such as higher temperatures, ice melting, and rising sea levels.

## 2.4. Concept of Maturity

Maturity as defined by the *Oxford English Dictionary* is “the state, fact, or period of being reached in the most advanced stage in a process.” In the software development industry, Paulk et al. [34] defined maturity as “a potential growth in capability, and it should also signify both the richness of an organization’s software process and the consistency with which it is applied in projects throughout the organization.” From the organization systems prospective, maturity is “the optimized ability and capability of a system or an organization versus its intended goals, and it is a state in which an organization is in a perfect condition to pursue its objectives [35].

In their article “The Development of a Supply Chain Management Process Maturity Model Using the Concepts of Business Process Orientation.” Lockamy and

McCormack [36] defined process maturity as “a process with a life cycle assessed by the extent to which the process is explicitly defined, managed, measured, and controlled with the growth in process capability, richness, and consistency across the entire organization.” In the view of the risk management, “maturity is the sophistication of an organization’s understanding of its risk portfolio, and how to manage those risks and the internal business continuity systems for coping with and recovering from the eventuality” [37].

## **2.5. Maturity Models**

Maturity models are considered benchmarks used to assess the strength, weakness, and capabilities of a system. They enable the identification of the criteria that need to be improved considering their priorities and help decision makers to select the most convenient actions to be taken to move the system from the current level to a more mature one. Maturity levels allow decision makers to obtain a clearer view of how they can further optimize the system and the operations that they are managing. Many different maturity levels have been defined, and each one of them addresses a different field. They vary in the number of their maturity levels, and each level has a different name and definitions of titles.

In the 1960s, the use of computers grew more widespread, more flexible, and less costly. Organizations began to adopt computerized information systems, and the demand for software development grew significantly. This phenomenon encouraged the development of the first maturity model in history when the United States Air Force in 1986 funded a study at the Carnegie-Mellon Software Engineering Institute to create the Capability Maturity Model. The aim of this model is for the military to employ it as an objective evaluation of software subcontractors. Due to the success of this model, many other models are now available, with many research studies being conducted to address this area.

## **2.6. Examples of Maturity Models in Different Industries**

### **2.6.1. Maturity Model for Software Engineering**

#### **Initial Level, Level 1**

Paulk, et al. [34] proposed the Capability Maturity Model for Software is a maturity model in software engineering that has five maturity levels. Typically, the organization does not provide a settled environment to develop and maintain the software at the initial level. Such organizations usually have difficulty making commitments that the staff can easily meet in an orderly engineering process, often resulting in a succession of crises [34].

Under the impact of a crisis, projects usually take a shortcut to coding and testing instead of the planned procedures, which are abandoned. Success under such circumstances highly relies on the availability of an excellent manager and an effective team. Although some managers are able to withstand the pressure and come up with effective solutions in the software process, once their duty is finished, their stabilizing influence stops.

#### **The Repeatable Level, Level 2**

At the repeatable level, strategies for handling software projects are created along with strategies to implement such policies. Managing new projects depends on previous experience with projects of a similar nature. The capability of the process can be enhanced by creating basic project management as regulation on a project-by-project basis. A process is considered effective when it allows application, documentation, enforcement, training, measurement, and improvement.

#### **The Defined Level, Level 3**

At the defined level, a typical process is used across the organization to maintain and develop software in both software engineering and management processes that are standardized, documented, and articulated in one coherent whole. Moreover, the processes developed at this level are used and changed whenever appropriate to assist in achieving the most effective performance from the software managers and technical staff. To standardize software processes in an organization, a

training program is implemented organization-wide to ensure that all the concerned staff has the required knowledge to fulfill their roles and responsibilities effectively. Preserving its unique characteristics, each project tailors the organization's standard software processes to develop a distinct software process of its own.

#### **The Managed Level, Level 4**

At the managed level, well defined quantitative goals are established and measured for software processes. Such measurements constitute the base of the quantitative information used to evaluate and assess the project's software processes and products. To gain control over their products and processes, projects try to eliminate variations in their process performance, allowing it to fall within acceptable quantitative boundaries that can be measured and assessed. Meaningful variations are clearly distinguished from random variations such as noise, mostly in established product lines.

#### **The Optimizing Level, Level 5**

At the optimized level, the entire organization's focus is shifted toward ensuring continuous improvement of the process. Using various means, the organization identifies the points of weakness in the process and comes up with solutions to strengthen it proactively, aiming at eliminating the occurrence of defects and ending with a flawless process.

At level 5, the project team analyzes defects occurring in the process to identify their causes and eliminate their occurrence. In any system, chronic waste is generated as a simple result of random variation; therefore, lessons learned during this process are transferred to other projects.

The second level of achievement, good management, defines a more formal statement of objectives about each phase of the collaboration engineering approach. At this stage, the collaboration engineer, along with the collaboration stakeholders, begins to assess the collaboration process against a pre-defined set of objectives and goals.

At the third maturity level, predictability, the collaboration engineering approach reaches a stage where it is amply refined and documented and is able to

achieve the anticipated outcomes. Once this level is achieved, it indicates that the collaboration engineer can fully trust the established CE approach and the building blocks accompanying it in regard to satisfying the objectives. The final level, optimization, indicates that the predictability of the collaboration engineering approach has been successfully implemented and comprehensively understood by the collaboration engineers and the organizational stakeholders.

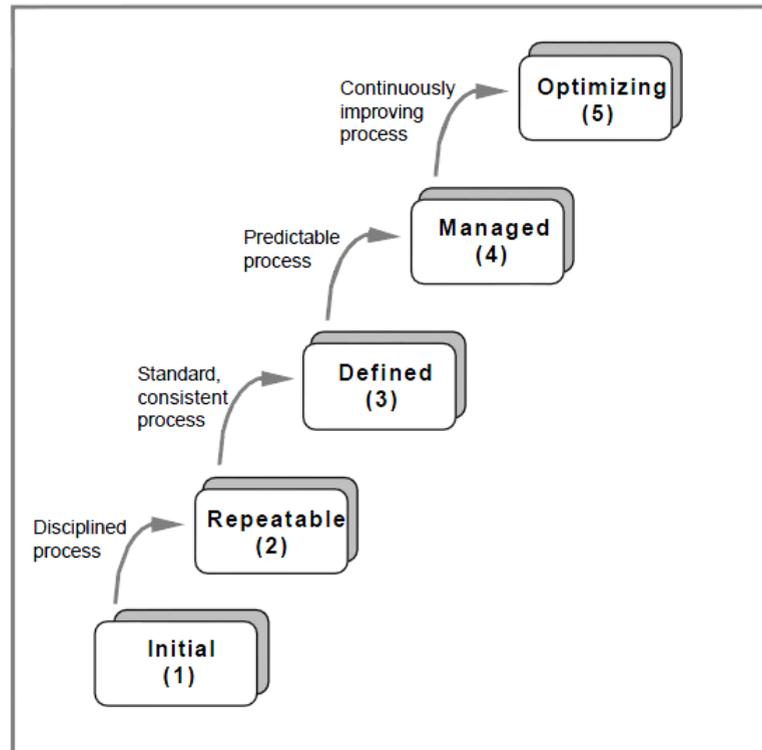


Figure 4: Representation of a maturity model for software engineering [34].

### 2.6.2. The Healthcare Performance Improvement Maturity Model

In their article “A Performance Improvement Maturity Model for the Healthcare Industry,” Ferrara et al. [38] proposed a Health Maturity Model that improves the performance of the healthcare industry by providing a shared vision for what an organization needs to do and what processes need to be redesigned to attain a specified level of quality. The model, as the authors describe it, is a common language and vision that the systems in the healthcare industry can adapt to reduce risk and accelerate enhancing [38]. The three distinct levels of the Health Maturity Model are represented in Figure 5.

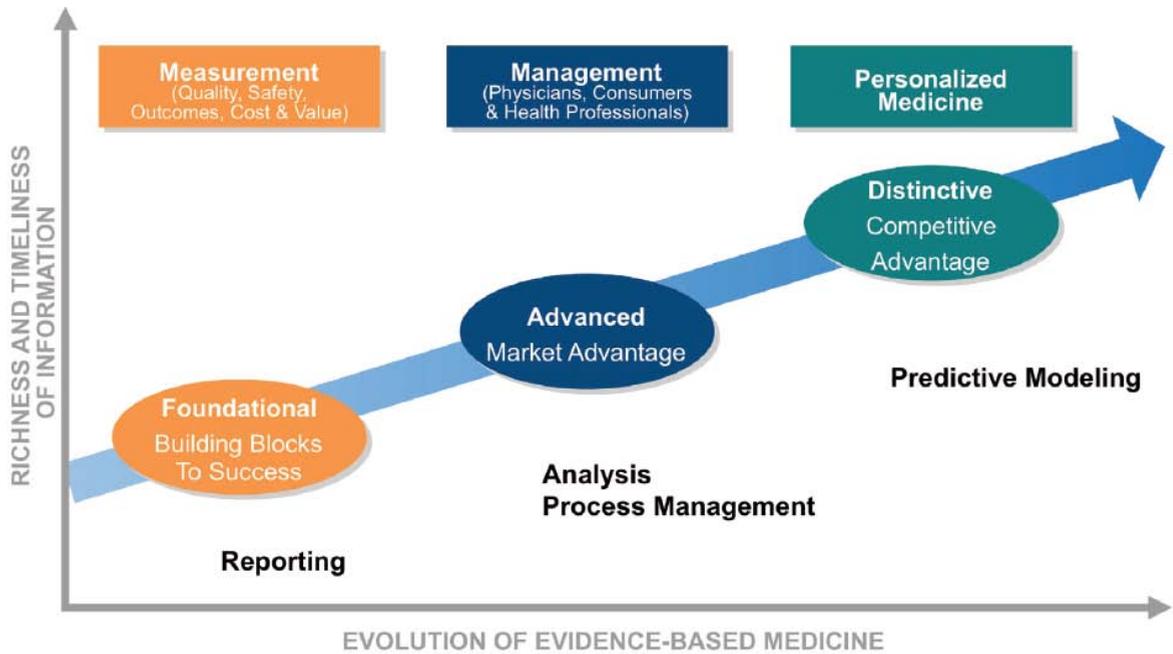


Figure 5: Healthcare Performance Improvement Maturity [38].

At the first level (the foundational level) the organization defines how to evaluate its efficiency and the quality of its processes. Furthermore, it compares its performance conformity with the international quality standards to determine a baseline for its operations. In the second level (the advanced level), healthcare systems manage quality improvement proactively. They have well defined goals and a methodology for meeting the quality improvement objectives. At the third level (the distinctive level), the processes of the organizations are mature such that the organizations are able to retrieve sufficiently rich information very quickly, which ensures that each patient receives high-quality, personalized care.

### 2.6.3. Safety Maturity Model

In “A Safety Culture Maturity Model for Petrochemical Companies in Brazil” Filho et al. [39] introduced their maturity model for the safety field, aimed to design a measurement tool that identifies safety culture maturity levels in Brazilian industry [39]. At the first level (the pathological level), safety problems are caused by laborers and staff, and the major drivers to implement safety practices are the business reputation and the fear of being caught by the government. The second level is called the reactive level, in which organizations start taking safety more into consideration,

but actions are usually taken only after incidents occur. At the third level, called the calculative level, organizations' managers are concerned about safety, and they tend to conduct more studies and collect more data about it. However, safe practices are still imposed and have not become a habit for the workforce.

The fourth level is called the proactive level. At this level, the workforce has begun performing a safety behavior with an obvious improvement in implementing it, and safety practices are viewed by the organization as one of the business commitments. At the last level, called the generative level, the workers start viewing the implementation of safety practices as a duty, and they are willing to apply them even if they are not monitored. The following figure is a representation of the model levels.

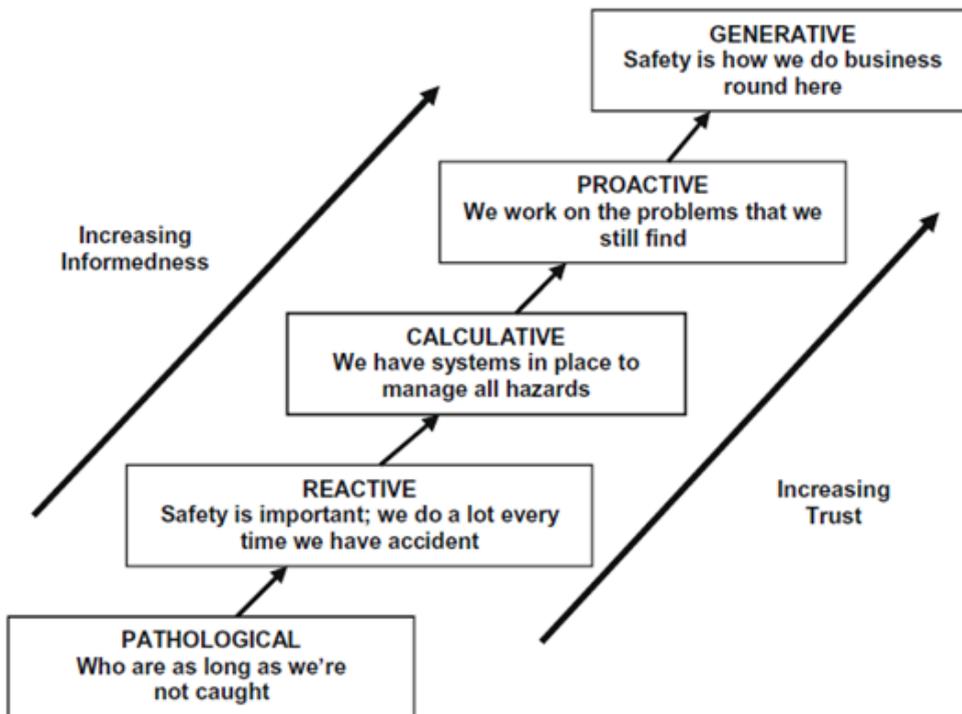


Figure 6: Safety Maturity Model [39].

#### 2.6.4. Project Management Maturity Model (PRINCE2)

PRINCE2 is a project management maturity model introduced by Jing Wu and Xian in their article "PRINCE2 Based Project Management Maturity Model." The model has five maturity levels numbered 1 through 5 [40]. At level 1, no formal planning session is done, and a clearly defined project plan is often unavailable.

At level 2, informal plans start to get developed, the organization receives informal training to develop and plan key project management (PM) tools and techniques, and the project teams are engaged in providing the necessary input into the planning process and reviews. At level 4, the PM process is integrated into the planning process. At level 5, the planning is finally optimized and sustained for continuous PM improvement. The five levels are clearly described in the following figure.

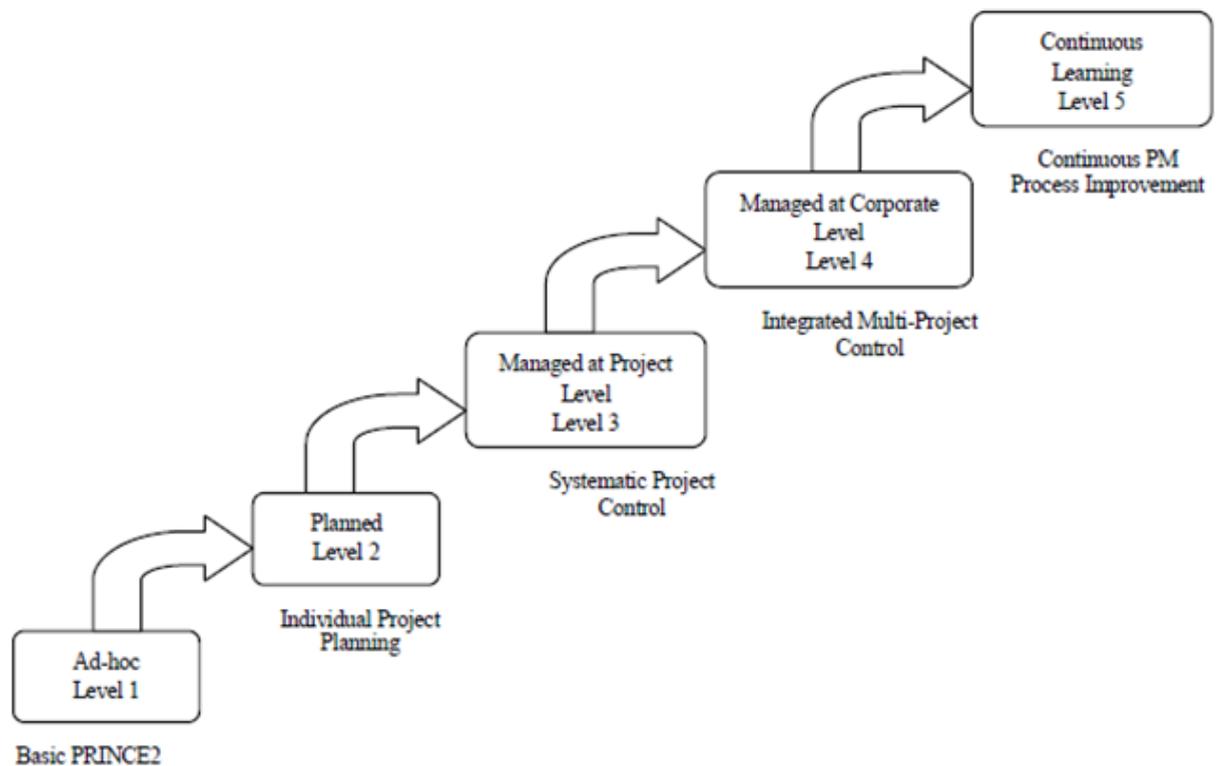


Figure 7: Project Management Maturity Model [40].

### 2.6.5. Change Management Maturity Model

In 2004, Prosci introduced a maturity model for change management based on a study that covered 150 organizations. It consists of five levels of organizational maturity involving how to manage people during the process of change in various endeavors [41]. At level 1 of the maturity model, project team members have little or no awareness about the change management process and the approach to manage the people. Project management is rather focused on the concrete aspects of the project, such as the schedule, funding, issue tracking, and management of resources.



Management has no information about the change at this level, so the change management skills required to train the team during the change process are lacking.

Change management, which is typically a response to a negative event, starts to emerge at level 2 of the maturity level within isolated parts of the organization. However, the efforts to manage people during a change are not centralized or shared among various divisions, and the process of change management is not controlled. At level 3, isolated parts are replaced by groups that use a more regulated change management approach. However, change management is still localized within specific areas or teams in the project, while knowledge is shared among the teams using change management within various departments and divisions. Moreover, training tools become available to managers and team members, and project leaders are now able to train their front-line staff members throughout the change process.

At level 4, the definition of change management and its significance to the project's success is widely acknowledged throughout the organization. A typical change management approach is selected, and plans are prepared to be introduced to the organization. Standards are implemented for the change management process such that they can be used with new projects and future changes. Moreover, functional groups are shaped with the goal of supporting change initiatives, and roles are created with specific titles, such as Director of Change Management. Organizations create a "center of excellence," which mainly represents individuals, groups, or administrative positions dedicated to support change management initiatives and enhance change management skills.

At the final level, level 5, the organization's set of skills includes competency in change management. A strategic goal of the organization is to manage change effectively, and it is set as a priority by the executives. At this level, change management becomes second-nature, as it comes to be commonly practiced and nearly inseparable from the initiatives.

#### **2.6.6. Maturity Model for Supply Chains**

Meng et al. [42] presented the "Maturity Model for Supply Chain Relationships in Construction" which is a maturity model for supply chains that includes four maturity levels. At level 1, no mutual agreements are reached between

the separate parties, and their positions are based solely on self-interest and mistrust. Parties focus on realizing their objectives, maximizing their profits with no consideration for predicted effects on other parties. The only trust that can be reached at this level is based on commitment to formal contracts. Moreover, price competition is common practice, and the business approach is based on a win-lose philosophy, which creates oppositional relationships.

At level 2, the main interest of the parties revolves around their own objectives and benefits. Although no mutual objectives are shared between the parties, a scenario where one party wins while the other partially wins creates a cooperative attitude between them. Moreover, quality competition takes over instead of price competition as common practice. Although the parties rely on formal contracts, some trust is formed based on their common understanding about their capabilities to perform their tasks. At level 3, objectives are brought into line within a single project, and trust based on goodwill develops between partners. The success of the project becomes the main focus of everyone; hence, partners work together collaboratively within an integrated project team to meet the mutual objectives.

At level 4, the alignment of objectives happens over a series of projects, directing the interest into a long-term relationship. Fair gain sharing guarantees full collaboration between partners across the whole supply chain. Moreover, the utmost level of trust is achieved between the partners, as they share the highest expectations and aim to achieve the best value. Continuous improvement is achieved as a result of performance management feedback and the implementation of innovative technical and managerial approaches.

### **2.6.7. Conceptual Maturity Model for Sustainable Construction**

Goh and Rowlinson [43] introduced a conceptual maturity model for sustainable construction that offers a baseline to evaluate the maturity of development within the construction industry. The authors proposed five domains in their models: performance, management capability and capacity, culture, long-term framework development, and research and development, as shown in Figure 8. Each domain is evaluated using a scale of five points in which level five indicates great performance. The levels used for this model were adopted from Paulk et al. [34]: initial, repeatable, defined, managed, and optimizing.

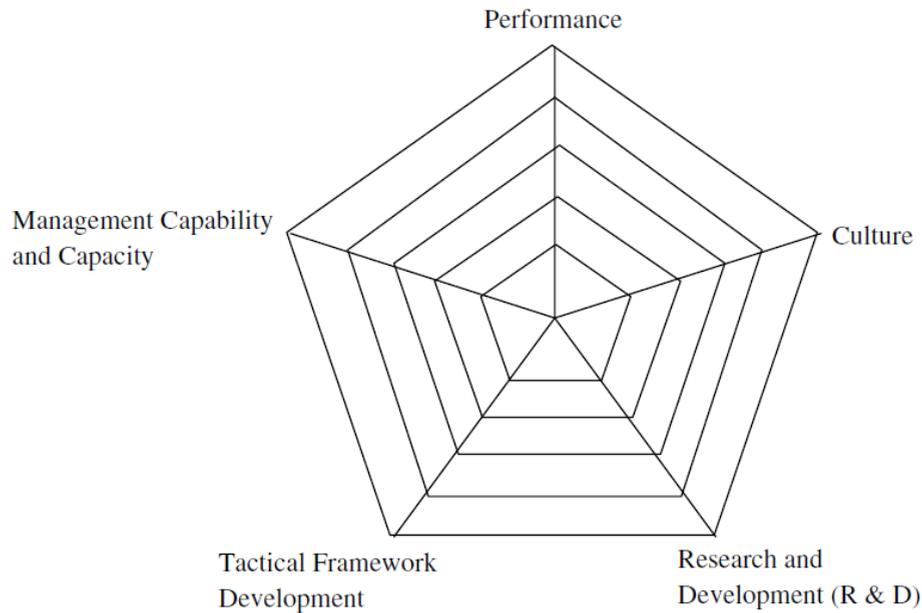


Figure 8: Conceptual maturity model of sustainable construction [43].

### **2.6.8. A Maturity Model for the Strategic Design of Sustainable Supply Networks**

Kirkwood et al. [44] introduced the Sustainable Supply Network Maturity Model, which assesses the practices used to support sustainable operations. The model also implements a network concept and offers an alternative metric methodology to study the organizational routines and business practices in a simpler way that makes more sense to the practitioner. The model is divided into five capability levels: strategic, sustainable, network design, network integration and connectivity, network processes and innovation, network efficiency and reporting, and network product and service enhancement.

### **2.6.9. The Standardized Process Improvement for Construction Enterprises Maturity Model (SPICE)**

In the article “Spice: Is a Capability Maturity Model Applicable in the Construction Industry?” Sarshar et al. [45] introduced a research-based project that aimed to apply the Capability Maturity Model (CMM) from the software industry to

the construction industry. SPICE offers a framework for the business to improve its process and serve as a tool to assess the maturity in the construction industry. The article highlights some similarities and differences between the CMM and the SPICE models; for example, cultural communications issues in the construction industry are similar to those in the software field. On the other hand, in the construction industry, the nature of the work and the professional qualifications are more mature, and the data used in construction is usually standardized and readily available.

# **Chapter 3: Developing a Sustainability Maturity Model and a Rating System for the Construction Industry**

## **3.1. Objectives**

- To define the meaning of mature sustainability in the construction industry.
- To develop a maturity model for sustainability in the construction industry.
- To develop a rating system that can be used to determine a country's maturity level.

## **3.2. Assumptions**

- All pillars (construction companies, government, and the public) have the same effect on the construction industry (uniform effect)
- The survey of the rating system is well controlled and monitored while it is conducted on a country; hence, the sample size and composition are not manipulated, nor are the answers.
- Due to the difficulty that the author faced in gaining access to governmental data, the questions that examine the government's sustainability performance are designed to elicit a “yes” or “no” answer; hence, the points awarded are either zero or three points.

## **3.3. Definition of Mature Sustainability in Construction**

None of the authors who previously developed construction sustainability maturity models such as Goh et al. [43], Kirkwood et al. [44], Sarshar et al. [45], etc. evaluated the sustainability of the construction industry considering its three major components: the government, construction companies, and the local public. However, the author of this thesis suggests that, to conduct a more accurate sustainability evaluation for the construction industry, it must be decomposed into its three major components, and the sustainability level of each must be determined individually. After determining the sustainability maturity levels of the components, the sustainability maturity level of the whole construction industry can be determined accordingly. Actually, this new evaluation technique is what makes this thesis

different from the previously developed construction sustainability maturity models, and it is the backbone of the author's contribution in this thesis.

The author suggests that a country's construction industry can be said to have mature sustainability only when its three main components are proved to be sustainable and to contribute effectively in creating a sustainable construction industry. If any of these three pillars fail to contribute effectively, maturity cannot be achieved Figure 9 demonstrates the meaning clearly.



Figure 9: Demonstration of the new concept of mature sustainability in the construction industry

### **3.3.1. The Government, Construction Companies, and the Public as the Major Pillars of the Construction Industry**

As a major owner and user of the country's constructed facilities and mega projects, the government has always been the leader of the country's construction industry [46]. Many studies have been conducted to study the influence of the government on the construction industry. For example, in 2001, Lenard and Abbott [47] highlighted in their article "The Role of Government in Supporting the Construction Industry in the United Kingdom" how the government plays a major role in the construction industry and significantly affects its growth. Moreover, in his article "Impact of Government Policy on Mobility in the Canadian Construction

Industry,” Grady [48] discussed the government’s effect on the construction industry and concluded that the government has a greater impact on the construction industry than all the other factors or sectors.

In addition, Gann et al. [49] stated that government rules and regulations have played a major role in shaping technological change in the construction industry. Dubois and Gadde [50] argued that the excessive intervention of the government in the construction industry has negatively affected the technological innovation growth in the construction field, which has resulted in a negative impact on the market as well.

Anderson and Manseau [51] argued that companies are a major part of the construction industry, as they are the builders of construction projects and the key sources of innovative components and building products. Moreover, a study conducted by the Flash Eurobarometer [52] showed that more than 50% of European citizens believe that companies have a positive effect on society and industry and that the behavior of companies has been a major factor in defining the economies of their countries.

Seaden and Manseau [53] stated that the public is also a major factor in shaping the county's construction industry since they are the end users of the constructed communities and structures. They also argued that the public has contributed to enhancing innovation in the construction industry, as their daily renewable needs and requirements create new challenges for the industry every day and increase competition in the market. For example, the public need for a sustainable built environment that keeps them healthy and socially active while saving money spent on energy generation has caused the construction industry to move toward sustainable solutions, such as constructing green buildings and manufacturing green construction products to satisfy the end users [17].

### **3.4. Design of a Sustainability Maturity Model in the Construction Industry**

The methodology involves the creation of a new maturity model that assesses how mature a country’s construction sustainability is. First, the author has defined five maturity levels based on the performance of the three pillars that play the major roles in the construction industry: construction companies, the government, and the public.

After defining each maturity level, the author developed a point-based rating system that can be used to determine the sustainability level of a particular country. The rating system is based on answering questions that address all the criteria mentioned in the definitions of the maturity levels. These questions are answered by conducting a survey on the construction companies, governmental departments that control the construction industry, and the public.

Since the main aim of this thesis is to enhance the construction sustainability of countries, it is essential in the first step to evaluate their current sustainability performance. The author looked for a proper tool that can be used to evaluate systems and lead to their enhancement and found that one of the most useful and popular tools used for the same purpose is the maturity model.

With reference to the literature review on maturity models presented in the previous chapter, covering Paulk et al. [34], Ferrara et al. [38], Filho et al. [39], Jing Wu et al. [40], Prosci [41], Meng et al. [42], and Goh et al. [43], it is noticed that all of them share some common criteria. For example, they were developed to assess a system or an organization, serve as a benchmark for further improvements, determine the strong and weak points in the system, and come up with convenient recommendations based on the assessment. In addition, all of the introduced maturity models consist of levels in which the performance of the system at the first level is weak and starts to improve gradually until it reaches maturity, the ideal case, at the highest level. The author of this thesis adopted this common structure in developing his sustainability maturity model of five maturity levels, which are unsustainable, poor, satisfactory, sustainable, and mature sustainable, and described the sustainability performance and criteria of the three components of the construction industry at each level.

This section defines in detail the criteria for each maturity level based on the performance of construction companies, the government, and the public. The following figure is a demonstration of the developed Maturity Model for Construction Sustainability.



Figure 10: Developed maturity model for a sustainable construction industry



### **3.4.1. Level Zero—Unsustainable**

#### **Construction Companies at Level Zero**

The company at this level has no awareness of the advantages of sustainability and will only implement sustainability applications that are forced by the government to avoid being penalized. The company believes that there is no point in implementing these applications and that these are just extra costs that they do not have to pay. It avoids taking projects that have sustainable designs, claiming that these projects are too complicated and result in a lower profit margin.

Moreover, such companies usually do not encourage their engineers to improve their knowledge about sustainability and do not offer them any educational courses about it. They are not interested in hiring engineers who hold degrees or certificates in sustainability such as LEED, BREEM, or Estidama.

#### **Government at Level Zero**

At this level, the government is unaware of the importance of adopting sustainability in the construction industry of the country and does not issue any regulations or rules that force its implementation. The government believes that such a step will result in high expenses and extra complications for the construction industry of the country.

#### **The Public at Level Zero**

The public at this level is not well aware of sustainability, and they do not believe in sustainable designs. Their daily life is itself unsustainable and does not reflect any responsibility toward the environment or the local economy. Additionally, they are unwilling to change their lifestyle.

### **3.4.2. Level 1—Poor Sustainable**

#### **Construction Companies at Level 1**

At this level, the company starts to recognize the importance of implementing sustainability and to introduce it to its employees and clients. It also starts accepting sustainable construction projects; however, it still does not have a defined strategy related to how sustainability practices will be included in the company's operations. The degree of success is still uncertain, as there is limited planning for this initiative.

### **Government at Level 1**

The government experiences growing understanding about the advantages of adopting sustainability in the construction industry but still implements it on a small scale and does not have a defined strategy for managing and controlling it.

### **The Public at Level 1**

At this level, the public is aware of sustainability but still reluctant to adopt it, as they do not want to pay any extra money. They consider only the short-run results and are still not convinced of the advantages of sustainability in the long run.

### **3.4.3. Level 2—Satisfactory**

#### **Construction Companies at Level 2**

A company at this level has a more formal and defined statement of the objectives of each sustainable practice and starts to build a system to measure the quality and efficiency of these practices. The company encourages its staff members to improve their knowledge about sustainable designs while searching for experienced people in the field to hire them.

#### **Government at Level 2**

The government at this level encourages sustainability implementations and launches sustainable projects. It appreciates those who choose to build or to own a sustainable property, gives them the priority, and offers them special discounts on governmental fees. However, sustainability at this level is not forced on the construction companies.

#### **The Public at Level 2**

At level 2, the public recognizes the advantages of sustainable construction, and their lifestyles start to become affected and sustainable due to that awareness. When they want to build a new property, they will allow for the minimum sustainability requirements in the design to save money.

### **3.4.4. Level 3—Sustainable**

#### **Construction Companies at Level 3**

The strategies and visions for adopting sustainability in the company are managed, optimized, and comply with international standards. A company at this level provides regular training to its employees about sustainable construction and strives to build a sustainable culture in the company. It always promotes sustainable designs for its clients and ensures that they are aware of the advantages.

#### **Government at Level 3**

At this level, the government does not permit any unsustainable design to be executed and requires all the engineers working in the construction industry to have a degree or an international certificate in sustainability; otherwise, they will not be permitted to work.

#### **The Public at Level 3**

The public at this level desires to live in a sustainable place and chooses to employ sustainable designs for their properties. Owners choose only contractors who commit to the use of sustainable construction materials and construction methods to build their properties.

### **3.4.5. Level 4—Mature Sustainable**

#### **Construction Companies at Level 4**

Sustainability at this level is involved in all the company's operations and processes, and it is considered one of the company's competitive advantages. The company believes that it has to take part in the evolution toward a sustainable construction industry. It recognizes sustainability as one of its core principles and as an inherent part of the business. The company highly encourages its employees to come up with innovative ideas that improve its sustainability practices and provide them with all the required support to do so.

#### **Government at Level 4**

The government has strict rules and regulation to force the adoption of sustainability. A dedicated authority within the government is established to monitor

and control the construction industry, and it has well-defined quality control and monitoring methodologies. The government considers sustainability a priority that cannot be compromised.

#### **The Public at Level 4**

The public's lifestyle is sustainable, and they feel responsible for the environment and the local economy. They want to deliver to the next generation a healthy and sustainable civilization. They lead construction companies and the government toward sustainability.

### **3.5. Design of the Point-Based Rating System**

The developed numerical method to determine the maturity sustainability level of a country is as follows:

- Five maturity levels were defined according to the level of sustainability performance: unsustainable, poor sustainable, satisfactory, sustainable, and mature sustainable.
- Each maturity level contains a description of the sustainability performance of construction companies, the government, and the public.
- The performance level of the pillar in each question is converted into a number of points, and the number varies from a minimum of zero points to a maximum of three points.
- There are different types of answers, and each type has a different way of being converted into points.
- In the following type of questions, the answer is either “yes” or “no,” and the points are awarded according to the percentage of “yes” answers.

**Example: Have you attended any course or lecture about sustainability?**

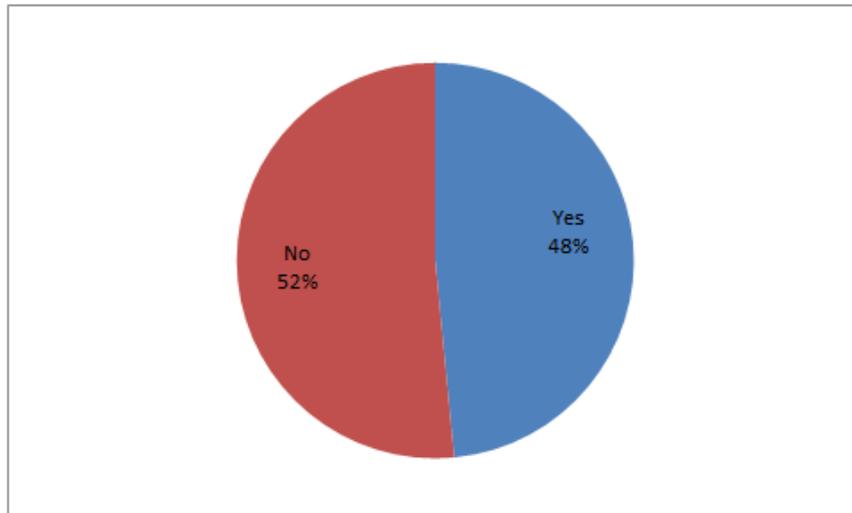


Figure 11: Percentage of participants who attended any course or lecture about sustainability

Point Range Definitions

- 0%–19%: 0
- 20–49%: 1
- 50–79%: 2
- 80%–100%: 3

Since the percentage of “yes” is 48%, the number of points awarded is 1.

Note that the point ranges of the awarded points are decided by:

$$\frac{100\%}{4 \text{ Ranges}} = 20\% \text{ per point range}$$

In questions such as "How much of the energy being consumed by the company's operations is derived from renewable energy?" the answer consists of different performance levels, and the number of points awarded is calculated as follows:

The maximum number of points to be awarded = 3 points, and the number of possible answers = 4. Therefore, the probability of each answer occurring = 1/4, so :

$$\begin{aligned} (1/4) (X) + (1/4) (X) + (1/4) (X) + (1/4) (X) &= 3 \text{ points} \\ &= X (1/4 + 1/4 + 1/4 + 1/4) = 3 \\ \text{Performance coefficient} &= X=3 \end{aligned}$$

The performance coefficient can be equal to 3 for all the answers only when all of them have the same level of performance, which is never the case. In reference to the example below, it is unfair to give the same performance coefficient value to a company that has been implementing sustainability for the last 11–20 years and to another company that has been implementing it only for the last 1–5 years. Therefore, to be fair and more logical, the formula is adjusted as follows:

$$\{(0) \times (\text{Result of the unsustainable answer})\} + \{(1) \times (\text{Result of the poor performance answer})\} + \{(3) \times (\text{Result of the sustainable answer})\} + \{(5) \times (\text{Result of the mature sustainable answer})\} = \text{Number of points awarded}$$

**Example: How much of the energy being consumed by the company's operations is derived from renewable energy?**

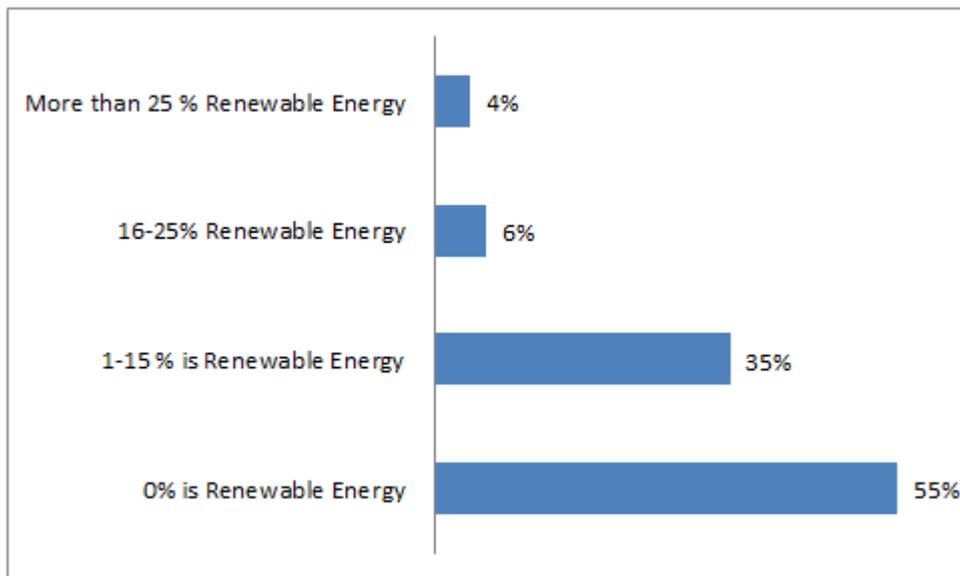


Figure 12: Percentages of renewable energy used by construction companies

Answer Evaluation:

0% renewable energy = (unsustainable answer)

1–15% is renewable energy = (poor sustainable answer)

16–25% renewable energy = (sustainable answer)

More than 25% renewable energy = (mature sustainable answer)

### Point Range Definitions

- 0–0.49 = 0 point
- 0.50–1.49 = 1 point
- 1.5–2.49 = 2 point
- 2.5–3.0 = 3 point

The average percentage of renewable energy generated by the company from renewable resources =  $(55\%)(0)+(1)(35\%)+(3)(6\%)+(5)(4\%) = 0.73$  points, so number of points awarded = 1

- The average number of points awarded to a pillar from all the questions that are related to it is calculated and considered the final number of points that the pillar deserves.
- After finding the final number of awarded points for each pillar, a three-dimensional point in a coordinate system is generated. For example, assume that the average number of points awarded for the construction companies = 1 point, the average number of points awarded for the government = 2 points, and the average number of points awarded for the public = 3 points. The points will be:

X = Average number of points awarded for the companies

Y = Average number of points awarded for the government

Z = Average number of points awarded for the public

$$(X, Y, Z) = (1, 2, 3)$$

- To determine the country's sustainability performance, a comparison is done between the country's coordinate points, and the comparison is done by calculating the distance between the two points. The distance is calculated using the following formula:

$$DIML = \sqrt{(3 - X)^2 + (3 - Y)^2 + (3 - Z)^2}$$

- In the best-case scenario, the country will have an average of 3 points in each pillar and achieve the “ideal maturity point,” which is (3, 3, 3). In the worst-case scenario, the country will have an average of zero points in each pillar and have the following coordinate points: (0, 0, 0).

- To determine the range of the possible distance to the ideal maturity level (DIML) values, the upper and the lower limits have to be calculated:
  - DIML upper limit =  $\sqrt{(3-3)^2 + (3-3)^2 + (3-3)^2} = 0$
  - DIML lower limit =  $\sqrt{(3-0)^2 + (3-0)^2 + (3-0)^2} = 5.196$
  - Therefore,  $0 < \text{DIML} < 5.19$
- Since the model consists of five maturity levels, the DIML range has to be divided by 5:
  - The DIML range of each maturity level =  $\frac{5.196}{5} = 1.0392$
  - Hence, the DIML range of each maturity level is as shown below

Level	Combinations
<b>Unsustainable (Level 0)</b>	$\text{DIML} = \sqrt{(3-x)^2 + (3-y)^2 + (3-z)^2}$ $= 5.196 \text{ to } 4.15$
<b>Poor Sustainable (Level 1)</b>	$\text{DIML} = \sqrt{(3-x)^2 + (3-y)^2 + (3-z)^2}$ $= 4.14 \text{ to } 3.10$
<b>Satisfactory (Level 2)</b>	$\text{DIML} = \sqrt{(3-x)^2 + (3-y)^2 + (3-z)^2}$ $= 3.11 \text{ to } 2.07$
<b>Sustainable (Level 3)</b>	$\text{DIML} = \sqrt{(3-x)^2 + (3-y)^2 + (3-z)^2}$ $= 2.06 \text{ to } 1.02$
<b>Mature Sustainable (Level 4)</b>	$\text{DIML} = \sqrt{(3-x)^2 + (3-y)^2 + (3-z)^2}$ $= 1.01 \text{ to } 0$

Table 1: Distance ranges of maturity levels

- The output from the formula is compared to the ranges given in Table 1, and the sustainability level is determined accordingly.



### **3.6. Development of the Rating System for the Sustainability Maturity Model**

Based on the previously conducted research and literature about sustainability maturity models, the author of this thesis found that there are common factors that have been addressed in most of them. These factors are sustainability awareness, society's readiness to change and improve, engagement and encouragement of stakeholders, defining a strategy, sustainability implementations, and society's lifestyle and readiness to change. The author of this thesis addresses these factors as well in his rating system, and the following is an elaboration of the factors based on previous research and literature.

#### **1- Sustainability awareness**

Raising awareness about sustainability and the need for it is the most important step to take to facilitate the movement toward a sustainable world [54]. People need to understand why they sometimes have to pay extra to buy a sustainable product or property, and they need to be convinced why they have to change their lifestyle to a more sustainable one [55]. It is true that sustainable behavior cannot be forced all the time. In some situations, sustainability is a voluntary choice that requires an internal belief in the positivity of the concept to choose it [56]. Sustainability awareness can be raised through offering a proper educational plan to the public and the people in the industry. It can also be enhanced by involving the whole society in the sustainability plans and actions and keeping them updated [54].

#### **2- Encouraging stakeholders**

As construction projects have become very sophisticated, involving stakeholders throughout the project life cycle has become a necessary practice [57]. Stakeholder engagement helps in delivering the intended project outcomes and improving the quality and comfort of life. On the other hand, it decreases the negative effects of the construction projects on the environment and results in the development of sustainable design that integrates all the inputs coming from all parties and meets everybody's needs [57].

### **3- Defined system strategy**

A clear strategy to implement sustainability applications leads to the achievement of goals with less effort and difficulty [58]. Each party involved in the construction industry (developers, manufacturers, consultants, contractors, etc.) has to define its own strategy that is aligned with its visions and goals. However, no strategy can stay as it is forever; a sustainability implementation strategy has to be reviewed regularly to ensure that it suits the current opportunities and threats [58].

### **4- Sustainability implementation**

Sustainability in the construction industry as a theory does not help only in protecting our environment and improving our lives [59]. Sustainability theories have to be translated into real applications that should be carried out by all the industry components. When evaluating the sustainability performance of a construction industry, it is important to measure the extent to which the sustainability practices are implemented by the stakeholders since it reflects the sustainability level in this particular industry [59].

Some researchers had doubts regarding whether construction sustainability applications can really save energy and resources and reduce emissions footprints, suspecting that it is all just some marketing claims made to increase sales. For example, Dobson et al. [60] in their paper “Sustainable Construction: Analysis of Its Costs and Benefits” conducted a comparison between the construction cost of a conventional building and a green building, and it was shown that a green building has the capability to save money in the long run for the building owner and residents as well.

### **5- Society’s lifestyle and readiness to change**

It is very important for a society to have a sense of responsibility toward future generations and the planet they live on [61]. Society's lifestyle plays a key role in achieving mature sustainability, which makes promoting sustainable lifestyles a priority action to move toward a sustainable life [62]. Many research studies have been done to study the effect of a society's lifestyle on the environment and the economy, and a strong relation has been observed between them. For example, Vladimirova [63] argued that a society's choices are the major factors that shape the

economic and environmental situation of their country. If the society chooses to go sustainable and green, then the local environment and economy will be influenced and have to adapt to their choice. Vladimirova suggested that sustainable lifestyles can be promoted to the society through the media, educational institutions, and campaigns.

Table 2 includes the survey questions that address the areas discussed above (sustainability, awareness, readiness to change and improve, encouraging stakeholders, defined system strategy, sustainability implementations, seniority of the system, feeling responsible, and attitude and lifestyle):

	Construction Companies	Government	The Public
<b>Sustainability Awareness</b>	<ul style="list-style-type: none"> <li>-Would you be interested in studying sustainability?</li> <li>-Have you attended any course or lecture about sustainability?</li> <li>-Has your company provided training courses on sustainable construction?</li> <li>-Does your company specifically look for engineers holding degrees or certificates in sustainability?</li> </ul>	<ul style="list-style-type: none"> <li>-Do you think that there is proper public awareness through the local education system or the local media about the values, techniques, and importance of sustainability?</li> <li>-Does the UAE government hold regular conferences and lectures for the public to raise their awareness about sustainability?</li> </ul>	<ul style="list-style-type: none"> <li>-In your opinion, do sustainable designs lead to financial savings?</li> </ul>
<b>Encouraging Stakeholders</b>	<ul style="list-style-type: none"> <li>-Does your company promote sustainable employee behavior?</li> <li>-To what extent has your company communicated its sustainability goals and policies to external stakeholders?</li> </ul>	<ul style="list-style-type: none"> <li>-Does the UAE government encourage and facilitate manufacturing local construction materials to reduce transportation energy consumption?</li> <li>-Does the UAE government have any recognition and award systems (such as fee discounts, priority, and recognition)?</li> </ul>	<p style="text-align: center;">-----</p>

Table 2: Survey question design

	Construction Companies	Government	The Public
<b>Defined System Strategy</b>	-Has your company defined strategies and plans regarding how to involve sustainability in the company's operations and processes?	-Does the UAE government have a defined plan for implementing sustainability?	-----
<b>Sustainability Implementation</b>	<p>-Have you ever worked on a project that employs green design and green construction methods?</p> <p>-Does your company measure the carbon emissions footprint produced by its construction projects?</p> <p>-Does your company measure emissions from staff travel related to their job?</p> <p>-How much of the energy being consumed by the company's operations is renewable energy?</p> <p>-How many years ago did your company start implementing sustainability?</p>	<p>-Does the UAE government calculate the emissions footprint of the public?</p> <p>-Has the UAE government established specialized organizations or departments to address sustainability issues in the construction industry?</p> <p>-Does the government have its own construction sustainability rating system or adopted an international one?</p> <p>-Has the UAE government undertaken any projects in the country to reduce the emissions footprint and the energy usage?</p> <p>-How many years ago did the UAE government start adopting sustainability in the construction industry?</p>	<p>-I buy or use locally manufactured products and services whenever possible to reduce transportation costs and to keep money in the local economy.</p> <p>-I refrain from using drive-through lanes for services, such as food purchases and banking. I always park my vehicle and turn off the engine.</p> <p>-I walk or use a bicycle for trips near my home.</p> <p>-Whenever the temperature outside is moderate, would you switch on the air conditioner?</p> <p>-Where possible, would you take the stairs rather than using the elevator?</p>

Table 2: Survey question design (cont.)

	Construction Companies	Government	The Public
<b>Society's Lifestyle and Readiness to Change</b>	-Approximately how much of your company's income does your company spend annually on sustainable initiatives?	-Does the UAE government have strict rules and regulations to mandate the implementation of sustainability in the construction industry?	<p>-Do you agree that implementing sustainability has to be mandated for everyone under the country's law?</p> <p>-Would you like to have an architectural design for your house that reflects your culture?</p> <p>-Do you feel that the local public is making enough efforts to have a sustainable country?</p> <p>-In making an investment, you are told that an additional initial cost of 20% will be required to make the project sustainable. Would you be interested in adding the 20% to the initial cost?</p>

Table 2: Survey question design (cont.)

## **Chapter 4: Application of the Construction Sustainability Model and Rating System**

The purpose of this case study is to present an example of how the developed Construction Sustainability Maturity Model and the rating system work. The country chosen to be rated is the United Arab Emirates, and the reason for choosing it is that it is where the author of this thesis resides. In other words, the developed Construction Sustainability Maturity Model as well as the rating system can be applied in any other country.

The United Arab Emirates has experienced one of the world's biggest construction booms in the last 20 years. Unfortunately, the negative effects of this boom on the local environment have been obvious. As a result, the environmental and economic authorities of the UAE have begun to realize the need for adopting sustainability and made this concern one of the top priorities of the country. During the last decade, the government of the UAE has spent huge amounts of money to direct the construction industry toward sustainability, but has it succeeded? The answer to this question can be answered by conducting an analysis using the point-based rating system on UAE and then comparing the results to the Construction Sustainability Maturity Model.

It is a fact that the growth of the UAE has rapidly increased during the last four decades due to the discovery of oil within its borders. This economic boom has been associated with an increase in the demand for energy along with increased CO<sub>2</sub> emissions, which have become two of the most crucial topics concerning the UAE.

Along with the economic boom, the UAE has experienced a huge growth rate in its population. Since its first census, which was conducted in 1968, the UAE population has increased more than 40 times. At the regional level, the Abu Dhabi Statistical Yearbook of 2010 shows a growth in the population of the Emirate up to 1.643 million, which implies an average annual growth rate of 6.3% since 1975. While the availability of space does not create a problem in the UAE, meeting the demand for energy and water remains a major concern. In a country where the arable land consists of no more than 1% of the total area, the inadequacy of natural resources accompanied with a high-consumption lifestyle prompt concerns about the future [64].

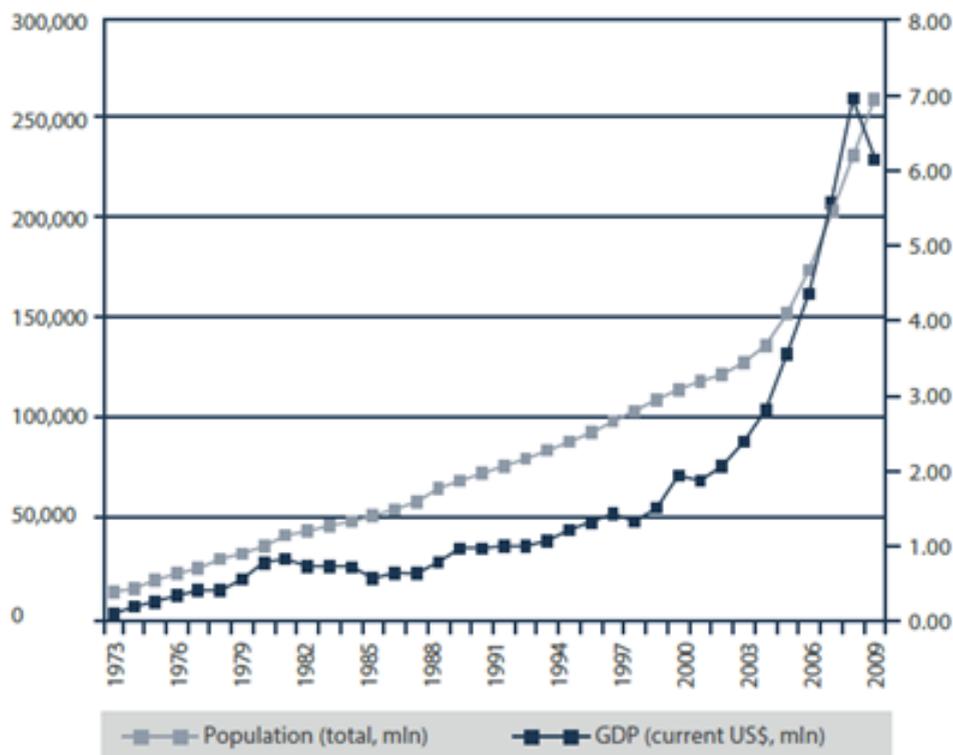


Figure 13: GDP growth in the UAE [64].

In developing countries, the proportion of the construction industry in the total energy consumption is much higher than in developed countries due to the rapid economic growth and fast urbanization, which increases energy production and usage. Urban areas are mostly situated in coastal locations, where economic assets and residents increasingly are at an elevated risk of climate-related events. Case studies have illustrated that the transportation infrastructure in coastal areas is vulnerable to sea level rise and extreme climate events [65]. This shows a clear indication that developing countries are in a critical situation to reduce their CO<sub>2</sub> emission levels.

The United Arab Emirates is a developing country. After the discovery of oil and its export over the last four decades, it has experienced very rapid growth. The growing demand for energy and the increase of CO<sub>2</sub> emissions are two important issues that have become important topics in the UAE. The Environment Agency of Abu Dhabi has stated that activities such as burning fossil fuel, land use changes, a lack of waste management, and industrial processing are among the main reasons for greenhouse gas emissions, which are accumulating in the atmosphere. Recently, at the Dubai Global Energy Forum, Mr. Yousuf Jebril, executive vice-president of planning and electricity projects at the Dubai Electricity and Water Authority (DEWA), stated



that, over the last eleven years, electricity and water consumption has significantly increased to reach a substantial 203% and 144% respectively. By 2021, the same values are expected to grow in Dubai by 93% and 59%, respectively [66].

#### 4.1. Data Collection

The author explained to the participants the aim of the survey to guarantee accurate replies, and he assured them that their identities will be confidential so that they will not face any kind of harm from any party due to their participation in the survey. The survey was self-administered, and the author did not supervise the people who filled it out. The targeted population of the survey was drawn through a simple random sampling method since it is impossible to cover the entire huge population. The sample selected to represent the construction companies includes companies from different construction fields, as the following chart shows.

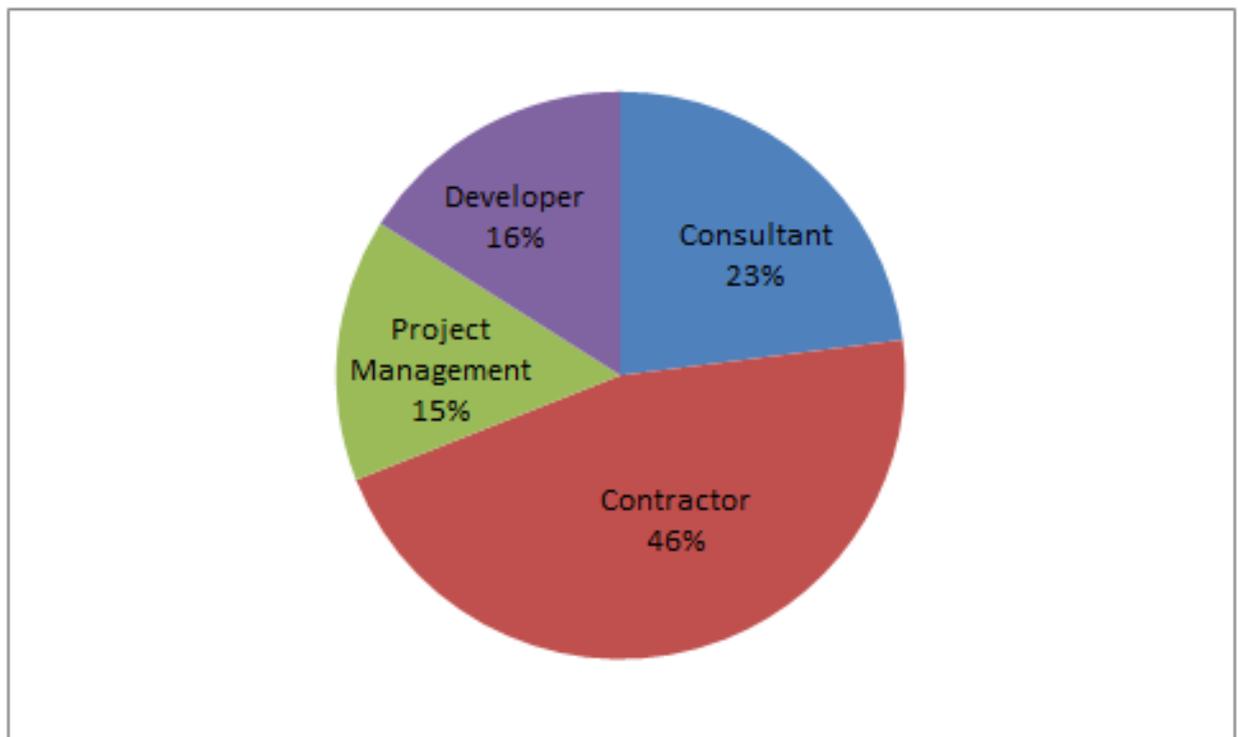


Figure 14: Percentages of participating construction companies

The time required to complete and analyze the survey was two months, and the location where the survey was conducted was the seven emirates of the UAE, as shown in table 3

<b>Company</b>	<b>Location</b>
Tebodin	Abu Dhabi
Abu Dhabi Distribution Company (ADDC)	Abu Dhabi
National Petroleum Construction Company (NPCC)	Abu Dhabi
Emirates Nuclear Energy Corporation	Abu Dhabi
Mott Macdonald	Abu Dhabi
Aecom	Abu Dhabi
Masdar Institute	Abu Dhabi
Technology Precast	Abu Dhabi
Amana Contracting and Steel Buildings	Dubai
Folcra Beach	Dubai
System Construct	Dubai
Atkins	Dubai
Consolidated Contractors Company (CCC)	Dubai
Schlumberger	Dubai

Table 3: Companies that participated in the survey

Company	Location
Buro Happold	Dubai
Max Bogl Emirates	Dubai
Henkel (Construction Materials Manufacturer)	Dubai
Al Futain Tarmaac Road Works	Dubai
Ras Al Khaima Precast	Ras Al Khaima
Al Khaleej Precast Concrete	Ras Al Kaima
Al Hamra Contracting Company	Fujairah
Fujairah National Construction (FNC)	Fujairah
QHC Consultants & Engineers	Sharjah
Acttell Construction LLC	Sharjah
Abraj Al Mansourah Const (LLC)	Sharjah
Al Hamadani General Contracting	Ajman
Al Jazeera Engineering Works LLC	Ajman
Abdul Latif Mohammed Al Zarooni Contracting Co	Um Al Quwin
Benna Construction & Development LLC	Um Al Quwin
Al Bushra Construction Co LLC	Um Al Quwin

Table 3: Companies that participated in the survey (cont.)

## 4.2. Rating the Construction Companies of the UAE

### 1. Would you be interested in studying sustainability?

Due to the increasing need for sustainability day after a day, it has become one of the most pressing issues being taught in educational institutions and construction companies. It is necessary for every engineer working in the construction industry to be knowledgeable about sustainability. However, according to the thesis survey, only 45% of the engineers who participated in the survey are interested in studying sustainability, 34% are neutral, and 21% are not interested at all.

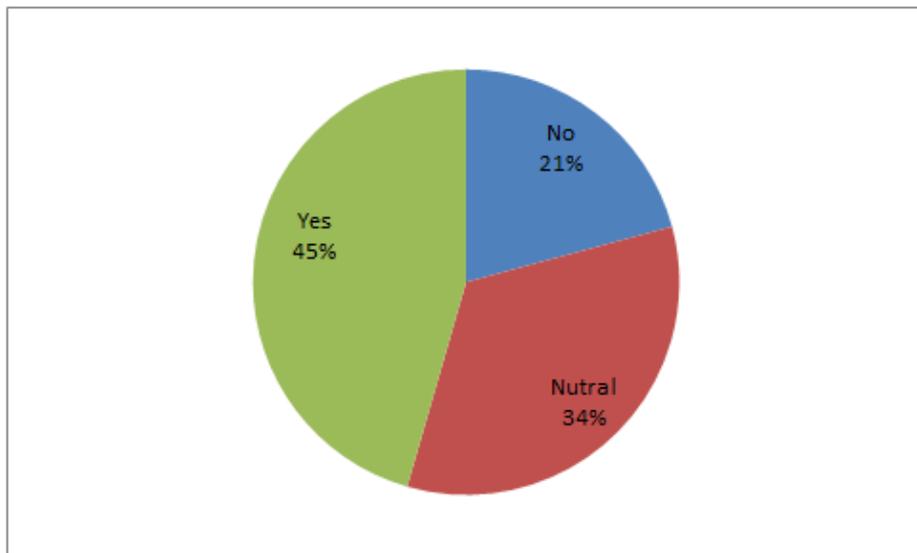


Figure 15: Representation of participants' interest in studying sustainability

- 0%–19%: 0
- 20%–49%: 1
- 50%–79%: 2
- 80%–100%: 3

Since the percentage of “yes” is 45%, the number of points awarded is 1.

The engineers were also asked whether they have attended any educational program that addresses sustainable construction, and it was found that only 48% of these engineers have done so.

**2. Have you attended any course or lecture about sustainability?**

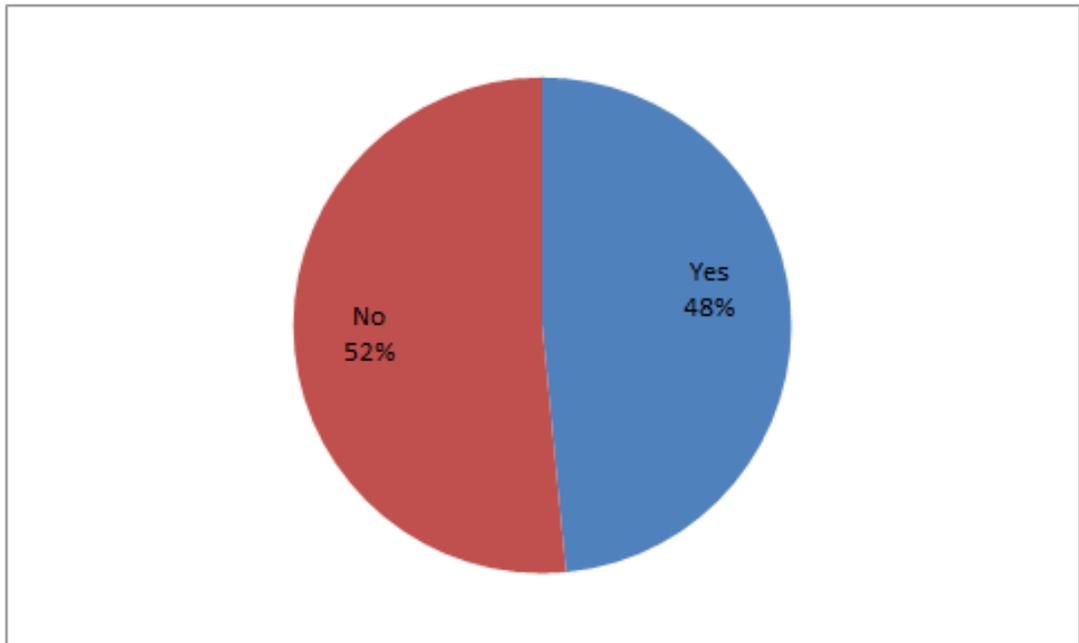


Figure 16: Representation of participants who attended sustainability courses (percentage of YES)

- 0%–19%: 0
- 20%–49%: 1
- 50%–79%: 2
- 80%–100%: 3

Since the percentage of “yes” is 48%, the number of points awarded is 1.

**3. Has your company provided training courses on sustainable constructions?**

The chart below shows that only 44% of the participants have received sustainability trainings from their companies.

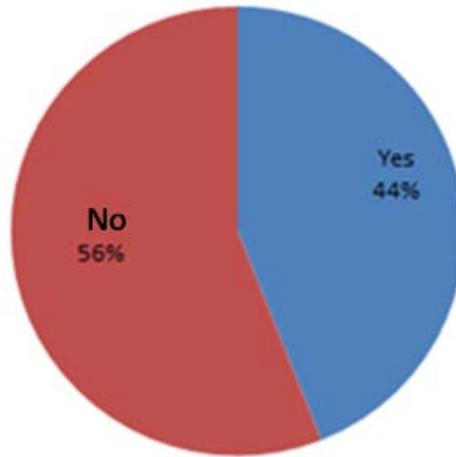


Figure 17: Percentage of participants who received training from their companies

- 0%–19%: 0
- 20%–49%: 1
- 50%–79%: 2
- 80%–100%: 3

Since the percentage of “yes” is 44%, the number of points awarded is 1.

#### 4. Does your company promote sustainable employee behaviour?

Construction companies must encourage their employees to adopt sustainable behavior to build a sustainable culture in the workplace. However, the survey indicated that 46% of the surveyed construction companies have never promoted sustainable employee behavior.

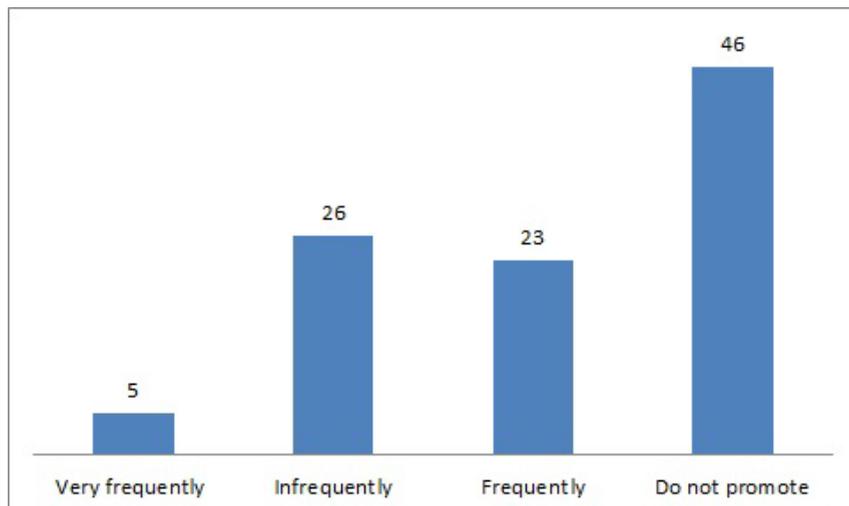


Figure 18: Frequency of sustainability promotion in construction companies

- 0%–19%: 0
- 20%–49%: 1
- 50%–79%: 2
- 80%–100%: 3

Percentage of companies that promote sustainable employee behavior:

= 26% + 5% = 31%; number of points awarded = 1

**5. How many years ago did your company start implementing sustainability?**

Since achieving maturity in sustainability is not an easy task, it requires time and effort. Obviously, the more experienced a company is in sustainability implementation, the more effective its contribution will be in terms of results and cost. According to the survey results, more than one-third of the companies that participated in the survey began implementing sustainability within the last five years.

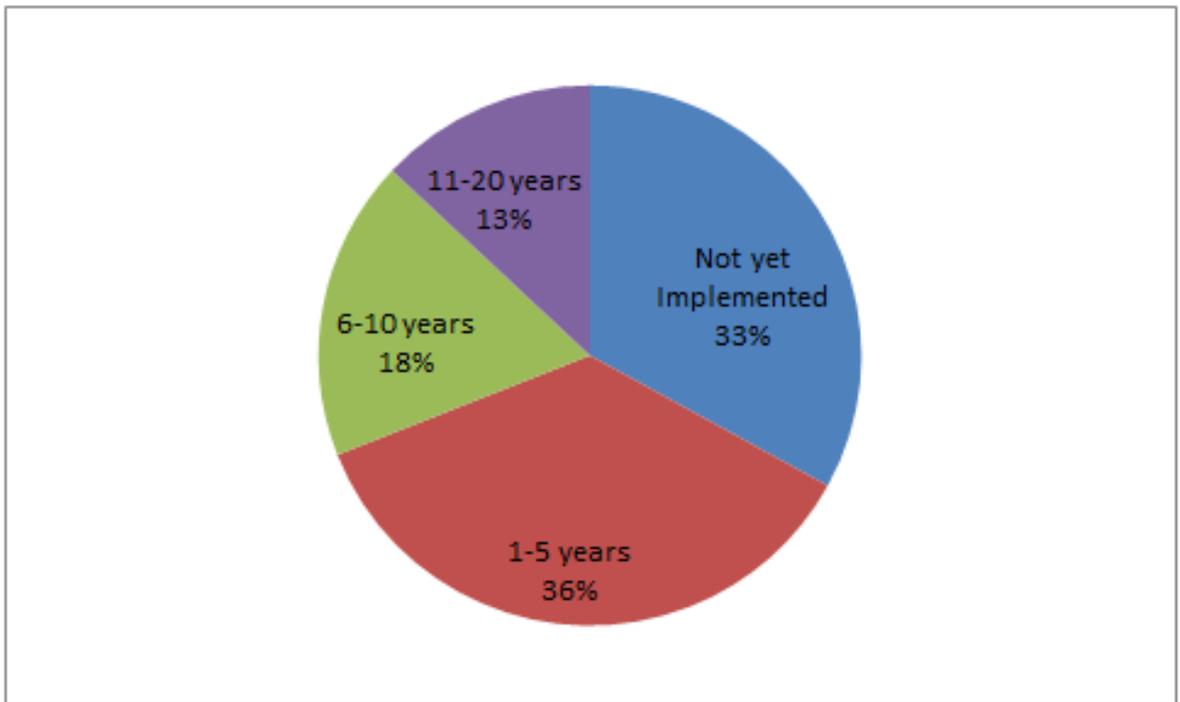


Figure 19: Years of sustainability experience

- 0%–0.49% = 0
- 0.50%–1.49% = 1
- 1.50%–2.49% = 2
- 2.5%–3.0% = 3

By multiplying each percentage by 1 point,

$(0.36) (1) + (0.18) (3) + (0.13) (5) + (0.35) (0) = 1.55$ , so number of points awarded = 2

Moreover, although the survey was conducted on big construction companies that have completed hundreds of projects, surprisingly, the survey shows that only 33% of the engineers working in these companies have worked on projects with sustainable designs.

**6. Have you ever worked on a project that employs green design and green construction methods?**

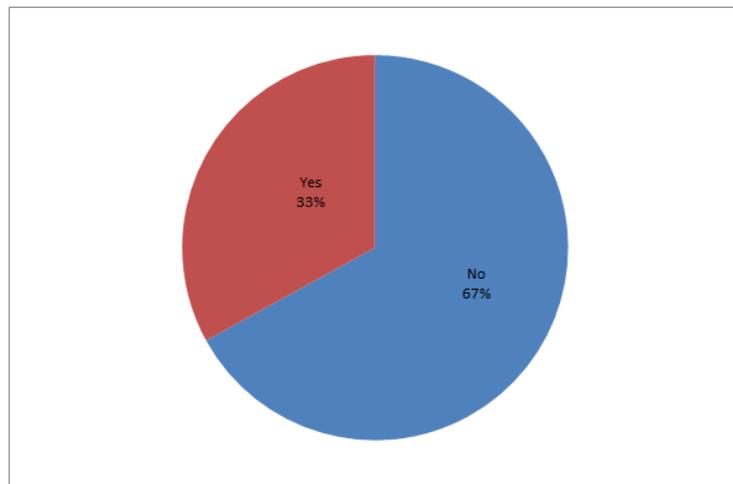


Figure 20: Percentage of engineers who worked on a green project

- 0%–19%: 0
- 20%–49%: 1
- 50%–79%: 2
- 80%–100%: 3

Since the percentage of “yes” is 33%, the number of points awarded is 1.



**7. To which category of the following do you believe your company belongs?**

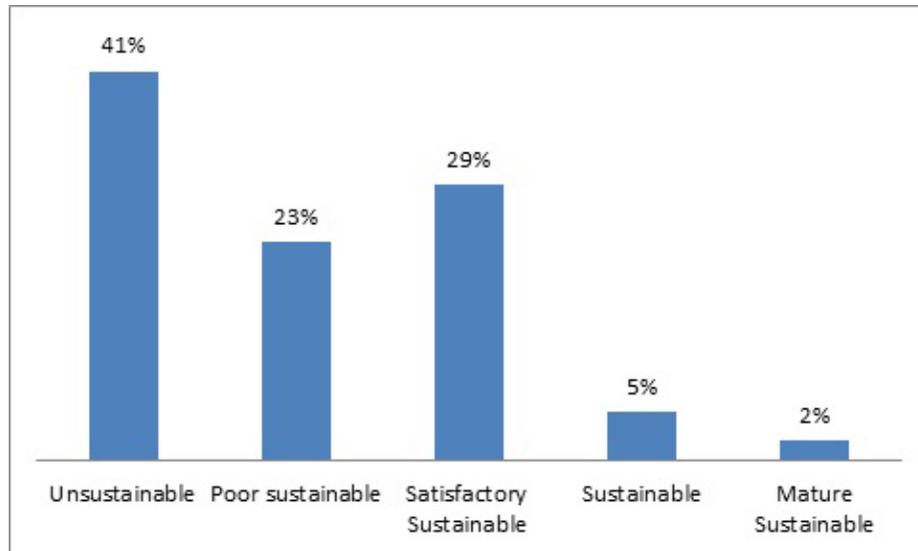


Figure 21: Maturity level of the companies in the engineers' view

- 0%–0.49% = 0
- 0.50%–1.49% = 1
- 1.50%–2.49% = 2
- 2.5%–3.0% = 3

By multiplying each percentage by 1 point, the number of rewarded points

$$= (0.02)(5) + (0.05)(3) + (0.29)(1) + (0.41+0.23)(0) = 0.54, \text{ so number of points awarded} = 1$$

**8. Does your company measure the carbon emissions footprint produced from its construction projects?**

When a construction company measures the emissions footprint caused by its operation, it starts to realize the extent to which it harms the environment and the economy. It also starts sensing how serious and dangerous the issue is if no action is taken against it. Unfortunately, the survey revealed that a majority of the surveyed construction companies (83%) do not measure the emissions footprint produced by their construction sites, and 88% do not measure the emissions footprint produced by their employees' travels that are related to the jo

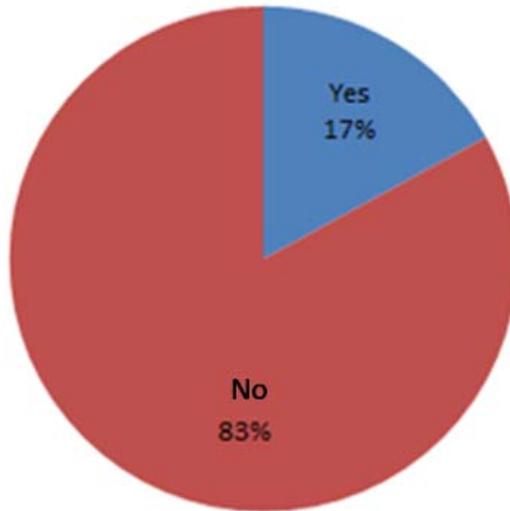


Figure 22: Percentage of companies that measure their emissions footprint

- 0%–19%: 0
- 20%–49%: 1
- 50%–79%: 2
- 80%–100%: 3

Since the percentage of “yes” is 17%, the number of points awarded is 0.

**9. Does your company measure emissions from staff travel related to their job?**

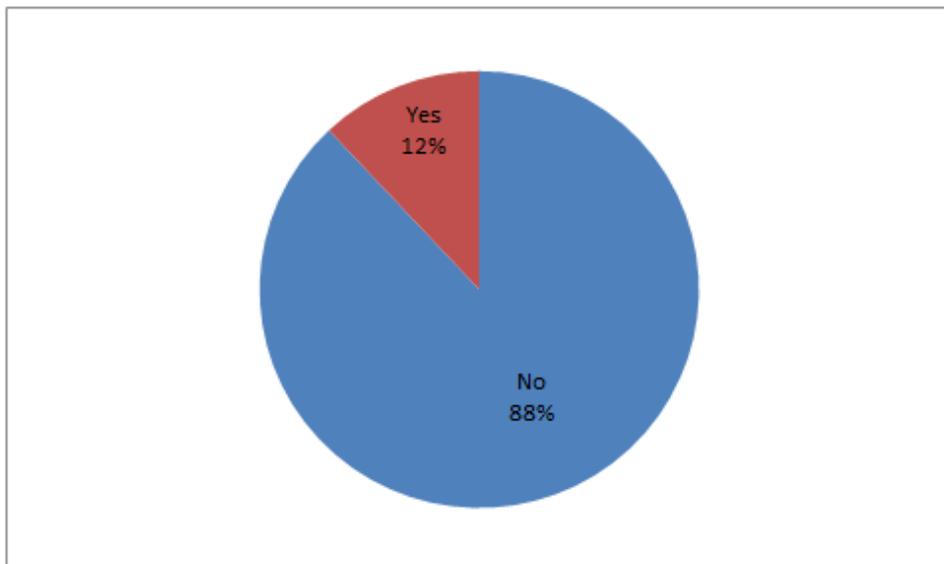


Figure 23: Percentage of companies that measure the emissions footprint of their employees' travels

- 0%–19%: 0
- 20%–49%: 1
- 50%–79%: 2
- 80%–100%: 3

Since the percentage of “yes” is 12%, the number of points awarded is 0.

**10. Approximately how much of your company's income does your company spend annually on sustainable initiatives?**

It is a fact that implementing sustainable practices in business results in extra cost to the construction company. Usually, companies that are committed to sustainability devote part of their revenues to cover these extra expenses, believing that sustainability will pay them back in the long run. The chart below is extracted from the research survey, and it shows how much of their revenues (in percentages) the surveyed companies have devoted to sustainability implementation

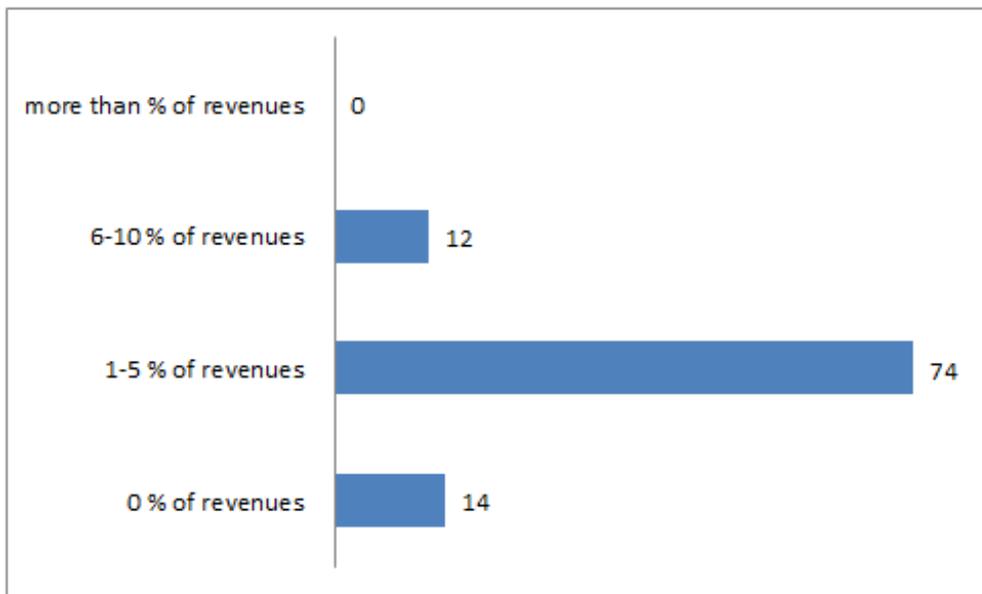


Figure 24: Percentages of revenues spent on sustainability by surveyed companies

- 0–0.49% = 0
- 0.50%–1.49% = 1
- 1.50%–2.49% = 2
- 2.5%–3.0% = 3

The average percentage of revenue that construction companies in the UAE spend on sustainable initiatives =  $(14\%)(0) + (1)(74\%) + (3)(12\%) + (5)(0\%) = 1.1$  point, so the number of points awarded is 1.

**11. How much of the energy being consumed by the company's operations is renewable energy?**

Construction companies consume a lot of energy, as their operations are not only office-based but also extend to construction sites, where huge quantities of energy are needed. Some companies nowadays have started to generate a portion of the energy they need from renewable resources such as solar and wind energy. According to the survey, only 45% of the surveyed construction companies generate part of their energy using renewable resources as shown below:

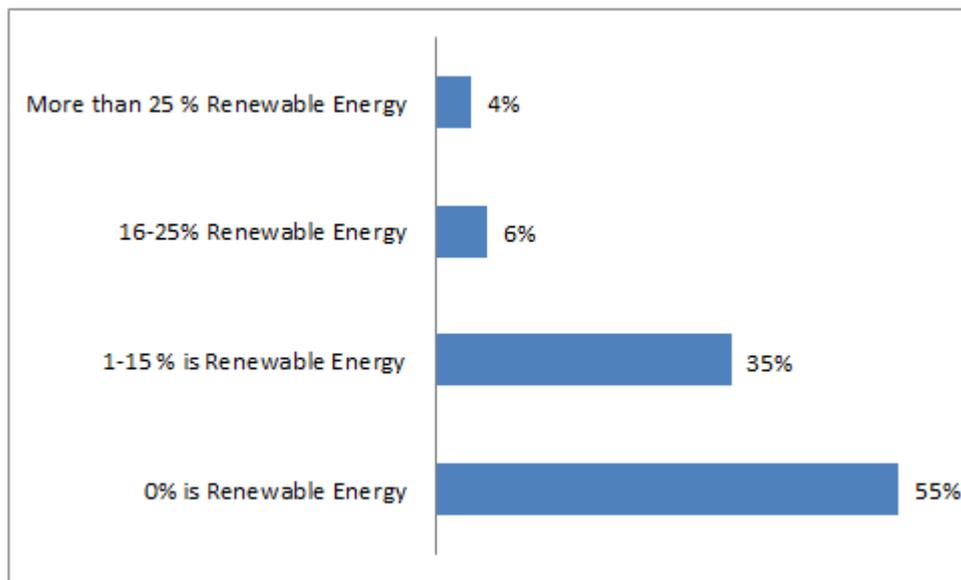


Figure 25: Percentage of renewable energy used by companies

- 0–0.49% = 0
- 0.50%–1.49% = 1
- 1.50%–2.49% = 2
- 2.5%–3.0% = 3

The average percentage of renewable energy generated from renewable resources =  $(55\%)(0)+(1)(35\%)+(3)(6\%)+(5)(4\%) = 0.73$  points, so the number of points awarded is 1.

**12. Does your company specifically look for engineers holding degrees or certificates in sustainability?**

Due to the passing of laws that mandate the implementation of sustainability and to the increasing public desire to live in sustainable buildings, construction companies

have started hiring engineers holding degrees or certificates in sustainability. The companies need these qualified engineers to come up with sustainable building designs and to execute these designs at their sites. This increasing interest was reflected in the survey results, showing that 71% of the surveyed companies were interested in hiring engineers holding degrees or certificates in sustainability.

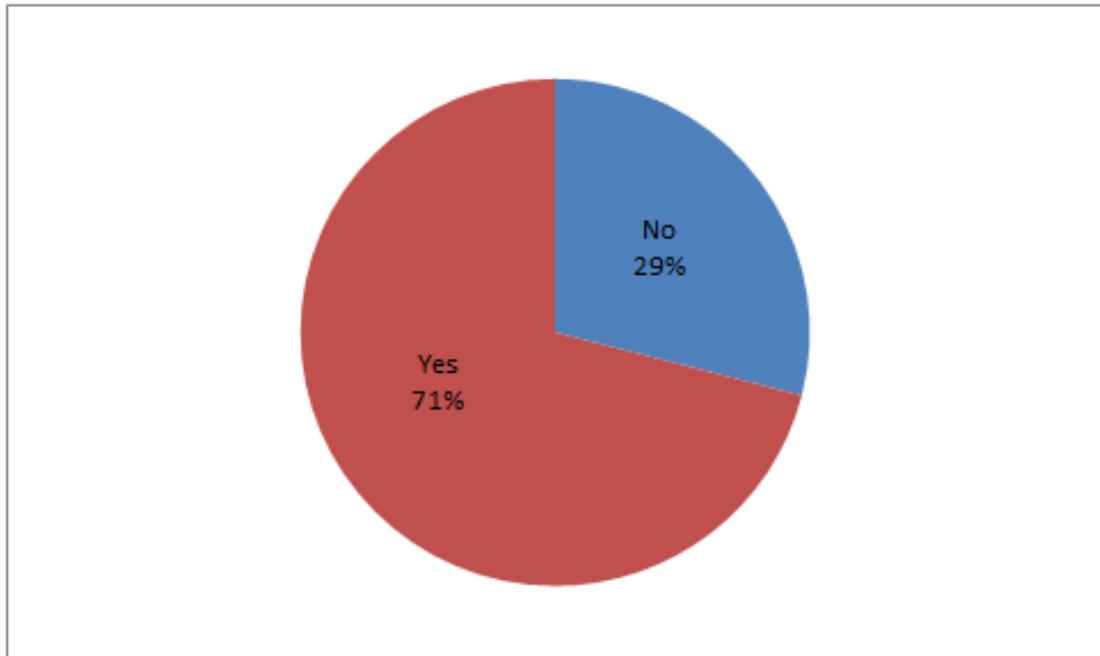


Figure 26: Percentage of companies that look for sustainability engineers

- 20%–49%: 1
- 50%–79%: 2
- 80%–100%: 3

Since the percentage of “yes” is 71%, the number of points awarded is 2.

### **13. To what extent has your company communicated its sustainability goals and policies to external stakeholders?**

It is vital for a company to share its sustainability goals and policies across the organization and outside it. This step raises the awareness of the employees and the external stakeholders about sustainability concepts and encourages them to participate in implementing it. The survey asked the engineers who participated in the survey about the extent to which their companies have communicated their sustainability goals and policies across the organization, and the results were as follow

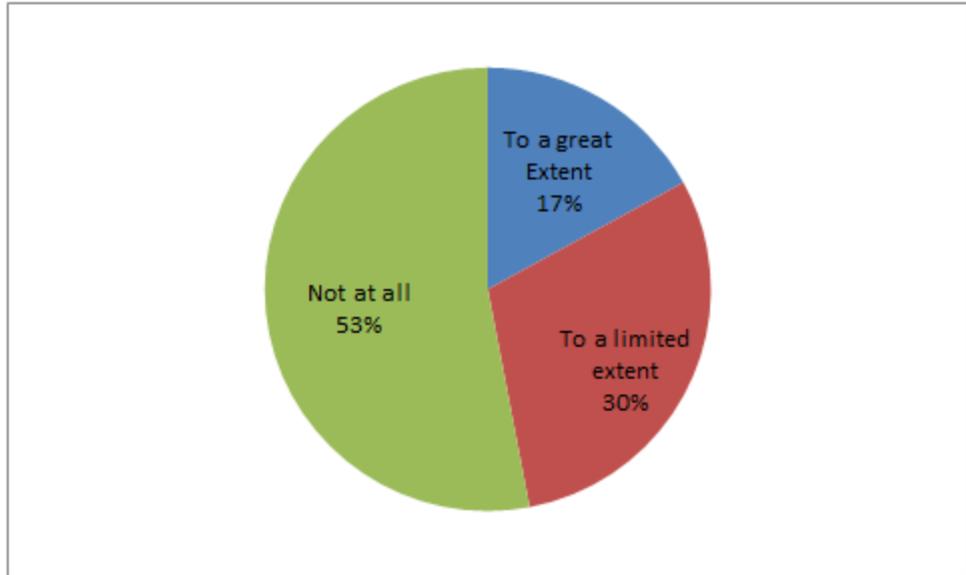


Figure 27: Sustainability communication between companies and stakeholders

- 0–0.49% = 0
- 0.50%–1.49% = 1
- 1.50%–2.49% = 2
- 2.5%–3.0% = 3

The percentage of companies that communicated goals and policies across the organization =  $(17\%)(6) + (30\%)(3) + (53\%)(0) = 1.92$  points, so the number of points awarded is 2.

**14. To what extent has your company communicated its sustainability goals and policies to external stakeholders?**

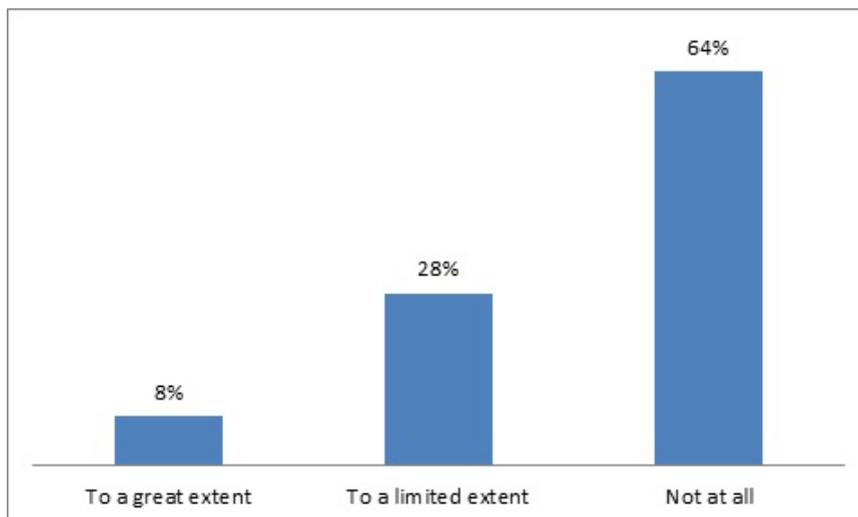


Figure 28: Sustainability communication between companies and external stakeholders

- 0–0.49% = 0
- 0.50%–1.49% = 1
- 1.50%–2.49% = 2
- 2.5%–3.0% = 3

The percentage of companies that communicated goals and policies to external stakeholders = (8%) (6) + (3) (28%) + (0) (64%) = 1.32 points, so number of points awarded is 1.

**15. Has your company defined strategies and plans regarding how to involve sustainability in the company's operations and processes?**

Good planning is one of the main factors in achieving success in every field. Construction companies have to plan properly how to involve sustainability in their operations and processes, especially because sustainability adoption needs time to be implemented well. According to the survey, less than half of the surveyed companies (47%) do not have defined strategies and plans about how to involve sustainability in their operations and processes.

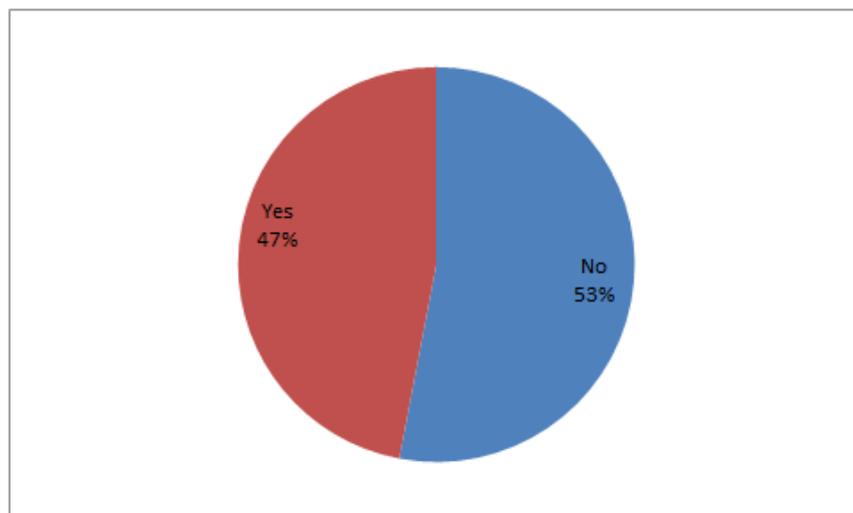


Figure 29: Percentages of companies that defined their sustainability plans and strategies

- 0%–19%: 0
- 20%–49%: 1
- 50%–79%: 2
- 80%–100%: 3

Since the percentage of “yes” is 47%, the number of points awarded is 1.

### **4.3. Rating the Governments of the UAE**

The government has to play a major role in the movement toward sustainability since it is the source of the regulations and rules that control the whole construction industry. The following questions are meant to evaluate the government's contribution in delivering a sustainable construction:

**16. Does the UAE government have strict rules and regulations to mandate implementing sustainability in the construction industry?**

- Yes = 3 points
- No = 0 points

The answer is yes, and the proof is that the UAE has very strict rules and regulations to force the implementation of sustainability practices in the local construction industry. For example, in Abu Dhabi, building permits will only be awarded to buildings complying with the local construction sustainability rating system, which is called Estidama [67]. In the emirate of Dubai, Sheikh Mohammed Bin Rashid Al Maktoum, the prime minister of the UAE and ruler of Dubai, has mandated LEED standards for all construction projects in Dubai, and no building permit shall be awarded to any building if it does not comply with this rule [68]. Therefore, the number of points awarded is 3.

**17. Do you think that there is proper public awareness through the local education system or the local media about the values, techniques, and importance of sustainability?**

With the current increasing concern regarding the environment and the economy, governments have to mandate that all the local universities and schools teach specialized classes about sustainability. They are also responsible for conveying this message via all media means, such as local TV and radio channels and through advertising posters in the country's streets. Unfortunately, the responses of the people who participated in the survey showed that 69% of them believe that there is no proper public awareness through education or the media about the need for sustainability.



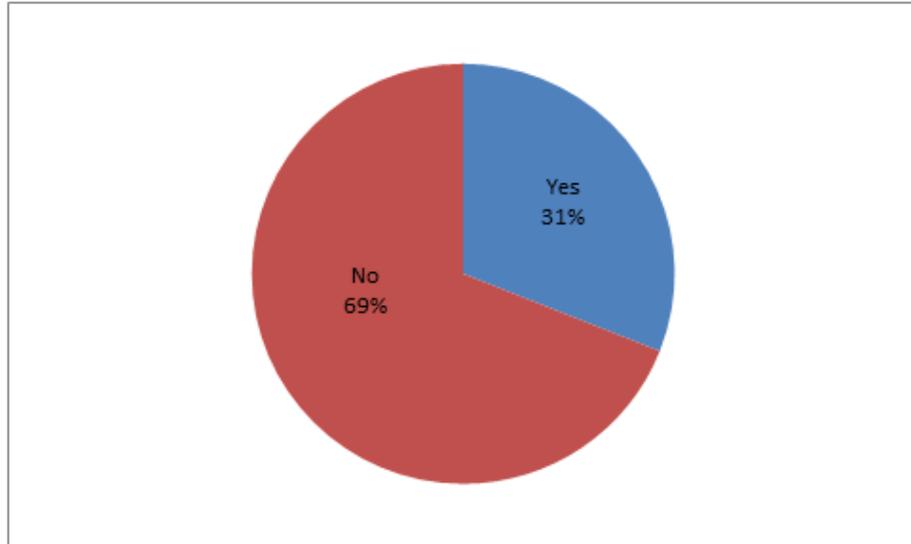


Figure 30: Percentage of participants who think that there is proper awareness local through media and schools.

- 0%–19%: 0
- 20%–49%: 1
- 50%–79%: 2
- 80%–100%: 3

Since the percentage of “yes” is 28%, the number of points awarded is 1.

### **18. How many years ago did the UAE government start adopting sustainability in the construction industry?**

Experienced governments in sustainability implementation tend to be more professional and effective in their decisions and contributions in the field. Most governments start their journey of sustainability adoption by passing through a phase of trial and error until they build experience and things start going smoothly.

- 0 years–5 years = 0
- 6 years–10 years = 1
- 11 years–20 years = 2
- 21 years–0 years = 3

In 1998, the government of UAE undertook the first sustainable initiative in the construction industry when they decided to construct the building of the Dubai Chamber of Commerce & Industry, which was first building in the Arab World with a LEED certification [69]. This means that the UAE has been implementing

sustainability in the construction industry since 1998, 15 years ago, so the number of points awarded is 3.

**19. Does the government of UAE calculate the emissions footprint of the public?**

Governments need to calculate the emissions footprints produced by its public and industries. Having this information helps the government in planning how to reduce this pollution and what to do to control it.

- Yes = 3
- No = 0

The answer is yes, and the following serves as proof. In October 2007, another initiative, the Al Basama Al Beeiya was launched in Ajman, aimed at measuring and understanding the UAE's ecological emissions footprint. The project focused on creating guidelines for the sustainable use of resources and reducing the CO<sub>2</sub> emissions, which contribute around 80% of the UAE's ecological emissions footprint.

In addition, the Dubai Municipality has launched a website ([footprint.dm.ae](http://footprint.dm.ae)) that shows some procedures that an individual can use to calculate his/her own emissions footprint. A quiz on the website asks questions on a number of topics ranging from a person's meat consumption, mode of transportation, and water wastage to the temperature setting of their air conditioning before calculating a carbon emissions footprint based on the answers. Therefore, the number of points awarded is 3.

**20. Has the UAE government established specialized organizations or departments to address sustainability issues in the construction industry?**

Governments must establish specialized departments and organizations to control the construction industry and make it sustainable. These organizations should have qualified personnel who have experience in both construction and sustainability.

- Yes = 3 points
- No = 0 points

The answer is yes, and some examples follow.

### **The Abu Dhabi Sustainability Group (ADSG)**

In June 2008, the emirate of Abu Dhabi established the Abu Dhabi Sustainability Group (ADSG) for the purpose of promoting sustainability management by providing learning and knowledge sharing opportunities for government, private, and not-for-profit organizations with a spirit of cooperation and open dialogue. The ADSG is a membership organization whose members, having signed the ADSG Declaration, are committing to adopt best practices of sustainability management and reporting and to active participation in ADSG activities [70].

### **The Emirates Green Building Council (EGBC)**

In 2006, the Emirates Green Building Council (EGBC) was formed in Dubai to advance green building principles to protect the environment and ensure sustainability in the UAE. To do so, the EGBC has offered remarkable support to its members, who work toward a more sustainable future in many ways, such as building capacity, strengthening the community supporting local green building practices, offering networking opportunities, influencing policy and regulation related to sustainable building environments, providing resources and information to those active in the sustainable building community, and providing a link between international green building movements and local industry [71].

### **The Emirates Environmental Group (EEG)**

Raising the cause of sustainable development, a number of groups and organizations have made efforts to find corrective solutions. The Emirates Environmental Group (EEG), based in Dubai, has been a major force behind mainstreaming effective and powerful issues such as introducing sustainability in education, waste management, the separation of recyclable materials at the source, the production of renewable energy, water and energy conservation, alternative transportation solutions and public transit, fighting desertification by expanding green spaces, and promoting social responsibility. The EEG strongly follows the three R's concept, "reduce, reuse, recycle," which is the core of sustainable development.

The EEG has raised awareness among concerned authorities, policymakers, community leaders, and professionals through various communication media. Meanwhile, the EEG remains the conscience behind the urge to maintain a green

movement in the UAE, aiming at establishing a minimum set of environmental values, building environmentally sustainable communities, and developing transparent rating systems. In this regard, the EEG has supported many national and local initiatives to enhance and promote public transportation by educating the public about the various benefits of using public transit, which pays back the environment as well as the economy. Therefore, the EEG has gained direct support from the corporate sector to pilot the growth of the UAE toward the path of sustainability. Therefore, the number of points awarded is 3.

**21. Has the UAE government undertaken any projects in the country to reduce the emissions footprint and energy usage?**

- Yes = 3 points
- No = 0 points

The answer is yes, and some examples follow.

Masdar, established in 2006, is a commercially driven renewable energy enterprise that aims at developing the scope that is necessary to face the current environmental issues. It acts in a large number of areas within the broad boundaries of renewable energy and sustainable technologies as a model of sustainable urban development regionally and globally. Masdar achieves its vision through five integrated units, including an independent, research-oriented graduate university that focuses on renewable energy and a clean environment. Committed to the optimum use of natural resources and renewable energy, Masdar seeks to become a source of knowledge and innovation to place Abu Dhabi at the global center of excellence and innovation.

Similarly, in May 2006, Al Zorah was launched by Al Zorah Development, a joint venture between the government of Ajman and Solidere International. The project, which is a 220 billion AED (60 billion USD) project, is a mixed-use free hold development with the key target of preserving the natural environment by designing energy-efficient buildings and infrastructure [72].

Officials have stated that the construction methods applied in Al Zorah should cut energy use by at least 50 percent, keeping the ecological emissions footprint of the development to a minimum. Moreover, the new city promotes an environmentally friendly and healthier lifestyle that encourages people to leave their cars at home and

use alternative methods of transportation. Several methods are used, such as providing an integrated network of pedestrian walkways, bicycles, and public transportation facilities as well as 20 kilometers of canals and waterways. In addition, the city provides vast green areas and white sandy beaches, which encourage people to walk and enhance quality of life and the environment [72].

**22. Does the UAE government hold regular conferences and lectures for the public to raise their awareness about sustainability?**

- Yes = 3 points
- No = 0 points

The answer is yes, and some examples are listed in the table below.

Conference Name	Location and Date
WETEX 2013	Dubai, 15–17 March 2013
Middle East Electricity	Dubai, 17–19 February 2013
Facilities Management ME	Abu Dhabi, 22–25 January 2012
World Future Energy Summit	Abu Dhabi, 16–19 January 2012
Ecoconstruct Expo	Abu Dhabi, 16–18 April 2013
ENERGY SAVERS UAE	Abu Dhabi, 17 March 2013
World Green Building Council Congress 2013	Queensland, Australia, 5–9 May 2013
Green Middle East	Sharjah, 17–19 October 2011
Smart Energy Middle East	Dubai, 27–29 September 2011
City Scape Global	Dubai, 27–29 September 2011
5th Annual Cost-Effective Sustainable Design & Construction Middle East Abu Dhabi	Abu Dhabi, 22–25 May, 2011
City Build Construction Summit	Abu Dhabi, 17–20 April, 2011

Table 4: Conferences held by the government about sustainable construction

So, the number of points awarded is 3.

**23. Does the UAE government have a defined plan for implementing sustainability?**

To turn a whole county into a sustainable one is not an easy challenge at all, and it takes a long time. For this reason, the governments have to implement proper planning and allocate the needed resources to accomplish this difficult change.

- Yes = 3 points
- No = 0 points

The answer is yes, and following are some examples.

The Abu Dhabi Urban Planning Council has developed the Abu Dhabi 2030 Urban Structure Framework Plan, which was published in September 2007. Plan 2030 is a quarter-century plan for 2007 to 2030 that envisions a more practical, flexible, and, most importantly, a more sustainable future for the city. The plan aims at a set of key goals that include increasing the economy's non-oil share from 40% to 60% and significantly broadening the scope of economic activities to cover priority sectors such as education, finance and banking, pharmaceuticals, tourism, media, aviation and aerospace, transportation, and manufacturing areas such as aluminum and petrochemicals. Furthermore, it highly emphasizes value-added knowledge-based industries, including sustainable technologies and renewable energy.

Similarly, Dubai also has set a plan called "EXPO2020," which aims to make the emirate fully sustainable by the year of 2020. Therefore, the number of points awarded is 3

**24. Does the government have its own construction sustainability rating system, or has it adopted an international one?**

Many rating systems for assessing sustainability in the construction industry have been designed around the world, such as LEED in the U.S.A. and BREEAM in the U.K. However, it is always better to have a local rating system that is tailored to the local environment and economy. In other words, it is not necessarily the case that everything in the LEED rating system, which is American, can be applicable in the United Arab Emirates, as they have different cultures, climates, and economies.

- Yes = 3 points
- No = 0 points

The answer is yes, and the following is an example.

The United Arab Emirates has a local rating system, which is called Estidama. Launched in May 2008, Estidama aims to create a new mindset of global capital that promotes forward thinking and consideration of the future. The main objective of Estidama is to ensure sustainable practice in all aspects of the society, and to create a distinctive framework for measuring sustainability that goes beyond the conventional planning and construction phases.

Estidama was established with the goal of transforming the current course of understanding while allowing for adaptability through ongoing education as new understandings and ideas evolve. The comprehensive system covers all stages of a project, being applicable in the development, design, construction, and operation of a project. Moreover, it employs new tools such as the Pearl rating system and stakeholders' engagement in integrated development with respect to regulatory and code alignments. Therefore, the number of points awarded is 3.

**25. Does the UAE government have any recognition and reward system (such as fee discounts, priority, and recognition)?**

Recognition and appreciation are very important to keep people's spirits high. It is essential for governments to reward individuals who prove to have sustainable lifestyle and behavior to keep them motivated. Moreover, it must reward construction companies that contribute to sustainability and should offer them special treatment and facilities.

- Yes = 3 points
- No = 0 points

The answer is yes, and the following are examples.

### **Zayed Future Energy Prize**

The Zayed Future Energy Prize is an annual prize with a budget of US\$2.2 million that is open to entities or owners that reflect innovation, long-term vision, and leadership in renewable energy and sustainability and have made a significant impact on the UAE's energy future. Therefore, the number of points awarded is 3.

### **Local Manufactured Construction Materials**

Every day, huge quantities of emissions are being produced, and large amounts of money and energy are being consumed to transport goods around the world. This is why it is necessary for all countries to rely on locally manufactured materials to reduce the travel distance and hence reduce its negative impact.

**26. Does the UAE government encourage and facilitate the manufacturing of local construction materials to reduce transportation energy consumption?**

- Yes = 3 points
- No = 0 points

The answer is yes, and the following is an example.

The government of the UAE has established many construction materials factories, such as Emal, which supplies 280 customers in 36 countries with high-quality aluminum. Another example is Emirates Steel, which has a capacity of 3.5 million tons per annum of steel. Furthermore, the UAE has made a tax-free trade agreement with all the countries of the Gulf Cooperation Council to encourage trade with them, as they are relatively very close to the UAE. Therefore, the number of points awarded is 3.

#### **4.4. Rating the UAE Public**

UAE statistics have indicated that, between 1997 and 2006, the increase in greenhouse gases emissions ranged from 33% to 35% [65]. In 2010, a record level of 30.6 gigatons of carbon dioxide was released into the atmosphere, an increase of 1.6 gigatons from 2009 levels due mainly to burning fossil fuel for energy production [10].

The Environment Agency of Abu Dhabi has stated that activities such as fossil fuel combustion, industrial processing, land-use change, and waste management are the main causes of greenhouse gas (GHG) emissions into the atmosphere in the UAE. Mr. Yousuf Jebri, executive vice-president of planning and electricity projects at the Dubai Electricity and Water Authority (DEWA), claimed that, over the last 11 years, the growth in electricity and water use has been substantial and reached 203% and 144%, respectively. The consumption of electricity and water in Dubai is expected to grow by 93% and 59%, respectively, by 2021.

To reduce this huge energy consumption and emission production, the public must adopt a sustainable lifestyle. The following are some questions that examine how sustainable the lifestyle of the surveyed people is.



**27. Where possible, would you take the stairs rather than using the elevator?**

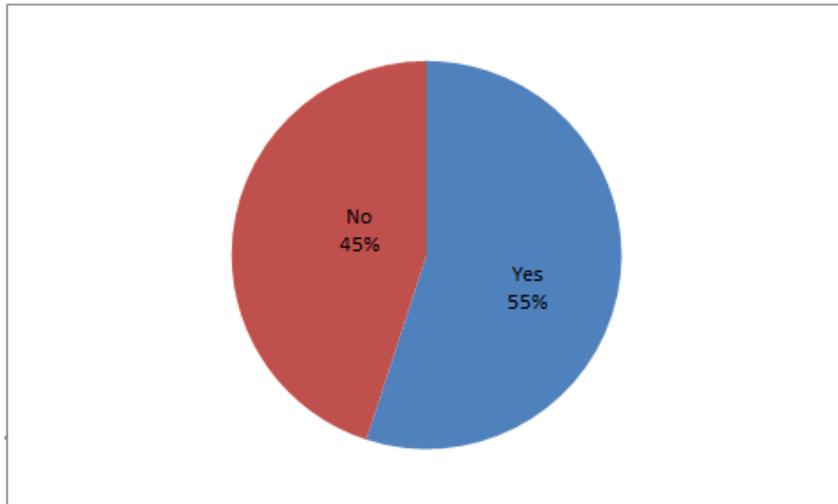


Figure 31: Percentage of respondents who would take the stairs rather than using the elevator

- 0%–19%: 0
- 20%–49%: 1
- 50%–79%: 2
- 80%–100%: 3

Since the percentage of “yes” is 55%, the number of points awarded is 2.

**28. I refrain from using drive-through lanes for services, such as food purchases and banking. I always park my vehicle and turn off the engine.**

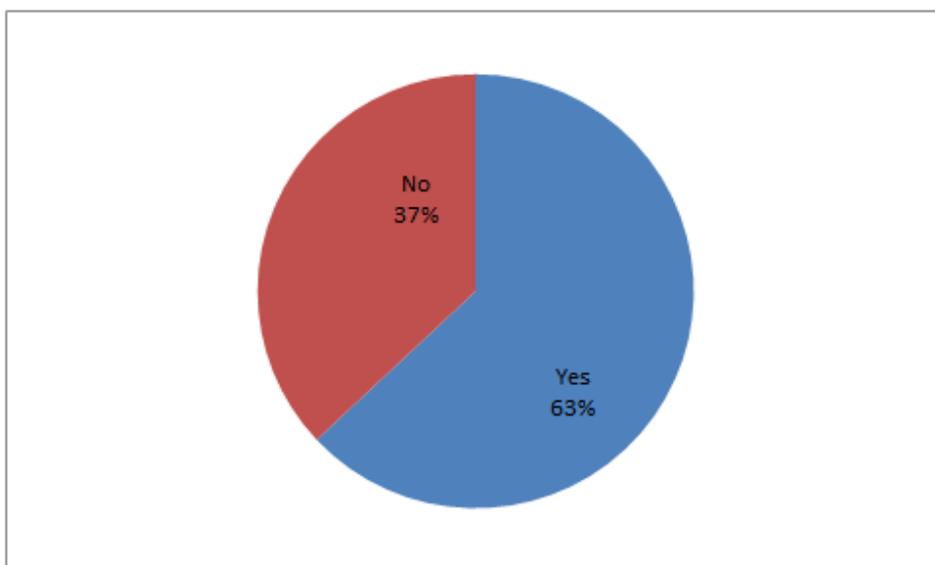


Figure 32: Percentage of participants who refrain from using the drive-through

- 0%–19%: 0
- 20%–49%: 1
- 50%–79%: 2
- 80%–100%: 3

Since the percentage of “yes” is 62%, the number of points awarded is 2.

**29. I walk or use a bicycle for trips near my home.**

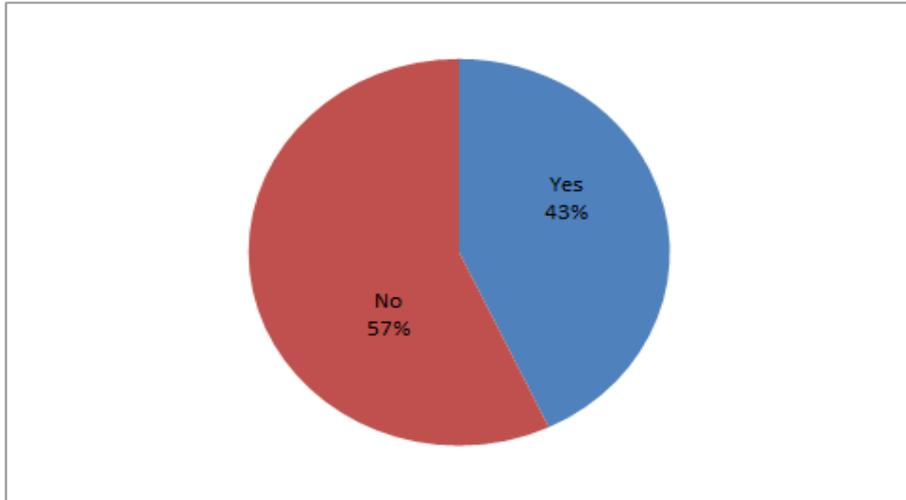


Figure 33: Percentage of participants who use bicycles for short trips

- 0%–19%: 0
- 20%–49%: 1
- 50%–79%: 2
- 80%–100%: 3

Since the percentage of “yes” is 44%, the number of points awarded is 1.

**30. I buy or use locally manufactured products and services whenever possible to reduce transportation costs and to keep money in the local economy.**

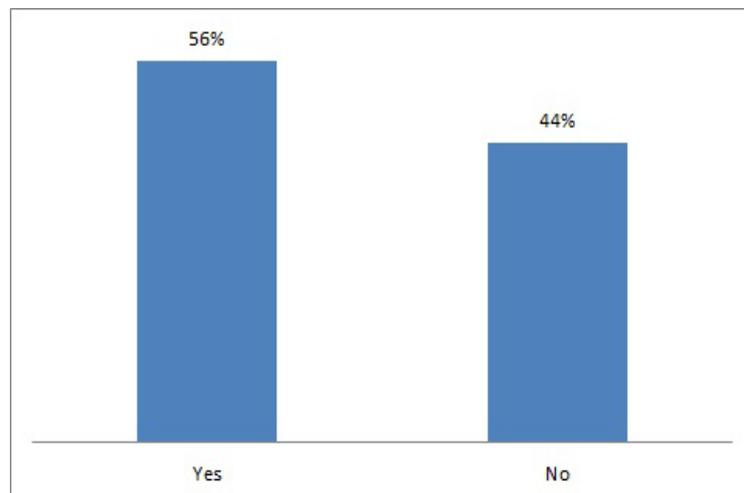


Figure 34: Percentage of participants who always buy local manufactured goods

- 0%–19%: 0
- 20%–49%: 1
- 50%–79%: 2
- 80%–100%: 3

Since the percentage of “yes” is 44%, the number of points awarded is 1.

**31. Whenever the temperature outside is moderate, would you switch on the air conditioner?**

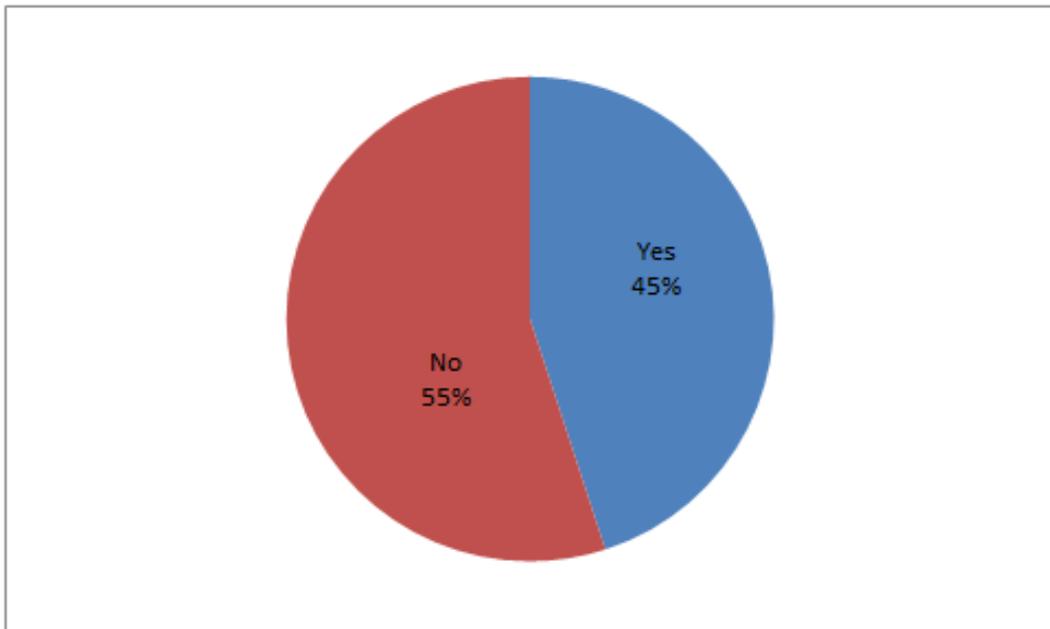


Figure 35: Percentage of respondents who would open the window to save energy

- 0%–19%: 0
- 20%–49%: 1
- 50%–79%: 2
- 80%–100%: 3

Since the percentage of “yes” is 45%, the number of points awarded is 1.

**32. I make shopping lists to minimize shopping trips and reduce unnecessary travel.**

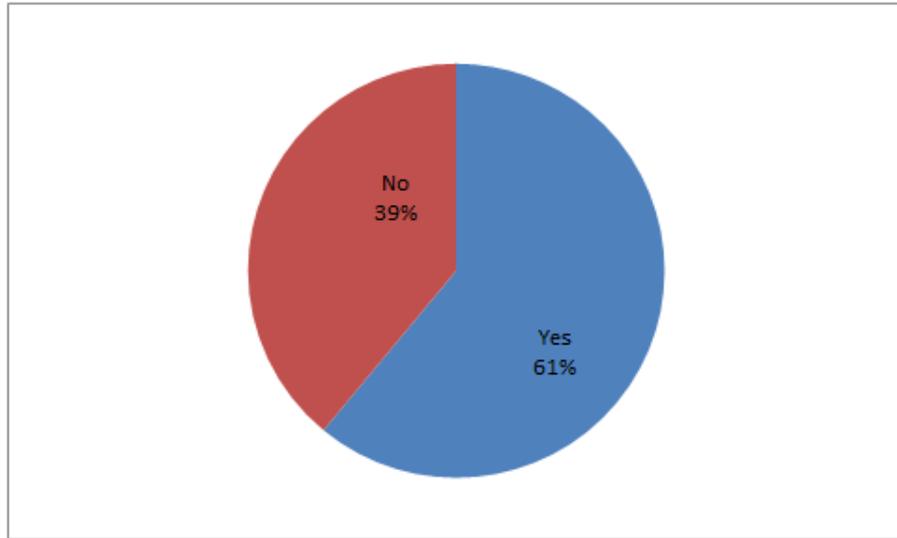


Figure 36: Percentage of respondents who make shopping lists to reduce shopping trips

- 0%–19%: 0
- 20%–49%: 1
- 50%–79%: 2
- 80%–100%: 3

Since the percentage of “yes” is 61%, the number of points awarded is 2.

**33. In making an investment, you are told that an additional initial cost of 20% will be required to make the project sustainable. Would you be interested in adding the 20% to the initial cost?**

The main reason that makes residents hesitate to own or rent a sustainable building is that these buildings are usually more expensive than regular ones. However, sustainable buildings save a lot of money in the long run. For example, they are designed to reduce the energy consumption required to cool or heat the building, and they are also designed to last longer than regular buildings, which results in more savings in the long run for the owners. The survey shows that 68% of the survey respondents are willing to live in sustainable buildings and bear their extra costs.

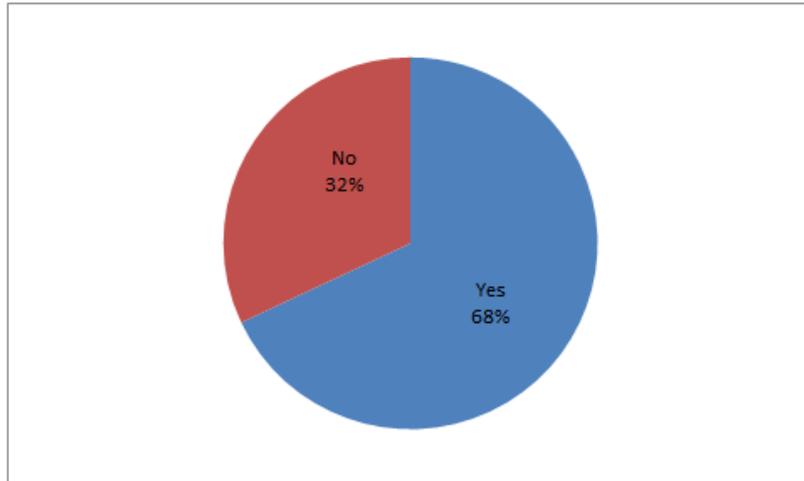


Figure 37: Percentage of participants who would pay extra for sustainability

- 0%–19%: 0
- 20%–49%: 1
- 50%–79%: 2
- 80%–100%: 3

Since the percentage of “yes” is 67%, the number of points awarded is 2.

**34. In your opinion, do sustainable designs lead to financial savings?**

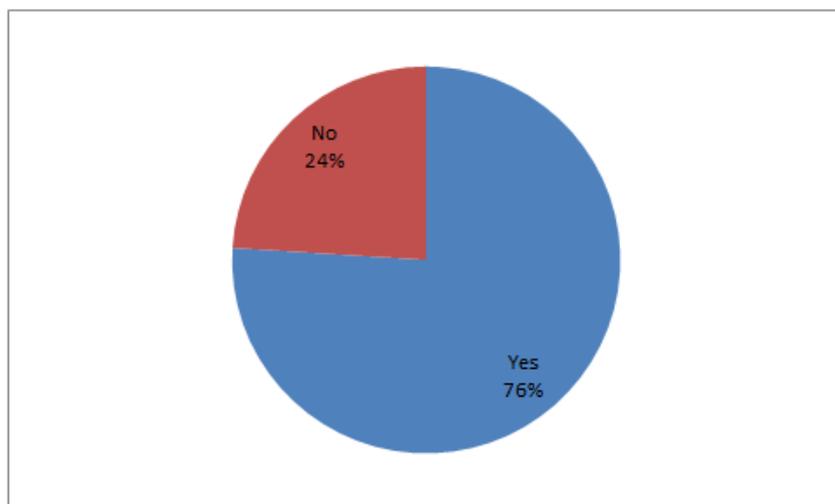


Figure 38: Percentage of people who believe that sustainability saves money

- 0%–19%: 0
- 20%–49%: 1
- 50%–79%: 2
- 80%–100%: 3

Since the percentage of “yes” is 76%, the number of points awarded is 2.

**35. Do you feel that the local public is making enough efforts to build a sustainable country?**

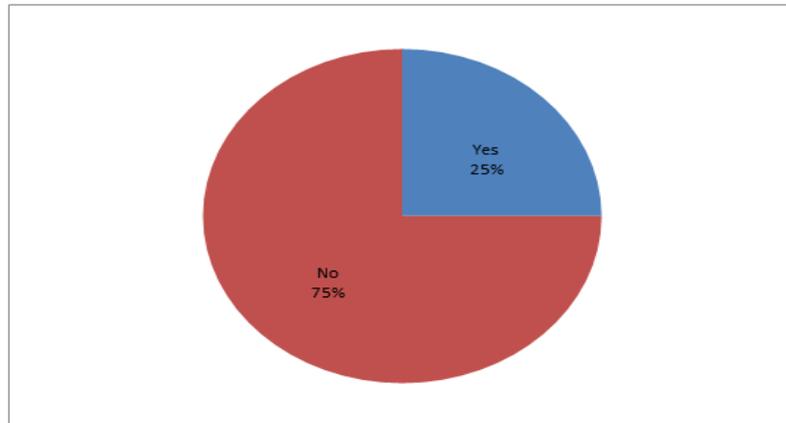


Figure 39: Representation of public participation in the local sustainability

- 0%–19%: 0
- 20%–49%: 1
- 50%–79%: 2
- 80%–100%: 3

Since the percentage of “yes” is 25%, the number of points awarded is 1.

**36. Do you agree that implementing sustainability has to be mandated for everyone by law?**

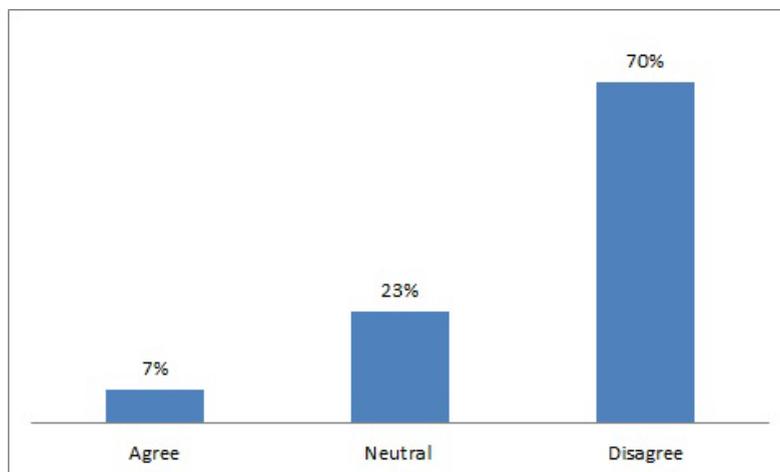


Figure 40: Responses concerning the government mandating sustainability

- 0%–19%: 0
- 20%–49%: 1
- 50%–79%: 2
- 80%–100%: 3

Since the percentage of “yes” is 79%, the number of points awarded is 2.

## 4.5. Rating Calculations and Results

Question	Points
1. Would you be interested in studying sustainability	1
2. Have you attended any course or lecture about sustainability?	1
3. Has your company provided training courses on sustainable construction?	1
4. Does your company promote sustainable employee behavior?	1
5. For how many years has your company implemented sustainability?	2
6. Have you ever worked on a project that employs green design and green construction methods?	1
7. To which category of the following do you believe your company belongs?	1
8. Does your company measure the carbon emissions footprint produced by its construction projects?	0
9. Does your company measure emissions from staff travel related to their job?	0
10. Approximately how much of your company's income does your company spend annually on sustainable initiatives?	1
11. How much of the energy being consumed by the company's operations is renewable energy?	1
12. Does your company specifically look for engineers holding degrees or certificates in sustainability?	2
13. To what extent has your company communicated its sustainability goals and policies to external stakeholders?	1
14. Has your company defined strategies and plans regarding how to involve sustainability in the company's operations and processes?	1
Average of points rewarded for companies' role in the construction industry = $\frac{1+1+1+1+2+1+1+0+0+1+1+2+1+1}{14} = \mathbf{1 \text{ point}}$	
15. Does the UAE government have strict rules and regulations to mandate the implementation of sustainability in the construction industry?	3

Table 5: Determining the sustainability maturity level of the UAE

16. Do you think that there is proper public awareness through the local education system or the local media about the values, techniques, and importance of sustainability?	1
17. For how many years has the UAE government been adopting sustainability in the construction industry?	3
18. Does the government of UAE calculate the emissions footprint of the public?	3
19. Has the UAE government established specialized organizations or departments to address sustainability issues in the construction industry?	3
20. Has the UAE government undertaken any projects in the country to reduce the emissions footprint and energy usage?	3
21. Does the UAE government hold regular conferences and lectures for the public to raise their awareness about sustainability?	3
22. Does the UAE government have a defined plan for implementing sustainability?	3
23. Does the government have its own construction sustainability rating system or adopt an international one?	3
24. Does the UAE government have any recognition and reward system (such as fee discounts, priority, and recognition)?	3
25. Does the UAE government encourage and facilitate the manufacturing of local construction materials to reduce transportation energy consumption?	3
Average of points rewarded for the government's role in the construction industry = $\frac{3+1+3+3+3+3+3+3+3+3+3}{11} = 2.8 \text{ points}$	
26. Where possible, would you take the stairs rather than using the elevator?	2
27. I refrain from using drive-through lanes for services, such as food purchases and banking. I always park my vehicle, and turn off the engine.	2
28. I walk or use a bicycle for trips near my home.	1

Table 5: Determining the sustainability maturity level of the UAE (cont.)



29. I buy or use locally manufactured products and services whenever possible to reduce transportation costs and to keep money in the local economy.	1
30. Whenever the temperature outside is moderate, would you switch on the air conditioner?	1
31. I make shopping lists to minimize shopping trips and reduce unnecessary travel.	2
32. In making an investment, you are told that an additional initial cost of 20% will be required to make the project sustainable. Would you be interested in adding the 20% to the initial cost?	2
33. In your opinion, does sustainable designs lead to financial savings?	2
34. Do you feel that the local public is making enough efforts to build a sustainable country?	1
35. Do you agree that implementing sustainability has to be mandated for everyone by law?	2
36. Would you like to have an architectural design for your house that reflects your culture?	2
<p>Average of points for the the public's role in the construction industry =</p> $\frac{2+2+1+1+1+2+2+2+1+2+2}{11} = 1.64 \text{ points}$	

Table 5: Determining the sustainability maturity level of the UAE (cont.)

Therefore, the 3D point of the UAE = (companies, government, public) =

$$(X, Y, Z) = (1, 2.8, 1.64)$$

Therefore, the UAE falls short of the ideal maturity level by:

$$\text{DIML} = \sqrt{(3 - x)^2 + (3 - y)^2 + (3 - z)^2} =$$

$$\text{DIML} = \sqrt{(3 - 1)^2 + (3 - 1.64)^2 + (3 - 2.8)^2} = \underline{\underline{2.427}}$$

According to the following table, the construction industry in the UAE belongs to Level 2 (satisfactory).

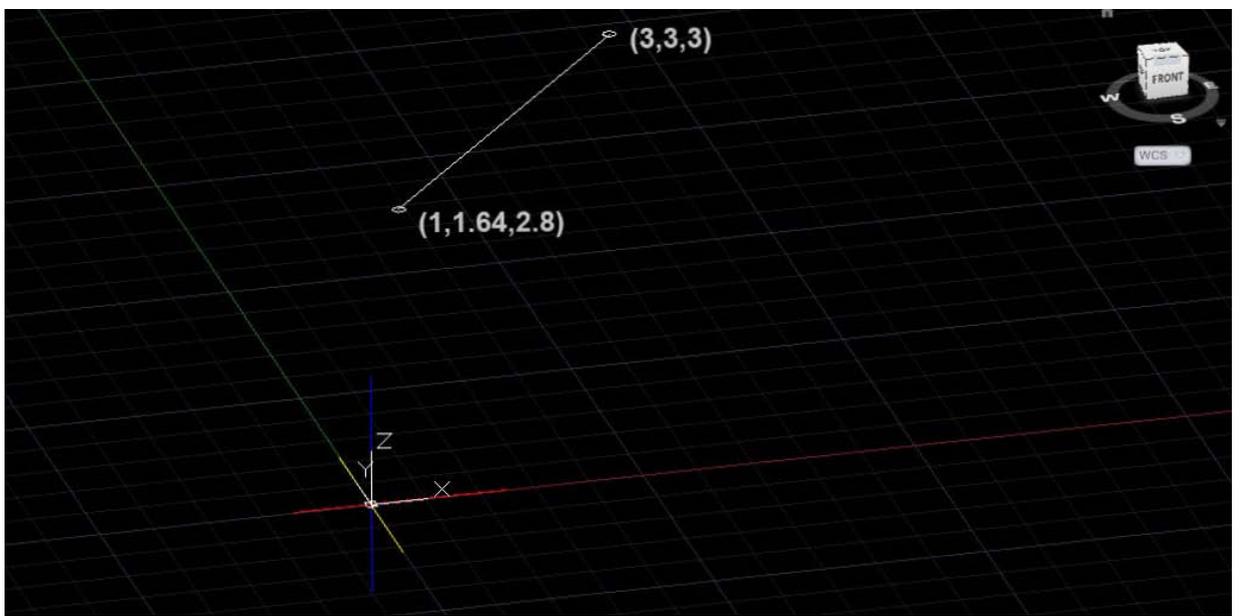


Figure 41: 3D demonstration of the distance between the IML and the sustainability level of the UAE's construction industry

Level	Combinations
<b>Unsustainable (Level 0)</b>	$\text{DIML} = \sqrt{(3-x)^2 + (3-y)^2 + (3-z)^2}$ $= 5.196 \text{ to } 4.15$
<b>Poor Sustainable (Level 1)</b>	$\text{DIML} = \sqrt{(3-x)^2 + (3-y)^2 + (3-z)^2}$ $= 4.14 \text{ to } 3.10$
<b>Satisfactory (Level 2)</b>	$\text{DIML} = \sqrt{(3-x)^2 + (3-y)^2 + (3-z)^2}$ $= \mathbf{3.11 \text{ to } 2.07}$
<b>Sustainable (Level 3)</b>	$\text{DIML} = \sqrt{(3-x)^2 + (3-y)^2 + (3-z)^2}$ $= 2.06 \text{ to } 1.02$
<b>Mature Sustainable (Level 4)</b>	$\text{DIML} = \sqrt{(3-x)^2 + (3-y)^2 + (3-z)^2}$ $= 1.01 \text{ to } 0$

Table 1: Distance ranges of maturity levels

#### 4.6. Recommendations for the Construction Industry of UAE

The results of the rating system show that construction companies in the UAE and the local public have the lowest sustainability performance. Table 6 summarizes the questions that received 1 or zero points in rating the UAE (weak points) and includes some recommendations to improve these areas.

Weakness in sustainability implementation from the Construction Companies			
Question	Number of points	Interpretation	Recommendation
-Would you be interested in studying sustainability?	1	-A majority of the engineers working in the construction industry are still not interested in studying sustainability. -Engineers do not see how important sustainability is.	-Government should require all engineers working in construction to study sustainability and examine them, and only those who pass should be permitted to work in the country. -The importance of studying sustainability has to be highlighted to the engineers by the companies and the government.
-Have you attended any course or lecture about sustainability?	1		
-Has your company provided training courses on sustainable construction?	1	-A majority of the construction companies in UAE do not provide training courses related to sustainability for their employees.	-All the companies should provide training courses about sustainability for their employees on a regular basis.
-Does your company promote sustainable employee behavior?	1	-Companies do not realize the benefits of sustainability for them and the country.	-----

Table 6: Recommendations for the construction industry in the UAE

**Weakness in sustainability implementation from the Construction Companies**

<b>Question</b>	<b>Number of points</b>	<b>Interpretation</b>	<b>Recommendation</b>
-Does your company measure the carbon emissions footprint produced by its construction projects?	0	-A majority of companies do not calculate the emissions footprint of their operations, which causes them not to feel the extent to which they harm the environment.	Government should force all the companies to calculate the emissions footprint of their operations, report them, and take serious action to reduce emissions.
-Does your company measure emissions from staff travel related to their job?	0		
-Approximately how much of your company's income does your company spend annually on sustainable initiatives?	1	-Construction companies in the UAE do not spend enough portion of their revenues on sustainable initiatives, which means that they do not make a significant contribution in making the country sustainable.	-Construction companies should allocate enough resources on sustainable initiatives and practices.
-How much of the energy being consumed by the company's operations is renewable energy?	1	Most of the construction companies in the UAE use non-renewable energy for their operations.	All construction companies should start relying on using renewable energy in their operations.

Table 6: Recommendations for the construction industry in the UAE (cont.)

**Weakness in sustainability implementation from the Construction Companies**

Question	Number of points	Interpretation	Recommendation
-To what extent has your company communicated its sustainability goals and policies to stakeholders?	1	There is a lack of communication between the companies and their stakeholders regarding the sustainability goals and policies, which makes it harder for the companies to move forward in sustainability.	Construction companies should have a communication system that keeps the companies and their stakeholders on the same page, which makes them work in alignment to achieve sustainability.
-Has your company defined strategies and plans regarding how to involve sustainability in the company's operations and processes?	1	A majority of the construction companies still do not have defined strategies and plans regarding how to involve sustainability in the company's operations and processes, which reflects their weak interest in adopting sustainability.	Construction companies in UAE need to build their own strategies and plans to involve sustainability in their operations. This step makes the initiative more organized and prevents the companies from making mistakes and experiencing losses.

Table 6: Recommendations for the construction industry in the UAE (cont.)

Weakness in sustainability implementation due to the government			
Question	Number of points	Interpretation	Recommendation
-Do you think that there is proper public awareness through the local education system or the local media about the values, techniques, and importance of sustainability?	1	The government does not provide enough education and awareness to the public about sustainability through schools and the media.	The government of UAE should place more stress on raising the awareness about sustainability through all possible means, such as schools, universities, and the media.

Table 6: Recommendations for the construction industry in the UAE (cont.)

<b>Weakness in sustainability implementation due to public behavior</b>			
<b>Question</b>	<b>Number of points</b>	<b>Interpretation</b>	<b>Recommendation</b>
-I walk or use a bicycle for trips near my home.	1	-The people of UAE still do not exhibit sustainable behavior that makes an effective contribution to the country's sustainability.	-The public of the UAE should start changing their attitude and behavior into sustainable ones and become more responsible about their country's environment economy, society, and culture.
-I buy or use locally manufactured products and services whenever possible to reduce transportation costs and to keep money in the local economy.	1		
-Whenever the temperature outside is moderate, would you switch on the air conditioner?	1		
-Do you feel that the local public is making enough efforts to have a sustainable country?	1		

Table 6: Recommendations for the construction industry in the UAE (cont.)



## Chapter 5: Conclusions

This thesis introduces the new concept of mature sustainability in the construction industry and develops a maturity model that can be used as a benchmark to assess a country's construction sustainability. In addition, a rating system is developed to determine the maturity level that a country belongs to using mathematical and statistical methods. Both the developed maturity model and the rating system were developed in view of the new concept of mature sustainability in the construction industry. This concept basically means that a country's construction industry can be considered as mature sustainable only when its three major components (companies, government, and the public) are performing sustainably.

Furthermore, a real application of the maturity model and the point-based rating system is conducted to show how they can be implemented. The input data used in the rating example was assimilated by conducting a survey on the construction companies, the government, and the public of the UAE. The study found that the DIML of the construction industry of the UAE is equal to 2.427, which means that the UAE can be categorized as "satisfactory." The best sustainability performance is exhibited by the government, then by the public, and the construction companies are the least effective.

The rating of the construction industry of the United Arab Emirates indicated that construction companies in the UAE must define proper strategies to involve sustainability in their operations. They also have to allocate more resources to sustainable initiatives and practices and increase their usage of renewable energy in their operations. Companies are advised to communicate their sustainable construction implementations with their stakeholders to raise their awareness and convince them of the importance of building a sustainable construction industry.

In fact, a majority of research studies used in developing this thesis suggested that proper education for all components of society is the best solution to facilitate the movement toward sustainability in all fields. For example, it is very important to educate professionals working in the construction industry about the advantages of sustainability and its applications in our lives. Construction professionals usually have a significant effect on the decisions and selections that their clients make because they are usually the source of options and proposals. Hence, as construction professionals are the key elements in the construction industry, changing their thoughts and attitudes

means changing the whole market.

Government should also take part in raising sustainability awareness. For example, the government needs to hold workshops and conferences about sustainable construction that gather members from different professions under one roof and let them exchange information about sustainable construction. It should also finance sustainability research studies and provide sustainability educational programs in local educational institutions.

Moreover, the government should mandate that professionals working in the construction industry obtain certification in construction sustainability, such as Pearl Qualified Professional by Abu Dhabi UPC or LEED AP by USGBC. Such a law is necessary to guarantee that all construction professionals are qualified to practice sustainable engineering. Raising the cost of water and electricity, enforcing high taxes on environmentally harmful products, and reducing the interest rates on loans used to fund sustainable projects would create an economic incentive for the society to conserve, and could be economic incentives for owners to make a sustainable choice.

Changing the lifestyle of a society (including government, construction professionals, and the public) to a sustainable one is not an easy task, and it takes a lot of time. Elkington [73] argued that it would be very difficult for a society to adopt a revolutionary concept such as a mature sustainable construction industry in less than a generation. The International Conference on GMS 2020, “Balancing Economic Growth and Environmental Sustainability” [74], suggested that it might take until 2020 at least to start having a mature sustainable construction industry in our world.

Society has to realize that their planet can no longer stand their irresponsible lifestyle and technological growth. However, it is not too late; they should start adopting a sustainable way of life that saves their resources and protects their health and environment. Indeed, all the efforts of construction professionals and the government will not have any use if the public does not contribute significantly. The fact that the public is the biggest component in the construction industry and that they are the end users of the built environment gives them the most important role in the movement toward sustainability. Actually, the public has many reasons to become interested in building a sustainable country, such as living in a healthy and stable climate and built environment, increasing the society’s productivity, redeveloping contaminated brownfields, preserving planted open spaces for social practices, etc.

The good thing is that, day after day, sustainability is becoming more mainstream, and it is expected in the future to become the first prerequisite to achieve in all projects and every field [75]. Society (including government, companies, and the public) over time will sense the advantages of living in a sustainable community, and then it will be an unacceptable idea to go back to the traditional one.

Future research studies about the construction sustainability maturity model can go deeper in describing maturity and add more detailed maturity levels. It also can be enhanced to calculate the time and cost required for a system to move from one maturity level to a higher one. Moreover, the rating system can be improved so that it can account for the fact that the three pillars of the construction industry (companies, government, and the public) do not have the same effect on the construction industry. For example, the rating system could assign weights to the pillars based on their actual effect on the industry, and these weights will be multiplied by the rewarded points to obtain a more accurate rating.

An international organization calling for sustainability must take the imitative and send agents to every country in the world to start conducting the previously developed survey. Once the surveys are completed, the organization has to use the developed rating system for all the surveyed countries to determine the maturity level and the deviation from the mature sustainable level.

The next step is to reveal the countries' rankings to the world and let every country know where it stands in regard to construction sustainability. This step will spark the movement toward a more sustainable world. For example, a country that is ranked as "unsustainable" will work hard to protect its local environment and economy before it is too late and both of them collapse. A further motivation would be that being ranked "unsustainable" will be unattractive to foreigner investors who would like to construct or buy a property and to the tourists who would like to reside in a healthy environment during their vacations.

Furthermore, since developed countries in particular tend to be in perpetual competition, they are likely to compete against each other to be ranked highest. Their intention might not necessarily be to preserve our planet, but regardless of their true intentions, the world will definitely benefit from this competition.

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## **VITA**

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