KADIR HAS UNIVERSITY
SCHOOL OF GRADUATE STUDIES
DEPARTMENT OF INDUSTRIAL ENGINEERING

BUILDING A FRAMEWORK FOR ADOPTING LEAN PRINCIPLES TO ACHIEVE SUSTAINABILITY IN SOLAR ENERGY FIRMS: TURKIYE AS A CASE STUDY

BILAL ALDEWACHI

DOCTOR OF PHILOSOPHY THESIS

ISTANBUL, SEPTEMBER, 2022

BUILDING A FRAMEWORK FOR ADOPTING LEAN PRINCIPLES TO ACHIEVE SUSTAINABILITY IN SOLAR ENERGY FIRMS: TURKIYE AS A CASE STUDY

BILAL ALDEWACHI

A thesis submitted to
the School of Graduate Studies of Kadir Has University
in partial fulfilment of the requirements for the degree of
Doctor of Philosophy in
Industrial Engineering

Istanbul, September, 2022

APPROVAL

This thesis titled BUILDING A FRAMEWORK FOR ADOPTING LEAN PRINCIPLES TO ACHIEVE SUSTAINABILITY IN SOLAR ENERGY FIRMS: TURKIYE AS A CASE STUDY submitted by BILAL ALDEWACHI, in partial fulfillment of the requirements for the degree of Doctor of Philosophy in (Industrial Engineering) is approved by

Prof. Dr. Zeki Ayağ (Advisor) ……..
Kadir Has University

Prof. Dr., Cengiz Kahraman ……..
Istanbul Technical University

Doç. Dr. Gökhan Kirkil ……..
Kadir Has University

Doç. Dr. Serkan Altuntaş ……..
Yıldız Technical University

Dr. Öğr. Üyesi Mustafa Hekimoğlu ……
Kadir Has University

I confirm that the signatures above belong to the aforementioned faculty members.

_____

Prof. Dr. Mehmet Timur Aydemir
Director of the School of Graduate Studies
Date of Approval: 02.09.2022

DECLARATION ON RESEARCH ETHICS AND PUBLISHING METHODS

I, Bilal Aldewachi; hereby declare

- that this Ph.D. that I have submitted is entirely my own work and I have cited and referenced all material and results that are not my own in accordance with the rules;
- that this Ph.D. does not contain any material from any research submitted or accepted to obtain a degree or diploma at another educational institution;
- and that I commit and undertake to follow the "Kadir Has University Academic Codes of Conduct" prepared in accordance with the "Higher Education Council Codes of Conduct".

In addition, I acknowledge that any claim of irregularity that may arise in relation to this work will result in a disciplinary action in accordance with the university legislation.

Bilal Aldewachi

_____

02.09.2022

I dedicate this thesis work to my parents, wife, brothers, sister and my son Yaman. I also dedicate this work to all my friends who supported me and to the soul of my friend Kağan Talip TIĞLI (R.I.P).

ACKNOWLEDGEMENT

First of all, I am deeply thankful to my advisor Prof. Dr. Zeki AYAĞ, for his appreciated advices, enduring support, and patience throughout my research and writing the thesis. Without his invaluable guidance, this study would have never been accomplished. His immense knowledge and plentiful experience have encouraged me all the time to complete my research. I would also like to thank the thesis monitoring committee for their valuable advices and comments. Many thanks to all staff members in the School of Graduate Studies at Kadir Has University for their kind help and endless support.

Last but not least, I would like to express my deepest gratitude to my parents, wife, brothers, sister, and son. Without their tremendous understanding and encouragement in the past few years, it would be impossible for me to complete my study. I also appreciate all the support and encouragement I received from the rest of my family and friends.

BUILDING A FRAMEWORK FOR ADOPTING LEAN PRINCIPLES TO ACHIEVE SUSTAINABILITY IN SOLAR ENERGY FIRMS: TURKIYE AS A CASE STUDY

ABSTRACT

The two terms lean, and sustainability have become one of the most important terms in the field of business because of their role in developing the work in line with increasing profits on the one hand and taking into account the future on the other. Solar energy firms are witnessing great competition to meet energy requirements and suffering from a huge amount of waste, which negatively affects in achieving sustainability. Hence, this study aims to build a framework for solar energy firms to achieve sustainability dimensions through adopting lean principles. The framework will help to solve problems that the solar energy sector is facing. The method in the study included reviewing the literature to examine the founding of the relation between lean and sustainability and using a questionnaire that was directed to the responsible people in Turkish solar energy companies. The results of the survey were analyzed to (1) Discover what the people in charge in solar energy firms think about lean and sustainability; (2) Measure the possible relationship between lean principles and sustainability dimensions by applying a linear regression and non-linear regression test; (3) Using the results of the second point to build the framework. The final results indicated a high level of the relative importance of the two terms from the perspective of the people in charge in the solar energy firms. Besides, the study found a relationship between adopting the two principles of lean, pull, and flow and achieving economic, social resources, and technology dimensions of sustainability; this finding is represented in a framework.

Keywords: Lean Principles, Sustainability Dimensions, Solar Firms, Framework, Renewable Energy, Influences.

GÜNEŞ ENERJİSİ FİRMALARINDA SÜRDÜRÜLEBİLİRLİĞİ SAĞLAMAK AMACIYLA YALIN İLKELERİN UYGULANMASINA YÖNELİK BİR ÇERÇEVE OLUŞTURMAK: TÜRKİYE ÖRNEĞI

ÖZET

Yalın ve sürdürülebilirlik terimleri, bir yandan artan kârlar doğrultusunda diğer yandan da geleceği dikkate alarak iş geliştirme konusunda oynadıkları roller nedeniyle iş alanındaki en önemli terimler arasında yerini almıştır. Güneş enerjisi firmaları, enerji gereksinimlerini karşılamak için büyük bir rekabete tanıklık etmektedir ve sürdürülebilirliğin sağlanmasını olumsuz bir şekilde etkileyen önemli miktarda israftan muzdariptir. Dolayısıyla bu çalışma, güneş enerjisi firmalarının yalın ilkeleri benimseyerek sürdürülebilirlik boyutlarına ulaşmaları konusunda bir çerçeve oluşturmayı amaçlamaktadır. Çerçeve, güneş enerjisi sektörünün karşılaştığı sorunların çözümü konusunda yardımcı olacaktır. Çalışmadaki yöntem, yalın ve sürdürülebilirlik arasındaki ilişkinin temellendirilmesini incelemek üzere literatür taramasını ve Türk güneş enerjisi şirketlerinde sorumlu kişilere yönelik bir anketin kullanılmasını içermektedir. Anket sonuçları, aşağıdakileri gerçekleştirmek üzere analiz edilmiştir: (1) Güneş enerjisi firmalarında sorumlu kişilerin yalın ve sürdürülebilirlik hakkında ne düşündüklerini anlamak; (2) Doğrusal bir regresyon ve doğrusal olmayan bir regresyon testi uygulayarak yalın ilkeler ve sürdürülebilirlik boyutları arasındaki olası ilişkiyi ölçmek; (3) Çerçeveyi oluşturmak için ikinci noktanın sonuçlarını kullanmak. Nihai sonuçlar, güneş enerjisi firmalarında sorumlu kişiler açısından iki terimin yüksek düzeyde göreceli öneme sahip olduğunu göstermiştir. Ayrıca çalışmada, yalın, çekme ve akış ilkelerinin benimsenmesi ile sürdürülebilirliğin ekonomik, sosyal kaynaklar ve teknoloji boyutlarına ulaşması arasında bir ilişki olduğu tespit edilmiş ve bu bulgu bir çerçeve dahilinde temsil edilmiştir.

Anahtar Kelimeler: Yalın İlkeler, Sürdürülebilirliğin Boyutları, Güneş Enerjisi Firmaları, Çerçeve, Yenilenebilir Enerji, Etkiler.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS

R	A statistic that tells the strength and direction of that relationship.
R^2	The measures of the proportion of variation in the dependent variable that can be attributed to the independent variable.
B	Coefficient of Correlation
n	Sample size
n_o	Sample size (in big population)
N	Population

LIST OF ACRONMYMS AND ABBREVIATIONS

JIT	Just in time
PV	Photovoltaics
V	Value
Va	Value stream
F	Flow
Pu	Pull
Pe	Perfection
RETs	Renewable energy technologies

1. INTRODUCTION

1.1 Overview:

In recent years, businesses have been under increasing pressure to find a way to manage their operations responsibly regarding their environmental and societal impacts. This has inspired companies and researchers to find ways to implement sustainable processes. The importance of sustainability caught considerable attention after the report of the united nations' world commission on environment and development in 1987 with the title "Our common future," which focused on the relationship between society, resources, and the environment through a long-term environmental perspective to achieve sustainability (Krut & Munis, 2019).

There are many definitions for sustainability, and the popular one by the world commission on environment and development in (1987): is "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (Kim, 2000) and the definition of the environmental protection agency (EPA) which defined sustainability as: "Sustainability creates and maintains the conditions under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic and other requirements of present and future generations." (Çakir et al., 2012) In fact, the three dimensions of sustainability are not enough in all sectors to implement sustainability. The need showed the importance of adding new dimensions, which must be taken care of to achieve greater sustainability. The added dimensions differ from one industrial sector to another according to the nature of the industry and the factors affecting it. In addition, these added dimensions are still under study to develop a framework that will help in making approval and adopting these dimensions as the three main popular dimensions of sustainability.

The situation in the solar energy sector is the same as in other different sectors with regard to the dimensions of sustainability. Recently, both the technological and resource dimensions have been adopted as sustainable dimensions.

As stated in the study of (Vacchi et al., 2021) that the technological dimension can be seen as a sustainability dimension in parallel with the other dimensions of sustainability (social, economic, and environmental). The study mentioned above-adopted technology as one of sustainability's dimensions after studying the claims about the existence of the relationship between technology and environmental dimension in a primary way and between technology and the other dimensions of sustainability (social and economic) in a rareness.

Also, the study of (Curry et al., 2013) studied the resource dimension as one of sustainability's dimensions. Where it studied the resource dimension in parallel with the environmental dimension, and it indicated the importance of increasing the resource efficiency to take place in the competition in the market.

In fact, as these dimensions have been adopted recently as sustainability dimensions, there is a huge need to study them to discover the right techniques and procedures that companies need to follow to improve and achieve them since the studies about them are still not sufficient compared with the studies about other dimensions of the sustainability.

The benefits of working to achieve sustainability are not limited to providing the needs of both current and future generations, but it also benefits companies that adhere to the rules of sustainability in terms of economic terms. As today many customers tend to companies that take into account the sustainable aspects of their production, especially those that have sustainability certificates for their products, and since this increase in the popularity of the companies will return with an increase in financial incentives for them, and this has been proven by a group of studies conducted on this matter in various sectors, as the study of (Blackman & Rivera, 2011).

In addition, currently, the sustainable product has become one of the global goals that many active institutions and governments overall the world is working to encourage its use and investment through the support for sustainable consumption; for example, the new European circular economy action plan has worked to encourage sustainable consumption, which has succeeded to a large extent in influencing consumer behavior, and the impact was more significant on the consumer who pays great attention to the

green product. This big change has led companies to compete to reach this sustainable product and win customers seeking green products; at this point, the need for new ways and processes to achieve this goal has become clearer.

The effect of the new European circular economy action plan was clear on companies operating in Romania; the reason is due to its geographical location linking both the European union, and middle east countries, as well as it's considered an important destination for foreign investment, on the other hand, the Romanian consumer is an interested consumer in the environment of course.

These conditions are very similar to the situation in Turkey, in terms of the importance of its geographical location, as well as considering it an investment destination besides its exports to Europe, as a result targeting the European consumer. All of this requires from Turkish companies to work to provide a sustainable product in order to reach sustainable consumers and achieve the necessary returns (Purc et al., 2022).

In fact, achieving a sustainable product is not an easy matter, and it requires from companies to work on finding suitable ways to achieve it.

The literature indicates that sustainability is one of the main considerations in 2021 for consumers. Based on the percentages of consumers who have become interested in this type of product, on the other hand, many consumers avoid the products of the companies that do not pay any environmental concern in their operations

Also, at the same time, the demand for a sustainable product remains different from one consumer to another. For example, many customers are asking companies to take the initiative in including sustainability in their operations. Also, customers are divided between customers willing to pay extra money to get the green product and customers on the other hand looking for the right price.

Still, the awareness remains higher than it was previously, and we can notice some generations, like the Z generation, tend to the sustainable products more than others. (Brand & Rausch, 2022).

In return, the term "lean" that Toyota Motor introduced in 1950 continued to evolve in a manner commensurate with the progress made in the field of operations management,

which was represented in two main stages. The first stage was represented by working to keep the continuous improvement of quality until the beginning of the 1990s, and then continued working on the quality, cost, and delivery side in the late 1990s, reaching the second stage that has been concerned with customer value since 2000 due to the increasing interest in sustainability in that time period, especially with regard to the field of operations management (B et al., 2016). The use of lean in different sectors helps in improving the companies in different ways, such as increasing profit, enhancing quality, eliminating waste, removing the non-added values, and reducing cost. However, a deference effect was found in adopting lean between the different sectors.

The literature supported the high return benefits of adopting lean, and many recommendations were found to adopt it to enhance the work and achieve new goals in business like sustainability and supporting green products.

Lean depends on five main principles to achieve its goals, which are (value, value stream, flow, pull, and perfection). These principles work in a sequential and connected manner. In addition, every principle has special tools that are used to achieve its purpose (Crawford, 2016).

Scientists also began to study the compatibility and synergy between traditional lean and sustainability (B et al., 2016). The increased interest in sustainability and the increased attention towards improving the environmental sector has made environmental sustainability a primary goal in the strategies of organizations, with the necessity to go along with each of the goals of traditional organizations represented in increasing profitability and efficiency (Garza-Reyes, 2015), which is involved under green industrialization that is considered an important way in the path of achieving sustainable development in the industrial sector. As a system, it does not require the increased use of natural resources for expansion and growth. Lean holds the same principle in manufacturing and management operations (Krut & Munis, 2019). In parallel, academics have studied the possible relationships between the adoption of lean and green production outcomes. The link between lean production and sustainable development has been called the lean–green manufacturing approach, which combines lean practices focused on customers' demand, and green practices focused on reducing the business' environmental impact; nevertheless, lean–green manufacturing is still a

new practice, lacking a clear and structured research definition; lean is “a systematic approach to process improvement. The method is based on finding and reducing waste coupled with continuous improvement”; in addition, using lean to produce renewable energy products will make the costs low, help the investment of capital to be more efficient, and provide products in the shortest possible lead time, and ensure the continued growth of the industry (Khodeir & Othman, 2018). Some scholars argue that lean firms can achieve environmental performance improvements since lean and green may have elements in common as both focus on reducing waste and increasing the efficiency of production processes (King & Lenox, 2001). Various countries’ economies are reliant on the energy market, and any improvements in this field can be seen in economic stability, sustainability, production, education, and health care, among other things. Since its activities are very distinct from those of other manufacturers, the energy industry is one of the industries that face a strong challenge in terms of efficiency and transformation to lean compared with other manufacturing (Albezuirat et al., 2020), and solar energy is one of these types of industry. In addition, the problem of high waste in the industry represents an obstacle to achieving sustainability from both the environmental and economic dimensions. Despite the role of solar energy in raising the economic return and helping to achieve the required value for the customer, the increase in growth in this sector created a new challenge represented by a large amount of waste in it. According to the joint report of the International Renewable Energy Agency (IRENA) and the International Energy Agency Photovoltaic Power Systems Program (IEA-PVPS), the waste of this sector will achieve 78 million tons (Weckend et al., 2016). This huge amount of waste will negatively affect access to sustainability as it results in a large loss of resources, which is reflected in multiple negative ways, such as economic loss. Thus, the work to get rid of problems that surround the solar energy sector will support it and reduce the cost of production, and, as a result, consumers are encouraged to use it; this will help in achieving sustainability goals. One of the methods is the use of lean, according to its contributions in this field. Despite the ability of a lean operation to solve a wide range of sustainability matters, when defined correctly, the benefits are not fully explored in many industrial sectors or in a wide range of cases study (Sajan & Shalij, 2017). This study will add an important contribution to the solar sector in Turkey. The country has a good opportunity to investigate in the solar energy

sector, with sunshine per day equal to 7.5 h and solar radiation equal to 4.2 kWh/m2 per day. As a result of the geographical location, the solar energy sector is at the top with wind energy in the energy market in Turkey and, as a renewable energy resource to achieve Turkey's goal in 2023, Turkey is among the largest developing solar markets. By the year 2018, the amount of installed solar collector area in Turkey was calculated as almost 20,200.000 m2; in addition, Turkey's policies supported the solar sector as a result of Turkey's need to increase energy supply security and to meet the growing need for energy because of the increase in the population and ongoing economic development. That is why Turkey is working to develop this sector as a part of the goal to achieve 100% renewable energy-powered electricity in 2050 (Kilickaplan et al., 2017). The contribution of the study will be through developing a framework to clarify the relationship between lean principles and sustainability dimensions, making the application of lean in this sector easier as well as achieving sustainability, which today is one of the most important goals for many firms around the world, and to obtain the benefits through fixing the many problems of waste and cost Thus; this study aims to build a framework for solar energy firms to adopt lean principles to achieve sustainability by studying companies in Turkey. The main purpose of this study is to work to achieve the sustainability of solar energy firms and measure the awareness of responsible people in companies in this sector towards lean principles and sustainability implementation.

1.2 Problem Statement:

Decrease the amount of waste in material, time, and cost; besides improving all the management processes in work must be the goal of Solar energy firms in Turkey to maximize their projects' value and profit. The solar energy sector in Turkey is suffering from a huge amount of waste, and reducing it, is considered an important step toward reducing the cost. It is also an important step towards achieving sustainability as a main goal of many companies and one of Turkey's energy sector policies. (Ozturk & Yuksel, 2016).

In this study, a new management direction which is the lean principles is studied to explore the awareness of lean principles and sustainability dimensions among the Solar energy firms in Turkey. By Investigating the awareness of the importance of implementation of the lean principles and sustainability dimensions in the companies in their processes and measuring the relationship between the lean principles and sustainability dimensions to link them in a framework that can help the companies to enhance the sustainability in the solar energy sector in Turkey, which will affect positively to reduce the cost and waste and maximize the value of their projects by giving them an advantage point to compete in the workplace, where the market is witnessing an increase in the demand of the consumers who prefer the sustainable product.

1.3 The Objective of the Study:

Achieving sustainable development becomes the main goal for various industries over the world and achieving sustainability in the solar energy sector is one of these sectors; in addition, it's one of the main goals for the Turkish policies in the energy sector in Turkey, so this study centered around the possibility of achieving the sustainability through adopting lean principles at solar energy firms. This study aims to:

1- Explore the awareness about the importance of implementation of lean and sustainability factors.

2- Investigate the relationship between lean principles and sustainability dimensions in solar energy sectors.

3- Build a framework to help the solar energy firms in Turkey to adopt lean principles in their process to achieve sustainability by identifying the factors that must be developed in the firms.

1.4 The Significance of the Study:

The importance of this study will appear through the significant effect on the solar energy sector in Turkey. This study represents an overall study about enhancing sustainability through adopting lean principles in the solar energy sector in Turkey. The study's main aim is to build a new approach to achieving sustainability in solar energy

firms by using an appropriate framework through adopting lean principles. Also, this study will shed light on the new dimensions of sustainability, the resource, and technology dimensions, besides studying the probability of achieving these dimensions in parallel with the common three dimensions of sustainability: social, economic & environmental. At the same time, the studies about these two dimensions are still few compared with the other dimensions of sustainability. Furthermore, this study may help the Turkish solar energy firms by suggesting some advices in their management practices and improving their organizational and human resources that may help to achieve sustainability.

1.5 Hypotheses Development:

To achieve the study's goal, the researcher tried to find certain facts about the impact of each principle of lean on the five dimensions of sustainability to assume the relationship in the solar energy sector. To develop the hypotheses, we need to come first to the definitions of each factor of lean and sustainability. According to (Weigel, 2000), the definitions of lean principles are as the following: value is the "capability provided to the customer at the right time at an appropriate price, as defined in each case by the customer." The value stream is the "specific activities required to design, order, and provide a specific product, from concept to launch, order to delivery, and raw materials into the hands of the customer." flow is defined as the "progressive achievement of tasks along the value stream so that a product proceeds from design to launch, order to delivery and raw materials into the hands of the customer with no stoppages, scrap or backflows", also we can notice that flow is referred to as "crews of different trades move from location to location and complete work that is prerequisite to starting work by the following crew " (Tommelein et al., 1999). The fourth lean principle of pull is defined as a "system of cascading production and delivery instructions from downstream to upstream in which nothing is produced by the upstream supplier until the downstream customer signals a need." And the last principle of lean is perfection, which is defined as the "complete elimination of muda so that all activities along a value stream create value." The five dimensions of sustainability are defined as the following: The social dimension, in fact, has no agreement to define it (Nugraheni et al., 2019), but we can summarize the most common ideas of the social dimension in that it aims to

establish justice and equality between the community to reach an acceptable degree of satisfaction. On the other hand, the environmental dimension aspects are focused on efficiency reducing waste and pollution, and using renewable energy and are defined as a way that enables organizations to value the influence of their operations on the environment (Othman et al., 2014). The economic dimension is defined as: “In the economic debate, sustainable development is most often described as the need to maintain a permanent income for humankind, generated from non-declining capital stocks” (Spangenberg, 2005); the fourth dimension of sustainability is the technological sustainability which means finding scientific methods and innovations that help to use available resources in a sustainable manner and replace unsustainable materials with modern sustainable materials. In fact, the need for sustainability is increasing with the increasing population density around the world and the increase in obstacles, and the increase in competition for production. Therefore, it has become necessary to find solutions and technological methods that serve the endeavor to achieve the goal of achieving sustainability. As it is seen, technology is a way to optimize the use of resources and reduce the amount of materials consumed in production processes, though people are still generally wary of using technology to solve these problems (Weaver et al., 2000). Also, the fifth dimension of sustainability which is the resource dimension appeared as an important step towards achieving the sustainability. the resource dimension means the saving for the resources through the aid of policer making to adopt a decision that supports the sustainability goals by supporting the sustainable consumption and production. So, the resource dimension’s effect can be seen through the use of the recycling materials or through minimizing the consumption of the resource which will work positively to enhance the saving for the resources for the next generations. (Curry et al., 2013) the hypotheses are developed as follow:

1. The relation between value and sustainability dimensions:

According to the definitions of the value and sustainability dimensions, we notice that the effect of value in the social dimension is shown with employees being involved in work decisions, which creates a high level of satisfaction and enhances service performance (Lee et al., 2012). Moreover, through increasing quality and efficiency, a high level of customer satisfaction is found, which is reflected in the increasing

economic return (Sánchez-Fernández & Iniesta-Bonillo, 2009), and the relationship between the value and environmental dimensions are shown in the reduction in the need for re-working by making quality control a job for every worker (Vinodh et al., 2011), Also, where the effect of value to the resource dimension can be noticed through using types of materials and the work to eliminate the waste. Finally, the relationship with the technology, the last dimension of sustainability, can be shown with the new technology that can be used to achieve the satisfaction of the customer on hand and support the production line on the other hand. Thus, the following variables derived V1 (Your company is ready to do any change in the project, to improve the value for the customer)(Mohammed & Obaid, 2016), V2 (Defective items "human and machine error" are identified promptly to take corrective action) (Wickramasinghe & Wickramasinghe, 2017), V3 (Identifying wastes through new management practices is vital for improving the quality, cost and time) (Vinodh et al., 2011), V4 (It is vital that the quality of the project will be the responsibility of each person in the project) (Mohammed & Obaid, 2016) and the following hypotheses H1, H2, H3, H4, and H5 were formulated:

Hypothesis 1 (H1). There is a significant relationship between adopting value on lean and achieving social indicators on sustainability in the solar energy sector.

Hypothesis 2 (H2). There is a significant relationship between adopting value on lean and achieving economic indicators on sustainability in the solar energy sector.

Hypothesis 3 (H3). There is a significant relationship between adopting value on lean and achieving environmental indicators on sustainability in the solar energy sector.

Hypothesis 4 (H4). There is a significant relationship between adopting value on lean and achieving resource indicators on sustainability in the solar energy sector.

Hypothesis 5 (H5). There is a significant relationship between adopting value on lean and achieving technology indicators on sustainability in the solar energy sector.

2. The relation between value stream and sustainability dimensions:

The effect of the value stream on the social dimension was found by enhancing the work environment and improving training programs (Hartini et al., 2021). Additionally,

a relationship with the economic dimension was found by reducing unwanted activities such as unnecessary testing in clinical practice (Vegting et al., 2012). In addition, the elimination of hidden and unwanted activities had a positive effect on the environmental dimension, as shown in the situation in a case study of (Plymouth Tube) through the decrease in lubrication use by 1400 gallons (Vinodh et al., 2011). On the other hand, we can suppose that adopting a value stream will have the same effect on the resource dimension as same as in the environmental side, whereas the effect of the value stream appeared in the elimination of the used materials. In addition, the relationship between the value stream and the technology dimension can be shown through the effect of technology by finding the suitable needed technology. According to these the following variables derived: Va1 (Your company is interested in minimizing wastes in materials, conveying of materials and labor, transportation, and inventory level, waiting time, over production, over processing) (Vegting et al., 2012),Va2 (Lot sizes are maintained at the minimum possible level), Va3 (Machine set-up and Machine down times are maintained at the minimum possible level) (Wickramasinghe & Wickramasinghe, 2017) Va4 (Your company follow special tools or standard for measuring the speed of the project) (Mohammed & Obaid, 2016).Thus H 6, H 7, H 8, H 9, and H 10 were formulated.

Hypothesis 6 (H6). There is a significant relationship between adopting value stream on lean and achieving social indicator in sustainability in the solar energy sector.

Hypothesis 7 (H7). There is a significant relationship between adopting value stream on lean and achieving economic indicator in sustainability in the solar energy sector.

Hypothesis 8 (H8). There is a significant relationship between adopting value stream on lean and achieving environmental indicator in sustainability in the solar energy sector.

Hypothesis 9 (H9). There is a significant relationship between adopting value stream on lean and achieving resource indicator in sustainability in the solar energy sector.

Hypothesis 10 (H10). There is a significant relationship between adopting value stream on lean and achieving technology indicator in sustainability in the solar energy sector.

3. The relation between flow and sustainability dimensions:

With regards to the effect of flow, a positive effect was found between flow and creating awareness among the employees about the plans for the job (Mohammed & Obaid, 2016). In a study to build a lean and green model for a production cell by adopting the flow principle in the processes, a positive impact was found to reduce resource use as an environmental aspect and reduce the total cost, which improved the economic side (Brasco et al., 2013).Also, another study supported that the using of flow will help in reducing the time of installation for the large-scale solar panels and will reduce the cost (Wang, 2014) which will be reflected positively on the economic dimension. Despite the positive impact of eliminating waste in resources to achieve an environmental dimension of sustainability, this reduction in the waste of resources is considered an essential step to achieve sustainability in resources. So, the relationship between flow and sustainability in resources dimension can be reached by reducing or limiting waste in the materials used, as well, the relationship between the flow and the sustainability of technology is represented by one of the main goals of technology dimension, which is based on finding a way and scientific methods to reduce the loss in materials, besides finding scientific methods to reduce the consumption of materials in production lines, in addition a study referred that unplanned flow process will create two kinds of waste, the first one is the waste that resulted due to the waiting of the resource and the second one is the high inventory as a result of the high variability (Tommelein et al., 1999). On the other hand, the adopting of flow will work to press the schedule of the project, in addition control the quality through balancing the workflow variability effect on the performance of the work, and in PV-system it can help to understand the analyzing of the process for value and waste, through that it will support sustainability too (Lapinski et al., 2007),so , we derived the variables as follows F1(Mapping the flow of material and information of any activity, helps to identify the non-added value activity) (Mohammed & Obaid, 2016), F2 (Material flow is adhered to consistently throughout the daily work activities), F3 (Make flow evident through organizational culture) (Wang, 2014), F4 (Strive to cut back to zero the amount of time any work is sitting idle or waiting for someone to work on it) F5 (Material, equipment, and other resources are provided in a “just-in-time” manner when needed) (Gao & Low, 2014), as a result, H 11, H 12, H 13, H 14, and H 15 were formulated:

Hypothesis 11 (H11). There is a significant relationship between adopting flow on lean and achieving social indicator in sustainability in the solar energy sector.

Hypothesis 12 (H12). There is a significant relationship between adopting flow on lean and achieving economic indicator in sustainability in the solar energy sector.

Hypothesis 13 (H13). There is a significant relationship between adopting flow on lean and achieving environmental indicator in sustainability in the solar energy sector.

Hypothesis 14 (H14). There is a significant relationship between adopting flow on lean and achieving resource indicator in sustainability in the solar energy sector.

Hypothesis 15 (H15). There is a significant relationship between adopting flow on lean and achieving technology indicator in sustainability in the solar energy sector.

4. Pull and sustainability dimensions:

The pull approach works through many effects that support the sustainability dimensions, such as lowering of work-in-process, the elimination of potential waste from damaged products, and working for lesser floor space utilization. The reduction in waste is presented as a positive effect on the environmental dimension (Vinodh et al., 2011). The application of pull alongside value stream principles to reduce waste management gave benefits on the economic and environmental dimensions, according to (Minh et al., 2019). The same study proposed that the work's in-depth results would help companies to identify the accurate impact of their waste improvement plan and enhance it in different dimensions: social, economic, and environmental. Also, where there is an effect of adopting pull to the works to approach the waste elements, we can assume here that there is a positive impact to support the resource dimensions. On the other hand, the technology dimension is supposed to give an advantage step to adopt pull and achieve the goal of using it, whereas they have the same plans, as the result of the study of (Albrecht et al., 2015) that recommended the policymakers to keep pull in their mind to support the renewable energy with the need to develop a new technology to achieve the benefit of it. Besides a study of (Singla et al., 2018) indicated that the failure in the implementation of pull demand will lead to inflation, furthermore it will effect negatively on the economic side due to the chasing of a lot of money for a small

number of goods. According to these facts we derived the following variables, Pu1 (Materials are ordered as close as possible to exact needs), Pu 2 (Strive for possible low level of (even stockless) material inventory), Pu 3 (Clear job contents, work time, material requirements, among other information are prepared before releasing a work task to a crew) (Gao & Low, 2014), Pu 4 (Amount of time spent in processing each order is maintained at the minimum possible level) (Wickramasinghe & Wickramasinghe, 2017), Pu 5 (New management tools that improve quality, speed, cost and waste are essential to improve competitive advantage) (Mohammed & Obaid, 2016). Thus, H 16, H 17, H 18, H 19, and H 20, were formulated.

Hypothesis 16 (H16). There is a significant relationship between adopting pull on lean and achieving social indicator in sustainability in the solar energy sector.

Hypothesis 17 (H17). There is a significant relationship between adopting pull on lean and achieving economic indicator in sustainability in the solar energy sector.

Hypothesis 18 (H18). There is a significant relationship between adopting pull on lean and achieving environmental indicator in sustainability in the solar energy sector.

Hypothesis 19 (H19). There is a significant relationship between adopting pull on lean and achieving resource indicator in sustainability in the solar energy sector.

Hypothesis 20 (H20). There is a significant relationship between adopting pull on lean and achieving technology indicator in sustainability in the solar energy sector.

5. Perfection and sustainability:

According to the definition of perfection, we can clearly show that this principle means working toward perfection; in addition to that, it encourages continuous improvement by investing in new opportunities (Thangarajoo, 2015). Adopting this principle is a way to achieve the sustainability dimensions depending on its effect in supplying the customer's product. The principle of perfection also enhances performance by selecting suitable delivery techniques and forces all organizational levels to work for continuous improvement (Othman et al., 2014). As a result we derived these variables Pe1 (A Statistical Approach To Lean Construction Implementations of Construction Companies in Turkey), Pe2 (Quality teams are operating in an effective manner) (Wickramasinghe

& Wickramasinghe, 2017), Pe3 (Your company depends on management practices that deal with quality and reduce wastes ratios in order to achieve high earnings ratios) Pe4 (Good vertical and horizontal communication systems reduce the time for decision taking) .Thus, H 21, H 22, H 23, H 24, and H 25 were formulated.

Hypothesis 21 (H21). There is a significant relationship between adopting perfection in lean and achieving social indicator in sustainability in the solar energy sector.

Hypothesis 22 (H22). There is a significant relationship between adopting perfection in lean and achieving economic indicator in sustainability in the solar energy sector.

Hypothesis 23 (H23). There is a significant relationship between adopting perfection in lean and achieving environmental indicator in sustainability in the solar energy sector.

Hypothesis 24 (H24). There is a significant relationship between adopting perfection in lean and achieving resource indicator in sustainability in the solar energy sector.

Hypothesis 25 (H25). There is a significant relationship between adopting perfection in lean and achieving technology indicator in sustainability in the solar energy sector.

This study will examine these hypotheses by following a group of analysis methods. The results will help to explain the relationship between lean principles and sustainability dimensions, besides building the framework that will help solar energy firms in Turkey to achieve sustainability.

For the purpose of explaining and understanding the hypotheses of the study, a supposed framework is built to explain all the proposed relationships between lean principles and sustainability dimensions that are listed in the hypotheses and that will be checked through different analysis methods, as shown in figure 1.1:

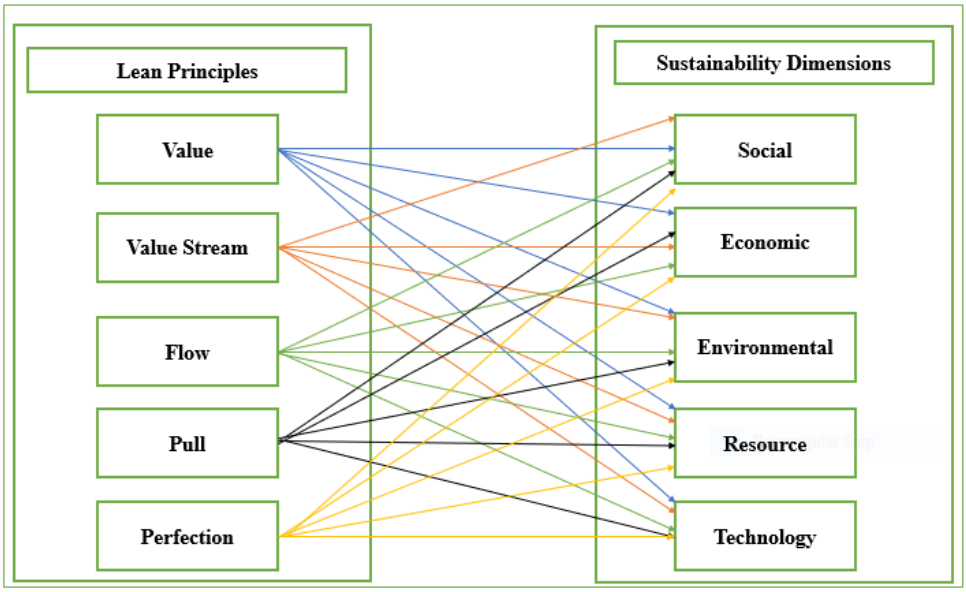

Figure 1. 1 The conceptual model

1.6 Organization of thesis:

The thesis structure has been divided into five sections, each of which contains a number of subsections, as follows:

Chapter one: The first chapter considers creating an introduction for the thesis. In addition, it's included a set of information related to the reason for adopting this study, the expected impact of announced results, and clarifying the mechanism of building and developing the hypotheses. Subsections of the first chapter are as follows: Introduction, problem statement, the objective of the study, the significance of the study, hypothesis development, and the thesis structure.

Chapter two: The second chapter includes a literature review in a way that helps to identify each of the two terms of the study (lean and sustainability), in addition to understanding the results of the studies and the opinions of researchers about the relationship between the two terms. Besides the information of the status of Turkish solar energy, and Turkey's strategic goals regarding both the solar energy sector and sustainability. Therefore, the main headings can be summarized as follows: literature review about the principles of lean and sustainability dimensions, the theory about the relationship between the two terms, and the possibility of achieving sustainability through adopting lean principles in the section with the titles: lean and sustainability,

The benefits of adopting lean principles and sustainability. In addition, an overview of the energy sector and sustainability in the titles: Solar energy sector in Turkey, sustainability goals of Turkey, Turkey's sustainable goals, and Turkish policies for sustainable and modern energy.

Chapter Three: The third section presents and clarifies the research methodology used to conduct this study and the basic tests that were implemented. The subsections in chapter three are as follows: research strategy, the population of the study, the sample size of the study, Questionnaire design and content, The scale of measurement: Procedure, and Testing the reliability of the questionnaire.

Chapter four: the fourth chapter is about the results and discussion of the study, besides clarifying the steps to build the framework and the strength points on it. The subsections titles are as follows: Descriptive analysis, a descriptive statistical difference between responders' firms, assessing the perception towards implementation of lean and sustainability principles, calculating the mean of lean and sustainability factors, testing and analysis of the research hypotheses, the results of testing the hypothesis through applying non-linear regression analysis, the final framework of the study, correlation test, the Finding of the Study, steps that are Used to Build the Framework, and the strength of the conceptual framework.

Chapter five: the fifth chapter includes the conclusion of the studies besides the recommendation and explanation for the study contributions.

2. LITERATURE REVIEW

2.1 Lean Principles and Sustainability:

Toyota Corporation created lean-to eliminate waste and increase efficiency in its manufacturing processes; lean has achieved great success in various industrial sectors in which lean has been adopted. Lean eliminates waste and components that do not represent any added value in operations. In the event that the process had not originally gone through in lean a few times, it would contain some waste. When done correctly, lean has the potential to deliver massive improvements in many aspects such as efficiency, cycle time, productivity, and material and scrap costs, which will result in lower costs and improved competitiveness. In fact, lean is not limited to manufacturing operations, but it extends to the development of the team's work mechanism and inventory management; in addition, lean can reach the interaction of the customer himself (Crawford, 2016). Lean is included five principles, according to Womack and Jones, which are (value, value stream, pull, flow, and perfection). In fact, these principles work together to achieve the goal of lean, and we can explain them as follows:

Value: The definition of value is done by identifying the customer's needs through knowing the vital information that must be known to define the value, such as the schedule for manufacturing and delivery of the product, knowing the price point, also, all the needs and expectations that must be adhered to.

Value stream: After determining the value, the second step is the "value stream," or all the steps that involve taking the product from the raw materials to the delivery of the final product to the customer. The "value stream" may be in any step of the business, such as in production, management, customer service, or delivery. The goal of the value stream is to determine which step among the work steps does not create an added value and then work to get rid of those steps. The value stream is similar to process engineering; in addition, the value stream is useful in eliminating non-valued processes, but it is also considered a way to fully understand the business process.

Flow: Flow is considered the next step after the value stream in which waste has been removed. The role of flow is to ensure the smooth flow of products and services to the customer. This step is considered one of the biggest challenges in the lean system, but at the same time, it leads to a significant increase and gains in productivity and efficiency. It may reach approximately 50%, according to various studies.

Pull: The basis of pull work is represented by the "Just in Time" rule for both of manufacturing and delivery processes of the product. Also, pull can allow the customer to withdraw the product at the time he desires according to his need, and on the other hand, will help the companies to avoid building the product or stockpiling. As a result, there will not be a need to create an inventory that may be expensive and needs to be managed. As a result, these things will save money for the producing company, supplier, and customer.

Perfection: Applying the first four lean principles is considered a great point, but applying the last step represented by the principle of perfection may be considered the most important step between them, making process improvement a part of the company's culture. As continuing the accumulate gains, one of the main points to remember is that lean is not a fixed system but rather a system that requires us to work with constant effort and vigilance to reach perfection. In addition, one of the essential requirements for the successful application of lean is that all employees participate in its application in the right way.

About the sustainability dimensions, in fact, sustainability is still under debate and discussion between researchers and practitioners. In addition, sustainability it's seen differently among players in the different industry sectors. So, there is still a need to search for commonalities between sustainability applications in other sectors in order to reach a consensual definition between them. However, the definition of (WCED) is still the popular one to describe sustainability goals. It's worth mentioning that. Despite the (WCED) sustainability declaration, which acknowledged the existence of three main dimensions, still, these dimensions are no longer sufficient for all industrial sectors. The need has become urgent to add new dimensions to sustainability corresponds to the need in these different sectors to help them to achieve sustainability, As proven in various studies conducted in this regard and as previously mentioned in this thesis.

Also, agreeing on the term “sustainability” is not as easy as we expect, as Brundtland’s definition opened a wide space for discussing the term “sustainability”. Philosophical opinions about defining the meaning of “needs” differ from one group to another, while what some consider needs are seen by others. As desires, the identification of needs and desires may differ from one society to another, and a particular society may turn towards desires with the same enthusiasm that another society turns toward needs, and the reason for this is due to the different levels of luxury between one society and another. In addition to that, the concept of “present” and “future” needs is considered the subject of an important debate that has the potential for many opinions and interpretations. Some may see it as a process of reaching the highest levels of luxury for the largest possible number of people, which cannot be achieved without reducing poverty, while Others see it in the opposite way as reducing the standard of living in high luxury, in other words reducing the level of quality of life to the average level or less than it.

In fact, the aforementioned interpretation of “future needs” will lead to large consumption of resources, which will greatly affect the provision of needs for future generations, which in turn raises another explanatory problem, namely the controversial topic about the amount of natural resources that will be consumed by future generations, as some argue that continuing using non-renewable natural resources such as petroleum will lead to depriving future generations of using it sufficiently to meet their needs, as any consumption of these resources at the present time will result in depriving future generations of this resource, but this opinion remains an extreme opinion to be considered an example of “Malthusianism,” It had previously predicted nearly 200 years ago that the world would go through a major food crisis and that it would not be available from providing adequate food to societies despite the smallness of societies at that time if compared to its size today. (Wendell Cox, 2005).

The application of this conservative pattern requires a great rationalization of consumption in order to ensure that the dues of future generations are preserved from sufficient resources to meet their needs. The party opposing this idea and those who bear the label adopt that the reliance should be on human ingenuity in meeting and providing for future needs. The truth may be between these two theories in relation to these two opposite theories. There is also another fact that must be paid attention to it,

which is that there are some needs that require a great organization, not only for future needs but also for the present generations today; an example of these needs is the issue of water pollution since if work is not done to solve these Problems at the present time, the inability to meet the needs of generations will not be limited to future generations, but to current generations as well. On the other hand, there are some needs that may not require an urgent study or even a long-term study, for example, the consumption of oil, where this topic is discussed in a large way, as some argue that man is able to develop technology and alternative sources of energy in a way that will provide the current needs. Without prejudice to the needs of future generations, the modern experience provides a good example on which the owners of this opinion can rely. This example revolves around the problem that appeared in the sixties and seventies of the last century when there was a significant increase in air pollution in cities due to the increase in the use of cars, which called for the need to find a solution to reduce this pollution, also to show some opinions, such as the opinion that it is important to shift towards the use of public transport, which seemed at the time as a compromise and logical solution to solve the crisis, but it was absent the solution represented by the development of technology, which proved to be the right solution, especially after it responded to government regulations and the standards set by it, to succeed in solving the problem to a large extent and achieve government and societal demands to reduce the amount of pollution in addition to improving energy efficiency. The results showed the amount of pollution generated in the 2000s compared to what it was in the sixties and seventies. From the above, it is clear that the issue of "sustainability" requires finding balanced and reasonable solutions (Cox & Ziv, 2005.).

However, this study will take into consideration five dimensions of sustainability (social, economic, environmental, resource indicators, and technology indicators). From a literature review, these dimensions can be explained as follow:

Social dimension: The social dimension is still under discussion; however, we can summarize the main idea that this dimension is working to guarantee the rights of all individuals at the different levels in society on an equal basis. In addition to that, it seeks to develop self-confidence and provide opportunities to participate in the performance of tasks, which supports self-confidence and a sense of belonging among workers in institutions on the one hand, and among members of society on the other.

Economic dimension: The economic dimension expresses sustainable meaning as the process of preserving the income of the human community in a sustainable manner and, at the same time, preserving the capital. The mechanism to achieve this goal can be summarized by developing and improving the mechanisms that preserve capital, such as avoiding waste of resources, proper planning of production rates for processing and demand, and other various processes that work to reach and achieve this goal.

Environmental dimension: The environmental dimension can be expressed as the process of preserving resources by using them in a perfect way that ensures the provision of needs for the current generation and guarantees the rights of future generations while working to reduce pollution. The mechanisms used to reach this sustainable dimension are to find methods and techniques that reduce the waste of resources, on the other hand find sustainable alternatives resources that can be used to meet the needs and ensure their availability for future generations while maintaining the optimum limit of unsustainable resources for the longest period of time possible to guarantee rights to the largest number of generations.

Resource dimension: The fourth dimension works in parallel with the environmental dimension in terms of preserving the resources, optimizing their use, and benefiting from them to the greatest extent possible by following different mechanisms such as directing resources towards recycling and reuse besides the other methods that help in reaching the goal of this dimension, also it works to find the alternatives appropriate from the available resources in a way that ensures meeting the needs of current generations of resources and ensures the meeting of the need for the future generations.

Technology dimension: The technological dimension is one of the dimensions that has been recently proven and which still needs many studies. However, this dimension can be described by finding the appropriate technology that works on the optimal use of resources and the removal of unnecessary processes that are considered waste in the industrial sector. Also, it can be said that this dimension overlaps with the other dimensions by providing the necessary technology that will help to achieve the other dimensions.

2.2. Lean and Sustainability Relationship: An Overview:

The topic of lean became common through a book, "The Machine That Changed the World," The lean concept is defined in many ways because lean is still evolving (Cherra et al., 2016). Lean manufacturing is a common means of continuous improvement that has reshaped global manufacturing processes, practices, and principles. It revolves around a philosophy of continuous performance improvement through systematic waste disposal on the manufacturing floor (Thangarajoo, 2015). A review of the literature agreed that the main principles of lean are (value, value stream, flow, pull, and perfection) (Mohammed & Obaid, 2016); the principles were presented to address the many challenges that arose inside and between business units as a result of variances in company culture and management thought process (Thangarajoo, 2015). The basis of the lean management philosophy is that the overall performance of an enterprise must be directed into a logical and singular system with the main objective of providing value to clients, and indicating that a lean process alone cannot be the source of all benefits (Cherra et al., 2016).

In parallel, the concept of sustainability started to be popular after the Brundtland report in 1987 (WCED, 1987), which was interested in the conflict between humanity's desire for a better existence on the one hand and nature's constraints on the other. Over time, the notion has come to be reinterpreted as embracing three dimensions: social, economic, and environmental (Kuhlman & Farrington, 2010). In fact, the dimensions of sustainability extend to include other dimensions in addition to the three commonly mentioned dimensions, such as the technological dimension that (Vacchi et al., 2021) proved in their study after he saw that the technological dimension remained a term that suffers from a lack of vision as an integral part of sustainability at the same level as the other dimensions: the environment and the economy and society. The reason behind extending the dimensions of sustainability is to return to the fact that sustainability is usually seen as a way for economic and social conditions in parallel with environmental conditions. More than two decades after the World Commission on Environment and Development (WCED) defined 'sustainable development' and put the concept of sustainability on the global agenda, the concrete meaning of these terms and their suitability for specific cases remains disputed. A new conceptual framework to address

sustainability issues is needed. The limitations of the WCED definition could be mitigated if sustainability is seen as the conceptual framework within which the territorial, temporal, and personal aspects of development can be openly discussed (Seghezzo, 2009)

There are many definitions for sustainability, and the popular one (WCED) in (1987) is: “economic development that meets the needs of the present generation without compromising the ability of future generation to meet their own needs.” (Herrero & Ibáñez, 2015). Sustainability aims to create mechanisms that contribute to maximizing profits while preserving environmental aspects, as well as the need for communities while preserving the rights and protection of employees (Cherra et al., 2016). The Global Goals of the Sustainability development (SDGs) adopted throughout all United Nations member States in 2015 represented work against poverty, protecting the planet, and making sure that all people around the world live in peace and prosperity (Fukuda-Parr, 2016) Because sustainability aims to create mechanisms that contribute to maximizing profits while preserving environmental aspects, as well as the need for communities while preserving the right and protection of employees, So, over time so many studies have been made to achieve the right standards and methods to assist businesses in establishing a comprehensive corporate social responsibility(Cherra et al., 2016).

Although many studies have supported the importance of using lean to improve the flow of operations, there are still many problems in its application. Perhaps the most important limitations are its weakness in dealing with variance and the lack of consideration for human aspects, in addition to the operational focus being confined to the workshop floor (Keitany & Riwo, 2014). There are also a number of other problems represented by complaints from trade unions and the increase in the responsibilities of employees in companies without an appropriate increase in terms of salaries. These problems are the result of a misunderstanding of the mechanism of the way lean works, and these problems appear more clearly in small and medium companies (Cowger, 2016). The reason for these problems is not related to lean as much as to the need to understand how it works. According to (Dombrowski & Mielke, 2013), the correct application of lean depends largely on the level of understanding of senior management

in companies of its work mechanisms and the correct way to implement it, with the need for an understanding between senior management in companies and workers to work together in order to create an image of the integrated application of it, in addition to the need for developing long-term employees and leaders. Many researchers advocate that lean is fundamentally linked to sustainability (Mollenkopf et al., 2010) because lean supports the following points, which are considered the main goals of sustainability, such as reducing cost, emission reduction, creating economic value, improving the condition of work, as is explained further. In fact, even today, the correlation between lean and sustainability is still not conclusive, and, also, the relationship is not well known between these two terms (Varela et al., 2019). Reviewing the literature showed that there are differences between various sectors about the influences of lean on sustainability. However, there are many sectors that need to be studied to evaluate the relationship between the two terms, as the situation in the solar energy sector in Turkey shows. Reviewing the literature showed that no framework to explain the relationship between lean principles and sustainability dimensions in the solar sector was found; however, the positive impact of adopting lean to reduce waste and, as a result, increase efficiency was proved through certain studies. This shows the probability of finding a relationship between lean principles and sustainability dimensions and that the effect is not a coincidence. However, even today, there are different opinions about the relationship between lean and sustainability, which will be explained in the next parts lean and sustainability relationship through different studies. The attention on the relationship between lean principles and sustainability development led the researchers to study the effect of lean to achieve sustainability and the degree of the relationships between them. In fact, there are differing viewpoints in the literature on the relationship between lean and sustainability. This statement can be divided into the following: (1) Studies support that lean achieves the sustainability agenda, (2) Studies advocate that lean does not match the main sustainability agenda, (3) Studies claim the integration between lean and sustainability; these points will be demonstrated in detail in the following section.

2.2.1. Lean Achieves Sustainability Agenda:

In general, the studies support the idea that lean is achieving the sustainability goals, that is, lean is removing waste and optimizing the whole operation. One research study found that lean promotes sustainability in manufacturing through an energy-saving and emission-reduction strategy (Cai et al., 2019), and, according to another piece of research, it is possible to create environmental benefits alongside economic value, for example, eco-friendly goods are less expensive to manufacture as lean and green methods are incorporated into the design and service delivery processes (Kumar & Rodrigues, 2020). A study that analyzed sustainability reporting found that adopting lean in different companies increases the quality of the work conditions (Varela et al., 2019); another study of analysis and synthesis models found in selected research reported that integrating lean–green policies is an effective way to maintain and expand a greener manufacturing operation (Abreu et al., 2017). A study about a solar power plant found that smart, lean manufacturing improves efficiency through the reduction in waste and non-value-added activities (Albezuirat et al., 2020). Another study, which examined the interaction between the principles of lean and sustainability in the AEC industry, showed that by adopting those principles in terms of optimizing processes and stakeholders' quality of life, reducing all forms of waste, the tracking and self-evaluation for performance growth, and marketing challenges, lean and sustainability production could have a virtually identical agenda (Khodeir & Othman, 2018).

2.2.2. That lean does not match the main sustainability agenda:

Other researchers have argued that lean does not match the main agenda of sustainability. A study to evaluate the relationships in the Iberian Peninsula adopted the view that the relationships remain poorly understood and were dispersed by various sustainability indicators because their results found that the evidence that lean manufacturing is linked to any of the sustainability foundations was inconclusive (Varela et al., 2019). A study using a green–lean simulation model claimed that implementing lean methods has a negligible impact on the company's environmental results (Golzarpoor & González, 2013), while another study reported that lean alone can not achieve the sustainability targets or address all of the sustainability matters (Inman & Green, 2018). This is because the matters of increasing production in the sector of

renewable energy, increasing the salary remuneration, or increasing turnover was not identified (Varela et al., 2019).

2.2.3. The integration between lean and sustainability:

Some researchers have attempted to incorporate sustainability into the lean concept to maximize its gains; a study about integrating sustainability and lean reported that "Sustainability and leanness are organizational approach concepts for more efficient activities and increased competitiveness" (Tăucean et al., 2019), and, in another study, the authors suggested the use of lean strategies to improve sustainable manufacturing with an effect on the environment since the study's research results showed that integrating the two dimensions enhanced the system's performance and led to the growth of a sustainable company (Florescu & Barabaş, 2018). Another study reported that lean is the first step towards achieving sustainability. They even declared that environmental sustainability is the next step in the lean philosophy to minimize the product's negative impact on the environment and safe resources, and this was what was happening in the Japanese auto industry; they were beginning to use lean toward the currently hybrid engines and vehicles with recycled components (Carneiro et al., n.d, 2012). In conclusion, we can notice that there are various opinions about the relationship between the two terms, but, at the same time, many researchers support the idea of the ability to find interaction and an alignment between lean and sustainability goals. Thus, to build a framework that aims to adopt the use of lean principles to achieve sustainability in the solar energy firms in Turkey, there must be a set of steps to follow to make sure that there is a relationship between the two terms in this sector. These steps will be explained in the methodology used in the study. Influence of lean on sustainability Dimension This section focuses on the degree to which the use of lean can improve the results of sustainability factors. As pointed out in this research, the views differed among researchers about the impact of the application of lean on sustainability and the relationship between them. In general, some companies have succeeded in achieving better results and higher competitiveness through the application of lean principles, while others have not been able to achieve these results as they have not been able to maintain medium- and long-term results (Souza & Alves, 2018). The following paragraphs outline some of the most important recent contributions made by a group of

scholars to explain the lean–sustainability area; the main influences are summarized as follows:

1- Influence of adopting lean in the social dimension:

Despite the importance of the social dimension as one of the main dimensions of sustainability, this dimension has not been sufficiently studied, as referred in the study of (Khodeir & Othman, 2018) to the need to pay attention to the social dimension as a goal affecting the situation in the environmental dimension side. The result of reviewing the literature showed that applying lean appeared to impact some sectors of the social dimension, such as increasing the quality of work (Ioppolo et al., 2014)(Vinodh et al., 2011) and increasing employee engagement in decision making (Vinodh et al., 2011).

2- Influence of adopting lean in the environmental dimension:

Many studies supported the view that environmental management is greater in the firms adopting lean in their progress: adopting lean will help in increasing performance, as well as help decrease industrial waste (Souza & Alves, 2018)(Gupta et al., 2018), energy saving, and emission reduction (Cai et al., 2019). Despite that, we notice that no references were found about the effect of lean on environmental sustainability in renewable energy companies (Varela et al., 2019).

3- Influence of adopting lean on economic dimension:

Economic performance, which is assessed by productivity, cost reduction, revenue, profit, cash flow, and business growth, is one of the pillars of sustainable performance. Achieving inclusive sustainability through the lean approach enables institutions to emphasize reaching economic sustainability (Dey et al., 2020). When reviewing the literature, the results showed that applying lean would help to maximize the profit (Brasco et al., 2013), increase the performance of the process, and decrease the operational cost (Díaz-Reza et al., 2016). However, there are few references about the effect of lean in the economic dimension, and even for the turnover impact, no references were discovered (Varela et al., 2019).

2.3 Adopting lean principles and sustainability: Benefits

According to several studies, implementing lean in their processes resulted in significant improvements.

1. Fewer defects and rework (in-house and at customer).

2. Weirder machines and processes

3. Lower Inventory levels

4. Increased Stock Turnover.

5. Less Space Needed

6. More output per hour.

7. Better delivery results.

8. Faster growth

9. More satisfied customers

10. Enhanced employee engagement and morale.

11. Better supplier relations

12. More profit

13. More business.

Meeting the energy SDG has the potential to reduce poverty and improve health and well-being. Energy access enables social and economic development, improving livelihoods and economic progress (United Nations Foundation, 2013). Energy access is essential for human development; no country has significantly reduced poverty without expanding energy access (UNEP & WHO, 2009). Access to clean and affordable energy can also help children study longer and prevent 800,000 premature child deaths due to indoor smoke exposure; many people still lack access to modern energy sources.

Sustainable energy also helps combat climate change. To stay within safe global climate limits, high per capita fossil-fuel energy users will need to drastically reduce their GHG

emissions. The 350 or 550 ppm CO2 threshold proposed by Rockström and others as one of the planetary boundaries will soon or has already been exceeded (Rockström et al., 2009). Although improvements in energy efficiency reduced global energy demand by over 25% from 1990 to 2010 and renewable energy supplied over 1,000 ex joules during the same period, rapid population and economic growth diluted these gains (World Bank, 2014). Overall energy consumption is expected to rise rapidly in parallel with rising global populations and economies, outpacing global progress in energy efficiency and renewable energy share. None of these measures alone can limit global warming to two degrees by 2030. (Rogelj et al; 2013). Some countries already have energy-saving targets in place as part of their integrated sustainable energy policies. Several EU nations have set national energy-saving goals.

Although energy has always been a contentious issue, the many benefits of sustainable energy are beginning to attract widespread support. Perhaps this is why an energy goal was so widely supported at Rio+20 and the Open Working Group (OWG). Back in Johannesburg in 2002, the EU and Brazil proposed adopting concrete renewable energy targets, but the G77 and OPEC refused, citing priority for the poor's access to energy (Ohga, 2012). It is critical that future universal goals include long-term visions supported by targets and indicators for use at regional, national, local, and even community levels. Those targets will need to be tailored to each country.

2.4 Solar Energy Sector in Turkey:

The Turkish government decided to encourage business in RETs for relatively clean electricity production and viable socio-economic development in Turkey. Evaluation of renewable energy investment risk factors for Turkey's sustainable development Traditional fossil fuel energy systems must be replaced by renewable energy technologies (RETs) to achieve Paris-compliant energy systems The risk factors of renewable energy investment for sustainable development in Turkey.

Population growth, rapid urbanization, and the development of new industries have all increased the demand for energy (Kul et al., 2020). However, a suitable option for countries like Turkey is to meet energy needs while reducing environmental damage. Risk factors for renewable energy investment in Turkey, current energy generation is

insufficient to meet current demand, and demand is expected to rise by 4–6% annually until 2023. Environmentally, the Turkish government offers many purchasing guarantees and high incentives. Also, since 2010, many positive regulations and incentive plans have come into force, making wind and solar energy the most suitable renewable energy source in Turkey. (Erdin & Ozkaya, 2019)

Turkey has a higher solar energy potential than many other European countries due to its location. The average annual sunshine duration in Turkey is 2640 hours (7.2 hours per day), and the average total solar radiation is 1311 kWh/m-2year (3.6 kWh/m2 daily [9]). In addition, the theoretical total power capacity of solar energy for Turkey is 300 TWh/year, which is 45 percent of the 2023 target. However, the 2023 solar energy targets (photovoltaic and condensed solar energy) may be exceeded (Ozturk & Yuksel, 2016). Due to its location, Turkey has high solar energy potential. The sun has a potential energy output of 380 billion kWh. The gross solar energy potential of Turkey is 87.5 MTOE. 26.5 of this is suitable for thermal use and 8.75 for electricity generation.

The Turkish Ministry of Energy and Natural Resources Solar Energy Potential Map (SEM) shows that:

1. Average annual sunshine hours = 2766.5

2. Daily average sunshine time = 7.58 hours, while

3. Radiation intensity = 1527.1 kWh/m2/year, then

4. ADR = 4.18 kWh/m2/day calculated as.

The sun can be used efficiently for up to 110 days per year. It can be economically and technically exploited on 63 percent of the country's surface during the ten months and 17 percent year-round. Table 2.1 shows Turkey's solar energy potential and sunshine duration by month. (Erdin & Ozkaya, 2019).

Table 2. 1 Turkey’s monthly average solar potential

Months	Monthly total sun energy		Sunshine time
	(kcal/cm2-month)	(kWh/m2-month)	(hours/months)
January	445	5175	1030

February	544	6327	1150
March	831	96.65	1650
April	10.51	122.23	1970
May	1323	153.86	2730
June	1481	168.75	3250
July	1508	175.38	3650
August	1362	158.40	3430
September	10.60	123.28	280.0
October	773	89.90	21-40
November	523	60.82	157.0
December	4.03	46.87	1030
Total	112.74	1311	2640
Average	308 0 Cal/cm: -daily	36 kWh/m2 daily	72 hours /dally

2.5 Sustainability Goals of Turkey:

The scope of sustainable development is to assess it in terms of industrial, environmental, social, and economic aspects. Aspects of environmental, social, and economic sustainability can be evaluated according to (Hales & Prescott, 2002).

Sustainable behavior should be measured, and the progress of sustainability assessments should be clearly applied. The need for clarification results in many descriptions and structures of sustainable development indicators, which are useful for informing the public, decision-makers, and managers about the outcomes of sustainability scenarios (Van & Manuel, 2008). Sustainable energy is defined as energy produced, conserved, and used in ways that promote or at least are compatible with long-term human well-being and ecological balance (UNDP, 2000). Sustainable development is a triangle with energy, environment, and economy as equal partners. While renewable energy is an important indicator of sustainability, it does not provide desired sustainable development without environmental protection and economic indicators (Baris & Kucukali, 2012). Sustainable energy focuses on energy security, energy resource management, and environmental protection (Stanford, 1997). Improving the security of the energy transit, decreasing the cost of energy production, and increasing the use of

green technologies are important targets for sustainable energy. Even though nature can tolerate small increases in CO2 emissions, high levels cause the global warming effect. Low carbon emission technologies are therefore vital for sustainable energy roadmaps. Also, sustainable energy requires energy flow and waste removal without exceeding nature's carrying capacity. A community's well-being is affected by the security of the energy transit. The cost of energy production is also a concern for industry and households. Access to energy sources is a human right, and technological advancement should reduce costs. Increasing global use of renewable energy technologies is an important target for sustainable development. Davidson (Oyedepo, 2012) that sustainable energy is defined as energy that meets economic, social, and environmental needs within the overall developmental context of the society it serves while recognizing the equitable distribution of those needs and efficient use of renewable energy. Sustainable development organizes natural resources to meet the needs of present and future generations. The efficient use of current energy resources is a critical goal for the future of energy. In this context, an energy efficiency is an important tool for achieving sustainable development. The indicators of sustainable development took into account the economic, social, environmental, and institutional dimensions. Environmentally friendly energy sources and generation structures should be expanded as part of Turkey's sustainable development strategy. One of the primary indicators for sustainable economic and social development is renewable energy. Like other developing countries, the country's energy consumption rate is rising due to rising population, urbanization, industrialization, technology, and wealth. The goal of sustainable development is to reduce energy consumption and thus supply costs while supporting economic and social growth while minimizing environmental damage. Sustainable development is achieved by increasing domestic production efficiency, diversifying energy sources to ensure fuel supply, speeding up existing construction programs, and initiating new investments. In terms of renewable energy, the country has a lot of potentials. The use of renewable energy sources in the country is vital for sustainable development and foreign capital flow. Using renewable energy reduces reliance on imported fossil fuels (especially oil and natural gas), reduces greenhouse gas emissions, and may even allow the export of green electricity to Europe. Concerns about global warming, air quality, and environmental destruction have prompted society

and governments to consider sustainability. So, to improve current energy strategies, sustainable energy resources should be used. In order to find sustainable energy sources and to use current energy sources efficiently, research has been done. Many researchers recommend limiting the use of fossil fuels and updating energy policies to include renewable energy sources. The importance of renewable energy grows as environmental issues like global warming, pollution, and degradation of natural resources worsen. When compared to conventional fossil fuel technologies, renewable energy sources will be able to solve or at least reduce environmental problems (Ozturk & Yuksel, 2016). Access to affordable, reliable, sustainable, and modern energy is a basic need and an important component of reducing poverty. In 2010, all Turks had access to electricity. In 2017, renewable energy accounted for around 12% of total energy consumption. 26 SDG 7 requires significant financial investment. It is impossible for the state to cover all costs. Private sector investments in renewable energy, energy efficiency, green buildings, and clean energy resources will help achieve SDG 7. (TURKEY's 2nd VNR, 2019).

2.6 Turkish Policies for Sustainable and Modern Energy:

Policies The National Energy Efficiency Action Plan, Electrical Energy Market and Supply Security Strategy, Turkey National Renewable Energy Action Plan, Energy Efficiency Strategy, National Climate Response Strategy, Climate Action Plan, Climate Adaptation Strategy, and action plan are key policy documents on SDG 7. The policy framework for SDG 7 includes the following key elements. Making the best use of domestic and renewable energy resources while ensuring their security, economics, and quality.

• Increasing the share of renewable energy in power generation through the different resources.

• Investing in renewable energy sources like hydropower, solar, wind, geothermal, and biomass.

• Subsidizing domestic equipment used in renewable energy production.

• promoting building energy efficiency.

• Improving energy efficiency.

• Industrializing high-efficiency motors.

• Increasing use of electric vehicles.

(TURKEY’s 2nd VNR, 2019).

3. RESEARCH METHODOLOGY

3.1 Research Strategy:

According to (Robson, 2002), for the purpose of answering the research questions, there are three research strategies. Which are (experimental, questionnaires, and case studies). To do any study, the researchers shall choose one of these strategies or all of them, according to the type of the study.

This study centers on the point of the agreements of responsible people in solar energy firms to implement the lean principle in their firm's processes to achieve sustainability dimensions. In addition, the approach of the research is to answer the study's questions, and it is exploratory-descriptive, explanatory, and correlative.

To fulfill the main aim of the research and to build the framework, a number of steps with a particular method for every single step are used; the steps are as follows:

1- Exploratory research through reviewing of the different literature such as articles, books, conferences, and papers.

2- Using a quantitative questionnaire. As a descriptive-analytical approach to conduct this study, the essential points to be inquired about each factor were identified in the questionnaire. The purpose of the survey was to answer the hypotheses formulated through reviewing the literature. The hypotheses were established to scout the significant relationships between respondents at ($\alpha = 0.05$) about adopting lean principles in the solar energy sector and achieving sustainability also; the purpose of using the survey is to measure the level of the relative importance of the two terms (lean and sustainability) from the point of view of managers and experts in solar energy firms.

3- The last step is testing the hypotheses of the study and building the framework of the study by analyzing the data of the study in two phases, descriptive and statistical analysis, through using SPSS_v25.

Different statistical methods were used to analyze the data; these methods included Independent T-test, ANOVA-Test, and LSD test; besides, frequencies and percentages were used too. In addition, the hypotheses were examined by applying linear regression analysis, and a correlation was used too to measure the correlation between the items.

Besides, a non–linear analysis is used to explore if there is any probable relationship between the principles of lean and sustainability dimensions.

3.2 Population and Sample Size:

According to (Parahoo, 2014), the population definition is "the total number of units from which data can be collected" also, (Burns & Grove, 2003) explained the research population as the units that can meet the criteria of the study.

The questionnaire of this study was designed to measure the awareness of the people in charge in solar energy firms about the importance of the two terms (lean & sustainability) and the implementation of lean principles to achieve the sustainability dimensions. In fact, the solar energy firms in Turkey are working in different sectors, so, in this study, it was decided to make a thorough sample.

In reality, no official statistics about the number of solar energy firms in Turkey is found. Therefore, in this study, the largest associations operating in these sectors were relied upon, such as "Solar Baba," which contains 120 members and supported, to direct the questionnaire to them as a population of the study.

The researcher works to measure the awareness about the implementation of the lean principles in solar energy firm projects in Turkey from the point of view of the responsible people in these companies (Expert & Managers).

In addition, the determination of the very acceptable sample size depends on the type of the research, namely: the sample size of the descriptive research is at least 10% of the population sample size (Hill, 1998). In this research, the total population is close to 110, and by using the formula of Cochran for calculation of the sample size in the Small Population with 95% confidence level and confidence interval 5, as follows:

$$n = \frac{no}{1 + (no - 1)/N} \quad \text{…….1}$$

n = Sample size

n_o = Sample size (in big population)

N =population

So, to calculate the n_o, will use the formula of Cochran**.**

$$n_o = \frac{Z^2pq}{e^2} \quad \text{..... 2}$$

Where:

- e is the desired level of precision (i.e., the margin of error) = (0.05)
- p (probability) = (0.5)
- q = 1 – p.
- 95 % confidence level gives us Z values of 1.96

$n_o = ((1.96)^2 (0.5) (0.5)) / (0.05)^2 = 385$

Then:

n = 385 / 1 + (385 -1 / 110)

85.74 = 86

The result showed that the required sample size is 86, but it collected 35 as 41% level of responders, which is considered as an acceptable response rate. In fact, the researchers who deal with top managers to gain data might face lower response rates than the researchers who study non-executive employees. In addition, some researchers have found that companies have explicit policies against providing company-level data to external parties in this research. This point is considered one of the most important reasons for decreasing the response rate. (Baruch & Holtom, 2008.)

3.3. Questionnaire design and its content:

In this study, the data is collected by adopting the questionnaire as the better way to gather the required numerical data and the adequate tool for this study to confirm the research hypothesis. Also, it's considered a rapid way to collect data. In this study, the

questionnaire was designed in two versions, the first one in English and the second one in Turkish, to receive a high level of responses.

The questionnaire was prepared in sequential steps according to the data collected through the literature review. The first step conducted the identification of the main research objective. The second step is to conduct the variables of the study that shall be studied and analyzed to achieve the objectives. The third step is to build questionnaire items to estimate each variable. The survey contains two sections besides the description part about the study to make the responders familiar with the purpose of the study. The two sections of the questionnaire were prepared as follows:

1- The first section is a demographic characteristic of the firms and contains eight questions; these descriptive questions were divided into two types, five of them as structured questions with predetermined response options, while the rest of the questions were structured as open response options. Such as position of the responders, company's location in Turkey, company experience in this sector, the capital of the company and the average size of the company's projects, and the number of employees working in the companies.
2- The second section is about the factors of the two terms and contains 44 questions, with 3–5 questions for every single factor of lean and sustainability. Questions were structured with predetermined response options by using five-point Likert scales ranging from "strongly disagree" to "strongly agree."
In preparing this questionnaire, it worked to take into consideration all the aspects of the literature review and take into account all the variables affecting the research objective.

The used survey is shown in appendix (A).

3.4 Scale of measurement:

In the questions of the survey, a five-point Likert scale was used structured with predetermined response options, which range from "strongly disagree" to "strongly agree" and scored as follows: (1) Strongly disagree, (2) Disagree, (3) Neutral, (4) Agree, (5) Strongly agree. The scales of responses are shown in Table 3.1:

Table 3. 1 The Likert-Scale.

Rank.	The responses	Grade value
1	Strongly disagree	1
2	Disagree	2
3	Neutral	3
4	Agree	4
5	Strongly agree	5

3.5 Research procedure:

The preparation of the questionnaire went through sequential steps, starting with reviewing the literature to determine the variables that shall be studied with the items for every single variable; the second step is obtaining approval from the supervisor and making the required adjustments; after that, the questionnaire is directed to a group of experts who have knowledge in the subject of the study to develop the questions and find the best formulation for the questions, taking into consideration the most important aspects to be focused on, and investigating through the opinions presented by them to ensure that the questions would be helpful for reaching the goal of the study. The last step before distributing the questionnaire to the samples of the study is to prepare the final copy of the questionnaire in Turkish and English language.

In the third step of the procedure, the questionnaire was directed to the responsible persons (Managers and Experts) in the solar energy companies in Turkey to fill out the questionnaire because of their direct participation in the work process, also, because of their sufficient knowledge and experience they had about their companies. The questionnaire is directed in two stages: The first use of the answers is to test the reliability by using Cronbach's Alpha test. According to the rule-of-thumb, values ≥ 0.7 were accepted by researchers to determine the strength of association as a good value (Hair et al., 2016), as shown in Table 3.2, and determine which questions would be adopted in the questionnaire. The second step starts by using the final copy of the questionnaire after making the adjustments according to the reliability results. The received information was used as a database and for doing the analysis.

Table 3. 2 The strength of association according to the rule-of-thumb.

Rank.	Alpha coefficient range	Strength of association
1	< 0.6	Poor
2	0.6 to < 0.7	Moderate
3	0.7 to < 0.8	Good
4	0.8 to < 0.9	Very Good
5	0.9	Excellent

The questionnaire was distributed as an online survey by using google forms to the companies. Also, the survey was resent to some of the companies again to increase the number of respondents. The response rate is 41.6 % which is considered an acceptable rate. Finally, all the received respondents were used as data to be analyzed using Spss_v25 and Excel programs.

The database is analyzed in two phases; the first one is the analysis of the descriptive information gathered in the first section of the survey to describe the difference between the participants according to the descriptive data and to know at which level the companies will be more familiar with the importance of adopting lean principles to achieve the sustainability dimensions, that many companies today working hard to achieve it, to help them in the competition in the marketplace. To do the first phase, a couple of analysis tools were used, such as the independent T-test, ANOVA-Test, and LSD test, besides frequencies and percentages were used too.

The second phase was the analysis of gathering the data for the second section of the survey to test the hypotheses of the study and to measure the relationship between lean principles and sustainability dimensions, in addition to exploring if there is any significant effect in adopting lean principles to achieve sustainability dimensions.

Also, the relationship between the items of the two terms of the study is studied by using the correlation to check if they are related to each other or not. Furthermore, the awareness of the responsible people in solar energy firms about the importance of implementing the two terms is measured by calculating the mean of the answers and comparing them with the Likert scale level of agreement.

The procedure that used in this study can be summarized in the flow chart, figure 3.1, as follow:

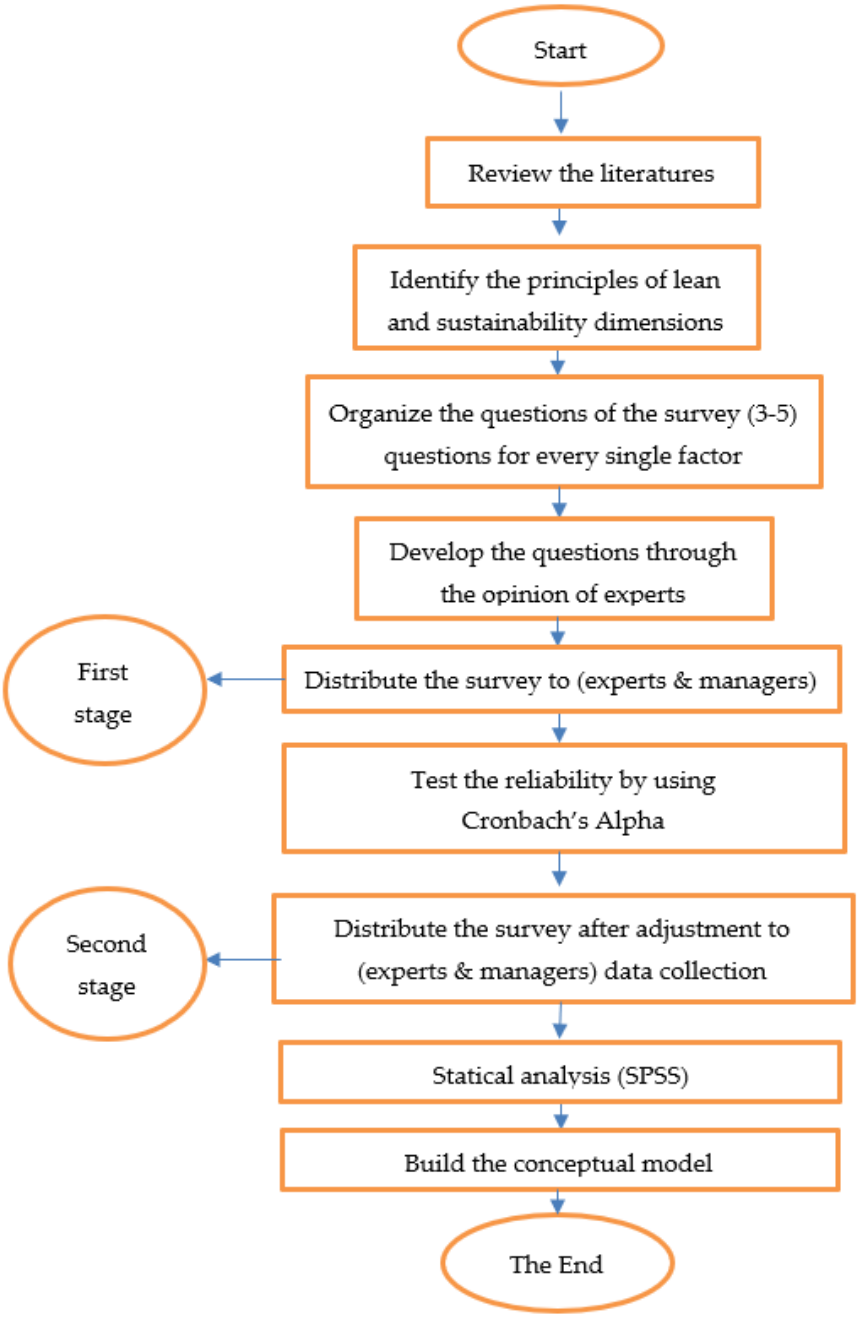

Figure 3. 1 An overview of the procedure of the study**.**

3.6 Testing the Reliability of the Questionnaire:

To make sure of the consistency of the questionnaire, the reliability analysis is conducted by using Cronbach's alpha test.

The research focused on using Cronbach's alpha because it is considered an ordinarily used technique that is known in the systematic literature as having major limitations. In addition, Cronbach's alpha is used as an indicator for different types of reliability, such as interrater and internal reliability, reliability of separation and coherence, or - and unidimensionality.

Gardner referred in his research (Gardner, 1995) in the part of the discussion the science education on the topic of " instruments to measure attitudes to science" that Cronbach's alpha is the most common statistic used in the present time to "estimate internal consistency."

However, Cronbach's alpha in addition to the uses of it as an indicator of internal consistency, it's used as a scale of reliability. Cronbach's alpha has been used in a common way since being discussed by Cronbach in 1951, and he declares his famous suggestion that the use of α is more suitable than the way of repeatedly referring to it (Taber, 2018). According to the rule of thumb, values that are more than 0.7 are considered acceptable values (Hair et al., 2016); besides, these values refer to high consistency. Table 3.3 shows the alpha values for all of the lean and sustainability factors, which ranged between 0.723 – 0.823. According to the rule of thumb, the values are considered acceptable results, and the strength of association for these values ranges between good and very good values.

Table 3. 3 Evaluation of the stability of the tool using Cronbach's Alpha.

Rank.	Factors	Cronbach's Alpha
	Lean factors	
1-	Value	0.724
2-	Value Stream	0.752
3-	Flow	0.753
4-	Pull	0.749
5-	Perfection	0.823
	Sustainability factors	
6-	Social	0.751
7-	Environmental	0.771
8-	Economic	0.723
9-	Resource Indicator	0.736
10-	Technology Indicator	0.786

4. RESULTS AND DISCUSSION

4.1 Descriptive Analysis of Responders' Firms:

The questionnaire included eight questions in section (1) as descriptive information about the Participants on the survey; the respondents' analysis appeared to have different statistical information. So, in this section, the description will be about the difference between respondents' results. Sample Character:

The frequency analysis is applied to determine the characteristics of the received respondents.

1- Position of the responders:

The questionnaire was directed to the people in charge in solar energy firms, who are the managers and experts; the results showed that (21) of the responses were received from the managers and (14) of the responses were received from the experts as shown in figure 4.1, these results will strengthen the outcomes of the study according to the high expected knowledge from these responders about all the process that solar energy firms are adopting.

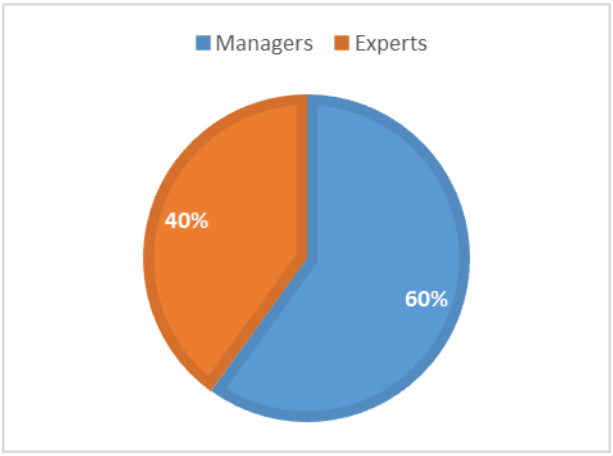

Figure 4. 1 The responders' positions

2- Company's location:

The following figure 4.2 displays the distribution of the participants in the survey according to the company's location in Turkey as follows: Istanbul (11), Ankara (5), Antalya (4), Izmir (5), and (10) from other cities in Turkey. The samples' distribution is considered reliable according to the large geographical scope it includes and is not

limited to one geographical area in Turkey. Besides, it indicates the great interest in this sector and the increase in awareness and demand for its use through the presence of companies specialized in it in various Turkish cities.

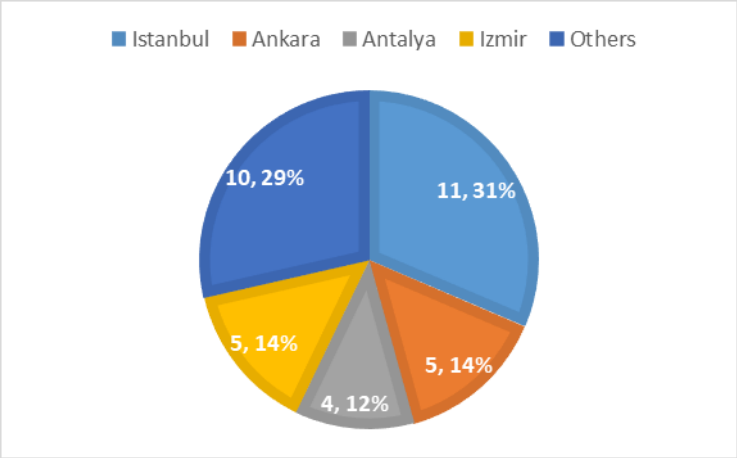

Figure 4. 2 The distribution of the participants according to the company's location in Turkey

3- Company's experience:

Figure 4.3 shows the distribution of the participants in the survey according to the company's experience as follows: 43 % less than five years, 34 % from (5-10) years, 12 % from (11-15) years, and 11 % more than 15 years. The result showed that most of the companies are between less than five years and from (5-10) years, which refers to the development in the solar energy firms sector through the increase in the number of companies in Turkey in the last ten years. It also clearly indicates that Turkey is working towards achieving its goals related to renewable energy and achieving the required production of energy by investing in the field.

of solar energy and developing this sector through the increase in the number of solar energy companies in Turkey.

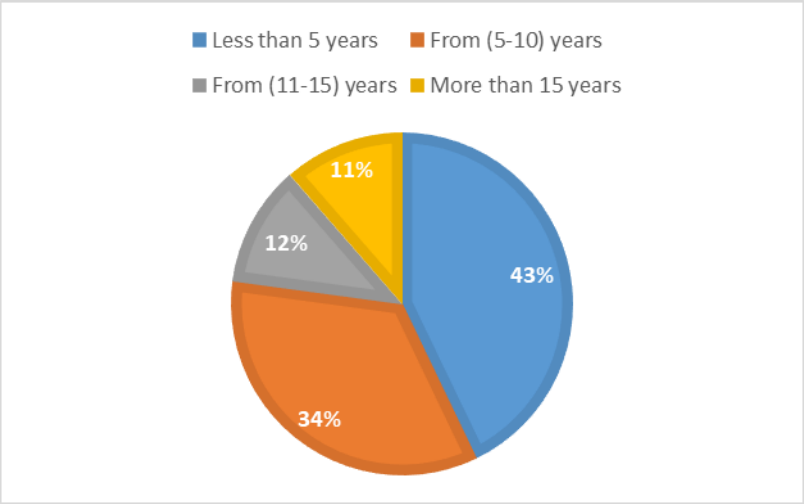

Figure 4. 3 The distribution of the participants in the survey according to the company's experience

4- Capital of the company (Thousand $):

Figure 4.4 shows the distribution of the participants in the survey according to the capital of the company (Thousand $) as follows: 23 % (less than 200), 29% between (200-400), 14 % between (400 – 800) and 34 % more than 800. The distribution showed the assortment of the financial capabilities between companies that reflected the size of these companies; in addition, the results indicated that many of these companies have a big budget. This big budget is assumed to help these companies to have the ability to participate in large projects, as well as the possibility of using this budget to add many improvements in the operations that are used in the company.

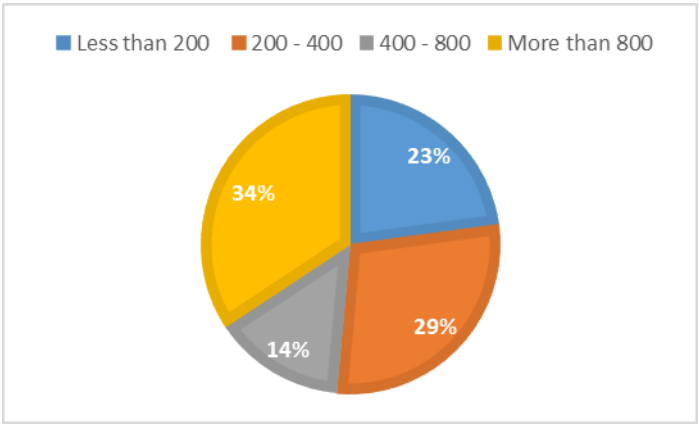

Figure 4. 4 The capital of the company (Thousand $)

5- The average size of projects the company is involved in (Thousand $):

Figure 4.5 shows the distribution of the participants in the survey according to the average size of projects the company is involved in (Thousand $): as follows: 6 % less than 200, 17% between (200-400), 29 % between (400-800) and 48 % more than 800, in fact, results referred that most of the participate firms in the study have the financial capabilities in the solar energy sector to involve with big projects more than their capital, also that they have a good experience in solar energy projects which reflected positively in increasing their level of interest to involve with a new management movement.

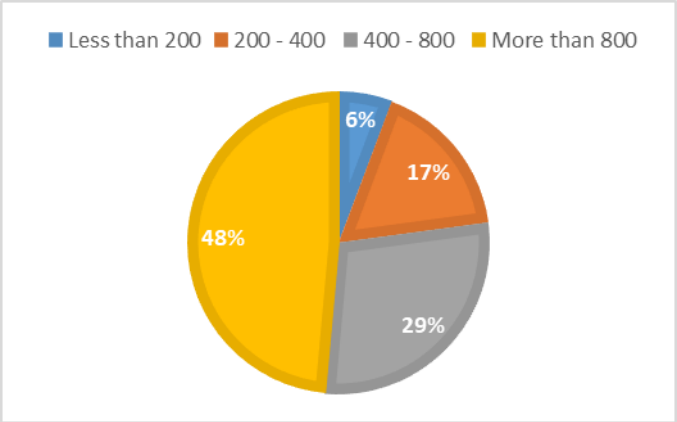

Figure 4. 5 The average size of projects the company is involved in (Thousand $)

6-The number of employees working in the company:

Figure 4.6 shows the distribution of the participants in the survey according to the number of employees working in the company as follows: 31 % (less than 20), 26 % between (20-40), 14 % between (41– 60), and 29% (more than 60). The results showed a real reflection in that most companies depend on temporary employees more than on permanent employees. This can be noticed in the results of the study, whereas a large part of the participating companies depends on a small number of employees.

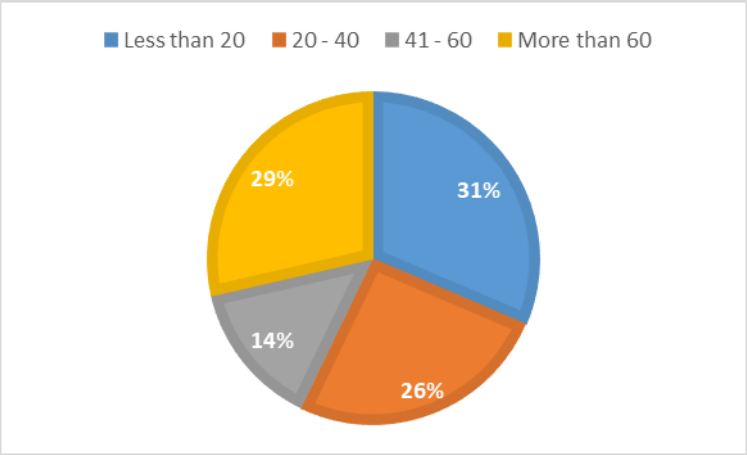

Figure 4. 6 Number of employees working in the company

7-The average number of contract employees working in the company:

Figure 4.7 shows the distribution of the participants in the survey according to the average number of contract employees working in the company as follows: 48 % less than 10), 26 % between (10 – 20), 9 % between (21 – 30), and 17 % (more than 30). The results referred to the hired employees as temporary jobs more than the employees as stable jobs. This may return to the increase in the involving firms to contracting with new projects and to the high competition between companies.

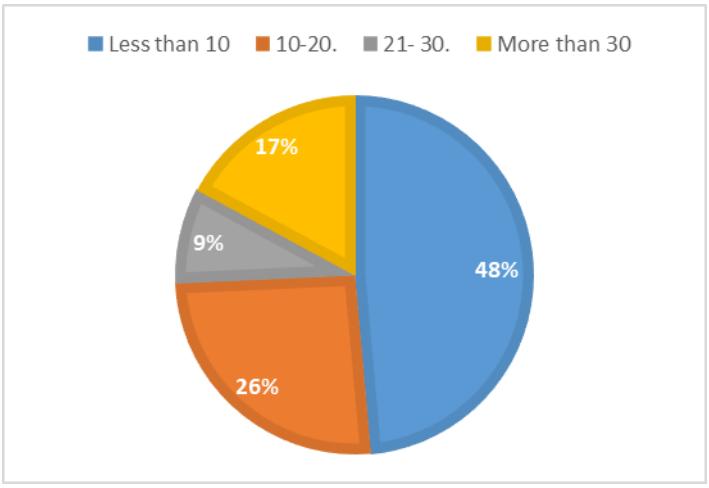

Figure 4. 7 Average number of contract employees working in the company

8-Company's field of work:

Figure 4.8 shows the distribution of the participants in the survey according to the company's field of work as follows: 30 % in the selling sector, 54 % in installation companies, 9 % in the manufacturing sector, and the other 7 % companies are working in different sides. The results indicated that most of the companies in Turkey are working in the selling and installation sectors, and it's obvious that the manufacturing sector still needs to increase the number of companies working on this side to meet the need of Turkey.

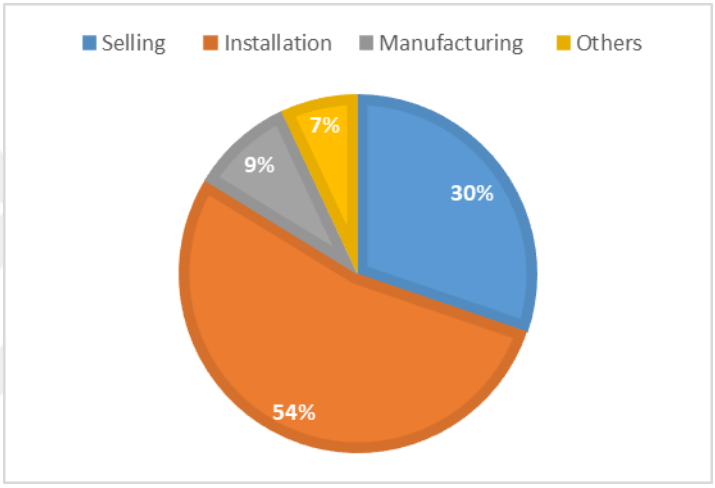

Figure 4. 8 Company's field of work

4.2 A descriptive Statistical Difference Between Responders' Firms:

This section aims to explore the differences statistical between responders according to their field's work, responder's position, company capital, and the size of the project

To explore this difference between the participant's T-test, ANOVA test, and LSD test are used because the ANOVA test works by comparing the means of the dependent variables that can be divided into three or more different groups or levels (Saunders et al.,2009). In the following paragraphs, an explanation for a couple of differences appeared in the results of the analyses:

1- The statistical difference according to the field's work of the participations:

The results of the study classified the field's work of the companies into four areas which are (selling, installation, manufacturing, and others); then Independent T-test is used because we have two groups to compare the means of independent groups to determine whether there is statistical evidence that the associated population means are significantly different. We can notice from the companies working on selling solar panels that they have a better mean or strong mean on the social factor, which indicate a high awareness, as shown in Table 4.1. While the companies working in the Installation sector give a better mean on the value and perfection factors, as shown in table 4.2, and the companies working in the manufacturing sector they provide a better mean on all of the flow, environmental, economic, and resources indicators factors as shown in table 4.3.

Table 4. 1 Companies selling Solar Panels

Group Statistics					
Selling Solar		N	**Mean**	Std. Deviation	Std. Error Mean
Social	No	21	**3.7579**	0.69147	0.15863
	Yes	14	**4.2308**	0.35446	0.09831

Independent samples test t-test for equality of means								
Factors		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the difference	
							Lower	Upper
Social	Equal variances assumed	-2.263	33	0.031	-0.47287	0.20899	-0.8996	-0.046

Group Statistics					
Solar Installation		N	Mean	Std. Deviation	Std. Error Mean
Value	No	10	4.1111	0.53196	0.17732
	Yes	25	4.4891	0.34934	0.07284
Perfection	No	10	4.3611	0.43501	0.14500
	Yes	25	3.8370	0.63786	0.13300

Table 4. 2 Companies Installation of solar panels

Independent Samples Test

t-test for Equality of Means								
Factors		T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
Value	Equal variances assumed	-2.367	33	0.025	-0.37802	0.15969	-0.7041	-0.05189
Perfection	Equal variances assumed	2.257	33	0.031	0.52415	0.23222	0.04990	0.99841

Table 4. 3 Companies working in the manufacturing sector

Independent samples test								
t-test for equality of means								
Factors		T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
Flow	Equal variances assumed	-2.748	33	0.010	-0.7928	0.2884	-1.382	-0.20
Environmental	Equal variances assumed	-2.211	33	0.035	-0.5571	0.2520	-1.071	-0.04
Economic	Equal variances assumed	-2.101	33	0.044	-0.5214	0.2481	-1.028	-0.01
Resource Indicator	Equal variances assumed	-2.085	33	0.046	-0.6517	0.3126	-1.290	-0.01

2- The statistical difference according to the responder's position of participation:

The questionnaire was directed to the responsible people (managers and experts) in the solar energy companies in Turkey to fill out the questionnaire because of their direct participation in the work process and their sufficient knowledge and experience about their companies. The results showed a statistical difference between responders related to the responder's position in solar energy firms using ANOVA-Test and LSD tests. ANOVA-test results showed that P-value is lower than the significant level in the

economic and resource dimension as follow, respectively (P=0.027 <0.05 & P=0.047<0.05); in addition, the LSD test results appeared that the awareness of engineering is higher than others on the Economic and Resources Indicators factors, as shown in table 4.4

Table 4. 4 The difference according to the responder's position of the participation

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Economic	Between Groups	2.040	3	0.680	3.540	**0.027**
	Within Groups	5.379	31	0.192		
	Total	7.419	34			
Resource Indicator	Between Groups	2.867	3	0.956	3.014	**0.047**
	Within Groups	8.881	31	0.317		
	Total	11.748	34			

Multiple Comparisons							
LSD							
Factors	**Position (i)**	**Position (j)**	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Economic	Engineering	General manager	.57222*	0.19327	**0.006**	0.1763	0.9681
		Expert	0.35556	0.23100	0.135	-0.117	0.8287
		Others	.62222*	0.24447	**0.017**	0.1214	1.1230
Resource Indicator	General manager	Expert	-.58333*	0.28159	**0.048**	-1.1601	-0.006
		Engineering	-.69444*	0.24834	**0.009**	-1.2031	-0.185
		Others	-0.40000	0.29977	0.193	-1.0141	0.2141

*. The mean difference is significant at the 0.05 level

3- The statistical difference according to company capital:

The company's capital was classified in the questionnaire into four levels. To explore the Statistical difference between them, for this reason, each ANOVA test and LSD test were used. The results showed a statistical difference between responders according to the company's capital; ANOVA-test results showed that P-value is lower than the

significant level in the technology as follows (P=0.007 <0.05); in addition, the LSD test results appeared that the awareness of the factors of technology dimension in the companies with capital (more than 800) is higher than others as shown in table 4.5.

Table 4. 5 The statistical difference according to the Company Capital

ANOVA						
Variables		Sum of Squares	df	Mean Square	F	Sig.
Technology Indicator	Between Groups	3.820	3	1.273	4.900	**0.007**
	Within Groups	7.277	31	0.260		
	Total	11.097	34			

Multiple Comparisons								
Dependent Variable:								
LSD								
Variables	Company Capital		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval		
	(i)	**(j)**				Lower Bound	Upper Bound	
Technology Indicator	400-800 Between	Less than 200	0.11111	0.34514	0.750	-0.595	0.8181	
		200-400 Between	-0.45556	0.33559	0.185	-1.143	0.2319	
		More than 800.	-.73737*	0.33205	**0.035**	-1.417	-0.057	

*. The mean difference is significant at the 0.05 level

4-The statistical difference according to the size of projects:

The company capital is classified in the questionnaire into four levels. Through using the ANOVA test and LSD test to explore the statistical difference between responders according to the size of the projects, the result of the ANOVA test showed that P-value is lower than the significant level in the value stream as follows (P=0.019 <0.05); in addition, the LSD test results appeared that the results in table 4.6 show that the awareness about the principles of the value stream in the companies of (400-800 thousand dollars) and (more than 800 thousand dollars) is higher than others.

Table 4. 6 The statistical difference according to the size of the project

ANOVA

Variables		Sum of Squares	df	Mean Square	F	Sig.
Value Stream	Between Groups	3.083	3	1.028	3.913	**0.019**
	Within Groups	7.353	31	0.263		
	Total	10.436	34			

Multiple Comparisons
Dependent Variable:
LSD

	(I) Project Size		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Value Stream	200 – 400 Between	Less than 200	-0.04167	0.41841	0.921	-0.8987	0.8154
		400 – 800 Between	-.82292*	0.27675	0.006	-1.3898	-0.2560
		More than 800	-.65104*	0.24532	0.013	-1.1535	-0.1485

*The mean difference is significant at the 0.05 level

4.3 Assessing the Perception Towards Implementation of Lean and Sustainability Principles:

One of the purposes of using the questionnaire in the study is to measure the awareness of the responsible people (experts and managers) in solar energy firms about the importance of adopting lean principles and sustainability dimensions; in addition, to measure the relative importance of the point of view of the responsible people. For this purpose, a Likert scale is used to measure the agreements by calculating the mean of the Likert-scale level of agreement, as shown in table 4.7, and measuring the mean of answers, after that comparing the mean of answers with the Likert-scale level of agreement.\

Table 4. 7 The mean of the Likert-scale level of agreement.

Mean	Key
1-1.8	Strongly disagree
1.81 – 2.6	Disagree
2.61-3.4	Neutral
3.41-4.2	Agree
4.21-5	Strongly agree

According to the analysis results of the total of (35) valid answers received from the solar energy firms, the results showed a high level of relative importance towards implementing both lean principles and sustainability dimensions in solar energy firms. Whereas, the results showed that both of value factor in lean and the environmental dimension in sustainability gives the highest level of agreement (strongly agree), while the other factors in lean (value stream, flow, pull, and perfection) and sustainability (social, economic, resource and technology) give a level of relative importance with the degree (agree) as shown in table 4.8, on the scale that is ranging in five degrees of agreement (strongly disagree, disagree, neutral, agree and strongly agree).

Table 4. 8 The level of the relative importance of lean and sustainability factors

Rank.	Factors	Relative importance
	Lean principles	
1-	Value	Strongly agree
2-	Value stream	Agree
3-	Flow	Agree
4-	Pull	Agree
5-	Perfection	Agree
	Sustainability Dimensions	
6-	Social	Agree
7-	Environmental	Strongly Agree
8-	Economic	Agree
9-	Resource	Agree
10-	Technology	Agree

This high level of agreement from the point of view of the responsible people in solar energy firms towards all the factors of lean and sustainability in the study indicates in a positive way that there is a high level of awareness about the importance of these factors and incorporation of them in the processes of solar energy firms in Turkey. In addition, the high level of awareness should make it easier to implement these factors in solar

energy firms. In fact, this point could be considered a positive one for the firms in the sector; compared with many other sectors; and they still need to pay more attention to the importance of these two terms, as indicated in many studies, as a result of the low level of awareness the work to implementation of these terms will be more challenging in these sectors.

4.4 Calculating Means of Lean and Sustainability Factors:

Calculating items means of lean principles and sustainability dimensions gave the result in table 4.9 and table 4.10, respectively.

Table 4. 9 The Mean and the Standard deviation of lean principles.

Value Principle	**Items No.**	**1**	**2**	**3**	**4**	
	Mean	4.28	4.53	4.28	4.44	
	Standard deviation	0.581	0.621	0.634	0.619	
Value stream principle	**Items No.**	**5**	**6**	**7**	**8**	
	Mean	4.13	4.53	4.25	4.06	
	Standard deviation	0.871	0.761	0.762	0.716	
Flow Principle	**Items No.**	**9**	**10**	**11**	**12**	**13**
	Mean	4.25	3.94	3.97	3.78	3.84
	Standard deviation	0.803	0.914	0.695	0.941	0.847
Pull Principle	**Items No.**	**14**	**15**	**16**	**17**	**18**
	Mean	4.28	3.91	4.19	3.84	3.69
	Standard deviation	0.683	0.931	0.738	0.884	1.176
Perfection Principle	**Items No.**	**19**	**20**	**21**	**22**	
	Mean	4.13	4.13	3.72	3.97	
	Standard deviation	0.660	0.751	0.813	0.897	

Table 4. 10 The mean and standard deviation of sustainability dimensions

Social dimension	**Items No.**	**23**	**24**	**25**	**26**	**27**
	Mean	3.78	4.13	3.53	3.97	4.34
	Standard deviation	0.975	0.751	0.879	0.861	0.865
Environment dimension	**Items No.**	**28**	**29**	**30**	**31**	**32**
	Mean	4.31	4.19	4.28	4.66	4.13
	Standard deviation	0.644	0.693	0.683	0.602	0.871
Economic dimension	**Items No.**	**33**	**34**	**35**	**36**	**37**
	Mean	3.94	3.88	4.22	4.19	4
	Standard	0.759	0.833	0.553	0.644	0.803

	deviation				
Resource dimension	**Items No.**	**38**	**39**	**40**	**41**
	Mean	3.5	3.94	4.16	3.88
	Standard deviation	0.984	0.878	0.677	0.833
Technology dimension	**Items No.**	**42**	**43**	**44**	
	Mean	4.09	4.16	4.19	
	Standard deviation	0.734	0.677	0.780	

Table 4.9 shows the means of lean principles, the means of value items that are concerned about improving the value for the customer, identifying defective items, identifying the waste to improve the quality and cost, besides sharing the responsibility with all the workers, have ranged between (4.28-4.53) in Likert-scale in the items (1,2,3,4) respectively. Value means refers to the high level of awareness and interest from the responsible people in these firms to the importance of applying these items. The means of value stream items which were about minimizing the waste in materials, transportation time, inventory level, lot size, machine time, and using tools to measure the speed of the project, have ranged between (4.06-4.52) in the Likert-scale of the items (5,6,7,8) respectively. Also, the value stream's means indicate that there is a high level of awareness and a good level of interest from the responsible people in these firms about the importance of applying these items. In addition, the means of both principles of lean value and value stream are considered good values. While the flow items that were directed to mapping the flow of materials to identify the non-added value, map flow as organizational culture, idle time, and work just in time have ranged between (3.78-4.25) in Likert-scale for the items (9,10,11,12,13), respectively, all the means showed good values. The minimum means are for the items (12,13) compared with the others, which were about the issues of idle time and just-in-time issues. These results showed that the responsible people are familiar with the issues related to identifying the materials flow and all the activity that is related to mapping the flow or discovering the non-value processes on this side; in addition, they are interested in making it an organizational culture, in contrast, they are still not familiar to the processes that are related with the times issues as minimizing the idle time. Also, pull items means contained aspects such as ordered materials, low inventory, clear job, the time spent in each order, and adoption of new management tools, which have ranged

between (3.69-4.28) in Likert-scale in the items (14,15,16,17,18) respectively, which considered as good means values, the minimum means of pull items are for (17,18) comparing with the others, which were about the issues of minimizing the required time in progressing the orders and adopting new management tools to improve the speed of work and minimizing waste and cost, These results referred that the responsible people in solar energy firms are familiar with the issues that related to the issues which is interested in the inventory of materials and the ordered time for the materials, while the issues that related to the time that spent in the different processes or finding the new management tools to develop the work, they are still not familiar as much as in others. Besides, on perfection items that are concerned about improving the procedure as involving actively employees, teamwork, and using the new management practice deals with qualities and improving the communication system, the means of it have ranged between (3.72-4.13) in Likert-scale for the items (19,20,21,22) respectively, all means results showed good values, the minimum mean of perfection items is for the item (21) comparing with the others, the item is about depending management tools that deal with the perfection of the quality and wastes ratios. The perfection items results appeared that the responsible people are familiar with matters that are linked with involving the employees in an active way in the discussion and giving their suggestions for the continuous improvement, the work of the quality teams efficiently and the communications ways that are reducing the required time for decision making. In contrast, the issues that are related to using the tools that engage with the perfection of the quality and waste ratio are still not familiar as they are on the other issues of perfection.

To summarize, the result of the mean for the items of lean principles showed that the minimum means values mentioned above in flow, pull, and perfection referred that the responsible people in solar firms are not familiar with these items as much as with the others. Also, it refers to the gap in the issues related to the time issues and the need for more work to help the responsible people in solar energy firms to be more familiar with it, to help them to adopt lean principles in the right way, and a high level of benefits can be reached from adopting lean principles in the different processes in their firms.

Also, table 4.10 shows the means of the items of sustainability dimensions, the items about the social dimension that care about enhancing work conditions, communication in a team, employees skills and work opportunities, showed good values were means have ranged between (3.53-4.34) in Likert-scale for the items (23,24,25,26,27) respectively, the minimum mean comparing with the other items was of the items (23,25), these items are concerned about the equality in the opportunity between workers and making the consulate with the local people. The social's items results showed that responsible people are aware of matters associated with following the newest communications to enhance the work of individuals in the team, the importance of the work conditions to improve the work and improve the employee abilities and retaining them. On the other hand, the results showed they are still not familiar enough with consulting the local experts and having equal job opportunities among employees.

Besides, the items about the environmental dimension that was about minimizing the resource wastes, reducing energy use, reducing emissions, energy type using, and using green material showed good values were means have ranged between (4.13-4.66) on Likert-scale for the items (28,29,30,31,32) respectively. Also, the results of the items of the economic dimension of sustainability, which involved around using local resources, job creation, and sustainable value of properties and tracts of land, showed good means too when it ranged between (3.88-4.22) in Likert-scale for the items (33,34,35,36,37) respectively, the minimum mean between them was for the item number (34) which was about job creations. The items result of the economic dimension appeared that responsible people are familiar with the almost processes such as Sustainable values of land and area properties, taking advantage of using the local resource, creating job opportunities before and after the project, and focusing on the issues related to the competition and marketing. At the same time, they are not familiar with creating equal job opportunities among sectors if we compare it with other actions in this dimension. In addition, the results of the resource dimension of sustainability, which care about the user area to do the project, the amount of the using materials in the processes. In addition, the type of the using energy, and the amount needed, appeared a good means; when it ranged between (3.5-4.16) in Likert-scale for the items (38,39,40,41), respectively, the minimum mean result between these items was for the item number (38) that was about the using area intensity. These results of resource items refer to the

familiarity of the responsible people in solar energy firms with the matters such as the interest in the needed materials to use in one unit, interest in the type of energy that is used to build the power system and pay attention to the energy that is using as fuel in the power system to produce every kWh of produced energy, while the level of familiarity in the issues of the using of the area intensity is still lower than other issues. Also, the results for the items of the technology dimension, the fifth dimension of sustainability, go in far to the matters of the required time to complete the work inside the system operation, the efficiency of the using system, and the lifetime of that system will work with full operational. Gave a good means, when it has ranged between (4.09 - 4.19) in Likert-scale for the items (42,43,44) respectively, the minimum mean result between these items was for the item number (42) that was about the capacity factor. However, all the means for the fifth dimension (technology dimension) are considered a high mean, which refers to the good level of familiarity of the responsible people in solar energy firms with these items.

In summary, the result of the mean for the items of sustainability dimensions showed that the minimum means values mentioned above for the items of social, economic, and resource refer that the responsible people in solar energy firms are not familiar with these items as much as with the other items on these dimensions. On the other hand, the items for the other dimensions give a good means, which refers to the good level of familiarity of the responsible people with these items.

4.5 Testing and Analysis Research Hypotheses:

To answer the hypotheses formulated through reviewing the literature. The hypotheses were established to scout the significant relationships between respondents at ($\alpha = 0.05$) about adopting lean in the solar energy sector and achieving sustainability through the five main principles of lean (value, value stream, flow, pull, and perfection). Each of these main factors was divided into five hypotheses to examine the significant relationships between the factors and the sustainability indicators for the five dimensions of sustainability, separately shown in Section 2.2. The indicators for the sustainability dimensions were, for example, increase profit as an economic indicator, decrease operational costs as an economic dimension; decrease energy consumption or use of renewable energy resources, and decrease industrial waste as the indicators for

the environmental dimensions; develop the work conditions and environment, and increase the participation of employees in the decision making as a social dimension). The result of analyzing the responses will lead to accepting or rejecting the hypothesis according to the (sig.) values. For everyone, there are two hypotheses depending on the values of the (sig). If the value of the (sig.) is greater than (0.05), it means there is no significant relationship at ($\alpha = 0.05$) between these factors, and there is success in adopting lean to achieve sustainability in solar energy firms in Turkey, and the null hypothesis cannot be rejected

But, if the value of the (sig) is less than (0.05), it means there is a significant relationship at ($\alpha = 0.05$) between these factors, and there is success in adopting lean to achieve sustainability in solar energy firms in Turkey. The null hypothesis cannot be accepted.

For this purpose, a linear regression analysis of the survey responses is used to describe the effect of adopting lean principles on achieving the sustainability dimensions in solar energy firms in Turkey. Linear-regression analysis is considered the main analysis to discover the possible relationship between lean principles and sustainability dimensions. After that, a non-linear regression analysis is used to ensure that all potential relationships between lean principles and sustainability dimensions are discovered if they are not found or appear in the linear regression analysis.

The results of the test for the hypotheses are as follows:

The results of testing the hypothesis through applying Linear – regression analysis:

1- First Hypothesis:

Hypothesis 1 (H1): There is a significant relationship between adopting value on lean and achieving social indicators on sustainability in the solar energy sector.

No statistically significant relationship was found between adopting value on lean and achieving social indicators on sustainability in the solar energy sector at ($\alpha=0.05$), as shown in Table 4.11.

That's, the p-value (sig.) is greater than the (sig.) level α=0.05, which means no statistically impact at (α=0.05) of adopting the value principle and achieving the social dimension of sustainability. As a result, the null hypothesis cannot be rejected.

2- The second hypothesis:

Hypothesis 2 (H2). There is a significant relationship between adopting value on lean and achieving economic indicators on sustainability in the solar energy sector.

No statistically significant relationship was found between adopting value on lean and achieving economic indicators on sustainability in the solar energy sector at (α=0.05), as shown in table 4.11.

That's, the p-value (sig.) is greater than the (sig.) level α=0.05, which means no statistically impact at (α=0.05) of adopting the value principle and achieving the economic dimension of sustainability. As a result, the null hypothesis cannot be rejected.

3- The third hypothesis:

Hypothesis 3 (H3). There is a significant relationship between adopting value on lean and achieving environmental indicators on sustainability in the solar energy sector.

No statistically significant relationship was found between adopting value on lean and achieving environmental indicators on sustainability in the solar energy sector at (α=0.05) , as shown in table 4.11.

That's, the p-value (sig.) is greater than the (sig.) level α=0.05, which means no statistically impact at (α=0.05) of adopting the value principle and achieving the environmental dimension of sustainability. As a result, the null hypothesis cannot be rejected.

4- The fourth hypothesis:

Hypothesis 4 (H4). There is a significant relationship between adopting value on lean and achieving resource indicators on sustainability in the solar energy sector.

No statistically significant relationship was found between adopting value on lean and achieving resource indicators on sustainability in the solar energy sector at (α=0.05), as shown in table 4.11.

That's, the p-value (sig.) is greater than the (sig.) level α=0.05, which means no statistically impact at (α=0.05) of adopting the value principle and achieving the resource dimension of sustainability. As a result, the null hypothesis cannot be rejected.

5- The fifth hypothesis:

Hypothesis 5 (H5). There is a significant relationship between adopting value on lean and achieving technology indicators on sustainability in the solar energy sector.

No statistically significant relationship was found between adopting value on lean and achieving technology indicators on sustainability in the solar energy sector at (α=0.05), as shown in table 4.11

That's, the p-value (sig.) is greater than the (sig.) level α=0.05, which means no statistically impact at (α=0.05) of adopting the value principle and achieving the technology dimension of sustainability. As a result, the null hypothesis cannot be rejected.

Table 4. 11 Regression analysis to explain the effects of the value principle on the sustainability dimensions

Independent	dependent	β	R^2	F	Sig.	H. no	Supported
Value	Social	0.127	0.016	0.456	0.505	1	Not supported
Value	Economic	0.089	0.008	0.224	0.640	2	Not supported
Value	Environmental	0.070	0.005	0.140	0.711	3	Not supported
Value	Resource	0.050	0.002	0.070	0.794	4	Not supported
Value	Technology	0.010	0.000	0.003	0.958	5	Not supported

6- The sixth hypothesis:

Hypothesis 6 (H6). There is a significant relationship between adopting a value stream on lean and achieving social indicators in sustainability in the solar energy sector.

No statistically significant relationship was found between adopting a value stream on lean and achieving social indicators on sustainability in the solar energy sector at (α=0.05), as shown in table 4.12.

That's, the p-value (sig.) is greater than the (sig.) level α=0.05, which means no statistically impact at (α=0.05) of adopting the value stream principle and achieving the social dimension of sustainability. As a result, the null hypothesis cannot be rejected.

7- The seventh hypothesis:

Hypothesis 7 (H7). There is a significant relationship between adopting a value stream on lean and achieving economic indicators in sustainability in the solar energy sector.

No statistically significant relationship was found between adopting a value stream on lean and achieving economic indicators on sustainability in the solar energy sector at (α=0.05), as shown in table 4.12.

That's, the p-value (sig.) is greater than the (sig.) level α=0.05, which means no statistically impact at (α=0.05) of adopting the value stream principle and achieving the economic dimension of sustainability. As a result, the null hypothesis cannot be rejected.

8- The eighth hypothesis:

Hypothesis 8 (H8). There is a significant relationship between adopting a value stream on lean and achieving environmental indicators in sustainability in the solar energy sector.

No statistically significant relationship was found between adopting a value stream on lean and achieving environmental indicators on sustainability in the solar energy sector at (α=0.05), as shown in table 4.12.

That's, the p-value (sig.) is greater than the (sig.) level α=0.05, which means no statistically impact at (α=0.05) of adopting the value stream principle and achieving the environmental dimension of sustainability. As a result, the null hypothesis cannot be rejected.

9- The ninth hypothesis:

Hypothesis 9 (H9). There is a significant relationship between adopting a value stream on lean and achieving resource indicators in sustainability in the solar energy sector.

No statistically significant relationship was found between adopting a value stream on lean and achieving resource indicators on sustainability in the solar energy sector at (α=0.05), as shown in table 4.12.

That's, the p-value (sig.) is greater than the (sig.) level α=0.05, which means no statistically impact at (α=0.05) of adopting the value stream principle and achieving the resource dimension of sustainability. As a result, the null hypothesis cannot be rejected.

10- The tenth hypothesis:

Hypothesis 10 (H10). There is a significant relationship between adopting a value stream on lean and achieving technology indicator in sustainability in the solar energy sector.

No statistically significant relationship was found between adopting a value stream on lean and achieving technology indicators on sustainability in the solar energy sector at (α=0.05), as shown in table 4.12.

That's, the p-value (sig.) is greater than the (sig.) level α=0.05, which means no statistically impact at (α=0.05) of adopting the value stream principle and achieving the technology dimension of sustainability. As a result, the null hypothesis cannot be rejected.

Table 4. 12 Regression analysis to explain the effects of the value stream principle on the sustainability dimensions

Independent	dependent	β	R^2	F	Sig.	H. no	Supported
Value stream	Social	0.57	0.003	0.090	0.766	6	Not supported
Value stream	Economic	0.053	0.003	0.078	0.782	7	Not supported
Value stream	Environmental	0.054	0.003	0.082	0.777	8	Not supported
Value stream	Resource	0.133	0.018	0.505	0.483	9	Not supported
Value stream	Technology	0.307	0.094	0.062	0.573	10	Not supported

11- The eleventh hypothesis:

Hypothesis 11 (H11). There is a significant relationship between adopting flow on the lean and achieving social indicator in sustainability in the solar energy sector.

A statistically significant relationship was found between adopting flow on lean and achieving social indicators on sustainability in the solar energy sector at (α=0.05), as shown in table 4.13.

That's, the p-value (sig.) is less than the (sig.) level α=0.05, which means there is a statistically impact at (α=0.05) on adopting the flow principle and achieving the social dimension of sustainability. As a result, the null hypothesis was rejected. And the null hypothesis was accepted.

12- The twelfth hypothesis:

Hypothesis 12 (H12). There is a significant relationship between adopting flow on the lean and achieving economic indicator in sustainability in the solar energy sector.

No statistically significant relationship was found between adopting flow on lean and achieving economic indicators on sustainability in the solar energy sector at (α=0.05), as shown in table 4.13.

That's, the p-value (sig.) is greater than the (sig.) level α=0.05, which means no statistically impact at (α=0.05) of adopting the flow principle and achieving the economic dimension of sustainability. As a result, the null hypothesis cannot be rejected.

13- The thirteenth hypothesis:

Hypothesis 13 (H13). There is a significant relationship between adopting flow on lean and achieving environmental indicators in sustainability in the solar energy sector.

No statistically significant relationship was found between adopting flow on lean and achieving environmental indicators on sustainability in the solar energy sector at (α=0.05), as shown in table 4.13.

That's, the p-value (sig.) is greater than the (sig.) level α=0.05, which means no statistically impact at (α=0.05) of adopting the flow principle and achieving the environmental dimension of sustainability. As a result, the null hypothesis cannot be rejected.

14- The fourteenth hypothesis:

Hypothesis 14 (H14). There is a significant relationship between adopting flow on lean and achieving resource indicator in sustainability in the solar energy sector.

A statistically significant relationship was found between adopting flow on lean and achieving resource indicators on sustainability in the solar energy sector at (α=0.05), as shown in table 4.13.

That's, the p-value (sig.) is less than the (sig.) level α=0.05, which means there is a statistically impact at (α=0.05) of adopting the flow principle and achieving the resource dimension of sustainability. As a result, the null hypothesis was rejected. And the null hypothesis was accepted.

15- The fifteenth Hypothesis:

Hypothesis 15 (H15). There is a significant relationship between adopting flow on lean and achieving technology indicator in sustainability in the solar energy sector.

A statistically significant relationship was found between adopting flow on lean and achieving technology indicators on sustainability in the solar energy sector at (α=0.05), as shown in table 4.13.

That's, the p-value (sig.) is less than the (sig.) level α=0.05, which means there is a statistically impact at (α=0.05) of adopting the flow principle and achieving the technology dimension of sustainability. As a result, the null hypothesis was rejected. And the null hypothesis was accepted.

Table 4. 13. Regression analysis to explain the effects of the flow principle on the sustainability dimensions

Independent	dependent	β	R^2	F	Sig.	H. no	Supported
Flow	Social	0.630	0.397	19.746	000	11	Supported
Flow	Economic	0.459	0.211	7.469	0.011	12	Not supported
Flow	Environmental	0.063	0.004	0.111	0.742	13	Not supported
Flow	Resource	0.358	0.148	5.220	0.030	14	Supported
Flow	Technology	0.351	0.123	4.224	0.049	15	Supported

16- The sixteenth hypothesis:

Hypothesis 16 (H16). There is a significant relationship between adopting a pull on the lean and achieving social indicator in sustainability in the solar energy sector.

A statistically significant relationship was found between adopting pull on lean and achieving social indicators on sustainability in the solar energy sector at (α=0.05), as shown in table 4.14.

That's, the p-value (sig.) is less than the (sig.) level α=0.05, which means there is a statistically impact at (α=0.05) of adopting the pull principle and achieving the social dimension of sustainability. As a result, the null hypothesis was rejected. And the null hypothesis was accepted.

17- The seventeenth hypothesis:

Hypothesis 17 (H17). There is a significant relationship between adopting a pull on the lean and achieving economic indicator in sustainability in the solar energy sector.

A statistically significant relationship was found between adopting pull on lean and achieving economic indicators on sustainability in the solar energy sector at (α=0.05), as shown in table 4.14.

That's, the p-value (sig.) is less than the (sig.) level α=0.05, which means there is a statistically impact at (α=0.05) of adopting the pull principle and achieving the economic dimension of sustainability. As a result, the null hypothesis was rejected. And the null hypothesis was accepted.

18- The eighteenth hypothesis:

Hypothesis 18 (H18). There is a significant relationship between adopting a pull on the lean and achieving environmental indicator in sustainability in the solar energy sector.

No statistically significant relationship was found between adopting pull on lean and achieving environmental indicators on sustainability in the solar energy sector at (α=0.05), as shown in table 4.14.

That's, the p-value (sig.) is greater than the (sig.) level α=0.05, which means no statistically impact at (α=0.05) of adopting the pull principle and achieving the environmental dimension of sustainability. As a result, the null hypothesis cannot be rejected.

19- The nineteenth hypothesis:

Hypothesis 19 (H19). There is a significant relationship between adopting a pull on lean and achieving resource indicator in sustainability in the solar energy sector.

no statistically significant relationship was found between adopting pull on lean and achieving resource indicators on sustainability in the solar energy sector at (α=0.05), as shown in table 4.14. That's, the p-value (sig.) is greater than the (sig.) level α=0.05, which means no statistically impact at (α=0.05) of adopting the pull principle and achieving the resource dimension of sustainability. As a result, the null hypothesis cannot be rejected.

20- The twentieth hypothesis:

Hypothesis 20 (H20). There is a significant relationship between adopting a pull on lean and achieving technology indicator in sustainability in the solar energy sector.

A statistically significant relationship was found between adopting pull on lean and achieving technology indicators on sustainability in the solar energy sector at (α=0.05), as shown in table 4.14.

That's, the p-value (sig.) is less than the (sig.) level α=0.05, which means there is a statistically impact at (α=0.05) of adopting the pull principle and achieving the technology dimension of sustainability. As a result, the null hypothesis was rejected. And the null hypothesis was accepted.

Table 4. 14 Regression analysis to explain the effects of the pull principle on the sustainability dimensions

Independent	dependent	β	R^2	F	Sig.	H. no	Supported
Pull	Social	0.394	0.156	5.528	0.025	16	Supported
Pull	Economic	0.376	0.141	4.927	0.034	17	Supported
Pull	Environmental	0.114	0.013	0.368	0.549	18	Not supported
Pull	Resource	0.261	0.068	2.047	0.164	19	Not supported
Pull	Technology	0.410	0.168	6.079	0.020	20	Supported

21- The twenty-first hypothesis:

Hypothesis 21 (H21). There is a significant relationship between adopting perfection in lean and achieving social indicator in sustainability in the solar energy sector.

No statistically significant relationship was found between adopting perfection on lean and achieving social indicators on sustainability in the solar energy sector at (α=0.05), as shown in table 4.15. That's, the p-value (sig.) is greater than the (sig.) level α=0.05, which means no statistically impact at (α=0.05) of adopting the perfection principle and achieving the social dimension of sustainability. As a result, the null hypothesis cannot be rejected.

22- The twenty - second hypothesis:

Hypothesis 22 (H22). There is a significant relationship between adopting perfection in lean and achieving economic sustainability indicators in the solar energy sector.

No statistically significant relationship was found between adopting perfection on lean and achieving economic indicators on sustainability in the solar energy sector at (α=0.05), as shown in table 4.15.

That's, the p-value (sig.) is greater than the (sig.) level α=0.05, which means no statistically impact at (α=0.05) on adopting the perfection principle and achieving the economic dimension of sustainability. As a result, the null hypothesis cannot be rejected.

23- The twenty - third hypothesis:

Hypothesis 23 (H23). There is a significant relationship between adopting perfection in lean and achieving environmental indicator in sustainability in the solar energy sector.

No statistically significant relationship was found between adopting perfection on lean and achieving environmental indicators on sustainability in the solar energy sector at (α=0.05), as shown in table 4.15.

That's, the p-value (sig.) is greater than the (sig.) level α=0.05, which means no statistically impact at (α=0.05) of adopting the perfection principle and achieving the environmental dimension of sustainability. As a result, the null hypothesis cannot be rejected.

24- The twenty – four hypothesis:

Hypothesis 24 (H24). There is a significant relationship between adopting perfection in lean and achieving resource indicators in sustainability in the solar energy sector.

No statistically significant relationship was found between adopting perfection on lean and achieving resource indicators on sustainability in the solar energy sector at (α=0.05), as shown in table 4.15

That's, the p-value (sig.) is greater than the (sig.) level α=0.05, which means no statistically impact at (α=0.05) of adopting the perfection principle and achieving the resource dimension of sustainability. As a result, the null hypothesis cannot be rejected.

25- The twenty-five hypothesis:

Hypothesis 25 (H25). There is a significant relationship between adopting perfection in lean and achieving technology indicators in sustainability in the solar energy sector.

No statistically significant relationship was found between adopting perfection on lean and achieving technology indicators on sustainability in the solar energy sector at (α=0.05), as shown in table 4.15. That's, the p-value (sig.) is greater than the (sig.) level α=0.05, which means no statistically impact at (α=0.05) of adopting the perfection principle and achieving the technology dimension of sustainability. As a result, the null hypothesis cannot be rejected.

Table 4. 15 Regression analysis to explain the effects of the perfection principle on the sustainability dimensions

Independent	dependent	β	R^2	F	Sig.	H. no	Supported
Perfection	Social	0.118	0.014	0.396	0.534	21	Not supported
Perfection	Economic	0.022	0.000	0.013	0.910	22	Not supported
Perfection	Environmental	0.010	0.000	0.003	0.956	23	Not supported
Perfection	Resource	0.039	0.002	0.044	0.836	24	Not supported
Perfection	Technology	0.064	0.004	0.116	0.736	25	Not supported

To summarize, the results of linear regression analysis to investigate the hypotheses and to measure the relationships between the lean principles and sustainability dimensions found a significant effect for the pull and flow factors of lean with the social, economic, resource, and technology factors of sustainability: the values of (P) between (flow and social), (flow and resource), (flow and technology), (pull and social), (pull and economic) and (pull and technology) were less than (0.05), while there was no significant effect found of lean factors on the environment factor in sustainability, value, value stream, and perfection also showed no significant impact on any of the three

sustainability factors; so, we can only accept H 11, H 14, H 15, H 16, H 17 and H 20, and reject the other hypotheses, in return accepting the alternative hypotheses as a result of not finding any significant relationship, as shown in table 4.16 and figure 4.9. This explains the founding of the relationship between the factors of the two terms of the study (lean and sustainability) according to the results of the linear regression analysis.

Table 4. 16. Regression analysis to explain the effects of independent factors.

Independent	dependent	β	R^2	F	Sig.
Flow	Social	0.630	0.397	19.746	0.000
Flow	Resource	0.385	0.148	5.220	0.030
Flow	Technology	0.351	0.123	4.224	0.049
Pull	Social	0.394	0.156	5.528	0.025
Pull	Economic	0.376	0.141	4.927	0.034
Pull	Technology	0.410	0.168	6.079	0.020

- significance level 0.05

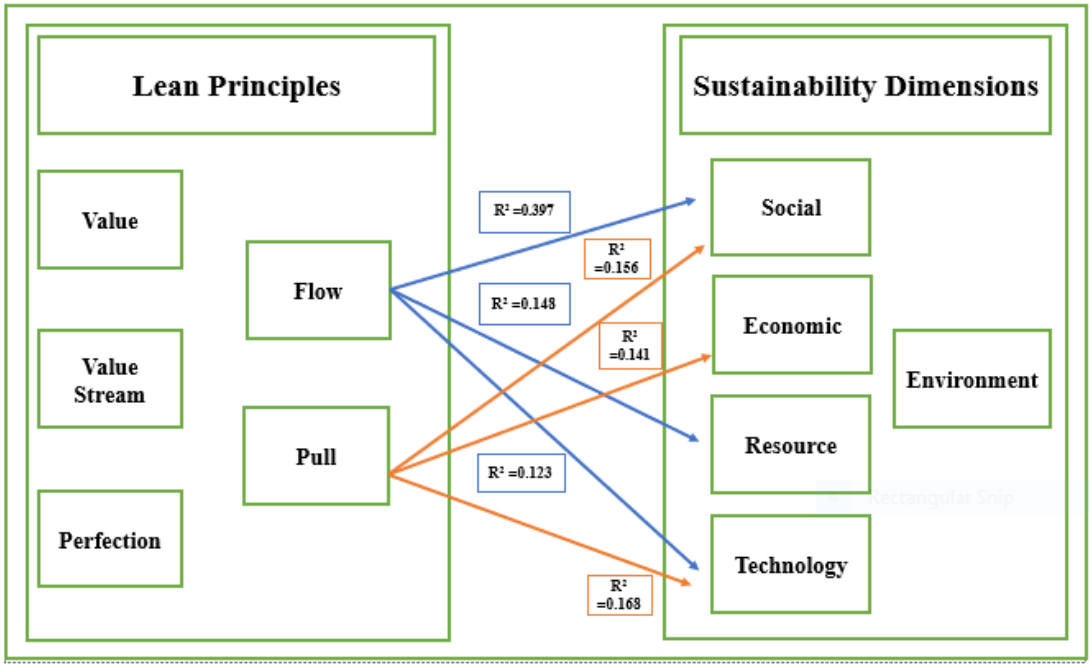

Figure 4. 9 The results of the linear regression between lean and sustainability factors.

4.6 Analyzing the Results of the Hypotheses Through Non-Linear Regression Analysis:

After conducting linear regression analysis to explore the potential relationships between lean principles and sustainability dimensions, the results presented a set of

possible effects of the lean principles on the dimensions of sustainability, as shown in figure 4.9. In contrast, some of the assuming relationships between lean principles and sustainability dimensions were not found in the linear regression results. So, to make sure that all kinds of potential relationships are explored, the non-linear regression analysis was applied to verify the possibility of non-linear relationships between lean principles and sustainability dimensions, which can be used in the framework of the study.

The result of applying non-linear regression analysis found only one relationship as a non-linear relationship between lean and sustainability factors.

The found relationship is between the flow principle of the lean and the economic dimension of sustainability.

So, Hypothesis 12 (H 12). There is a significant relationship between adopting flow on lean and achieving the economic dimension of sustainability in the solar energy sector.

A statistically significant relationship was found between adopting flow on the lean and achieving economic dimension on sustainability in the solar energy sector at (α=0.05), as shown in table 4.17.

That's, the p-value (sig.) is less than the (sig.) level α=0.05, which means there is a statistical impact at (α=0.05) of adopting the flow principle and achieving the economic dimension of sustainability. As a result, the null hypothesis was rejected. And the null hypothesis was accepted.

In fact, many opinions support the use of non-linear regression analysis. Once bearing in mind non-linear connections rather than linearity in technology adoption models, the use of non-linear postulates in analysis has the potential to reduce the exaggeration or misjudging of the most important impact of the results of the linear presumption; avoid the incorrect, incomplete, or partial explanation of the outcomes that caused through linearity clarification (Titah & Barki, 2009), earn the probable opportunities to be aware of the existing of the difficult relationship between the constructs of technology acceptance models; discover the complex and emergency relationship that the original theory suggested between the constructs; in addition, introduce better-detailed

information about the relationship that exists between the two types of variables (independent and dependent) (Salim et al., 2015). Moreover, in comparison to linear analysis, this kind of model that uses a non-linear relationship can introduce a finer explanation power than the one followed by the common linear method, where it maximizes the magnitudes of effect size and β (Rondan-Cataluña et al., 2015) besides, it helps in offering a better understanding of the behavior of the constructs (in particular the linear relationship) in the model which represents the slopes at threshold points on the curve of nonlinearity; hence it present highly segment of specific path coefficients that have the potential of otherwise to be grossly underestimated (Bervell & Umar, 2017), where the effect may be negative or positive depending on the direction of those slopes, in contrast to the linear assumptions and interpretations that were reversing the direction of influence. (Kock, 2016), argues that nonlinearity helps in reaching the findings that obviously differ from their linear consequent results. Furthermore, it gives an adequate model and prediction that is better than linear models for predicting technology adoption, which captures more complex non-linear integrating effects through behavioral decisions (Al Ghuwairi et al., 2019).

The results of applying non-regression analysis to explore the non-linear relationship are explained in figure 4.10.

Table 4. 17 Non-regression analysis to explain the effects of independent factors.

Independent	Dependent	β	R^2	F	Sig.
Flow	Economic	0.527	0.278	5.202	0.012

Also, the other assuming relationship appeared that there's no non-linear relationship between lean principle and sustainability dimensions.

The founding of the non-linear regression analysis can be explained in figure 4.10.

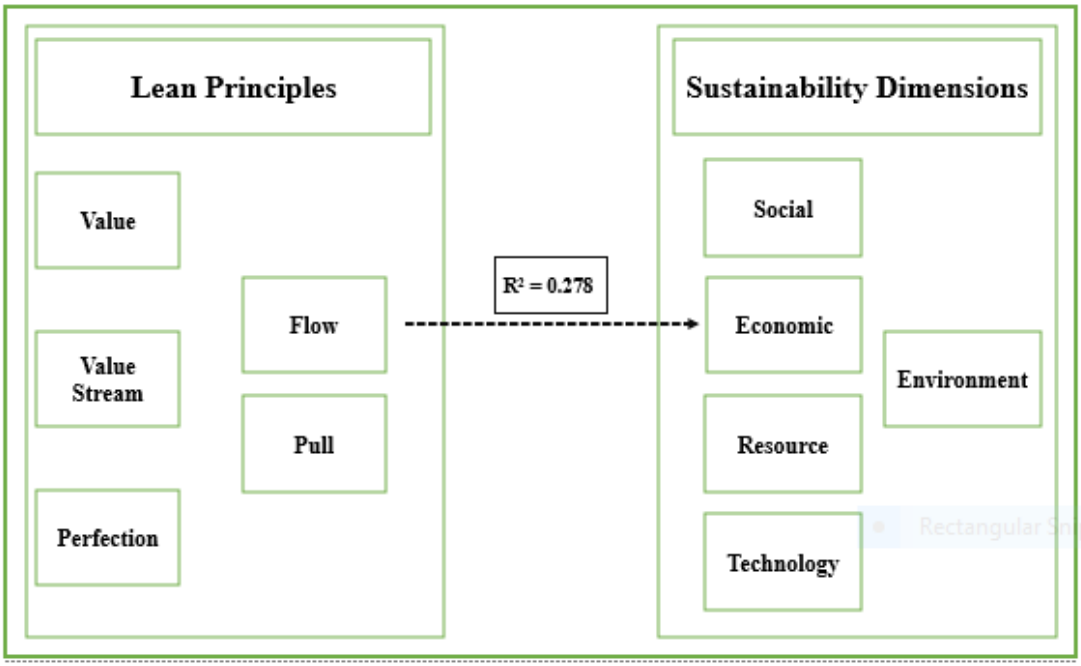

Figure 4. 10 The results of non-linear regression between lean and sustainability factors.

4.7 Correlation:

Correlation between the items of each factor of lean and sustainability showed a relationship between them; so, the items for each factor seem to be related to each other, as shown in tables 4.18 and 4.19, for the lean factor items and the sustainability factor items, respectively.

In addition, a correlation between the factors showed a relationship between them so, which means that the factors seemed to be related to each other's as shown in table 4.20; these results refer to the advanced practice for some of these factors in the firms and how these companies tend to be more advanced on other. Besides, the negative values, or inverse correlation among two variables refer if one variable increases the other will decreases, and vice-versa. This relationship may or may not represent causation between the two variables, but it does describe an observable pattern.

Table 4. 18. Correlations between the items of each principle of lean

Item	Va1	Va2	Va3	Va4	VS5	VS6	VS7	VS8	FL9	FL10	FL11	FL12	FL13	Pu14	Pu15	Pu16	Pu17	Pu18	Pe19	Pe20	Pe21	Pe22
Va1	1	0.198	0.304	.454**	0.056	-0.05	-0.01	0.189	-0.08	-0.02	0.262	-0.00	-0.10	-0.20	-0.13	-0.12	0.088	0.133	0.158	-0.15	-0.03	0.017
Va2	0.198	1	.591**	0.131	0.291	0.339	0.187	.358*	0.242	0.117	-0.03	-0.01	0.040	0.169	-0.04	0.128	0.097	0.014	0.148	0.337	0.305	.378*
Va3	0.304	.591**	1	0.334	0.051	0.081	-0.01	0.244	0.047	.365*	0.021	-0.05	0.145	0.109	-0.29	-0.11	-0.03	-0.00	-0.01	0.195	0.284	0.129
Va4	.454**	0.131	0.334	1	0.195	.381*	-0.03	.373*	-0.03	.449**	.408*	-0.05	0.258	0.005	-0.13	-0.18	0.129	0.327	0.020	0.156	0.253	0.258
VS5	0.056	0.291	0.051	0.195	1	.675**	0.292	.505**	0.138	0.132	0.007	-0.24	0.115	.373*	0.269	.414*	0.278	0.134	.477**	.518**	.553**	.748**
VS6	-0.05	0.339	0.081	.381*	.675**	1	0.320	.470**	0.198	0.142	0.032	-0.01	0.033	0.262	0.054	0.219	0.271	0.119	0.313	.500**	.406*	.592**
VS7	-0.01	0.187	-0.01	-0.03	0.292	0.320	1	0.148	.527**	-0.07	0.015	0.034	-0.08	0.232	0.250	0.086	0.347	0.162	-0.12	-0.05	-0.14	0.248
VS8	0.189	.358*	0.244	.373*	.505**	.470**	0.148	1	0.028	0.253	0.264	0.021	0.176	0.293	0.163	0.221	.424*	0.292	0.188	0.165	0.253	.355*
FL9	-0.08	0.242	0.047	-0.03	0.138	0.198	.527**	0.028	1	.462**	0.130	.501**	.391*	.397*	0.194	0.191	.375*	.359*	0.061	0.107	-0.18	0.235
FL10	-0.02	0.117	.365*	.449**	0.132	0.142	-0.07	0.253	.462**	1	.505**	0.246	.738**	0.339	0.024	0.162	0.347	.432*	-0.04	0.294	0.193	0.194
FL11	0.262	-0.03	0.021	.408*	0.007	0.032	0.015	0.264	0.130	.505**	1	0.088	0.266	0.019	0.190	-0.24	.412*	.461**	-0.06	-0.05	0.098	-0.10
FL12	-0.00	-0.01	-0.05	-0.05	-0.24	-0.01	0.034	0.021	.501**	0.246	0.088	1	0.320	0.099	-0.01	0.015	0.151	0.257	0.305	0.040	-0.33	-0.04
FL13	-0.10	0.040	0.145	0.258	0.115	0.033	-0.08	0.176	.391*	.738**	0.266	0.320	1	.525**	0.289	.462**	.354*	.500**	0.036	0.285	0.075	0.206
Pu14	-0.20	0.169	0.109	0.005	.373*	0.262	0.232	0.293	.397*	0.339	0.019	0.099	.525**	1	.593**	.532**	.449**	0.274	0.063	0.055	0.031	0.225
Pu15	-0.14	-0.04	-0.29	-0.13	0.269	0.054	0.250	0.163	0.194	0.024	0.190	-0.01	0.289	.593**	1	0.335	.590**	0.298	-0.01	-0.24	0.013	-0.00
Pu16	-0.12	0.128	-0.11	-0.18	.414*	0.219	0.086	0.221	0.191	0.162	-0.24	0.015	.462**	.532**	0.335	1	0.195	0.070	0.282	0.247	0.037	0.301
Pu17	0.088	0.097	-0.03	0.129	0.278	0.271	0.347	.424*	.375*	0.347	.412*	0.151	.354*	.449**	.590**	0.195	1	.510**	-0.07	-0.16	-0.15	0.116
Pu18	0.133	0.014	-0.00	0.327	0.134	0.119	0.162	0.292	.359*	.432*	.461**	0.257	.500**	0.274	0.298	0.070	.510**	1	0.094	0.009	-0.09	0.082
Pe19	0.158	0.148	-0.01	0.020	.477**	0.313	-0.12	0.188	0.061	-0.04	-0.06	0.305	0.036	0.063	-0.01	0.282	-0.07	0.094	1	.488**	.368*	.443*
Pe20	-0.15	0.337	0.195	0.156	.518**	.500**	-0.05	0.165	0.107	0.294	-0.05	0.040	0.285	0.055	-0.24	0.247	-0.16	0.009	.488**	1	.641**	.628**
Pe21	-0.03	0.305	0.284	0.253	.553**	.406*	-0.14	0.253	-0.18	0.193	0.098	-0.33	0.075	0.031	0.013	0.037	-0.15	-0.09	.368*	.641**	1	.563**
Pe22	0.017	.378*	0.129	0.258	.748**	.592**	0.248	.355*	0.235	0.194	-0.10	-0.04	0.206	0.225	-0.00	0.301	0.116	0.082	.443*	.628**	.563**	1

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed)

Table 4. 19. Correlations between the items of each dimension of sustainability

Rank.	Soc23	Soc24	Soc25	Soc26	Soc27	Env28	Env29	Env30	Env31	Env32	Eco33	Eco34	Eco35	Eco36
Soc23	1	0.259	.629**	0.338	0.283	-0.196	0.063	0.095	-0.187	0.185	0.068	0.164	0.211	0.067
Soc24	0.259	1	.385*	0.306	.527**	0.183	0.201	0.244	.384*	0.321	0.127	0.232	0.087	.483**
Soc25	.629**	.385*	1	0.236	0.346	-0.132	-0.010	0.065	-0.131	0.037	0.051	0.138	0.019	0.103
Soc26	0.338	0.306	0.236	1	.535**	0.076	0.281	0.235	0.165	0.178	0.046	.444*	.422*	0.244
Soc27	0.283	.527**	0.346	.535**	1	0.148	0.104	0.213	0.234	0.027	0.328	0.241	0.310	0.343
Env28	-0.196	0.183	-0.132	0.076	0.148	1	.443*	.453**	.452**	0.331	.437*	.496**	0.255	0.243
Env29	0.063	0.201	-0.010	0.281	0.104	.443*	1	.635**	0.237	.495**	0.207	0.322	0.142	.425*
Env30	0.095	0.244	0.065	0.235	0.213	.453**	.635**	1	0.321	.373*	0.346	0.291	0.344	0.243
Env31	-0.187	.384*	-0.131	0.165	0.234	.452**	0.237	0.321	1	0.146	0.163	0.233	0.233	.504**
Env32	0.185	0.321	0.037	0.178	0.027	0.331	.495**	.373*	0.146	1	0.256	.512**	0.344	.417*
Eco33	0.068	0.127	0.051	0.046	0.328	.437*	0.207	0.346	0.163	0.256	1	0.293	.495**	.486**
Eco34	0.164	0.232	0.138	.444*	0.241	.496**	0.322	0.291	0.233	.512**	0.293	1	.482**	0.285
Eco35	0.211	0.087	0.019	.422*	0.310	0.255	0.142	0.344	0.233	0.344	.495**	.482**	1	0.334
Eco36	0.067	.483**	0.103	0.244	0.343	0.243	.425*	0.243	.504**	.417*	.486**	0.285	0.334	1

**, Correlation is significant at the 0.01 level (2-tailed). *, Correlation is significant at the 0.05 level (2-tailed).

Table 4. 20 Correlations between factors of the two terms.

Rank.	Value	Value Stream	Flow	Pull	Perfection	Social	Environmental	Economic	Resource Indicator	Technology Indicator
Value	1	0.307612	0.191628	0.00701	0.280554	0.121419	-0.05603	-0.02817	0.060429	0.016129
Value Stream	0.307612	1	0.14873	.447*	.553**	-0.01912	0.086497	0.109212	0.126829	0.31314
Flow	0.191628	0.14873	1	.522**	0.11909	.630**	0.151732	0.33094	.385*	.351*
PULL	0.007016	.447*	.522**	1	0.055755	.394*	0.182523	.376*	0.266564	.410*
Perfection	0.280554	.553**	0.1190	0.05575	1	0.205575	0.077615	0.065254	0.093482	0.127799
Social	0.121419	-0.01912	.630**	.394*	0.205575	1	0.210807	.396*	.482**	.497**
Environmental	-0.05603	0.086497	0.1517	0.18252	0.077615	0.210807	1	.623**	.527**	.468**
Economic	-0.02817	0.109212	0.33094	.376*	0.065254	.396*	.623**	1	.609**	.411*
Resource Indicator	0.060429	0.126829	.385*	0.26656	0.093482	.482**	.527**	.609**	1	.529**
Technology Indicator	0.016129	0.31314	.351*	.410*	0.127799	.497**	.468**	.411*	.529**	1

** Correlation is significant at the 0.01 level (2-tailed). *, Correlation is significant at the 0.05 level (2-tailed).

4.8 Steps to Build the Conceptual Framework and Its Strength:

To build the conceptual framework, a set of steps is used, and the initial method is using the survey to calculate the required data, also reviewing the different pieces of literature such as articles, books, papers, and conferences and all the related resources is did to choose the factors of the two terms of the study (lean and sustainability), these factors divided into two types first one as independent factors and the second one as dependent factors. After that, the questionnaire was directed to the responsible people in solar energy firms in Turkey in two stages to explore the point of view of the responsible people in these firms about adopting lean principles to achieve sustainability dimensions, where all the adjustments done in the first stages and the received responders in the second stages were used as a data for the study. The collected data were analyzed in two ways, descriptive and statistically, by using two programs first one is Spss_V25, and the second one is Excel.In addition, different techniques were used in order to achieve the required results to build the framework, such as the One-way nova test (ANOVA), LSD-test, Linear regression analysis, non-linear regression, Correlation, and T-test; besides, the frequencies and percentages are also used. The hypothesis was tested through linear regression, and non-linear regression was also used. Finally, the results were used to explore the relationship between the factors of the two terms of the study (lean and sustainability). The achieved results were used to build the conceptual framework.

In parallel, the framework's strength can be explored through some points that identify the strength point of the framework and support it. These supporting points are summarized as follows:

1- The first point is related to the intensive review of the literature to find the points that support the framework and the factors that support the successful implementation of lean principles with the goal of achieving sustainability.

2- All the factors of lean and sustainability were studied to achieve this model with a high focus on the items supporting the factors included in the study.

3- This model explored all the possible relationships between lean principles and sustainability dimensions in the solar energy sector. It is considered a step in the direction of reaching the goal of the companies to achieve the benefits of adopting sustainability in their progress.

4- The questionnaire that was used in this study to collect the data and build this framework was directed to the responsible people in the solar firms, and these people have an important advantage, which is the great knowledge about their companies also to their direct participation in the work process, and these advantages make their answers more accurate.

4.9 The Final Framework and Finding:

After applying both linear regression analysis and non-linear regression to test the hypotheses of the study and explore the possible effects and relationship between lean principles and sustainability dimensions, the result appeared a linear relationship between some of the lean principles and sustainability dimensions was a significant effect found for the pull and flow factors of lean with the social, economic, resource, and technology factors of sustainability as follow: (flow and social), (flow and resource), (flow and technology), (pull and social), (pull and economic) and (pull and technology) where the values of (P) were less than (0.05). On the other hand, the results of applying the non-linear regression analysis found a significant effect of the flow principle of lean on the economic dimension of sustainability where the values of (P) were less than (0.05).

The results conducted that we can accept the following hypotheses (H 11, H 12, H 14, H 15, H 16, H 17, and H 20) and reject the others. Also, the values of (R^2) showed that the size of effect ranged between (medium – large) according to (Cohen, 1988).

The finding of both analyses (linear regression analysis and non-linear regression analysis) can be presented in figure 4.11, which shows the final framework of the study. That can help the solar energy firms in Turkey to achieve sustainability by adopting lean principles in their different operation and department.

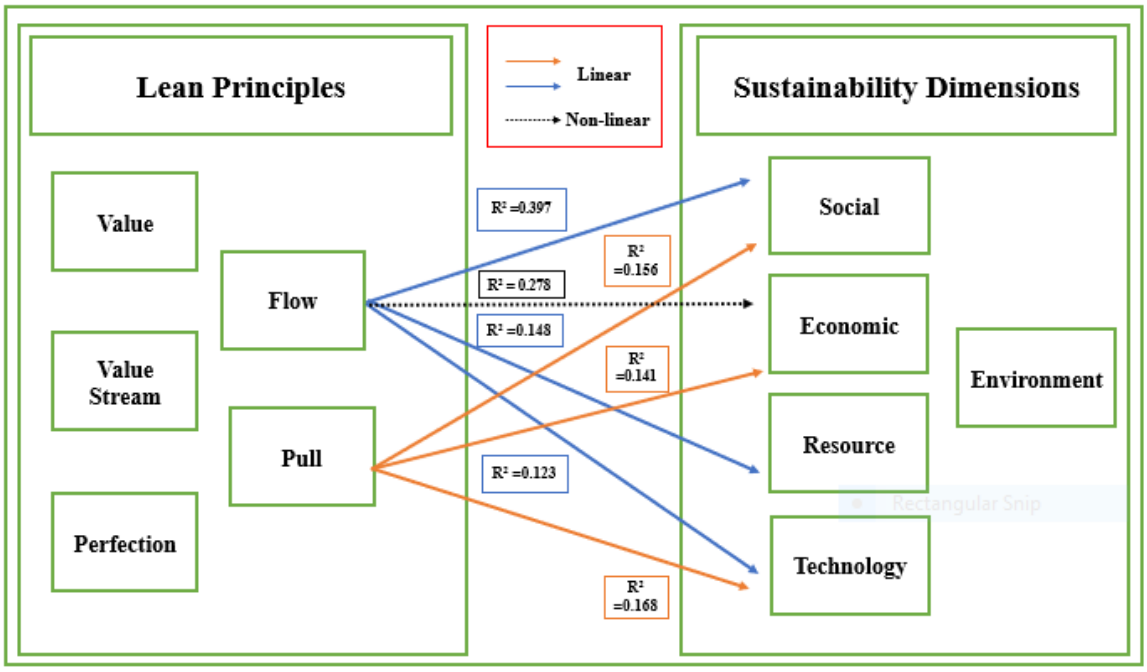

Figure 4. 11 The final framework of the study.

The finding of the study showed a high level of agreement from the point of view of the responsible people on solar energy firms towards all the factors of lean and sustainability in the study, which means there is a high level of awareness about the importance of these factors and incorporation of them in the processes of solar energy firms. The high level of awareness should make it easier to implement these factors in solar energy firms. This point could be considered a positive one for the firms in this sector because many sectors still need to pay more attention to the importance of these two terms, which makes implementing these terms harder. Additionally, all the means of the items for the two terms, lean and sustainability, showed a good level. However, the weakest items were the result of the unfamiliarity of the responsible people with these items as much as with others. Nevertheless, this can be improved by increasing awareness about the importance of these items to achieve better outcomes. Despite the different views among researchers about the relationship between lean and sustainability, the results showed that there are interrelationships between them in the solar energy sector and that this may be due to the lean role in addressing many problems that negatively affect achieving sustainability, such as minimizing the waste in solar power plants (Albezuirat et al., 2020), and minimizing the cost (Mohammed & Obaid, 2016). In addition, the role of lean.

is important in many other aspects of the interests of society, such as raising efficiency (Moyano-Fuentes et al., 2021), due to the methodology that lean follows in dealing with these issues. The results found a significant effect of the implementation of some of the lean principles (flow and pull) on other factors of sustainability (economic, social, resource, and technology); this effect helps to achieve sustainability. The relationship with the social dimension that was found is considered an interesting result because many researchers have neglected the relationship between lean principles and social dimensions, which has caused an unclear view about the importance of this dimension. Additionally, the results correspond with many researchers' results about the relationship between lean and sustainability and the ability of lean to achieve or influence sustainability dimensions in a positive way. The relations found between flow in lean with social, economic, resource and technology dimensions of sustainability, besides the relations between pull with social, economic, and technology dimensions on the other side, support the results on the benefit of adopting lean to achieve sustainability dimensions. Moreover, the results of the study support the opinions about the importance of studying each sector separately because of the different correlations between different sectors. For example, the correlations in the study showed a correlation between the pull principle with the economic, social, and technology dimensions of sustainability, but no correlation with the environmental dimension was found, while, in another study, the results showed a correlation between the pull principle with the Economic and Environmental dimensions and, at the same time, no correlation with the social dimension was found (Minh et al., 2019). Also, in the study of (Khader & Nada, 2019) to enhance the energy performance in the seas waves' energy sector, the value stream principle of lean has been used for this purpose which is connected with the flow principle because of its influence in identifying the non- added activities. On the other hand, the results corresponded with the results of other studies such as the effects of following rules of flow principle in wind energy sector to improve the sustainability (Gijo & Sarkar, 2013). However, the finding of the study about the relationship between lean principles and sustainability dimensions specially for the economic and resource dimensions is corresponded with (Safina & Khokhlov, 2017) about the positive effect of lean in the renewable energy sector for these two

dimensions. Also, the finding of the relationship between pull and sustainability dimensions corresponded with the effect that is found in the study of (Albrecht et al., 2015) about the importance of using push and pull strategies in the renewable energy resources such as wind, solar and ocean energy to avoid the losing between demand and supply, which is reflected negatively on the economic and resource dimensions.

In addition, the study highlighted the relationship between lean principles with the technology dimension of sustainability which is considered a new dimension that is still needed for more studies, as mentioned in (Vacchi et al., 2021). The relationships found in the study between the factors are as follows:

1-Lean manufacturing and economic sustainability:

The correlation that was discovered was the effect of the pull factor on the Economic factor in sustainability. The apparent effect is the possibility of increasing profits and decreasing the working capital thanks to reducing the inventory and decreasing the required space as one of the procedures that the pull works on according to its tools just in time (JIT). Lean, with these strategies, work to reduce the additional costs simultaneously as continuing the work. Thus, it is similar to the goal of economic sustainability, which works to support the long-term growth and preservation of financial resources. However, finding this correlation is the first step towards achieving economic sustainability as companies must work on applying lean tools correctly in order to achieve economic sustainability; on the other hand, the economic result of this application of the lean tools is not immediate in most cases. The main reason that led to the failure of many companies in various sectors to reach the goal of achieving or developing economic sustainability was that these companies did not follow the right way of implementing the lean tools.

2. Lean manufacturing and social sustainability:

The discovered correlation between the pull and flow factors of lean beside the social sustainability dimension represents the possibility of improvement and development in the social dimension of sustainability when applying lean tools. Lean works to preserve the safety of workers; at the same time, it tends to make work successful when all participants share the responsibility of developing the work and completing the tasks in

a better way: this makes workers feel positive about the importance of their role and status at work and not just because they are only task executives. As a result, this facilitates work for the managers and responsible persons in companies as well, improving the general situation of the work, facilitating the implementation of tasks, and creating higher efficiency. In a way, the effort that is made is a collective effort to finish the tasks in the company. On the other hand, lean is interested in finding programs and tools that contribute to arranging, facilitating, and developing work to carry out their duties. The tools used in lean manufacturing are concerned with creating a better atmosphere of work more than their quest to reduce the number of jobs, and this matter contributes to removing the fears that some workers may have about implementing lean in their companies. However, the role of lean in achieving or improving societal sustainability depends on its successful application, as lean is a double-edged tool in this matter. Using it in the wrong way may add obstacles to employees and lead to tension in the general atmosphere of work.

3. Lean and environmental sustainability:

No correlation was found between these two dimensions in the solar energy companies, and this result is similar to the results obtained in other types of renewable energy companies. Lean aims to reduce waste and energy use, as well as reduce the use of resources; these tasks are considered environmentally friendly tasks. Still, the lack of interconnection between the two dimensions may be because they work in parallel, which does not allow for any intersection between them. However, some expectations indicate that the development of both dimensions may lead them to a stage where they will move in one line towards achieving the goal of both environmental sustainability and lean.

4. Lean and resource sustainability:

The correlation that was discovered between the flow factor and resource dimension will help to achieve and support this dimension. One of the essential goals of the flow is the work to minimize the waste of materials. In contrast, the essential goal of the resource indicator is to save the resource, reduce waste, and find the right way to use it—the achievement of resource indicators in parallel with sustainability's economic and

environmental dimensions. In fact, the application of the flow is considered the biggest challenge, so the achievement of the resource will not be easy as it seems, but the return benefits deserve to take this challenge, according to the high level of return benefits in different dimensions.

5. Lean and technology Sustainability:

The relationship that was discovered between each application of flow and pull in lean and the technological dimension of sustainability shows the possibility of supporting the technology dimension by implementing lean principles. At the same time, one of the most important goals of the technology dimension is to reduce losses in all units and processes, especially the operations in the production department. Here we can notice the effects of using the lean principles (flow and pull). Whereas the flow works on the "progressive achievement of tasks along the value stream so that a product proceeds from design to launch, order to delivery and raw materials into the hands of the customer with no stoppages, scrap or backflows." Hence, it's clear that flow is originally working to support the correct use of resources and avoid the accumulation of materials when there is no need for them. On the other hand, the pull principle works with the concept of just in time (JIT), so the customer can withdraw the product at the time he wants, corresponding to his needed; this point can also help to reduce the waste in different processes and one of them the waste in materials, by avoiding the overproduction.

In fact, the problem of the high level of waste is one of the most important problems that the solar sector is suffering from it, so the companies that are applying these factors in the right way will help them to get the high benefits and solve a major problem in this sector and will give these firms an advantage to compete in the market.

5. CONCLUSION AND RECOMMENDATIONS

5.1Conclusions:

The study aims to find a model that helps solar energy firms in Turkey reach the sustainability dimensions by using lean principles. The scientific contribution of this paper is to explore the way for solar energy firms to achieve the sustainable development that companies in various sectors are seeking today, which is witnessing great competition in the market to achieve it. Also, since the debate about the relationship between lean principles and sustainability dimensions still exists among scientists, and the review of the literature revealed the need to study the relationship between these two terms in each industrial sector separately, so, it was necessary to study the relationship in the solar energy sector individually to find the model of this sector, which will hopefully lead to support solar energy companies in their mission to achieve sustainability and solve the problems they face in this regard.

The study worked by exploring the lean factors that help in achieving sustainability in this sector and knowing which sustainable dimensions can be reached by applying lean principles. Also, the study measured how the responsible persons in solar energy companies think about the importance of the implementation of both terms (lean and sustainability) in this sector, where the research relied on a questionnaire directed to the responsible people in solar energy companies in order to ensure achieving the most accurate set of information to analyze it and build the model of the study, that the managers and experts in companies are characterized by having a high degree of knowledge about the processes that are implemented in their companies and on the other hand, their knowledge the problems facing their companies is higher than workers' knowledge, in addition to their scientific knowledge that makes it easier for them to understand and answer the ideas presented in the questionnaire. However, the results showed a high level of awareness about understanding the importance of these two terms. This awareness will help managers use these results to understand the positive return of the integration of lean and sustainability in their companies. The studies proved the possibility of achieving four dimensions in sustainability which are (economic, social, resource, and technology) due to implementing the two factors of lean (pull and flow). However, there was no direct correlation between lean and

environmental sustainability found in the study. The found results reached by the study regarding the relationship between lean with the environmental dimension and the absence of the relationship between them are consistent with the found results in the literature about the relationship between them and the absence of a direct relationship between lean and the environmental dimension in the energy sector, nevertheless, the result reached by the study regarding the interrelationship between the principles of lean and each of the technological and resource dimensions of sustainability is an important addition to the literature and an important discovered fact, as studies on these two dimensions and the details about their relationship to lean are still require many studies and exploration to illuminate the important points that may facilitate access to sustainability.

Still, the found results do not necessarily mean there is a distance between these two topics (lean principles and environmental dimension). Still, it may indicate that they follow a parallel path, and this is what was found from the literature review about the path of lean and sustainability towards the environmental sustainability dimension. In addition, the literature supported the importance of improving the resource and technology dimensions of sustainability in improving the environmental dimension, especially the impact of the technology innovations to minimize the impact of the business in the environmental dimension. Even if the connection between the sustainability dimension is still missing and the need for many studies to evacuate it, on the other hand, it's still possible to prove the claims about the possibility of improving the environmental dimension through achieving the resource and technology dimensions. However, the model created by this study clarified the correlation between the use of lean factors and achieving sustainability, considered just a step in the direction of reaching the goal of the companies to achieve the benefits of adopting sustainability in their progress.

A group of studies must be made to determine the level of the actual impact of the implementation of lean in supporting the four dimensions of sustainability (economic, social, resource, and technology), also for knowing which tools of lean will give a better result and the level of benefit that companies will obtain in this sector by achieving the four dimensions (economic, social, resource and technology) of sustainability, in

addition, the possibility of achieving environmental dimension through supporting both of technology and resource dimensions of sustainability.

5.2 The Contribution and the Recommendations of the Study:

The contribution of the study is the addition that has been made to the solar energy sector in Turkey by building a framework that will help the solar energy firms to achieve sustainability at the time they are working to achieve it to help them in the competition in the market and to take a workplace on it, as well as it is consistent with Turkey's strategic plan with regard to both the solar energy sector and sustainability, which Turkey is working hard to reach. This model presented in the study is considered the first model for solar energy companies. The study also sheds light on two dimensions of sustainability (resource and technology), whereas these two dimensions suffer from a significant lack of research, despite their great benefit and their effective role in achieving sustainability at a time when negative factors affecting sustainability increased due to the population increase and the growing demand for products.
According to the study's findings and the conclusion, a set of recommendations was formulated in order to adopt the factors of lean and sustainability in the best possible way in the solar energy sector in Turkey; the recommendations are as follows.

1. It is recommended to do a group of studies to determine the actual impact of the implementation of lean in supporting the four dimensions of sustainability (economic, social, resource and technology).

2. A group of studies is recommended to be made to explore which lean tools will give a better result and the level of benefit that companies will obtain in this sector by achieving the four dimensions (economic, social, resource, and technology) of sustainability.

3. It is recommended to do a group of studies to discover the possibility of achieving environmental dimensions through supporting both technology and resource dimensions of sustainability.

4. Since the awareness about the importance of the factors for the two terms lean and sustainability is different between the responsible people on the one hand and

companies at different levels, on the other hand, it is recommended to raise the awareness of the importance of these factors for all levels in order to ensure the perfect application of both lean principles and achieve the sustainability.

5. It is recommended to train workers in the solar energy companies about the importance of these two terms.

6. It is recommended to train about the importance and the right processes to implement the lean tools such as just in time (JIT) and mapping the value stream.

7. It’s recommended to raise the client's awareness about the two terms.

REFERENCES

Abreu, M. F., Alves, A. C., & Moreira, F. (2017). Lean-Green models for eco-efficient and sustainable production. *Energy*, *137*, 846–853. https://doi.org/10.1016/j.energy.2017.04.016

Al Ghuwairi, A. R., Al Hassan, M., Salah, Z., Baarah, A. H., Aloqaily, A., & Al Nawayseh, M. K. (2019). A neural network analytical model for predicting determinants of mobile learning acceptance. *International Journal of Computer Applications in Technology*, *60*(1), 73. https://doi.org/10.1504/ijcat.2019.10020933

Albezuirat, M. K., Hussain, M. I., Ahmad, R., & Zulkepli, N. N. (2020). Improving the Efficiency of Solar Power Plants Through Smart Lean Manufacturing Assessment. *International Journal of Renewable Energy and Engineering Research*, *1*(1), 10-29

Albrecht, J., Laleman, R., & Vulsteke, E. (2015). Balancing demand-pull and supply-push measures to support renewable electricity in Europe. *Renewable and Sustainable Energy Reviews*, *49*, 267–277. https://doi.org/10.1016/j.rser.2015.04.078

B, B. R., Dotti, S., Gaiardelli, P., & Boffelli, A. (2016). Lean Manufacturing and Sustainability : An Integrated View. *In IFIP International conference on advances in production management systems* (pp. 659-666). Springer, Cham.

Baruch, Y., & Holtom, B. C. (2008). Survey response rate levels and trends in organizational research. *Human Relations*, *61*(8), 1139–1160. https://doi.org/10.1177/0018726708094863

Bervell, B., & Umar, I. N. (2017). Validation of the UTAUT model: Re-considering non-linear relationships of exogeneous variables in higher education technology acceptance research. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(10), 6471–6490. https://doi.org/10.12973/ejmste/78076

Blackman, A., & Rivera, J. (2011). Producer-level benefits of sustainability certification. *Conservation biology*, *25*(6), 1176-1185. https://doi.org/10.1111/j.1523-1739.2011.01774.x

Brand, B. M., Rausch, T. M., & Brandel, J. (2022). The Importance of Sustainability Aspects

When Purchasing Online: Comparing Generation X and Generation Z. *Sustainability*, *14*(9), 5689. https://doi.org/10.3390/su14095689

Brasco, A., Found, P., & Moura, A. (2013). A Lean & Green Model for a production cell. *Journal of Cleaner Production*. 85, 19-30. https://doi.org/10.1016/j.jclepro.2013.06.014

Cai, W., Lai, K. hung, Liu, C., Wei, F., Ma, M., Jia, S., Jiang, Z., & Lv, L. (2019). Promoting sustainability of manufacturing industry through the lean energy-saving and emission-reduction strategy. *Science of the Total Environment*, *665*, 23–32. https://doi.org/10.1016/j.scitotenv.2019.02.069

Çakir, U., Çomakli, K., & Yüksel, F. (2012). The role of cogeneration systems in sustainability of energy. *Energy Conversion and Management*, *63*, 196–202. https://doi.org/10.1016/j.enconman.2012.01.041

Carneiro, S. B. D. M., Campos, I. B., Lins, D. M. D. O., & Barros Neto, J. D. P. (2012). Lean and green: a relationship matrix. Annual Conference of the International Group for Lean Construction.

Cherrafi, A., Elfezazi, S., Chiarini, A., Mokhlis, A., & Benhida, K. (2016). The integration of lean manufacturing, Six Sigma and sustainability: A literature review and future research directions for developing a specific model. *Journal of Cleaner Production*, *139*, 828-846. https://doi.org/10.1016/j.jclepro.2016.08.101

Cohen, J. (1988). Statistical power analysis for the behavioral sciences. Lawrence Erlbaum Assoc., Hillsdale, NJ. *Statistical power analysis for the behavioral sciences. 2nd ed. Lawrence Erlbaum Assoc., Hillsdale, NJ.*

Cowger, G. (2016). All Out Lean. *Mechanical Engineering*, *138*(01), 30-35.

Crawford, M. (2016). 5 Lean Principles Every Engineer Should Know. https://www.asme.org/topicsresources/content/5-lean-principles-everyshould-know. ASME organizations.

Curry, R., Barry, J., & McClenaghan, A. (2013). Northern Visions? Applying Q methodology to understand stakeholder views on the environmental and resource dimensions of sustainability. *Journal of Environmental Planning and*

Management, *56*(5), 624-649. https://doi.org/10.1080/09640568.2012.693453

Dey, P. K., Malesios, C., De, D., Chowdhury, S., & Abdelaziz, F. Ben. (2020). The Impact of Lean Management Practices and Sustainably-Oriented Innovation on Sustainability Performance of Small and Medium-Sized Enterprises: Empirical Evidence from the UK. *British Journal of Management*, *31*(1), 141–161. https://doi.org/10.1111/1467-8551.12388

Díaz-Reza, J. R., García-Alcaraz, J. L., Martínez-Loya, V., Blanco-Fernández, J., Jiménez-Macías, E., & Avelar-Sosa, L. (2016). The effect of SMED on benefits gained in maquiladora industry. *Sustainability (Switzerland)*, *8*(12), 1–18. https://doi.org/10.3390/su8121237

Dombrowski, U., & Mielke, T. (2013). Lean Leadership - Fundamental principles and their application. *Procedia CIRP*, *7*, 569–574. https://doi.org/10.1016/j.procir.2013.06.034

Erdin, C., & Ozkaya, G. (2019). Turkey's 2023 energy strategies and investment opportunities for renewable energy sources: Site selection based on electre. *Sustainability*, *11*(7), 2136. https://doi.org/10.3390/su11072136

Florescu, A., & Barabaş, B. (2018). Integrating the Lean concept in sustainable manufacturing development. *IOP Conference Series: Materials Science and Engineering*, *399*(1). https://doi.org/10.1088/1757-899X/399/1/012018

Fukuda-Parr, S. (2016). From the Millennium Development Goals to the Sustainable Development Goals: shifts in purpose, concept, and politics of global goal setting for development. *Gender and Development*, *24*(1), 43–52. https://doi.org/10.1080/13552074.2016.1145895

Gao, S., & Low, S. P. (2014). The Toyota Way model: An alternative framework for lean construction. *Total Quality Management and Business Excellence*, *25*(5–6), 664–682. https://doi.org/10.1080/14783363.2013.820022

Garza-Reyes, J. A. (2015). Lean and green-a systematic review of the state of the art literature. *Journal of Cleaner Production*, *102* (1), 18–29. https://doi.org/10.1016/j.jclepro.2015.04.064

Gijo, E. V., & Sarkar, A. (2013). Application of Six Sigma to improve the quality of the road for wind turbine installation. *TQM Journal*, *25*(3), 244–258. https://doi.org/10.1108/17542731311307438

Golzarpoor, H., & González, V. (2013, July). A green-lean simulation model for assessing environmental and production waste in construction. In *Proceedings of the 21th Annual Conference of the International Group for Lean Construction, Fortaleza, Brazil* (pp. 885-894).

Gupta, V., Narayanamurthy, G., & Acharya, P. (2018). Can lean lead to green? Assessment of radial tyre manufacturing processes using system dynamics modelling. *Computers & Operations Research*, *89*, 284-306. https://doi.org/10.1016/j.cor.2017.03.015

Hartini, S., Manurung, J., & Rumita, R. (2021). Sustainable-value stream mapping to improve manufacturing sustainability performance: Case study in a natural dye batik SME's. *IOP Conference Series: Materials Science and Engineering*, *1072*(1), 012066. https://doi.org/10.1088/1757-899x/1072/1/012066

Herrero, M., & Ibáñez, E. (2015). Green processes and sustainability: An overview on the extraction of high added-value products from seaweeds and microalgae. *Journal of Supercritical Fluids*, *96*, 211–216. https://doi.org/10.1016/j.supflu.2014.09.006

Hill, R. (1998). What Sample Size is "Enough" in Internet Survey Research? *Interpersonal Computing and Technology: An Electronic Journal for the 21st Century*, *6*(3–4), 1–10. http://www.reconstrue.co.nz/IPCT-J Vol 6 Robin hill SampleSize.pdf

Inman, R. A., & Green, K. W. (2018). Lean and green combine to impact environmental and operational performance. *International Journal of Production Research*, *56*(14), 4802–4818. https://doi.org/10.1080/00207543.2018.1447705

Ioppolo, G., Cucurachi, S., Salomone, R., Saija, G., & Ciraolo, L. (2014). Industrial ecology and environmental lean management: Lights and shadows. *Sustainability (Switzerland)*, *6*(9), 6362–6376. https://doi.org/10.3390/su6096362

Keitany, P., & Riwo-Abudho, M. (2014). Effects of lean production on organizational performance: a case study of flour producing company in Kenya. *Eur J Logistics*

Purchasing Supply Chain Mgmt, *2*(2), 1-14.

Khader, K. M., & Nada, O. A. (2019). Efficiency enhancement of sea waves energy converter via lean principles using an effective mechanical mechanism. *ERJ. Engineering Research Journal*, *42*(1), 1-9.

Khodeir, L. M., & Othman, R. (2018). Examining the interaction between lean and sustainability principles in the management process of AEC industry. *Ain Shams Engineering Journal*, *9*(4), 1627–1634. https://doi.org/10.1016/j.asej.2016.12.005

Kilickaplan, A., Bogdanov, D., Peker, O., Caldera, U., Aghahosseini, A., & Breyer, C. (2017). An energy transition pathway for Turkey to achieve 100% renewable energy powered electricity, desalination and non-energetic industrial gas demand sectors by 2050. *Solar Energy*, *158*(September), 218–235. https://doi.org/10.1016/j.solener.2017.09.030

Kim, A. (2000). Sustainable development and environmental values. *Socijalna Ekologija*, *9*(3), 149–162.

King, A. A., & Lenox, M. J. (2001). Lean and green? An empirical examination of the relationship between lean production and environmental performance. *Production and Operations Management*, *10*(3), 244–256. https://doi.org/10.1111/j.1937-5956.2001.tb00373.x

Kock, N. (2016). Advantages of nonlinear over segmentation analyses in path models. *International Journal of E-Collaboration*, *12*(4), 1–6. https://doi.org/10.4018/IJeC.2016100101

Krut, R., & Munis, K. (2019). Sustainable Industrial Development. *Sustainable Measures*, *December 2015*, 426–437. https://doi.org/10.4324/9781351283007-23

Kuhlman, T., & Farrington, J. (2010). What is sustainability? *Sustainability*, *2*(11), 3436–3448. https://doi.org/10.3390/su2113436

Kumar, M., & Rodrigues, V. S. (2020). Synergetic effect of lean and green on innovation: A resource-based perspective. *International Journal of Production Economics*, *219*, 469–479. https://doi.org/10.1016/j.ijpe.2018.04.007

Lapinski, A. R., Horman, M. J., & Riley, D. R. (2006). Lean processes for sustainable project delivery. *Journal of construction engineering and management*, *132*(10), 1083-1091.

Lee, C., An, M., & Noh, Y. (2012). The Social Dimension of Service Workers' Job Satisfaction: The Perspective of Flight Attendants. *Journal of Service Science and Management*, *05*(02), 160–170. https://doi.org/10.4236/jssm.2012.52020

Minh, N. D., Nguyen, N. D., & Cuong, P. K. (2019). Applying lean tools and principles to reduce cost of waste management: An empirical research in Vietnam. *Management and Production Engineering Review*. *10*(1), 37–49. https://doi.org/10.24425/mper.2019.128242

Mohammed, W., & Obaid, A. (2016). *Towards Enhancement of Lean Practices in the West Bank Construction Industry*.

Mollenkop, D., Stolze, H., Tate, W.L. and Ueltschy, M. (2010), "Green, lean, and global supply chains", International Journal of Physical Distribution & Logistics Management, Vol. 40 Nos 1-2, pp. 14-41.

Moyano-Fuentes, J., Maqueira-Marín, J. M., Martínez-Jurado, P. J., & Sacristán-Díaz, M. (2021). Extending lean management along the supply chain: impact on efficiency. *Journal of Manufacturing Technology Management*, *32*(1), 63–84. https://doi.org/10.1108/JMTM-10-2019-0388

Nugraheni, A. I. P., Priyambodo, T. K., Kusworo, H. A., & Sutikno, B. (2019, October). The social dimension of sustainable development: defining tourism social sustainability. In *ICESC 2019: Proceedings of the 1st International Conference on Engineering, Science, and Commerce, ICESC 2019, 18-19 October 2019, Labuan Bajo, Nusa Tenggara Timur, Indonesia* (p. 168). European Alliance for Innovation.

Othman, A. A. E., Ghaly, M. A., & Zainul Abidin, N. (2014). Lean Principles: An Innovative Approach for Achieving Sustainability in the Egyptian Construction Industry. *Organization, Technology and Management in Construction: An International Journal*, *6*(1), 917–932. https://doi.org/10.5592/otmcj.2014.1.2

Ozturk, M., & Yuksel, Y. E. (2016). Energy structure of Turkey for sustainable development.

Renewable and Sustainable Energy Reviews, *53*, 1259–1272. https://doi.org/10.1016/j.rser.2015.09.087

P, Sajan M, S. P. R. (2017). The Relationship between Lean Operations and Sustainability Among the Different Production Systems in Small and Medium Enterprises (SMES). *International Journal of Engineering Technology, Management and Applied Sciences*, *Volume 5 I*(July).

Purc, T., Ioan-franc, V., Lorin, V., Purc, I., Mateescu-soare, M. C., & Platon, O. (2022). *Lean Manufacturing and Sustainability: An Integrated View*. 1–51.

Robson colin (2002). Real world research: A resource for social scientists and practitioner-researchers {Book}. Malden: Blackwell publishers, 2002.

Rockström, J., Steffen, W., Noone, K., Persson, A., Chapin, III, F. S., Lambin, E., … Foley, J. (2009). Planetary Boundaries: Exploring the Safe Operating Space for Humanity. *Ecology and Society*, 14 (2), 32.

Rogelj, J., McCollum, D. L., Reisinger, A., Meinshausen, M., & Riahi, K. (2013). Probabilistic cost estimates for climate change mitigation. *Nature*, *493*(7430), 79-83.

Rondan-Cataluña, F. J., Arenas-Gaitán, J., & Ramírez-Correa, P. E. (2015). A comparison of the different versions of popular technology acceptance models a non-linear perspective. *Kybernetes*, *44*(5), 788–805. https://doi.org/10.1108/K-09-2014-0184

Safina, E., & Khokhlov, S. (2017). Paradox of alternative energy consumption: Lean or profligacy? *International Journal for Quality Research*, *11*(4), 903–916. https://doi.org/10.18421/IJQR11.04-11

Salim, S. A., Sedera, D., & Sawang, S. (2015). Non-linear and linear postulations of technology adoption determinants. *ARPN Journal of Engineering and Applied Sciences*, *10*(23), 17679–17689.

Sánchez-Fernández, R., & Iniesta-Bonillo, M. Á. (2009). Efficiency and quality as economic dimensions of perceived value: Conceptualization, measurement, and effect on satisfaction. *Journal of Retailing and Consumer Services*, *16*(6), 425–433. https://doi.org/10.1016/j.jretconser.2009.06.003

Seghezzo, L. (2009). The five dimensions of sustainability. *Environmental politics*, *18*(4), 539-556.

Singla, A., Sethi, A. P. S., & Ahuja, I. S. (2018). A study of transitions between technology push and demand pull strategies for accomplishing sustainable development in manufacturing industries. *World Journal of Science, Technology and Sustainable Development*, *15*(4), 302–312. https://doi.org/10.1108/WJSTSD-09-2017-0028

Souza, J. P. E., & Alves, J. M. (2018). Lean-integrated management system: A model for sustainability improvement. *Journal of Cleaner Production*, *172*, 2667–2682. https://doi.org/10.1016/j.jclepro.2017.11.144

Spangenberg, J. H. (2005). Economic sustainability of the economy: Concepts and indicators. *International Journal of Sustainable Development*, *8*(1–2), 47–64. https://doi.org/10.1504/ijsd.2005.007374

Taber, K. S. (2018). The use of Cronbach's alpha when developing and reporting research instruments in science education. *Research in science education*, *48*(6), 1273-1296.

Tăucean, I., Tămășilă, M., Ivascu, L., Miclea, Șerban, & Negruț, M. (2019). Integrating Sustainability and Lean: SLIM Method and Enterprise Game Proposed. *Sustainability*, *11*(7), 2103. https://doi.org/10.3390/su11072103

Thangarajoo, Y., & Smith, A. (2015). Lean thinking: An overview. *Industrial Engineering & Management*, *4*(2), 2169-0316.

Titah, R., & Barki, H. (2009). Nonlinearities between attitude and subjective norms in information technology acceptance: A negative synergy? *MIS Quarterly: Management Information Systems*, *33*(4), 827–844. https://doi.org/10.2307/20650329

Tommelein, I. D., Riley, D. R., & Howell, G. A. (1999). Parade Game: Impact of Work Flow Variability on Trade Performance. *Journal of Construction Engineering and Management*, *125*(5), 304–310. https://doi.org/10.1061/(asce)0733-9364(1999)125:5(304)

TURKEY's 2nd VNR. (2019). *TURKEY's 2nd VNR 2019 SUSTAINABLE DEVELOPMENT GOALS "Strong Ground towards Common Goals."*

Vacchi, M., Siligardi, C., Demaria, F., Cedillo-González, E. I., González-Sánchez, R., & Settembre-Blundo, D. (2021). Technological sustainability or sustainable technology? A multidimensional vision of sustainability in manufacturing. *Sustainability*, *13*(17), 9942.

Varela, L., Araújo, A., Ávila, P., Castro, H., & Putnik, G. (2019). Evaluation of the relation between lean manufacturing, industry 4.0, and sustainability. *Sustainability (Switzerland)*, *11*(5), 1–19. https://doi.org/10.3390/su11051439

Vegting, I. L., Van Beneden, M., Kramer, M. H. H., Thijs, A., Kostense, P. J., & Nanayakkara, P. W. B. (2012). How to save costs by reducing unnecessary testing: Lean thinking in clinical practice. *European Journal of Internal Medicine*, *23*(1), 70–75. https://doi.org/10.1016/j.ejim.2011.07.003

Vinodh, S., Arvind, K. R., & Somanaathan, M. (2011). Tools and techniques for enabling sustainability through lean initiatives. *Clean Technologies and Environmental Policy*, *13*(3), 469–479. https://doi.org/10.1007/s10098-010-0329-x

Wang, Y. (2014). *Lean Approach to Production Planning for Large Solar PV Installations*. *August*.

WCED, S. W. S. (1987). World commission on environment and development. *Our common future*, *17*(1), 1-91.

Weaver, P., Jansen, L., van Grootveld, G., van Spiegel, E., & Vergragt, P. (2000). Sustainable Technology Development (1st ed.). Routledge. https://doi.org/10.4324/9781351283243.

Weckend, S., Wade, A., & Heath, G. (2016). End of life management solar PV Panels. *IRENA: Abu Dhabi, United Arab Emirates*, 100.

Weigel, A. L. (2000). A Book Review : Lean Thinking by Womack and Jones. *Review Literature And Arts Of The Americas*, *November*, 5.

Wendell Cox, J.-C. Z. (2005). Dimensions of Sustainability. *3 Rd International SIIV Conference*.

Wickramasinghe, G. L. D., & Wickramasinghe, V. (2017). Implementation of lean

production practices and manufacturing performance: The role of lean duration. *Journal of Manufacturing Technology Management*, *28*(4), 531–550. https://doi.org/10.1108/JMTM-08-2016-0112.

World Bank Group. (2013). Financing for Development Post 2015. Washington DC: World Bank.

APPENDIX

Appendix (A): The questionnaire:

Dear:

First of all, I would like to thank you for your valuable time and effort that will be allocated in filling this survey.

This survey aims to build a framework for Solar energy firms to adopt Lean principles to achieve sustainability in Turkey.

Lean practices are based on improving the value of final product and eliminating waste through all processes of a project and the sustainability is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

This study identifies the key success factors that are essential when creating a model for to adopt Lean principles to achieve sustainability, **this information in this survey will be used only for academic research, with a complete commitment to absolute confidence.**

Researcher name:

Bilal Aldewach

Section one: Profile of company:

1- Your position in the company: ……..
2- Company's location: ……..
3- Company experience:
☐ Less than 5 years ☐From (5-10) years ☐From (11-15) ☐ More than 15 years.

4- Capital of the company (Thousand $) is:
☐ Less than 200 ☐ 200-400 ☐ 400-800 ☐ More than 800.

5- Average size of projects the company involved in (Thousand $) is:
☐ less than 200 ☐ 200 - 400 ☐ 400 - 800 ☐ more than 800.

6- The number of employees working in the company is:
☐ 1 – less than 20 ☐ 20 – less than 40 ☐ 40 – less than 60

☐ more than 60.

7- Average number of contract employees working in the company is:
☐ 1-less than 10 ☐ 10-less than 20 ☐20-less than 30 ☐ more than 30

8- What is the company's field of work?
☐ Selling the Solar panels ☐ Installation of Solar Panels ☐Manufacturing of Solar panels.

Section 2:

These factors examine the implementation of lean principles and sustainability in the company, please put (√) to the degree to which you agree with these statements.

Rank.	QUESTION	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1-	Your company is ready to do any change in the project, to improve the value for the customer.					
2-	Defective items (human and machine error) are identified promptly to take corrective action.					
3-	Identifying wastes through new management practices is vital for improving the quality, cost and time.					
4-	It is vital that the quality of the project will be the responsibility of each person in the project					
5-	Your company is interested in minimizing wastes in materials, conveying of materials and labor, transportation, and inventory level, waiting time, over production, over processing.					
6-	Lot sizes are maintained at the minimum possible level.					
7-	Machine set-up and Machine down times are maintained at the minimum possible level					
8-	Your company follow special tools or standard for measuring the speed of the project.					
9-	Mapping the flow of material and information of any activity, helps to identify the non-added value activity					
10-	Material flow is adhered to consistently throughout the daily work activities					
11-	Make flow evident through organizational culture					
12-	Strive to cut back to zero the amount of time any work is					

	sitting idle or waiting for someone to work on it
13-	Material, equipment, and other resources are provided in a "just-in-time" manner when needed
14-	Materials are ordered as close as possible to exact needs

15-	**Strive for possible low level of (even stockless) material inventory**
16-	Clear job contents, work time, material requirements, among other information are prepared before releasing a work task to a crew
17-	Amount of time spent in processing each order is maintained at the minimum possible level
18-	New management tools that improve quality, speed, cost and waste are essential to improve competitive advantage.
19-	Employees actively involved in providing suggestions for continuous improvement
20-	Quality teams are operating in an effective manner
21-	Your company depends on management practices that deal with quality and reduce wastes ratios in order to achieve high earnings ratios.
22-	Good vertical and horizontal communication systems reduce the time for decision taking.

23-	**The company consulting local people.**
24-	Your company follow new means of communications to improve the work of individuals

	within a team
25-	Equal employment opportunities existence.
26-	Work conditions are essential to improve the work.
27-	Enhance employee skills and retention them
28-	Intelligent selection and use of raw materials to minimize the resource wastes.
29-	Reduction of office energy and water usage.
30-	Reduced emissions of pollutants to prevent the Global warming
31-	Using Sustainable or renewable energy technologies.
32-	Using Green material in project design.
33-	Sustainable values of properties and tracts of land.
34-	Job creation for all sectors Combined
35-	Use of local resources.
36-	Creating employment during and after the project.
37-	Your company focus on marketing and compotation issues.

38-	**Minimizing the Area intensity that using for the unit of the project**
39-	Interesting to the amount of materials used in the one unit
40-	Pay attention to the energy used to construct the power system
41-	Interest to the energy (in MJ) that is consumed as fuel by the power system to generate each kWh of delivered energy.
42-	Interest about the Capacity factor [%], The fraction of

	time, expressed as a percentage that a power system operates at its rated power
43-	Interest about the System efficiency [%], The efficiency, expressed as a percentage, with which the fuel or resource is converted into electricity.
44-	Interest about the Lifetime [years] The expected time (in years) that the power system will remain fully operational

Thank you for taking the time to complete this questionnaire If you have any questions about the survey, please feel free to contact me.

Curriculum Vitae

Personal Information

Name: Bilal Aldewachi

Academic Background

-Bachelor of Environmental Science, University of Mosul, College of Environmental Science and Technology, Iraq, (2012).

-Master of Environmental Science and Technology, University of Mosul, College of Environmental Science and Technology, Iraq, (2016).

Languages

Arabic – Native

English – Fluent

Turkish – Beginner / Basics

Work Experience

(2009-2014) Editor ALSHAJARA ALTAYBA at the University of Mosul, Iraq.

(2012–2014): Active member in AL-HADBA society for Iraqi environmental protection, Iraq.

(2016 – 2017): Lecturer about environmental issues, non-governmental organization, Iraq.

(2018-2020): Researcher, The Center of Making Policies for International and Strategic Studies, Turkiye**.**

Publications and Presentations Derived from the Thesis

Aldewachi, B., & Ayağ, Z. (2021). Achieving Sustainability in Solar Energy Firms in Turkey through Adopting Lean Principles. *Sustainability*, *14*(1), 108. **https://doi.org/10.3390/su14010108**

Aldewachi, B., & Ayağ, Z. (2022). Achieving Technology and Resource dimensions in Solar Energy Firms Through Adopting Lean Principles (Under review).