# Aggregate Planning with Sustainability Consideration and Business Model Assessment

by

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# Aggregate Planning with Sustainability Consideration and Business Model Assessment

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*To my dearest family and my beloved husband*

# ABSTRACT

**Aggregate Planning with Sustainability Consideration and Business Model Assessment**

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Industrialization and technology have wreaked havoc on the planet during the previous century. As humans have grown conscious of the devastation they have created and the threats they have posed to future generations, sustainability has risen to the fore as a method of decreasing it. The three bottom lines (TBL) of sustainability are economic, social, and environmental. These three aspects should simultaneously involve in the sustainable decision-making process. The literature review has shown that many academic and practical studies have been done for the economic objective comprehensively, yet few studies have done analytically considering the three bottom lines.

An inclusive business model, which encourages sustainable growth, aims to derive value for low-income communities by engaging them into the value chain. Although the inclusive business model has been studied extensively by academicians and practitioners, there is a lack of systematic research on how the inclusive business model affects the companies and base of the pyramid (BOP) quantitively; therefore, many inclusive business models model implementations turned into philanthropy.

The TBL accounting for the aggregate planning problem is addressed in this thesis using a methodological framework based on mathematical programming. The framework is a multi-objective mixed-integer linear programming model with the following objectives: maximizing profit, minimizing environmental damage, and maximizing social benefit. Additionally, the inclusive business model is integrated into the sustainable aggregate planning problem. The multi-objective mixed-integer model

was examined in four different phases, and a realistic case study was conducted for each phase.

The proposed framework demonstrates how sustainability bottom lines and business strategies can be included in the aggregate planning model. Framework proves that decision-makers will make a profit while being environmentally and socially conscious. Although companies may have to sacrifice some profits initially to enhance their social and environmental impact, their reputation and profitability will increase in the long run.

# ÖZETÇE

**Sürdürülebilirlik Değerlendirmesi ve İş Modeli Değerlendirmesi ile Toplu Planlama**

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**Endüstri Mühendisliği, Yüksek Lisans**

**21 Ocak 2022**

Sanayileşme ve teknoloji, geçen yüzyılda gezegende hasara yol açtı. İnsanlar yarattıkları tahribatın ve gelecek nesillere yönelik tehditlerin bilincine vardıkça, bunu azaltmanın bir yöntemi olarak sürdürülebilirlik ön plana çıktı. Sürdürülebilirliğin üç temel çizgisi ekonomik, sosyal ve çevreseldir. Bu üç yön, aynı anda sürdürülebilir karar verme sürecine dahil edilmelidir. Literatür taraması, ekonomik amaç için kapsamlı bir şekilde birçok akademik ve pratik çalışmanın yapıldığını, ancak üç ana çizgiyi dikkate alan analitik olarak çok az çalışmanın yapıldığını göstermiştir.

Sürdürülebilir büyümeyi teşvik eden kapsayıcı iş modeli, düşük gelirli toplulukları değer zincirine dahil ederek değer elde etmeyi amaçlar. Kapsayıcı iş modeli, akademisyenler ve uygulayıcılar tarafından kapsamlı bir şekilde çalışılmış olmasına rağmen, kapsayıcı iş modelinin şirketleri ve piramidin (BOP) tabanını matematiksel olarak nasıl etkilediğine dair sistematik araştırma eksikliği vardır, bu nedenle birçok kapsayıcı iş modeli uygulaması hayırseverliğe dönüşmüştür.

Bu tezde, matematiksel programlamaya dayalı metodolojik bir çerçeve kullanılarak TBL muhasebesi toplu planlama problemi ele alınmaktadır. Çerçeve, aşağıdaki hedeflere sahip çok amaçlı karma tamsayılı doğrusal programlama modelidir: kârı en üst düzeye çıkarmak, çevresel etkiyi en aza indirmek ve sosyal etkiyi en üst düzeye çıkarmak. Ek olarak, kapsayıcı iş modeli, sürdürülebilir toplu planlama problemine

entegre edilmiştir. Çok amaçlı karma tamsayılı model dört farklı aşamada incelenmiş ve her model için gerçekçi bir durum çalışması yapılmıştır.

Önerilen çerçeve, sürdürülebilirlik temel çizgilerinin ve iş stratejilerinin toplu planlama modeline nasıl dahil edilebileceğini göstermektedir. Çerçeve, karar vericilerin çevreye ve topluma fayda sağlarken kar elde edebileceklerini kanıtlıyor. Şirketler, sosyal ve çevresel etkilerini artırmak için başlangıçta bir miktar kârlarından fedakarlık etmek zorunda kalsalar da, uzun vadede itibarları ve kârları artacaktır.

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# ABBREVIATIONS

| | |
|---|---|
| BoP | Base of the Pyramid |
| SSCM | Sustainable Supply Chain Management |
| IB | Inclusive Business |
| TBL | Triple Bottom Lines |
| SDGs | Sustainable Development Goals |

# Chapter 1:
# INTRODUCTION

The Industrial Revolution started in the second half of the 18th century due to the start of mechanization and the discovery of power sources necessary for industry, such as the steam engine. Since then, industry and technology have constantly been developing. Later, towards the end of the 20th century, production and consumption have accelerated with the production of computers and the development of technology in different fields. The usage of non-renewable energy resources, the depletion of natural resources, and many more used for this production and consumption are destroying the world. During these last two centuries, our planet has suffered more than previous civilizations could have done in a thousand years. In this age of industrialization and technology, we have done great harm to the atmosphere, the soil, and the planet's genetic diversity. These destructions and changes have created global apprehension and led to calls for sustainable development from the exploitative industry. These concerns have evolved, and sustainable development has been defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [Report of the World Commission on Environment and Development: Our Common Future, 2008]

Sustainable development has three dimensions, also called as three bottom lines (TBL), and differs from the term "development" by considering not only the economic point of view but also the environmental and social aspects in which all three dimensions are intertwined [Wasiluk, 2013]. Socially, the aim is to end poverty, eradicate hunger, provide good health, provide quality education, achieve gender equality, reduce inequalities. In the environmental aspect, the ambition is to provide clean water and sanitation, serve affordable and clean energy as well as protect land, water, and air. Third, the purpose of the economic objective is to ensure decent work and economic growth, support responsible consumption, and production, and encourage sustainable industry. Many studies have been carried out on environmental and economic aspects by academics and practitioners, but the social dimension has remained relatively weak on the academy and practical side compared with the other dimensions

[Moreno-Camacho et al., 2019]. In order to genuinely achieve sustainable development, it needs to be examined in all three aspects. This thesis aims to establish a decision support mechanism for the aggregate planning problem that considers the inclusive business strategy and the three aspects of sustainable development together. With this framework, we intend to ensure sustainable profits, reduced environmental damage, and increased social benefit while making more reliable and accurate decisions. Hence, we have created a mathematical model that examines aggregate planning problems.

In 1932, the term "bottom of the pyramid" was initially coined by Franklin D. Roosevelt in his radio address. He stated, "[to] build from the bottom up and not from the top down, that put their faith once more in the forgotten man at the bottom of the economic pyramid [Gupta A. , 2013]. However, Stuart Hart and C.K. Prahalad were the first authors to use "base of the pyramid (BOP)" in a written format for the first time in 1999 [Prahalad and Hart, 1999]. Since "Base" has a more empowering framework, most cite it as a base of the pyramid instead of the bottom. Not only when BOP was first written, but still the measure of poverty is not precise despite the fact that much research has been done on those at BOP for 20 years. Different limits have been set for the definition of BOP in various articles for the last two decades. In most articles, it is defined as societies with incomes below US$1500-US$2000 dollars per year, which is the limit set by BOP pioneer Prahalad, Hammond, and Hart [Prahalad and Hammond, 2002; Prahalad and Hart, 2002]. According to Prahalad, Hammond, and Hart, there are 4 billion people with an income level of less than US$2000 annually [Prahalad and Hammond, 2002; Prahalad and Hart, 2002]. Another common BOP community definition limit used by academics and practitioners is that communities acquire US$1-US$3 per day [Banerjee and Duflo, 2007]. According to Anderson and Billou, the average per capita income of more than one billion people worldwide is US$1 per day [Anderson and Billou, 2007]. Additionally, research conducted by Cañeque and Hart in 2017 indicated that four and a half billion people are trying to survive on less than 8 dollars per day [Cañeque and Hart, 2015; García-Feijoo et al., 2020]. As a result, different measurement limits have been set for BOP by different researchers in the literature. However, the constant and vital knowledge is that whether it is under US$8 or US$1 per day, a considerable proportion of the world's population is in poverty. Sustainable development becomes a necessity in order to reduce this poverty and achieve a sustainable world. Being aware of this, in 2015, the United Nations (UN) has made a global call with 17 sustainable development goals (SDGs) to eradicate poverty and protect the planet by 2030 [sdgs, 2015]. More than 190 countries have committed to meeting these 17 SDGs, which aim to achieve sustainable social and economic development and strengthen universal peace by 2030 [García-Feijoo et al., 2020]. The pledge of 190 countries to achieve these goals is, in fact, an indication that countries are aware of economic and social inequalities, and countries are striving to tackle them [Davies et al., 2021].

To examine BOP, which is the lowest segment of the wealth inequality pyramid, and wealth inequality in the world in detail, figures will be used. In below, Figure 1 represents the global wealth pyramid. The bottom of the global wealth pyramid shows people with less than $10,000 in wealth. In 2021, 55% of the adult population in the world has a wealth level of less than $10,000. The combined wealth of these adults is approximately 5.5 trillion, making up only 1.3% of the world's total wealth. Unfortunately, as can be seen from this information, the wealth of more than half of the world's population is incredibly low. This is a heartbroken picture of wealth inequality in the world. The next segment can be named as the low-middle segment. The wealth of the low-middle segment is between $10,000 and $100,000, with 1.7 billion people living in this segment. Considering that the population living in this segment was 0.5 billion in 2000, the number of people living in this segment has more than tripled in the last two decades [Davies et al., 2021]. This change is an indication that the welfare, especially for developing countries, has slightly improved. The average wealth of the low-middle segment, which makes up 32% of the world's population, is $33,400, and unfortunately, the average wealth of this segment is still below the average wealth of the world. This is evidence that the remaining 12% of the population owns most of the world's assets and drives up the average assets. The next segment can be named as the upper-middle segment, and the people living in this segment have a wealth of between $100,000 and $1 million. While the upper-middle segment constitutes 11.1% of the world's population, they own 39.1% of the world's wealth. The 11.1% population in this segment represents the middle class in developed countries, and as can be seen from Figure 1.1, it has more than 2.5 times the presence of 88% of the world's population that makes up the low segments. Finally, top of the pyramid is the segment whose fortunes are more than US$1 million. USD millionaires make up only 1.1% (56 million) of the world's adult population; however, these 56 million people own 45.8% of the world's total wealth. Until 2020, the population of USD millionaires was consistently below 1% of the world's population, but for the first time in 2020, 1% was exceeded [Davies et al., 2021]. According to the Bloomberg Billionaires Index (BBI), a total of 31% increase in wealth has been recorded in the list of billionaires in 2020 [bloomberg, 2021]. This index has been published for the last eight years, and this increase has been the highest increase in wealth. The reason for this increase is the covid 19 epidemic that took place at the end of 2019. Events such as an epidemic, war, global crisis cause wealth inequality to increase because, at these times, the rich get richer by taking advantage of the opportunities, while the poor get poorer due to the obstacles they face. For example, one of the world's well-known names, Jeff Bezos 57%, Elon Musk 560%, and Mark Zuckerberg 89%, increased their wealth in 2020 [bloomberg, 2021]. According to the BBI, 164 of the world's 500 richest people are from the United States [bloomberg, 2021]. This shows that income distribution also differs between countries [bloomberg, 2021].

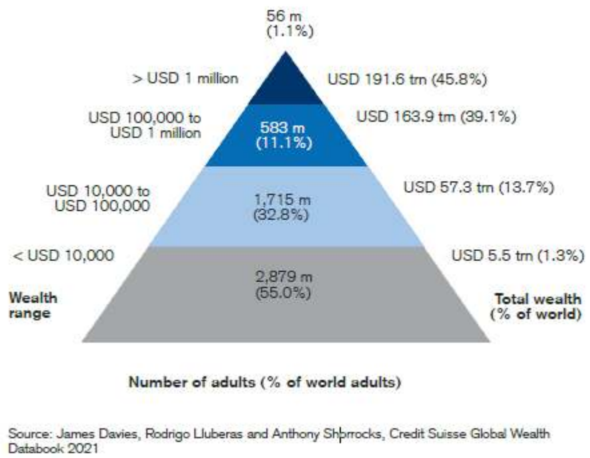


Figure 1.1 Global Wealth Distribution.

Although wealth inequality exists in every country globally, it may be more in some countries and less in others. In below, Figure 1.2 and Figure 1.3 show the regional distribution of global wealth for 2000 and 2020. As seen from the figures, although North America and Europe are mainly at the top of the pyramid, they also have significant populations at the bottom of the pyramid, especially in Europe. Africa and

India in 2000 concentrated the majority of their populations base of the pyramid. While the population of the Asia-Pacific region is distributed in similar proportions to each segment of the pyramid, in 2000, China was generally concentrated in the middle of the pyramid. As the comparison of 2000 and 2020 distributions presents that China has shifted a significant part of its population from the middle part to the top decile. While China has increased its population at the top of the pyramid, North America, Europe, and Asia-Pacific shares at the top tier have shrunk in 2020. Even though North America has shrunk a little from its top decile from 2000 to 2020, it has the largest share at the top decile according to 2020 data. At the top of the pyramid, the largest share in this region and the largest share in country-based comparison is the United States, with 39% [Davies et al., 2021]. Although the judgment that income inequality is low in developed countries is not entirely correct, it can be interpreted that more people live at the bottom of the pyramid in underdeveloped and developing countries. In the last 20 years, millions of Chinese have increased their incomes with the economic reforms of the Chinese government. Nevertheless, economic development has not reduced wealth inequality in China. On the one hand, a significant middle class and an increasing upper segment are seen; on the other hand, it is observed that the population of the BOP level is increasing. Although there has been economic development in China, there has been an improvement for some of the population regarding welfare and worsening for others. In order to decrease wealth inequality, companies should follow the path of sustainable development, "development" is not enough.

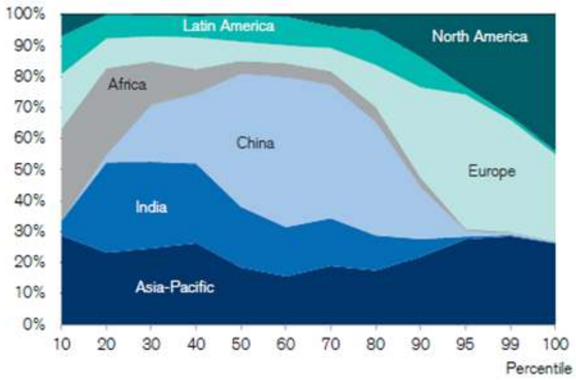


Figure 1.2: Regional Wealth Distribution in 2000

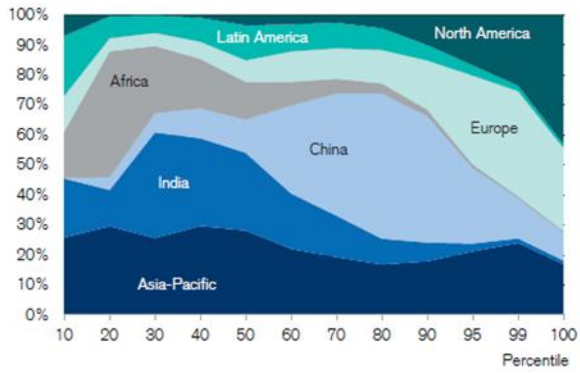


Figure 1.3: Regional Wealth Distribution in 2020

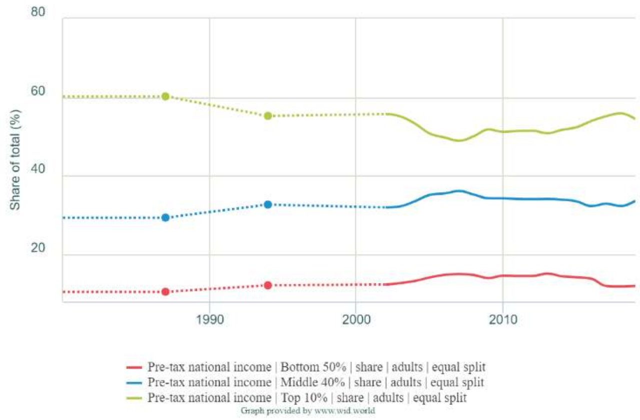


Figure 1.4: Income Inequality in TURKEY

Since we are implementing our case study with a company in Turkey, we will examine the income distribution of Turkey in more detail. Figure 1.4 represents the Turkey's income inequality from 1980 until 2019. After 1994, income distribution slowly began to stabilize until 2003. It is observed that income inequality decreased from 2003 to 2007 and the top tier approached to the middle 40% between these years. It is observed that with the global economic crisis in 2008, things turned around and income inequality increased again. Although income inequality follows a slope that increases and decreases since 2008, the gap between the top 10 and bottom 50 percent of the population has tended to broaden again.  World Inequality Database has divided the income inequality of countries into 5 classes according to the income of 10% of the country's population. If the share proportion of 10% of the population of the country is between 21 and 35, it is the lowest and 1st class, if 35-42 is in the 2nd class, if 42-47 is in the 3rd class, if 47-51 is in the 4th class and above 51 is designated as 5th grade

[World Inequality Database, 2021]. Since 10% of Turkey's population has approximately 54% of its income, Turkey is in the 5th class in the income inequality table and is among the countries with one of the highest income inequalities in the world. Considering the high-income inequality in Turkey, it is imperative to direct companies in Turkey towards sustainable development. We did our case study with an organic fruit seller in Turkey to set an example for other companies especially in Turkey.

Since we are implementing our case study with a company in Turkey, we will examine the income distribution of Turkey in more detail. Figure 1.4 represents Turkey's income inequality from 1980 until 2019. After 1994, income distribution slowly began to stabilize until 2003. It is observed that income inequality decreased from 2003 to 2007, and the top tier approached the middle 40% between these years. It is observed that with the global economic crisis in 2008, things turned around, and income inequality increased again. Although income inequality follows a slope that has increased and decreased since 2008, the gap between the top 10 and bottom 50 percent of the population has tended to broaden again. World Inequality Database has divided the income inequality of countries into five classes according to the income of 10% of the country's population. If the share proportion of 10% of the population of the country is between 21 and 35, it is the lowest and 1st class, if 35-42 is in the 2nd class, if 42-47 is in the 3rd class, if 47-51 is in the 4th class and above 51 is designated as 5th grade [World Inequality Database, 2021]. Since 10% of Turkey's population has approximately 54% of its income, Turkey is in the 5th class in the income inequality table and is among the countries with one of the highest income inequalities in the world. Considering the high-income inequality in Turkey, it is imperative to direct companies in Turkey towards sustainable development. We did our case study with an organic fruit&vegetable seller in Turkey to set an example for other companies, especially in Turkey.

There is more or less wealth inequality all over the world. If companies do not prefer sustainable development, even if there is economic growth, as in China, wealth inequality will increase. While developing to reduce wealth inequality, including the bottom of the pyramid in the system is necessary. In this case, how will companies put the bottom of the pyramid into the system? The answer is Inclusive Business (IB). IB model acts as a bridge between companies and those at the bottom of the pyramid, providing a win-win situation. The BOP may take a role as a supplier, distributor, retailer, or customer to the organizations' value chains. In return, companies may offer products and services to low-income populations. IB is not charity work or philanthropy; incorporating people excluded from the value chain into the system creates sustainable development systems of mutual gain [Menden et al., 2019]. The benefits of IB to companies can be listed as follows. Companies establish new markets in developing countries and increase the number of customers to offer their products and services. IB strengthens companies' supply chain by incorporating new suppliers, who may sell cheaper than traditional suppliers or produce more specialized products, into the supply chain. As companies improve social impact through IB, they increase their reputation and attract more attention from customers and investors. On the other hand, the benefits of IB to BOP can be listed as follows. The poor are able to meet their basic needs such as clean water, nutritious food, health system, security, electrical power, telecommunication, etc. Productivity in their work increases as opportunities such as electricity and the internet are offered; for example, productivity increases as they learn new things about their expertise thanks to the internet. As the BOP producers can reach new sales channels as well as new job opportunities are created as the need for service increases. Hence, generally, the wealth level raises at the BOP. Unfortunately, businesses must also face considerable challenges when including the bottom of the pyramid to the value chain. Firstly, insufficient or absent infrastructure such as roadways, electricity, and other energy sources may raise transaction costs. Second, uncertainty, capacity limits, insufficient knowledge, regulations of new markets, and supply chain networks may cause extra costs for companies. However, it is expected that when businesses utilize the inclusive business model, the total benefit will grow. The reality is that achieving a balance between economic, environmental, and social aspects leads to cost savings, productivity gains, competitive advantages, and improved environmental and social consequences. For instance, reduced wastes lead to reduced expenses and reduced health and safety expenses. Lower recruiting and turnover costs were the result of safer and better working conditions, and development in working conditions lead to decreased absenteeism and increased production rate [Carter and Rogers, 2008].

Nowadays, multinational companies have gradually begun to understand that they cannot grow sustainably without putting the bottom of the pyramid into the system. For this reason, at the bottom of the pyramid, attempts were made to integrate them as producers, suppliers, distributors, or customers. However, many of them later turned into just charity work due to difficulties. In order to the IB model to be sustainable, companies must first be aware of what challenges BOP producers to face. 50% of the BOP population living in developing countries are small farmers who own or lease land, and 1.3 billion farm workers and smallholders generate income from agriculture [IFPRI, 2002; World Development Report, 2008]. Since at least 50% of the producers living at the bottom of the pyramid work in the agricultural sector, we will usually give examples of agriculture. Also, we chose our case study on the agriculture sector. The difficulties faced by producers living at the bottom of the pyramid can be divided into two general headings: value creation (productivity constraints) and value capture (transactional constraints). The primary constraint affecting productivity is the lack of quality raw materials. For example, quality seeds for agriculture, quality fertilizer, and water affect productivity to a great extent. In the absence of these, they get low quality and/or inefficient products. As a result, they are forced to stay in a circle of poverty where they cannot earn enough income for the following agricultural season and must produce products of low quality again. Another productivity challenge for producers at the bottom of the pyramid is the limited financial resources. For example, BOP farmers should provide the necessary inputs at the beginning of the planting period; in order to provide these inputs, they need to have savings from previous periods. However, most BOP farmers lack of savings. Therefore, they need debt to purchase inputs. Official lending institutions such as banks require guarantees and charge high-interest rates to people with low credibility. Despite these high-interest rates, farmers take out the loan to provide the input, and if everything goes well, there is not any problem. However, when productivity decreases due to unexpected reasons such as excessive precipitation, drought, insect infestation, etc., BOP farmers struggle with extreme difficulties to pay off the debt and survive.

On the other hand, transactional constraints can be summarized in three main headings. First, access to the market has become an obstacle for BOP producers, as production is often carried out in locations far from urban centers. Especially in underdeveloped or developing countries, due to the weak infrastructure (roads and transportation systems), it is challenging for small-scale producers to deliver their products to their market points. Second, BOP producers often sell their products to local traders since they have difficulty reaching the final market points and customers. Sometimes local traders come to an agreement among themselves, manipulate domestic small-scale producers, and buy products at low prices from the producers. This situation raises the number of difficulties faced by BOP producers. The third issue is that significant price fluctuations from one season to the next cause a devastating effect for BOP producers. BOP producers are vulnerable to such fluctuations as they do not have a wide variety of market alternatives and may have no choice but to sell to local traders who use these situations to their advantage. Suppose companies are aware of the difficulties experienced by those at the bottom of the pyramid. In that case, they are one step closer to making the inclusive business model they have established sustainable.

Considering the above discussions, it is necessary and vital to make a decision support tool for designing and analyzing options that will take into account an inclusive business model, the three aspects of sustainable development, and the constraints of the aggregate planning problem. This framework is anticipated to illustrate the feasible aggregate plan. The purpose of this framework is to ensure sustainable development while assisting make more reliable network decisions.

The thesis consists of 5 chapters: Introduction, Literature Review, Method, Application, Conclusion. In Chapter 2, we examine the literature review as well as the gaps in the literature. Chapter 3 demonstrates our methodology for combining the TBL of sustainability and IB into the aggregate planning problem. In Chapter 4, we will present a realistic case study that applied to our mathematical model, and we analyze and discuss the results. Finally, Chapter 5 evaluates the results and examines future research opportunities.

Chapter 2:

# LITERATURE REVIEW

Sustainable supply chain management focuses on the fair and transparent distribution of money, balanced use of natural resources, positive impact on the environment, and the protection and development of society in order not to lose their competitive advantage [sdgs, 2015]. According to Khan, sustainable supply chain management is the combination of the triple-bottom-line (TBL) dimensions with traditional supply chain (SC) practices [Khan et al., 2019]. Combining the TBL dimensions with classical supply chain management has attracted the attention of many academics and practitioners as one of the most attractive topics in supply chain management [Moreno-Camacho et al., 2019]. An increasing amount of research is being conducted in the field [Ansari and Kant, 2017; Gupta and Palsule-Desai, 2011; Rajeev et al., 2017; Seuring and Müller, 2008; Touboulic and Walker, 2015]

The papers in the literature focus on sustainable development written from various countries; the USA, which has 14% of share, is in the first place, followed by Germany and UK with a share of about 12% [Ansari and Kant, 2017]. India and China come together in fourth place in the literature, which may be surprising, but SSCM is of great importance for developing economies [Ansari & Kant, 2017]. Most multinational companies (MNCs) target developing and underdeveloped countries to supply low-cost raw materials, provide low-cost labor, or expand their market. Thus, developing countries such as India and China will play an essential role in sustainable development. Approximately 60% of the case studies on the sustainable supply chain problem were conducted in the Asian region. Especially China and India are the countries that contribute the most in academia. Due to the destruction caused by the expeditiously increasing production and consumption in China and Iran, sustainability concerns have increased in these regions, and the orientation to SSCM has increased

Researchers have carried out their discussion by using combinations of TBL dimensions which are economic, environmental, and social, or all three aspects together in their research. The economic perspective is irrefutably covered in almost all SSCM research. From the economic point of view, the most mentioned topics are respectively; transportation costs, facility establishment costs, logistics-related costs, purchasing, inventory/raw material holding, operational costs [Moreno-Camacho et al., 2019]. Finally, the effects of some environmental criteria on cost are also examined, such as carbon emission taxes, carbon trades, etc. [Jin et al., 2014]. The majority of articles that addressed two of the three perspectives in SSCM research examine the environmental aspect in addition to the economic aspect. The environmental bottom line has generally been researched on pollution (air, land, water) [Cholette and Venkat, 2009], resource consumption (water, waste) [Georgiadis and Besiou, 2009], and sustainable energy sources (wind, solar, geothermal). However, air pollution, especially CO2 emission, is the most discussed environmental criterion, unlike water and land pollution [Moreno-Camacho et al., 2019]. The number of studies examining social perspective combined with the economic or the environmental perspective is proportionally very few [Seuring and Müller, 2008; Moreno-Camacho et al., 2019]. From the social point of view, subjects such as unemployment rate, job opportunities, health and safety systems, and social development are discussed. However, studies of social aspects are few compared to environmental and economic fields. Most research that considers the social aspect is qualitative since it is difficult to quantify social constraints and scarcity of available data from a social point of view [Barbosa-Povoa et al., 2018; Finkbeiner et al., 2010].

Qualitative studies have been more dominant in SSCM literature from the very beginning. Qualitative research, such as case studies and conceptual models, makes up almost 65%, and quantitative 35% of the literature. Nevertheless, desk-quantitative research, such as mathematical modeling and simulation, only make up 15% of the literature [Ansari and Kant, 2016]. The main reasons for the lack of qualitative research are that available data is limited and mathematical models become complex with TBL of sustainability and many constraints from SCM. The inadequate number of mathematical models in SSCM decelerates the spread of sustainable development because practitioners hesitate to implement the SSCM since they cannot predict the mathematical consequences of the difficulties, they will face [Seuring, 2013]. Many articles have been published that enhance conceptual frameworks, literature reviews, and empirical studies, which have laid the groundwork for the SSCM theoretical framework. However, only a few articles have been published that connect the developed theories in a realistic system using mathematical modeling [Ansari and Kant, 2016]. As a result, more mathematical models should be developed so that businesses, regardless of sector, can utilize them as a decision-making mechanism to disseminate SSCM more quickly [Ansari and Kant, 2016].

Sustainable supply chain practices can be seen in various sectors, including manufacturing (especially electronic components) [Eskandarpour et al., 2015], education [Zhu and Sarkis, 2006a], agriculture [Chavez et al., 2018], bioenergy [Eskandarpour et al., 2015] and several other fields. Many sustainability research has been done on the economic and environmental perspectives from production to consumption stages in the agricultural sector, yet the social perspective has rarely been considered [Moreno-Camacho et al., 2019]. This creates a gap in the field in the agriculture sector, so in this study we have implemented our mathematical model, which includes all 3 perspectives of sustainability, with a case study in the agricultural sector.

The primary goal of sustainable development is to eradicate poverty, and the inclusive business model is the key to reducing poverty [Hart et al., 2016; Hart, 2015]. The inclusive business model aims to lift those at the bottom of the pyramid (BoP), the poorest socio-economic group that makes up almost half of the world population group, out of poverty by including them in the value chain as customers, suppliers, retailers, or/and distributors [Halme et al., 2012]. When small-scale actors (BoP) are involved in value chains, they will get many benefits such as revenue growth [UNDP, 2013] access to products, services, infrastructure and finance [IFC, 2010; UNDP, 2013], new and quality job opportunities [WorldBank, 2014], and improvement on skills [Kelly et al., 2015]. While the IB model was initially coined by the World Business Council for Sustainable Development in 2005, its origins traced back to the 1990s, when structural adjustment programs (SAPs) included inclusiveness in low-income countries [Likoko and Kini, 2017]. There are more than 2350 papers written on inclusive business in the literature [Likoko and Kini, 2017]. Most of them were written after 2007. The type of research on these papers is generally (45%) qualitative studies (case study) [Han and Shah, 2020]. The IB case studies and examples in the literature have generally been conducted in developing countries. Even India and China are at the top of the literature, as is SSCM [Kolk et al., 2014]. These case studies have been developed in various sectors, but especially examples are from information and communication technologies, fast-moving consumer goods (FMCG), service, and energy sectors. Papers containing mathematical models related to IB are 10% of all research focus on IB [Han and Shah, 2020]. As with SSCM, the number of studies conducted by establishing a quantitative model in IB is less than other types of research [Han and Shah, 2020]. The number of studies dealing with SSCM and IB topics together is few, and the literature of quantitative studies combining these two areas is frail [Speelman et al., 2019]. While some companies have tried the IB model before, many of them have only turned it into charity work due to the difficulties they have encountered. More mathematical models and realistic applications of these models in the literature will enable more companies to focus on IB and SSCM applications.

To sum up, despite all the research on sustainable supply chain management and inclusive business model, most organizations throughout the world find it extremely difficult to implement it in their end-to-end supply chains [Carter and Rogers, 2008]. During the last two decades many research has been done on sustainable supply chain management [Govindan, Rajendran et al., 2015; Khan et al., 2016; Wolf and Seuring, 2010; Raut et al., 2019; Anvari and Turkay, 2017; Rasmi and Turkay, 2020] and inclusive business model [Lashitew et al., 2018; Gupta et al., 2015; Chamberlain and Anseeuw, 2019]. A limited fraction of scholarly research papers assists in quantitatively understanding sustainable supply chain management and inclusive business model. Companies are under pressure from customers and regulators. However, they hesitate to implement SSCM due to their difficulties during sustainable supply chain and inclusive business implementations, resulting in poor SSCM and IB adoption [Xie, 2016; Khan et al., 2020a; Kumar et al., 2019]. It is necessary to boost the pace and frequency of SSCM and IB implementation since much quantitative research is required that will examine SSCM and IB areas from various perspectives to support the decision-making process [Seuring, 2013]

According to the above arguments, sustainability and the IB model have an important place in academia and practice. However, there are still many gaps in the literature that need to be filled. This work serves as a bridge in the mentioned gaps in the literature that still exist in academia and practice. We have created a comprehensive framework for the aggregate planning problem to understand the difficulties and advantages of sustainability and IB. We have developed a mathematical model that companies, including IB, TBL, and supply chain network constraints, can use as a decision-making tool while implementing sustainable development. The model's objective functions and constraints were created according to 3 aspects of sustainability. Our linear models can cope with large amounts of data sets and develop feasible solutions while considering all limits, parameters, and a variety of variables. Therefore, it is an effective model for dealing with aggregate planning problems, IB, and sustainability, which have a variety of constraints and parameters. According to this aggregate planning problem evaluation, businesses can efficiently cope with actual difficulties and obstacles and foresee their potential possibilities and advantages. The multi-objective mixed-integer problem is solved, and optimum alternatives are defined. Analyses were made in order to define the advantages and disadvantages of the identified alternative solutions. The model aims to minimize risks and obstacles by creating the best possible aggregate plan, including economic, social, and environmental factors. Since most people living at the bottom of the pyramid work in agriculture, we focused on the agricultural sector in the IB aggregate planning problem. We implemented our mathematical model on a network of organic agriculture producers and vendors in Turkey; the results will be presented and discussed in the next sections.

# Chapter 3:
# METHOD

## 3.1 Problem Definition

Aggregate planning's objective is to synchronize supply and demand and create an aggregate plan that meets demand while maximizing overall profit [Russell and Taylor-Iii, 2008]. All steps of the supply chain, from the start to the end, cause lots of costs to the companies. To minimize these costs, such as production amount, inventory, stock-outs, number of employees, etc., a decision support tool can be produced with aggregate planning. A lot of work has been done by academicians and practitioners on aggregate planning, but we have also integrated sustainability and inclusive business concepts. We created an aggregate planning problem based on mathematical programming to assist the decision support mechanism for medium-term decisions of companies that we included sustainability's three perspectives and inclusive business concept. We solved the multi-objective model using the augmented epsilon constraint method. As a result, we obtained Pareto optimal solution sets. In each Pareto optimal solution, economic, environmental, and social objective values are comprised. After then, a sensitivity analysis is performed to observe how the solution alters as the parameter values shift.

## 3.2 Model

***Sets:***

$i \in SL$: potential supply location.

$j \in WL$: potential warehouse location.

$v \in CL$: potential customer location.

$m \in TM$: the set of available transport mode between farm and warehouse.

$n \in TMW$: the set of available transport mode between warehouse and customer.

$t \in T$: monthly time index.

$e \in E$: potential of educated or non-educated employee.

***Parameters:***

*CSW*: average salary of one worker.

*CS*: cost of supply transportation with transit.

*CSS*: cost of supply transportation with truck.

*CP*: cost of product transportation.

*CI*: cost of inventory perishment.

*CE*: energy cost for each product.

$CX_t$: cost of amount of supply purchase at time $t \in T$.

$Tax_j$: tax rate selling at $j \in WL$.

$SP_t$: selling price at time $t \in T$.

$dis_{mij}$: distance between $i \in SL$ *to* $j \in WL$ via transport $m \in TM$.

$dist_{njv}$: distance between $j \in WL$ to $v \in CL$ via transport $n \in TMW$.

$COE_m$: $CO_2$ emission via transport $m \in TM$.

$CO_n$: $CO_2$ emission via transport $n \in TMW$.

*JLRS*: jobless rate at supplier location.

*JLR*: jobless rate at warehouse location.

*PRS*: population density at supplier location.

*PRW*: population density at warehouse location.

*HSL*: highest security level national.

*SLS*: security level at supplier.

*SLW*: security level at warehouse.

*ROSL*: national range of security level.

*EI*: expected education improve in warehouse location.

*EEL*: existing education access in warehouse location.

*EIS*: expected education improve in supplier location.

*EELS*: existing education access in supplier location.

*HI*: expected health improve in warehouse location.

*EHL*: existing health level in warehouse location.

*HIS*: expected health improve in supplier location.

*EHLS*: existing health level in supplier location.

*EMI*: expected empower improve in warehouse location.

*EMIS*: expected empower improve in supplier location.

*teta*: transform rate, (1 - waste rate)

*CSO*: cost of stock out

$DM_{tv}$: demand in $v \in CL$ at time $t \in T$.

*WR*: water req for 1 kg lemon production.

*CW*: cost of unit water.

*PR*: Pesticide Requirement.

*CPR*: cost of unit pesticide.

*COP*: cost of organic packaging (unit).

*CIP*: cost of inorganic packaging (unit).

*W*: packing waste amount of kg's of lemon.

*WS*: waste sensitivity.

*CEP*: carbon emission per kg product.

*AES*: carbon emission sensitivity.

*CF*: firing cost.

*CH*: hiring cost.

*SOS:* soil emission sensitivity.

***Decision Variables:***

*Continuous Variables:*

$X_{tmij}$: amount of supply shipment from supplier $i \in SL$ to warehouse $j \in WL$ with transport mode $m \in TM$ at time $t \in T$.

$Y_{tnjv}$: amount of fined product shipment from warehouse $j \in WL$ to customer $v \in CL$ with transport mode $n \in TMW$ via mode $m \in TM$ at time $t \in T$.

$I_t$: amount of inventory at time $t \in T$.

$S_t$: number of kg' s sold in period $t \in T$.

$OP_t$: number of organic packaging at $t \in T$.

$IP_t$: number of inorganic packaging at $t \in T$.

$P_t$: total packaged product at time $t \in T$.

*Integer Variables:*

$NW_{te}$: number of e $\in E$ educated or non-educated workers at time $t \in T$ at warehouse.

$NWS_{te}$: number of e $\in E$ educated or non-educated workers at time $t \in T$ at supplier.

$H_t$: number of people is hired at time $t \in T$ in supplier.

$F_t$: number of people is fired at time $t \in T$ in supplier.

$HW_t$: number of people is hired at time $t \in T$ in warehouse.

$FW_t$: number of people is fired at time $t \in T$ in warehouse.

*Binary Variables:*

$b_t$ : 1 if truck is used for transportation, 0 else at time $t \in T$.

### *3.2.1 Defining economic objective and parameters:*

In the economic objective, the goal is to maximize profit by minimizing costs and maximizing revenue. While choosing the parameters, we benefit from the company's actual data, which is the seller of organic fresh fruits and vegetables, and the literature in this context. We assumed that the market demand was known based on the company's experience. A minimum of 90% of the demand must be satisfied because it causes a severe decrease in customer dissatisfaction if it is not met. Since customer dissatisfaction damages brand value, this limit has to be set. The following parameters are considered as economic criteria:

**Labor Cost**: Labor cost varies depending on whether the employee is educated or uneducated. Uneducated employees receive 2825₺, which is the minimum wage in Turkey for 2021, and the reflection of this to the employer with other expenses is 4200₺. On the other hand, the reflection of the average salary of educated employees in the agricultural and fast-moving consumer goods sector to the employer is 5500₺ [csgb, 2021].

**Inventory Perishment Cost:** The company's demands are usually fluctuating. Therefore, if the company can keep inventory, it will reduce costs. However, the company we did the case study cannot keep inventory because the deterioration time of the products sold by the company is short (a few days). Even if the company keeps inventory, it cannot be used next month. Inventory should not be kept according to the economic objective. However, while finding the optimum value for three objectives, inventory may need to be kept, in which case the cost of perishing this inventory at the end of the month should be added to the economic objective. In addition to destroying this inventory, products can be donated, without spoiling, to employees or those in need. The donation can increase the company's social impact and increase the number of customers.

**Fossil Energy Cost for Production:** Although our model is suitable for a comprehensive study, we conducted our case study on the company's single product (lemon). While producing lemons, 62977 MJ of energy is consumed per hectare. This energy corresponds to 17493 kW per hectare (10.000m2) [Ozkan et al., 2004]. Since 100,000 kilos of product are produced from 120,000 m2 of land, an average of 2 kW of energy is needed for 1 kilo of product. The cost of 1kW energy for businesses is 0.136 Turkish lira [Global Petrol Prices, 2021]. The average cost of producing one kilo of lemon is 0.272 Turkish lira.

**Economic objective:**

$Z_{Economic}$ = Economic Profit = Revenue - Cost

**where:**

Economic Cost = Wage Cost + Transportation Cost + Product Supply Cost + Energy Cost + Inventory Perishment Cost + Tax Cost + Stock-out Cost + Water Cost + Pesticide Cost + Packaging Cost + Hiring Cost + Firing Cost

$$\textit{Wage Cost} = \sum_{t \in T} \sum_{e \in E} (NW_{te} + NWS_{te}) \times CSW_e \tag{3.1}$$

$$\textit{Transportation Cost} = \sum_{t \in T} CSS \times b_t + \sum_{t \in T} CS \times (1 - b_{t)} + \sum_{t \in T} \sum_{n \in TMW} \sum_{j \in WL} \sum_{v \in CL} Y_{tnjv}/1500 \times CP \tag{3.2}$$

$$\textit{Inventory Perishment Cost} = \sum_{t \in T} I_{t \in T} \times CI \tag{3.3}$$

$$\textit{Energy Cost} = \sum_{t\,\in\,T} \sum_{m\,\in\,TM} \sum_{i\,\in\,SL} \sum_{j\,\in\,WL} X_{tmij} \times CE \tag{3.4}$$

$$\textit{Product Supply Cost} = \sum_{t\,\in\,T} \sum_{m\,\in\,TM} \sum_{i\,\in\,SL} \sum_{j\,\in\,WL} X_{tmij} \times CX_t \tag{3.5}$$

$$\textit{Tax Cost} = \sum_{t\,\in\,T} \sum_{n\,\in\,TMW} \sum_{j\,\in\,WL} \sum_{\mathrm{v}\,\in\,\mathrm{CL}} Y_{tnjv} \times SP_t \times Tax_j \tag{3.6}$$

$$\textit{Stock-out Cost} = \sum_{t\,\in\,T} CSO \times SO_t \tag{3.7}$$

$$\textit{Water Cost} = \sum_{t\,\in\,T} \sum_{m\,\in\,TM} \sum_{i\,\in\,SL} \sum_{j\,\in\,WL} X_{tmij} \times WR \times CW \tag{3.8}$$

$$\textit{Pesticide Cost} = \sum_{t\,\in\,T} \sum_{m\,\in\,TM} \sum_{i\,\in\,SL} \sum_{j\,\in\,WL} X_{tmij} \times PR \times CPR \tag{3.9}$$

$$\textit{Packaging Cost} = \sum_{t\,\in\,T} OP_t \times COP + \sum_{t\,\in\,T} IP_t \times CIP \tag{3.10}$$

$$\textit{Supplier Hiring and Firing Cost} = \sum_{t\,\in\,T} \sum_{e\,\in\,E} CH \times H_{te} + \sum_{t\,\in\,T} \sum_{e\,\in\,E} CF \times F_{te} \tag{3.11}$$

$$\textit{Warehouse Hiring and Firing Cost} = \sum_{t\,\in\,T} \sum_{e\,\in\,E} CH \times HW_{te} + \sum_{t\,\in\,T} \sum_{e\,\in\,E} CF \times FW_{te} \tag{3.12}$$

$$\textit{Revenue} = \sum_{t\,\in\,T} \sum_{n\,\in\,TMW} \sum_{j\,\in\,WL} \sum_{\mathrm{v}\,\in\,\mathrm{CL}} Y_{tnjv} \times SP_t \tag{3.13}$$

### *3.2.2 Defining environmental objective and parameters:*

Significant damage has been done since the damage to the environment has not been paid attention to until the last two decades. In order to prevent this from continuing, it is necessary to analyze what kind of damage has been done in order to minimize the damage to the environment. Companies pollute the air because they prefer vehicles that still work with unsustainable energy sources during the transportation of raw materials and final products. Spraying, unnecessary water consumption, wastes, and much more cause water and land pollution. Although such factors harm the environment, the magnitude of the damage is not the same in every city. For example, the air pollution is created in a city with less forest area will be affected more negatively than a city with a large forest area. Therefore waste, emission, and soil sensitivities for each location should be evaluated separately. When evaluating the waste sensitivity, the city's normalized population density is multiplied by the city's waste status. When quantifying the sensitivity of the emission, the normalized population density is multiplied by the forested area ratio of the location. Finally, soil sensitivity equals the normalized population density by multiplying the location's agricultural area. While maximizing the economic and social objective, we minimize the damage we cause to the environment. The parameters we will use while minimizing environmental damage are explained below.

**Air Pollution from Transportation:** CO2 emission occurs due to the vehicles used to reach the products from the supplier to the warehouse and the warehouse to the customers. The amount of carbon emission varies according to the type of vehicle used. The company we conducted our case study uses two different transportation modes, transit, and truck. Transit vehicles cause less air pollution than trucks, but their capacity is less than trucks. Therefore, trucks are used when the amount of transporting products is above the transit capacity.

Moreover, equipments such as tractors used in the field also cause air pollution [Business, 2015]. When using fossil energy sources while producing 1 kilo of lemon, the required energy is 2 kWh, and the amount of Co2 emission it causes is 0.77 kg [Eia, 2021]. The emission sensitivity of the region was taken into account when modeling the damage caused by CO2 emission to the region.

**Water and Land Pollution: Carbon Emission and inorganic packages:** The company has two alternatives for packaging, organic and non-organic. According to the information received from the company, using organic products increases the packaging cost three and a half times. However, The use of non-organic products for packaging causes land and water pollution. In this case, the company has two options: bear organic packaging cost or harm to nature by avoiding the cost. In the model, there is no obligation to make the packaging organic. While the model optimizes all three objectives, it also decides whether the packaging will be organic or not. The waste sensitivity of the region was taken into account when calculating the damage caused by non-organic packaging to the region. The waste sensitivity of the region was found by multiplying the population density and waste situation of the region.

The pesticides are used to increase crops' productivity and protect plants from diseases yet cause soil pollution. The average amount of pesticide used to produce 1 kilogram of lemon is 0.42 kg [Garcerá et al., 2017]. Although spraying increases efficiency, it has been proven to harm the environment, humans, and animals [Mahmood et al., 2016].

In addition, an average of 640 liters of water is required to produce 1 kg of lemons. This high-volume water consumption harms our limited water resources [befresh, 2018]. With the developing technology, more efficient irrigation methods have been created that will reduce water consumption. The most used and costless one is distillation, and with drip irrigation, water consumption can be reduced to 1 in 2 ratios [Maisiri et al., 2005].

**Environmental Objective:**

$Z_{Environmental}$= Environmental Objective = Packaging Waste + Transportation $CO_2$ Emission + Product Emission + Pesticide Emission

$$\text{Packaging Waste} = \sum_{t \in T} IP_t \times W \times WS \tag{3.14}$$

$$\text{Transportation } CO_2 \text{ Emission} = \sum_{t \in T} \sum_{m \in TM} \sum_{i \in SL} \sum_{j \in WL} X_{tmij} \times COE_m \times dis_{mij} + \sum_{t \in T} \sum_{n \in TMW} \sum_{j \in WL} \sum_{v \in CL} Y_{tnjv} \times CO_n \times dist_{njv} \tag{3.15}$$

$$\text{Product Emission} = \sum_{t \in T} \sum_{m \in TM} \sum_{i \in SL} \sum_{j \in WL} X_{tmij} \times CEP \times AES \tag{3.16}$$

$$\text{Pesticide Emission} = \sum_{t \in T} \sum_{m \in TM} \sum_{i \in SL} \sum_{j \in WL} X_{tmij} \times PR \times SOS \tag{3.17}$$

### *3.2.3 Defining social objective and parameters:*

Due to the complexity, diversity, and difficulty of the mathematization of the social effect, there are few quantified studies on the social criterion in the literature. While we were creating the model, we did not include an option for overtime in order not to harm the work-family balance and modeled to increase the number of employees when necessary. Due to increased job opportunities, the number of unemployment decreases, and the social impact increases. Recruitments are made regardless of gender, race, or religion. The model's most important detail decided during recruitment is educated or uneducated employers. Educated employers' productivity is higher, and the salary paid to trained personnel is higher. On the employer's side, this encourages society to receive education in order to earn higher incomes. Income inequality has been increasing day by day, as companies usually only think about the economic side. It is necessary to overcome some difficulties in order to work with those at the bottom of the pyramid. Because those difficulties are reflected in costs, the social impact companies will create is not considered. However, in order to grow as a society, companies need to face these challenges and create a sustainable supply chain by including those at the bottom of the pyramid in the value chain. The importance levels of each criterion in the social objective are different, and weights are assigned to the criterias by pairwise comparison. The following parameters are considered as social criteria:

**Job opportunities:** The concentration of people in metropolitan cities is increasing since people in rural areas cannot find a source of income. This immigration causes population density to reach the point where infrastructures and nature cannot handle it in some cities. Therefore, there should be a balanced amount of job opportunities in all parts of the country. In order to calculate this metric mathematically, the unemployment rate in the region is not sufficient because one of the two cities with the same unemployment rate may be less populated than the other, in this case there are more unemployed people in the crowded city and reducing the unemployment rate in this region requires more job opportunities. So, we multiply the unemployment rate by the population rate of the region to see the effect of job opportunity creation.

**Security level:** The level of security is an essential factor for the sustainability of job opportunities. Both the employees and the companies may negatively affect the security level. Companies may suffer economic losses due to security problems that may occur in transporting their raw materials or products. In addition, if employees come to work or encounter serious safety problems in the work environment, it will be challenging to focus on the work environment, and productivity will decrease. Safety is an important factor for employees to continue their social lives. While quantifying the security level, we normalized it by subtracting the safety index of the region from the highest safety index and dividing it by the security level of the country.

**Education level:** Education is another crucial criterion. The productivity of educated employees is 7% higher on average than the uneducated ones [Asadullah and Rahman, 2009]. In the long run, educated employees are more likely to make strategic contributions. The high level of access to education in the region increases the possibility of trained personnel employed in the future. In our case study, job requirements do not expect to complete high-level training from the employers. Therefore, the ratio of primary school graduates to the number of adults in the city defines the level of access to education. However, the company will create a job opportunity in the lower level of access to education; more added value is created. For example, the trainings provided by the company itself will be more beneficial in regions where access to education is limited. Another point of view is that when the company works with regions where access to education is limited, people who are far from education can send their children and families to education with the money they earn. When quantifying, the level of access to education has been subtracted from 1 since the effect grows as the level of access to education decreases.

**Health access level:** Access to the health system is more critical than many social criteria. In order to find the access level of the health system, criteria such as the number of hospitals per capita, the number of physicians per capita, and the number of hospital beds per capita were taken into account. Unfortunately, although there are free hospitals, the number of hospitals and doctors in every city is not enough. Income is needed to benefit from paid hospitals or free hospitals in other cities. Just as with the level of access to education, as the level of access to the health system decreases, the company's creation of job opportunities creates higher value. For this reason, access to the health system was removed from 1 while designing the model.

$Z_{Social}$= Social Objective= R1 × Job Distribution + R2 × Security Level + R3 × Education Improve + R4 × Health Improve + R5 × Empower Improve

$$\text{Job Distribution} = \sum_t \sum_e JLRS \times PRS \times NWS_{te} + \sum_t \sum_e JLR \times PRW \times NW_{te} \quad (3.18)$$

Security Level= $\sum_t \sum_e \frac{(HSL - SLW)}{ROSL} \times NW_{te} + \sum_t \sum_e \frac{(HSL - SLS)}{ROSL} \times NWS_{te}$ (3.19)

Education Improve= $\sum_t \sum_e EI \times (1 - EEL) \times NW_{te} + \sum_t \sum_e EIS \times (1 - EELS) \times NWS_{te}$ (3.20)

Health Improve= $\sum_t \sum_e HI \times (1 - EHL) \times NW_{te} + \sum_t \sum_e HIS \times (1 - EHLS) \times NWS_{te}$ (3.21)

Empower Improve= $\sum_t \sum_e EMI \times NW_{te} + \sum_t \sum_e EMIS \times NWS_{te}$ (3.22)

Our multi-objective mixed integer linear programming model problem is as follows:

$$Max\ [Z_{Economic} \quad - Z_{Environmental} \quad Z_{Social}] \tag{3.23}$$

**Subject to:**

$$\sum_{e \in E} NP_e \times NWS_{te} \times 176 \times ES \geq \sum_{m \in TM} \sum_{i \in SL} \sum_{j \in WL} X_{tmij}, \ \forall t \in T \tag{3.24}$$

$$\sum_{e \in E} NP_e \times NW_{te} \times 176 \times EW \geq P_t, \ \forall t \in T \tag{3.25}$$

$$\sum_{n \in TMW} \sum_{j \in WL} \sum_{v \in CL} Y_{tnjv} \geq DM_{tv} \times 0.9, \ \forall t \in T, \ \forall v \in CL \tag{3.26}$$

$$P_t \leq \sum_{m \in TM} \sum_{i \in SL} \sum_{j \in WL} X_{tmij} \times teta, \ \forall t \in T \tag{3.27}$$

$$P_t \geq \sum_{n \in TMW} \sum_{j \in WL} \sum_{v \in CL} Y_{tnjv}, \ \forall t \in T \tag{3.28}$$

$$I_t = P_t - \sum_{n \in TMW} \sum_{j \in WL} \sum_{v \in CL} Y_{tnjv}, \ \forall t \in T \tag{3.29}$$

$$\sum_{n \in TMW} \sum_{j \in WL} \sum_{v \in CL} Y_{tnjv} + SO_t = \sum_{v \in CL} DM_{tv}, \ \forall t \in T \tag{3.30}$$

$$OP_t + IP_t = P_t,\ \forall t \in T \tag{3.31}$$

$$NW_{te} = NW_{(t\text{-}1)e} + H_{te} - F_{te},\ \forall t \in T,\ \forall e \in E \tag{3.32}$$

$$NWS_{te} = NWS_{(t\text{-}1)e} + HS_{te} - FS_{te},\ \forall t \in T,\ \forall e \in E \tag{3.33}$$

If $\sum_{m \in TM} \sum_{i \in SL} \sum_{j \in WL} X_{tmij} \geq 1500$ : (3.34)

$X_{t,\ transit,\ ij} = 0,\ \forall t \in T$

else:

$X_{t,\ truck,\ ij} = 0,\ \forall t \in T$

$$X_{tmij}, Y_{tnjv}, I_t, S_t, OP_t, IP_t, P_t, NW_{te}, NWS_{te}, H_t, F_t, HW_t, FW_t \geq 0 \tag{3.35}$$

Equation (*3.1*(3.24) provides the work-family balance by employing the supplier workers for 22 days a month, 8 hours a day, and limits the amount of product to be produced on the supplier according to the number of employees and their productivity. Equation (3.25) provides a work-family balance by employing the employees in the warehouse for 22 days a month, 8 hours a day. It limits the number of products to be sorted and packaged in the warehouse according to the number of employees and their productivity. Equation (3.26) ensures that at least 90% of the demand is met every month. The reason for this is that the demand is not met more than a certain rate, which damages the company value. Equation (3.27) restricts the amount of product packed in the warehouse. Multiplying the products from the supplier by the average margin of error creates the upper limit for the products packed in the warehouse. Equation (3.28) limits the products sold. The amount of products sent to customers cannot exceed the amount of packaged products per month. Equation (3.29) defines the amount of inventory. Inventory amount is calculated by subtracting the number of items sold from the packaged items. Equation (3.30) defines the sum of the products sold, and the stock-out quantity will equal the demand quantity. Equation (3.31) defines that the amount of product packaged with organic packaging and the amount of product packaged with non-organic packaging is equal to the total amount of packaged product. Equation

(3.32) defines the number of employers working on the warehouse, is quantified by adding new hires to previous month workers and subtracting those laid off. It is assumed that there are no employees in the warehouse at the time 0. Equation (3.33) defines the number of employees working on the supplier, which is calculated by adding new hires to previous month workers and subtracting those laid off. It is assumed that there are no employees in the supplier at the time 0. Equation (3.34) states that if the amount of product coming from the supplier to the warehouse is more than 1500 kg, then the products must be transported by truck, and if it is less than 1500 kg, it should be transported by transit. This is because the transit vehicle is less costly, less harmful to nature but cannot carry products over 1500 kg. In this case, since the transit vehicle goes twice, it costs more than the truck and causes damage to the environment; when 1500 kg is exceeded, it is necessary to transport by truck. Equation (3.35) defines that all variables must be equal or bigger than 0.

## 3.3 Phase 2 Model

In the inclusive business model, companies provide the necessary training for the suppliers they work with inclusively, especially the small-scale ones. Although these trainings seem to be an extra cost for the company in the short term, trainings provide many benefits. When suppliers receive training, they may work more efficiently, reduce their costs, and produce raw materials at a lower cost and with higher quality. Training can be done online, through workshops, demonstrations, or other methods. Trainings can be given on various subjects, but throughout this project our focus is on three training topics.

The first training is irrigation training. In agriculture, 80% of the world's agricultural area is applied surface irrigation, yet the efficiency of surface irrigation is relatively low [Postel, 2000]. Therefore, with the development of technology, different irrigation methods have emerged. There are various irrigation methods. Irrigation systems such as expensive, complex, conventional distillation systems that require pressure above 1 bar are unsuitable for small-scale farmers. However, low-cost drip kits are suitable for small-scale farmers because they have low initial costs and do not require 1 bar pressure. The prices of these distillation kits are pretty low, and even in some countries, non-governmental organizations can distribute them free of charge

[Chigerwe et al., 2003]. The irrigation efficiency of these distillation kits varies between 70-90%, while surface irrigation efficiency is usually at the level of 40-50% [Postel, 2000]. In addition, while the amount of water used for a region irrigated with drip irrigation is 7.87 m3, the same area consumes 23.88 m3 of water when the surface irrigation method is used [Maisiri et al, 2005]. The cost of irrigation equipment is negligible, but there is more than a 50% increase in water efficiency when irrigation is done with the drip irrigation [Maisiri et al., 2005].

Since low-cost distillation kits are not a fully automated systems and there is still a need for workers, its application necessitates training for employers. After providing the drip irrigation equipment and training to the farm employers, the changes that will occur in our model are as follows: The amount of water used in production will be reduced by half. Training costs will be added to the model. There will be a negligible reduction in the need for workers; if more technological irrigation methods are used, such as fully automatic, there may be no need for employees for irrigation.

Additionally, irrigation with distillation indirectly affects productivity. Surface irrigation causes an increase in weeds, which causes an increase in the number of harmful insects and reduces the yield of the products. However, we assumed that changing the irrigation method does not cause a positive or negative change in product efficiency.

The second training topic is on pesticides. Due to the epidemics experienced nowadays, organic food consumption has increased considerably to strengthen people's immune systems. Pesticide spraying increases productivity and protects the products from insects yet spraying causes harm to nature and human health. In particular, it causes short and long-term damage to the people's health involved in the application of pesticides. These damages range from chronic diseases to the brain and reproductive disorders and cancer [Brouwer et al., 1999]. This means that it can cause simple ailments, or it can cause fatal effects, which is usually directly proportional to how much exposure they had to these drugs. In the examinations made on the foods, it has been revealed that the foods that are sprayed contain these drugs at high rates [Karunakaran, 1958]. People's interest in organic products has increased tremendously since it was realized that the foods people eat to be healthy harm their body and immune system. Therefore, integrated pest management (IPM) system is developed. IPM is an ecosystem-based pest management method that combines biological control, ecological modifications, cultural practice adjustment, and the use of resistant cultivars to prevent pests or their harm over time.

IPM main aims to prevent pests and their harm by managing the ecosystem. IPM has three steps: To begin, simply observing a pest does not require intervention; thus, it should be determined at what level and under what conditions the pests will be intervened. Second, not all insects and weeds are harmful for plants; in fact, some are beneficial. Pests can be reliably identified with IPM, and appropriate control decisions may be taken at the level where they need to be intervened. Third, IPM agricultural approach employs a combination of solution strategies to get better outcomes by interfering with pests. Solution strategies are divided into four; biological control, cultural control, mechanical and physical control, chemical control [fao, 2021]. In biological control, natural enemies of the pest are used to reduce and control the pest and its damages. Predators and parasites are examples of natural enemies. With cultural control, the possibility of pests to establish, reproduce and survive is reduced. For example, the number of weeds increases with surface irrigation, which causes pests. However, the weeds cannot grow when the irrigation method is changed with the distillation method, and the number of pests decreases. The third strategy is mechanical and physical controls. With this method, the environment is made unsuitable for the pests or killed directly. Wood chips for weed control, steam sterilization of the land for disease control, and obstacles like panels to keep animals out are all examples of physical controls. The last one is chemical control, managing pests using pesticides. This method should use in combination with other methods because it is necessary to use as few chemicals as possible to protect the environment and human health. However, in our case farmers will use herbal spraying instead of chemicals and pesticide-free products will be produced. Pesticide-free crops are in great demand because of their improved quality. Since the quality of the products improves, the product's price also increases.

When spraying training is given, the things that will change in our model are as follows: Spraying training cost will be added. Since farmers will have done spraying, the chemicals' impact on the soil will be reset in time. Spraying costs will be zero. The quality of the products will increase, so the price of the products will increase.

Completely natural herbal solutions will be used to protect the plants. The cost of these herbal solutions is meager. However, herbal solutions cannot protect the products as much as it does in chemical spraying, so there will be some decrease in the amount of the product. When organic product cultivation is compared with traditional farming, the amount of product decreases by 25% on average [Seufert et al., 2012]. However, when herbal solutions are utilized, the amount of product will not be reduced that much. It has been revealed that people are willing to pay an average of 30% more for organic products than for traditional products [Aryal et al., 2009]. Since we believe that organic food consumption is a natural necessity and should be accessible to people of all economic classes, we will update the product base price, in purchase from the supplier, increases by 10%, and the sales price to the customer increase by only 10%.

The subject of the third training should be good farming practices for sustainable production. The aim is to produce quality, safe, environmentally and socially responsible products that meet consumer needs. Good farming practices can take various forms. In this project we will focus on two points on this issue and the company will provide training on these topics.

Firstly, conservation agriculture(CA) is an agricultural strategy that helps preserve agricultural land while also restoring damaged areas. It encourages the preservation of a permanent soil cover, little soil disturbance, and plant diversity. This agriculture increases productivity over time. The CA farming method has many benefits. It preserves irrigation water, increases soil organicity over time, reduces mechanization costs, and reduces fuel costs. Leaving the soil to itself will increase water infiltration and keep the soil moist. It will continue to provide stable yields in prolonged droughts or heavy rains, where climate changes are exacerbated. CA farming has its benefits as well as its challenges. The farmer must have sufficient crop residues. Since crop residues are used as feed for animals, there may not be enough leftovers. Knowledge and education are fundamental in the CA farming method, and not every farmer may have access to them. Appropriate seeders are required to start this farming. With this farming management, 60% fewer fossil energy sources are used than the traditional method, therefore reducing air pollution [fao, 2021]. With this method, the use of fertilizers and chemicals is reduced by 20% [fao, 2021]. Investments in machinery such as tractors are reduced by 50% [fao, 2021]. This method provides environmental and economic contributions to the farmers [fao, 2021].

The second topic for good agricultural practices is that pollinators play an essential role in ecosystem sustainability and diversity. With pollination management, crop quality and quantity can be increased and improved. Animals pollinate approximately 90% of flowering plants, and the lack of these animals affects biodiversity negatively [fao, 2021]. Damages to the habitat by humans, such as land clearing for agriculture, chemicals use, and climate changes caused by global warming, reduce the number of pollinators. In order to prevent pollinators from decreasing, farmers should make a connection between agricultural areas and natural habitats; it is vital for pollinators to adapt to changing climatic conditions, disperse quickly and take the necessary range shifts. In addition, the pollinators must connect with the natural life to provide the seasonal resources they need before and after the flower blooms. The pesticides that the farmers use for harmful insects also harm the pollinators, so farmers should use different solution methods to remove the harmful insects while increasing the number of pollinators. As the number of pollinators increases, the amount and quality of the product will increase over time.

As a result, the changes that will occur at the end of these 3 trainings are listed: The cost of 3 trainings will be added. There is no class capacity limit for the trainings and is only held once a year. Therefore, the sum of the costs of irrigation training, pesticide training and good farming practices training will give the training cost. Training costs are calculated according to the average cost of agricultural training in Turkey. There will be a 50% reduction in the amount of irrigation [Maisiri et al., 2005]. The use of pesticides will be eliminated. The carbon emission while producing will decrease by 60% [fao, 2021]. As the quality of the products will increase, there will be an %10 increase in selling price and in purchasing (from the supplier) price. The education levels of the employees will increase 10% on average, their productivity will improve approximately 10 percent with the trainings and certificates they receive, their opportunities to find a new job will increase 7.5% in case of leaving their jobs [Blundell et al, 1999]. Since no chemicals are used, the level of health will increase by 50% and security will increase %10. Empower will increase by 10% as the knowledge level of the employees increases. As the quality of the products increases, the long-term demand will also increase. However, since this is not a parameter that will take place in the short or medium term, it will not cause a change in the model.

With trainings, the following will be added to the economic function:

Training Cost= $T_1+T_2+T_3$

The following will be removed from the economic function:

Pesticide Cost= $\sum_{t \in T} \sum_{m \in TM} \sum_{i \in SL} \sum_{j \in WL} X_{tmij} \times PR \times CPR$

The following will be removed from the environmental function:

Pesticide Emission= $\sum_{t \in T} \sum_{m \in TM} \sum_{i \in SL} \sum_{j \in WL} X_{tmij} \times PR \times SOS$

## *3.4 Phase 3 Model*

Farmers produce goods, and traditionally, a business adds value to the farmer's products in order to fulfill customer demands. In this business model, the farmer's profit is minuscule in comparison to the profits of the companies. This is due to the farmer's inability to add value to their product. Large-scale farmers can afford to obtain the certifications and training they need to add value and grow rapidly. Small-scale farmers can generally only support their families until the following harvest season, and they use their savings to fund the initial harvest season's investments. That is why they are unable to grow. In fact, if they do not generate enough revenue for the following crop due to natural (drought, heavy precipitation, bug infestation) or external (economic balance, interest on raw materials) circumstances, they will go into debt. Small farmers must add value to their products in order to mitigate these circumstances. Adding value to products can be done in many ways: cleaning, packaging, processing, labeling, cooking, etc. [Born and Bachmann, 2006]. In addition to generating more income by adding value to the products, it also creates different opportunities to discover new markets. However, increasing the value of farm products is not as easy as pie, especially for small-scale farmers. To add value to the product, the farmers must have sufficient capital, management skills, and the skills of their employees. Small-scale farmers cannot create added value; mainly, they do not have sufficient capital. However, suppose large companies provide inclusive support to the farmers they work with to gain the necessary skills and training. In that case, they will generally contribute to the development of small-scale farmers living at the bottom of society. Such contributions can reduce income inequality in the long run. As the third model, we will examine what changes will happen if our company offers such an opportunity to its small farmers. The added value created by the company is the sorting and packaging of products. We will examine the changes the farmer and the company will experience if they transfer this added value to the farmer. Since small-scale farmers cannot get the packaging certificate and training themselves. The company will support farmers in this regard.

As the farmers will do the packing job for the first time, the company will pay a maximum of 15% more for this task, but in the long run, the farmers will learn the job, and the costs will decrease. Therefore, there will be no increase in the company's costs over time, yet we assumed the worst case and increased the packaging cost by %15 in this model. In fact, losses(wastes) at the supply chain stages will be reduced as farmers sort and pack and ship the products. Since we could not determine how much the decrease in this rate of spoiled products would be, we accepted the worst-case scenario as no reduction in our model. There will be a severe increase in the income of the farmer. In addition, since he received the packaging certificate, the probability of finding more different jobs in the future will increase at least %7.5 [Blundell et al., 1999]. With the increase in his income, farmers will be able to make additional investments in the farms. Since there is no sorting and packaging in Phase 3, there will be no need for personnel in the warehouse for these issues. Employees are required only to control the quality of incoming products and send them to customers. Since sorting and packaging processes are done at the supplier, the number of employees in the supplier will increase. The supplier will be strengthened because the supplier can add value and earn more profit.

## *3.5 Phase 4 Model*

The products can be sold to the customer in two different ways: value-added products, non-value-added products. Adding value to the product can be done in many ways; sorting, packaging, converting to another product, drying, freezing, etc. When more value is added to product, customers purchase less defective and standard items. The fact that the items are mistake-free also promotes customer satisfaction, however customers might tolerate a certain error rate in exchange for more affordable products. In phase 4, we examined the situation of selling products without adding value. Since we removed the added value from the model in Phase 1, neither the farmer nor the company separates fault products in this phase. Therefore, there will be no need for employer who do the sorting work in the warehouse, and there will not be an increase in the need for employer in the farm. Since there is not any additional cost, the costs will decrease. However, since the products will contain more defective products compared to the products sent in phase 1, they should be sold at a more affordable price. As a result of market research, we concluded that there was at least 5% reduction in the selling price of the products, so we assumed that there would be a 5% reduction in the selling price of the model.

The changes in the model in phase 4 are as follows. The sales price of the products will be 5% less than the normal sales price in phase 1. The number of employers will be reduced as there is no need for the personnel required for segregation. Since the separation of faulty product is not considered, the number of rotten products sent to the customer will increase. Since there are no measures to reduce environmental damage, there will be no change in the environmental objective of the model.

# Chapter 4:
# APPLICATION

We implemented an actual case study to understand the model better, see the results and guide the company managers. The case was made with fresh fruit&vegetable company, which is located in Turkey. With the development of technology, many people prefer to purchase their needs online. In the company for which we conducted the case study, the demand for fresh and organic products in Turkey is met online from warehouses without opening a showroom. Fruits and vegetables are collected from various locations in Turkey, brought to the warehouse, sorted, packaged, and sent to customers in various cities of Turkey. Since 80% of the customers are around Istanbul, Istanbul was chosen as the warehouse and operation center.

Turkey's climate, soil structure, land area is quite suitable for farming. However, the number of small-scale farmers is steadily decreasing. There are several reasons for this. Due to the long distances between agricultural areas and regions with high demand, small-scale farmers have problems transporting their products, and large grocery companies generally purchase their fruits and vegetables from intermediary companies. Intermediary companies take the products from small-scale farmers, bring them to big cities, and sell them to big grocery markets. However, since the intermediary company needs to profit addition to the farmer and the grocery company, product prices are high in the grocery store, and the farmers have to sell their products for a low price. Even though the farmers sell their products to intermediate companies for a low price, the customers usually buy them 4-5 times the farmers' price. Due to this situation, both farmers who sell their products cheaply and the customers who pay high prices suffer. In 2021, various farmers in Turkey left their products to rot on the branch, as they could not get the cost of collecting their products from the sale of the products. Another reason for the decrease in the number of small farmers is the increase in raw materials and equipment used by the farmer. Small-scale farmers often earn only enough to support themselves and meet the agricultural needs of the next season. However, they have to sell their produce cheap despite the fact that the price hikes in raw materials and fossil energy. These situations cause farmers to go bankrupt. As Turkey's arable lands attract the attention of domestic and foreign investors, the number of various large-scale farms established with new technologies is increasing. However, as discussed throughout this project, our focus is on small-scale farms, reducing income inequality, and increasing social equality. Thus, large companies need to establish their own supply chains, eliminate the intermediary companies in between, and make direct agreements with local small-scale farmers. Since a single small farmer will not meet the demands of large companies, it may be necessary to work with more than one supplier for each product. These suppliers should be approached inclusively, and the essential training should be given so that they can produce the products in the standard desired by the company.

The Turkish fruit and vegetable market is quite suitable for displaying sustainability and inclusive business concepts. The model offers opportunity to see possible alternatives for the large companies and investors. Since 80% of the customers are around Istanbul, Istanbul was chosen as the warehouse and operation center. The company has online sales of variety products, but we will conduct our case study on the sale of lemons. The company has only one lemon supplier and is located in Hatay. The company's customers generally order from 5 regions. These locations are: Kadıköy, Sarıyer, Beşiktaş, Üsküdar, Çankaya. The company uses two types of vehicles to bring products from the supplier to the warehouse. Only one sort of vehicle, transit, is used to transport products from the warehouse to the consumer. Both trucks and transit vehicles are turned into suitable environments to preserve fruits and vegetables. In this way, the deterioration of products on the road is minimized.

Criteria in the economic and environmental objectives give equal weight, yet the weights in the social objective are not the same. Economic objective criteria include revenue and total cost. We provide equal importance to see the profit. Similarly, there are air and soil pollution criteria in the environmental objective. Protecting the environment is equally important in these two criteria to create a sustainable environment. On the other hand, social-objective criteria do not have equal importance. The security level criterion is more important than the unemployment level and access to education criteria. In an insecure area, farmers cannot survive, and companies do not want to work in an uncertain place, so the impact of this criterion should be higher than the criterion of access to education. The weights are weighted pairwise based on the

AHP method, yet as the case changes, these weights in the model may change. There are current value and expected improvements in the criteria in the social objective. Current values give the actual existing status of the criteria. The expected improvement values that will occur when the company works with the supplier. We made a case study of our model with a company that is an online seller of fresh fruits and vegetables, but our model can be used or implemented in other problems that are desired to be made in aggregate planning. We solved our multi-objective mixed integer model in Python with the augmented epsilon constraint method.

## *4.1 Analysis*

The model is run in Python with four intervals, and 25 unique Pareto optimal solutions are obtained. In *Figure 4.1*, Figure 4.3, Figure 4.5 and *Figure 4.7* the x-axis shows the number of unique Pareto optimal solutions, while the y-axis displays the normalized values of the three objectives together in 4 phases. In *Figure 4.2*, Figure 4.4, Figure 4.6 and Figure 4.8 the x-axis shows the number of Pareto optimal solutions, while the y-axis presents the regulated values of the three objectives. For all the regulated values below, the regulated profit value gives the real profit values, while the regulated environmental values are arranged as 1/100 of the actual environmental values, and the regulated social values are 100 times the actual social values. This arrangement has been made to analyze the objective values together in detail.

Below, *Figure 4.1* and *Figure 4.2* show the normalized and regulated values of the three objectives for Phase 1 as can be seen from the normalized values; profit increases while social and environmental objectives fluctuate (increase and decrease) together. This means environmental damage increases when social value increases; therefore, there is an inverse link between environmental and social objectives except for the first seven solutions. Until the first seven solutions, while the social purpose increased, the environmental goal increased, but while the social objective decreased, the environmental angle remained constant. When the model is most profitable, there is severe environmental damage, while the social benefit is low. In the model in Phase 1, the investors who want the highest profitability will, unfortunately, have chosen the solution with the highest environmental damage and the least social impact. Even in this case, little social impact is achieved. However, when profit is lowered slightly, as in the

21st Pareto unique solution, the social benefit is greater while environmental damage is less. Investors can benefit from the solution that fits their strategy. In Phase1, the highest and lowest profitability was 41.486₺, and 3.141₺, the lowest and highest environmental damage was 8.153.831 and 8.942.611 units, and the highest and lowest value of social impact was 491,99 and 131,85 units.

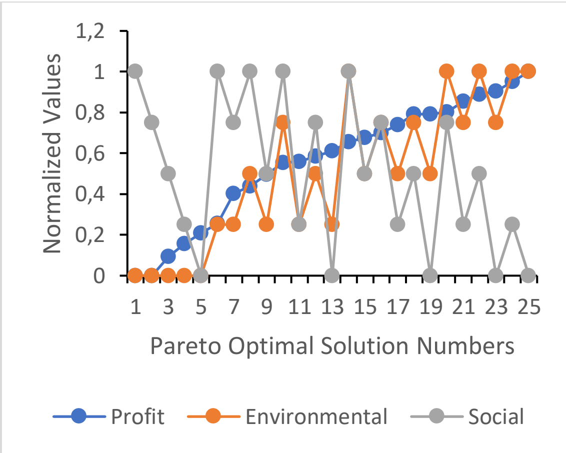


Figure 4.1: Normalized Pareto Optimal Solutions for the Case Study Phase 1

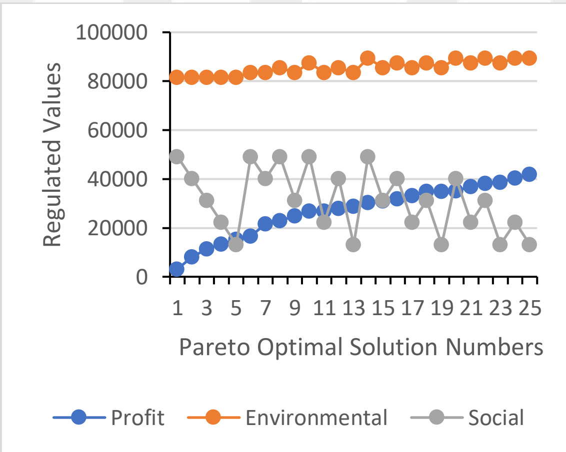


Figure 4.2: Pareto Optimal Solutions for the Case Study Phase 1

Figure 4.3 and Figure 4.4 present the normalized and regulated values of the three objectives for Phase 2. When the normalized values are examined, as in phase 1, profit increases while social and environmental goals fluctuate, there is not vice versa relationship between environmental and social dimensions. It is observed that the environmental damage increases as the social impact increases, yet in cases where the social objective decreases, the environmental impact does not behave similarly. When the model is most profitable, the environmental effect is the highest (the environmental damage is the highest), and the social value is the lowest. As in Phase 1, the most profitable solution does not provide a good social and environmental impact. When evaluating the actual values, the highest profitability was 58.144₺ and the lowest 17.934₺, the highest social effect was 494,49, and the lowest social effect was 133,13, the greatest environmental damage was 6.272.827, and the lowest was 5.722.083. As can be understood from these results, the environmental damage was significantly reduced with the three trainings received in phase 2, and the social value and profitability increased despite the expense of these trainings. When an investor using the model in phase 2 prefers the highest profitability, the investor will obtain the solution with the lowest social impact and the highest environmental damage solution in Phase 2. Yet, this solution has higher profit, higher social value, and less environmental damage than the highest profitable solution in Phase 1.

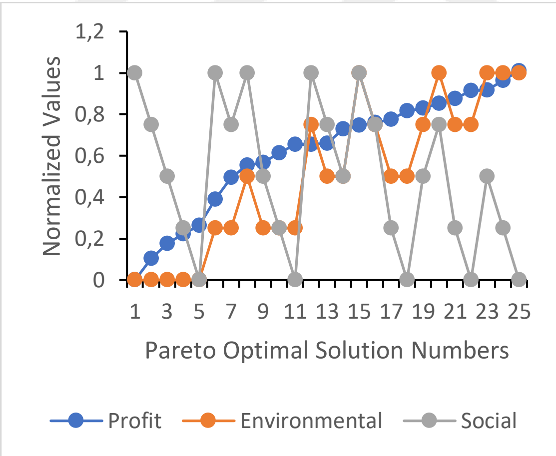


Figure 4.3: Normalized Pareto Optimal Solutions for the Case Study Phase 2

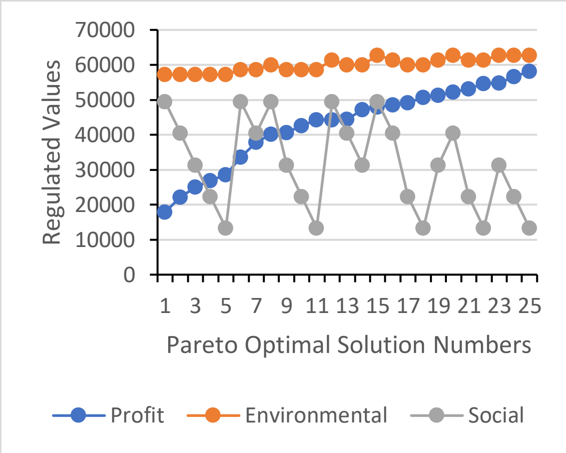


Figure 4.4: Pareto Optimal Solutions for the Case Study Phase 2

Figure 4.5 and Figure 4.6 display the normalized and regulated values of the three objectives for Phase 3. When normalized values are examined, while profit increases, environmental and social objectives fluctuate as in phase1 and 2. There is no direct linear relationship between social and environmental dimensions. Environmental damage may increase or remain constant when social value increases or environmental damage may decrease or remain constant when the social impact decreases. In phase 3, when considering the most lucrative solution, although the environmental damage is at the top, the social value has a medium value, unlike phase 1 and phase 2. In Phase 3, the highest and lowest profit values were 54.063₺, and 5.056₺, the highest and lowest social impact were 548,19 and 141,34, and the most serious and lowest environmental damage were 5.908.374 and 5.338.845. Although the highest and lowest profit in phase 3 is lower than phase 2, it is higher than phase 1. Additionally, the lowest environmental damage and the highest social impact occur in the phase 3 model. In Phase 3, added value to the products is contributed on the farm, which provides a significant social benefit to farm workers. However, it causes some reduction in profitability for the companies. When an investor chooses the most profitable solution in phase 3, he will have chosen the solution that gives the greatest environmental damage of phase 3 but provides the middle-level social benefit of phase 3. Although this solution causes the highest environmental damage in phase 3, it falls below the environmental damage caused in phase1 and phase2 (for the same profitability). According to the investor's strategy, higher social and lower environmental harmful solutions can be preferred by reducing profits.

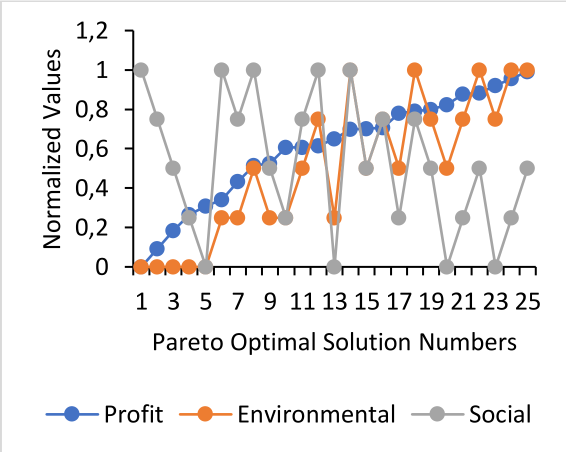


Figure 4.5: Normalized Pareto Optimal Solutions for the Case Study Phase 3

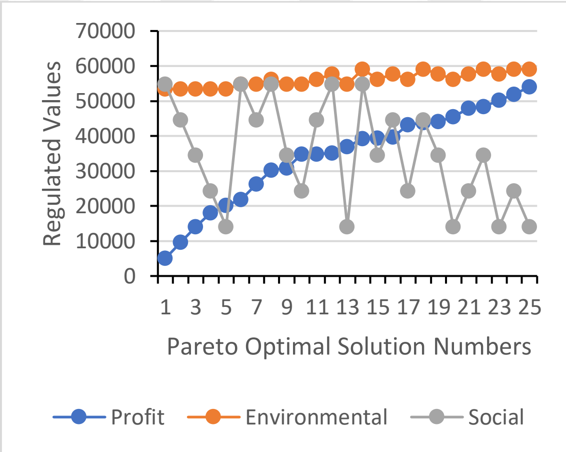


Figure 4.6: Pareto Optimal Solutions for the Case Study Phase 3

Figure 4.7 and Figure 4.8 display the normalized and regulated values of the three objectives for Phase 4. Considering the normalized values in phase 4, environmental and social values decrease or increase during the profit increase. While social values decrease, environmental objective values decrease or remain constant; environmental damage increases or remains constant while the social value increases. In Phase 4, the solution with the highest profitability has the most severe environmental damage and the lowest social benefit. As in other phases, social and environmental values can improve when profitability is reduced. In Phase 4, the highest and lowest profit values were 32.850₺ and -292₺, the highest and lowest environmental damage values were 8.942.611 and 8.153.831, and the highest and lowest social impact values were 19.871

and 5.662. In the most profitable solution in phase 4, the profit and social impact remain below the most profitable solutions' values of the other 3 phases, and the environmental damage is the same as the environmental damage in phase 1.

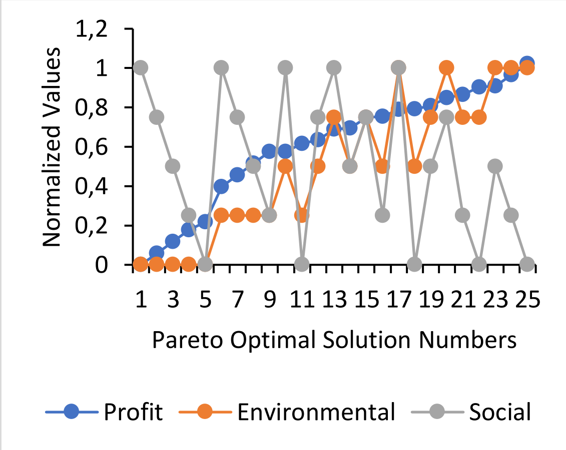


Figure 4.7: Normalized Pareto Optimal Solutions for the Case Study Phase 4

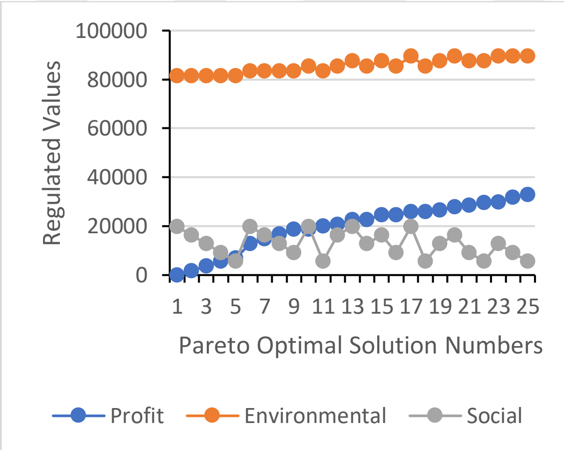


Figure 4.8: Pareto Optimal Solutions for the Case Study Phase 4

Figure 4.9, Figure 4.10, Figure 4.11 and Figure 4.12 present that three-dimensional graph for normalized profit, normalized environmental effect, and normalized social impact value for the four phases. There are 25 solutions with four intervals in all 3D graphics. Since the values are normalized, all solutions fall between 0 and 1. The solutions in which the values are normalized in each phase seem analogous, yet the actual values differ significantly. Although the 3D graphics are quite like each other, it can be understood that the model in phase 4 gives worse results than other models.

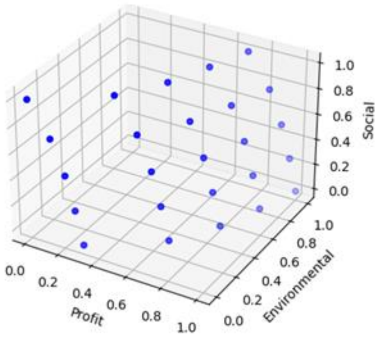


Figure 4.9: The 3D Graph for Normalized Profit, Normalized Environmental Effect and Normalized Social Impact for Phase 1

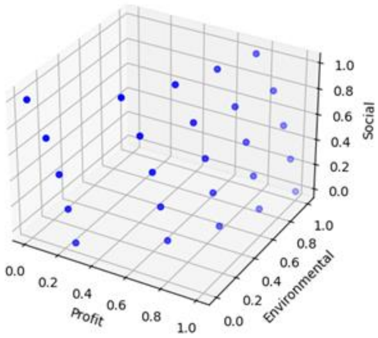


Figure 4.10: The 3D Graph for Normalized Profit, Normalized Environmental Effect and Normalized Social Impact for Phase 2

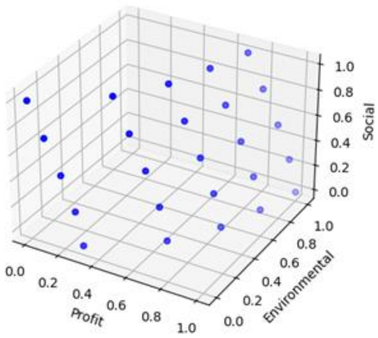


Figure 4.11: The 3D Graph for Normalized Profit, Normalized Environmental Effect and Normalized Social Impact for Phase 3

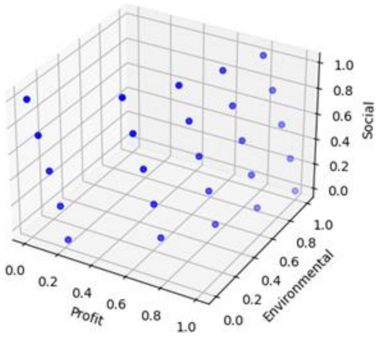


Figure 4.12: The 3D Graph for Normalized Profit, Normalized Environmental Effect and Normalized Social Impact for Phase 4

In order to observe the relationship between economic and environmental objectives, the bi-objective model was solved for four phases. Figure 4.13, Figure 4.14, Figure 4.15 and Figure 4.16 display the results of bi-objective models in four different phases. The results show that as the profit increases, the damage to the environment increases. Therefore, at the highest profitability, the environmental damage is the highest. To reduce environmental damage, companies must make less profit.

The solutions in all phases are in the form of an exponential graph. This means that good environmental damage reduction can be achieved with a slight reduction in profits. However, this is true up to a certain reduction in environmental damage. After reducing the environmental damage below a specific value, it is necessary to reduce the profitability significantly to achieve further reduction in environmental damage. For example, when profitability falls from 1 to 0.8 in phase 1, environmental damage decreases from 1 to about 0.6, but to reduce environmental damage from around 0.2 to 0, profitability decreases from 0.4 to 0. Companies can make optimum environmental loss-profit preferences for these four models according to their regulations and strategies.

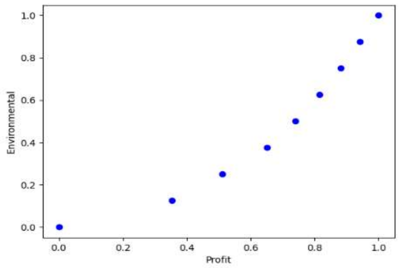


Figure 4.13: Normalized Profit vs. Normalized Environmental Effect in Phase 1

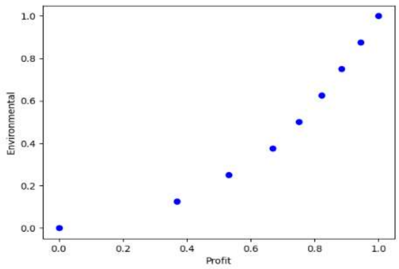


Figure 4.14: Normalized Profit vs. Normalized Environmental Effect in Phase 2

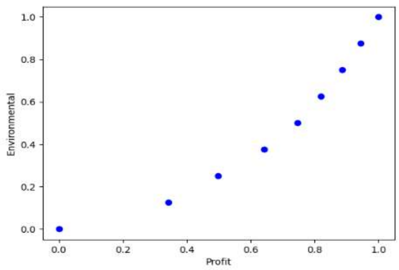


Figure 4.15: Normalized Profit vs. Normalized Environmental Effect in Phase 3

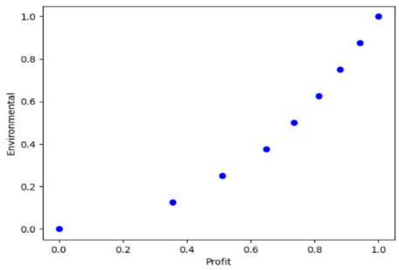


Figure 4.16: Normalized Profit vs. Normalized Environmental Effect in Phase 4

The bi-objective model was solved in four phases to understand the relationship between economic and social objectives. Figures 17, 18, 19, and 20 show the results of bi-objective (economic-social) models in four different phases. The results show that as profit increases, the social value decreases. Therefore, the lowest social benefit is provided when the highest profitability is achieved. In order to increase the social benefit, the number of employees (inclusively in farm and warehouse) must increase. As the number of employees increases, the costs increase, and the profitability decreases. For this reason, companies should reduce their profitability in order to increase their social benefit, but a good social benefit can be achieved with a slight decrease in profitability. In each model, a different amount of decrease in profitability is required for the same ratio of social benefit, but it is more accurate to evaluate actual values. As with the environmental objective, too much profitability is sacrificed to raise the social objective after a specific rate. Therefore, it does not make sense to increase the social benefit more than a certain amount for investors and companies whose aim is profitability. Nevertheless, companies will choose the solution that suits their strategies and regulations.

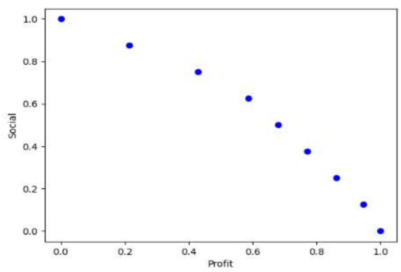


Figure 4.17: Normalized Profit vs. Normalized Social Impact in Phase 1

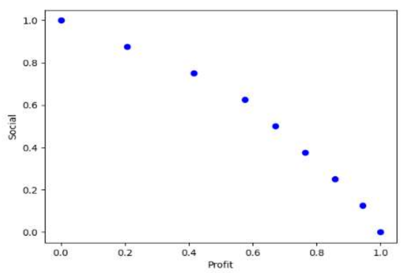


Figure 4.18: Normalized Profit vs. Normalized Social Impact in Phase 2

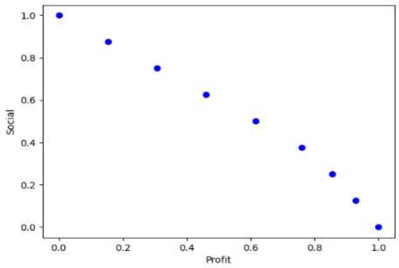


Figure 4.19: Normalized Profit vs. Normalized Social Impact in Phase 3

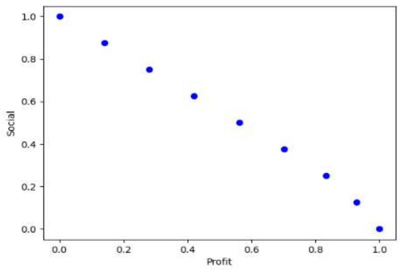


Figure 4.19: Normalized Profit vs. Normalized Social Impact in Phase 4

## *4.2 Sensitivity Analysis*

Some parameters in the model are not based on any study or survey. These parameters are assigned according to the average values in the market in Turkey. We performed sensitivity analyses to measure the sensitivity of these values to the model. These sensitivity analyses provide a clearer picture for companies to understand better the problems and uncertainties and how the problems take shape as the parameters change.

Purchase price of fruits from inclusive farms and selling price of fruits:

Figure 21, 22, 23, and 24 gives the results of the sensitivity analyses made in selling and purchasing prices of fruits in 4 phases for three objectives. The value of the original model was assumed to be 50% as the average amount, and the purchase price and selling price were increased or decreased in the same proportion to observe the adjustment on different decisions.

Figure 21 shows the sensitivity analysis for phase 1. As a result, the change in selling and purchasing prices in phase 1 does not cause a change in the max and min values in the social output. In Phase 1, profit max and min values increase when purchase and sales values increase at the same rate. This output is significant because since the selling value is greater than the purchase value, the same ratio changes will increase the difference between the purchasing and selling prices. Another noteworthy situation in the sensitivity analysis for profit is that the maximum and minimum value at 0.25 profit is below zero, which is not logical for an investment with the aim of profitability. As a result of the sensitivity analysis, while the environmental damage does not change up to the 0.75 point, the maximum environmental damage increases between 0.75-1. This is because the model sells products to its customers whose demand does not meet 100%, and environmental damage increases due to reasons such as producing more products, transporting, and packaging.


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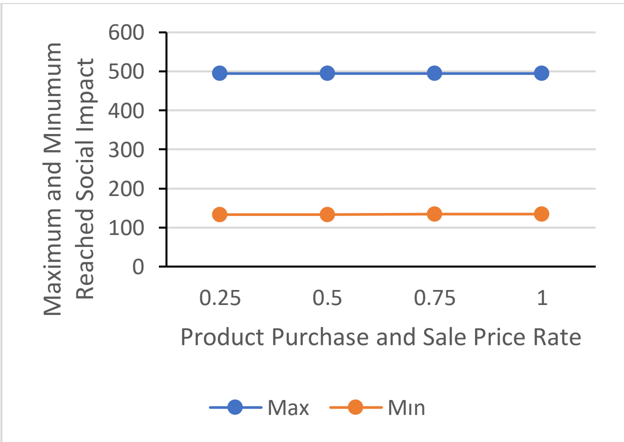


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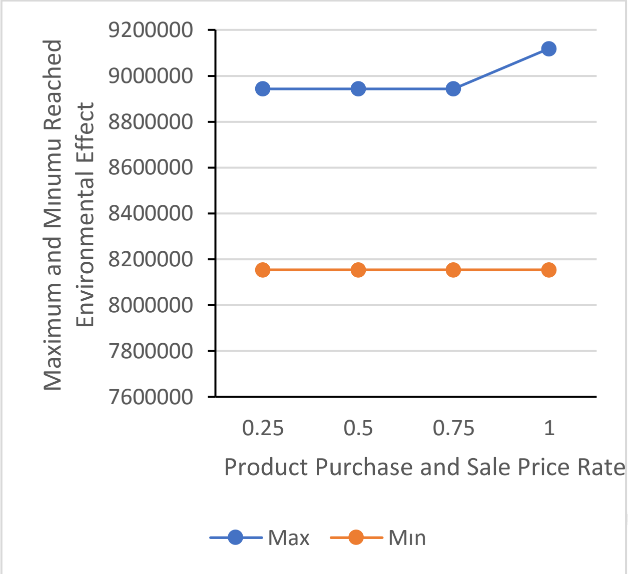


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Figure 4.20: Product Purchase and Sale Price Rate versus Objective Values Max-Min Values in Phase 1

Figure 22 shows the sensitivity analysis of the sale to the customer and purchase price of fruits from inclusive farmers for phase 2. In the sensitivity analysis performed in phase 2, as in phase 1, social value does not change with the change in sales and purchase prices. Profitability increases according to the proportional increase in sales and purchase prices. As the purchase and sale price of the product increases, the difference between the maximum and minimum values of the model increases. In phase 2, the 0.25-point max and min profitability values remain below zero, and it is an investment in the loss for these prices. However, it is less in loss than in phase 1, and the highest profitability in phase 2 is above the highest possible profitability in phase 1. As a result of the sensitivity analysis, in phase 2, the environmental impact remains the same when the price drops; however, the environmental impact (damage) increases when the price rises above the original prices. Even the most severe environmental damage in phase 2 is below the minimum environmental damage in phase 1.

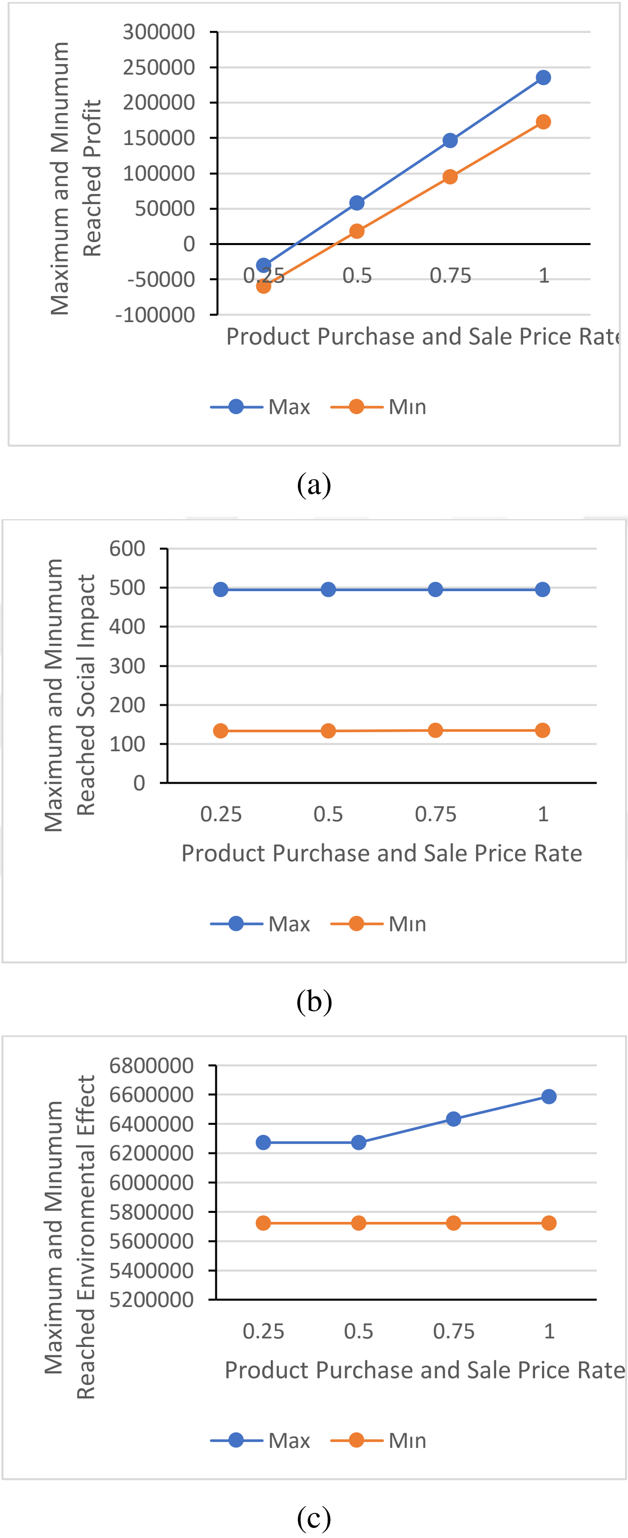
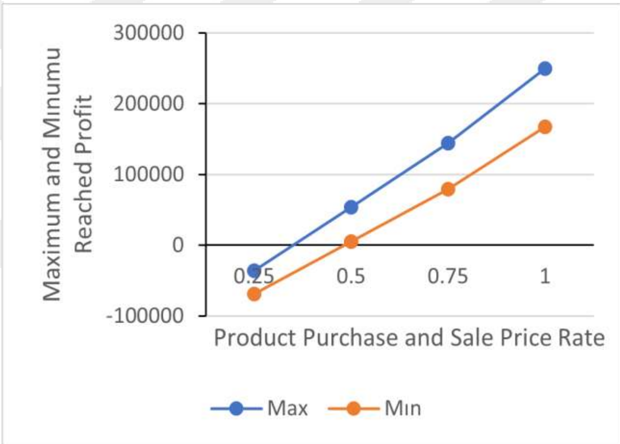



Figure 4.21: Product Purchase and Sale Price Rate versus Objective Values Max-Min Values in Phase 2

Figure 23 shows the results of the sensitivity analysis of purchasing and selling prices for phase 3. Profit increases as in phases 1 and 2, and the difference between the maximum and minimum value increases as the purchase and sale price raises. While the rate is 0.25, the maximum and minimum profit values are still below 0. While the maximum profitability value of the model in phase 3 is higher than in phase 1, it is slightly below phase 2. The social effect was not affected by the price change as in the previous phases, but since the social effect of the model is higher than other models, the social effect is higher than in phase 1 and phase 2. Contrary to the other phases, the environmental impact was not affected by the changes in prices in the model.

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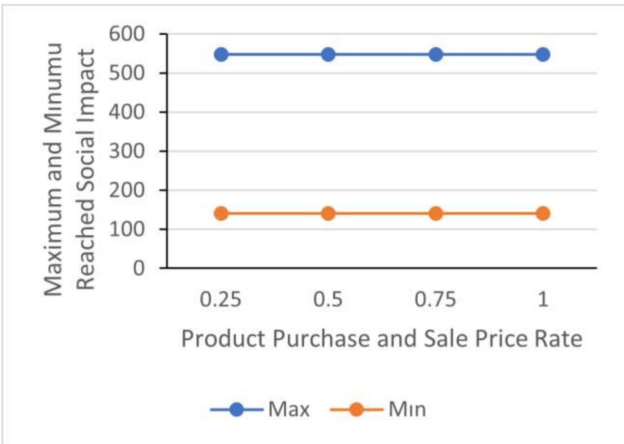


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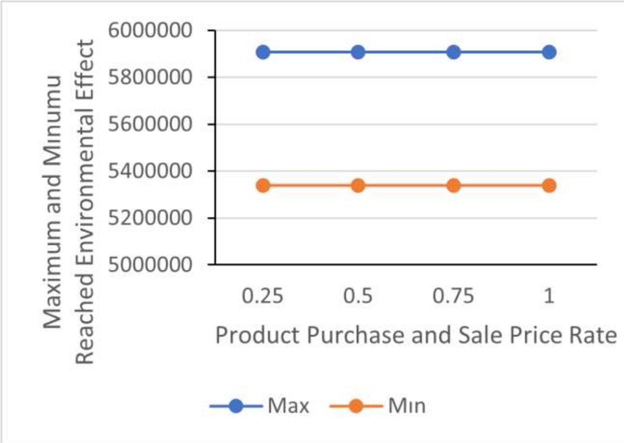


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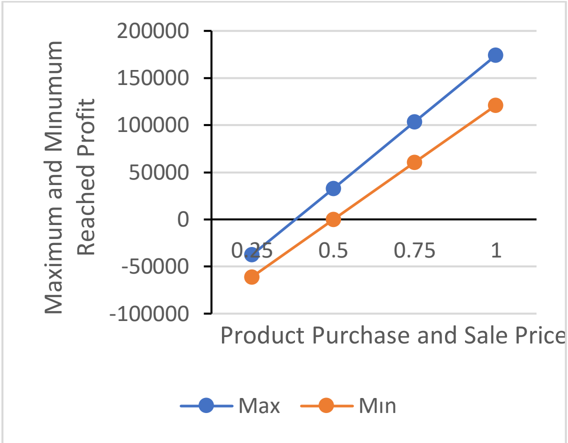
Figure 4.22: Product Purchase and Sale Price Rate versus Objective Values Max-Min Values in Phase3

Figure 24 shows the results of the price sensitivity analysis for phase 4. As in the other phases, the profitability increases as the purchase and sale prices increase at the same rate. However, the most profitable solution of phase 4 is lower than the other phases' most profitable solutions. While the ratio is 0.25, the profitability is below 0 since the model is not feasible to invest in that ratio. The social impact does not change from the price change in phase 4, yet the social impact is relatively low compared to the other phases. While the environmental impact (damage) does not differ at the minimum value, the damage increases after 0.75 at maximum because the model makes more sales after this rate. Since no measures are taken to reduce environmental damage, the environmental effect is higher than phases 2 and 3. In the sensitivity analysis of purchasing and selling prices, other phases dominate phase 4, so phase 4 is a model that the investor should not choose under these conditions.

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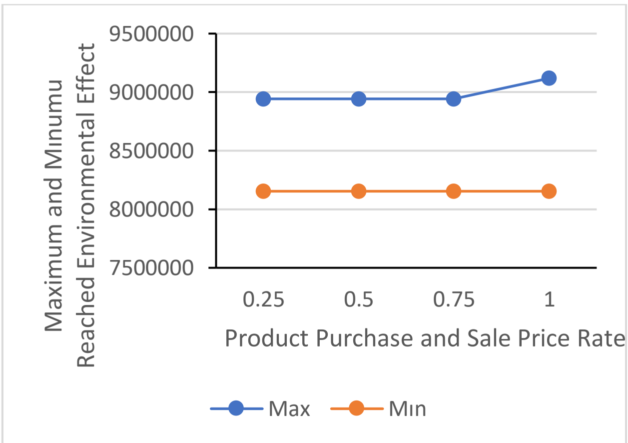


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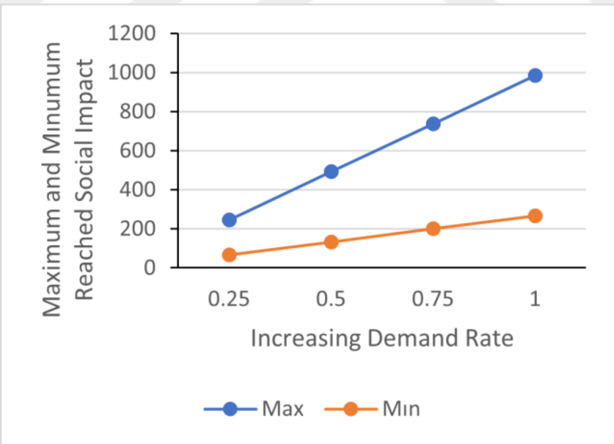
Figure 4.23: Product Purchase and Sale Price Rate versus Objective Values Max-Min Values in Phase4

**Demand fluctuation of fruits:**

Figure 25, 26, 27, and 28 indicates the results of the sensitivity analyses made in demand fluctuation of lemons in 4 phases for three objectives. The value of the original model was considered to be 50% as the average amount, and the demand was raised or declined to observe the adjustment on diverse decisions.

Figure 25 shows the three objectives change with respect to the change in demand for phase 1. In Phase 1, profitability increases as demand increases. When the demand is reduced to 0.25 rate, the maximum and minimum values of the profit remain below zero. Therefore, it is not profitable when the original demand is halved. As the demand increases, the social impact increases in phase 1 because as the demand increases, more personnel will be needed both on the farmer's side and on the warehouse side. As the number of working personnel increases, the social impact will increase. As demand increases, environmental damage also increases due to reasons such as the production and transportation of products with fossil energy. A striking detail is that the difference between the min and max values for all objectives increases when demand raises.

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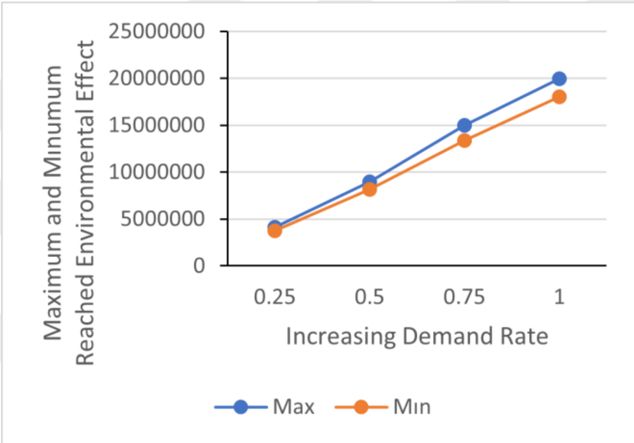


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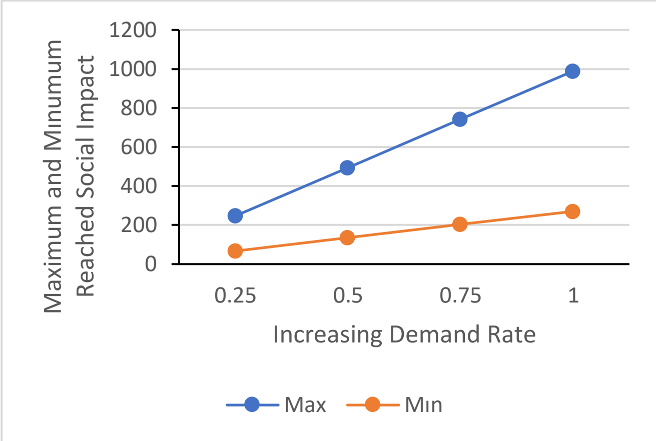
Figure 4.24: Increasing Demand Rate versus Objective's Max-Min Values in Phase1

Figure 26 shows the sensitivity analysis results according to the change in demand for phase 2. Profitability increased with the increase in demand in phase 2, and profitability is greater than phase 1. While the profitability between phase 1 and phase 2 with the original parameters is not much, the difference in profitability between phase 1 and phase 2 increases with the increase of the demand parameter. In Phase 2, with the increase in demand, the social impact increased. As in phase 1, with the increase in demand, the number of personnel will increase, and this causes an increase in social impact. The social impact in phase 2 is slightly higher than in phase 1. The environmental impact (damage) increased as demand increased but remained below the environmental damage in phase 1. This is because the model in phase 2 is more sensitive to the environment.

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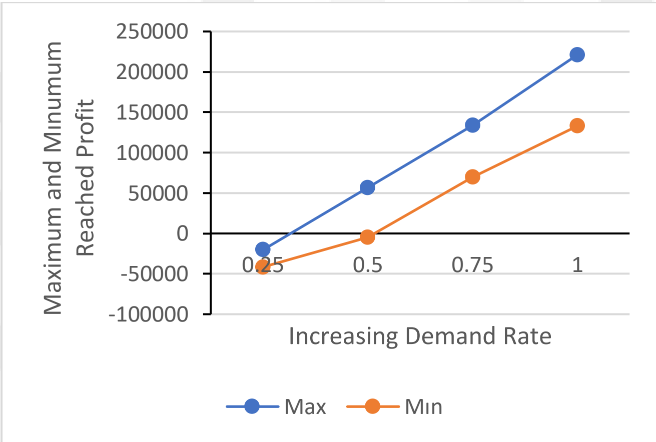


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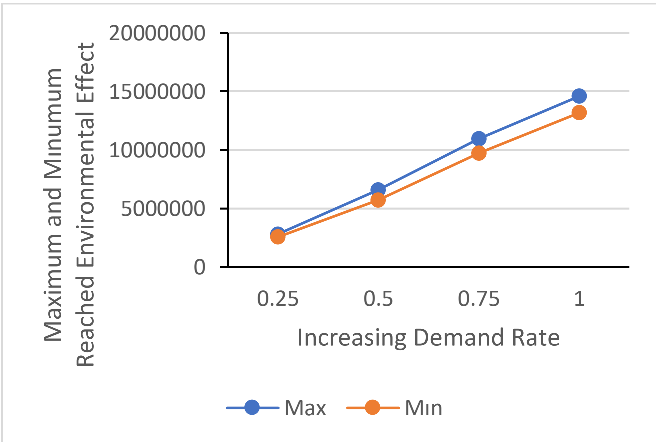


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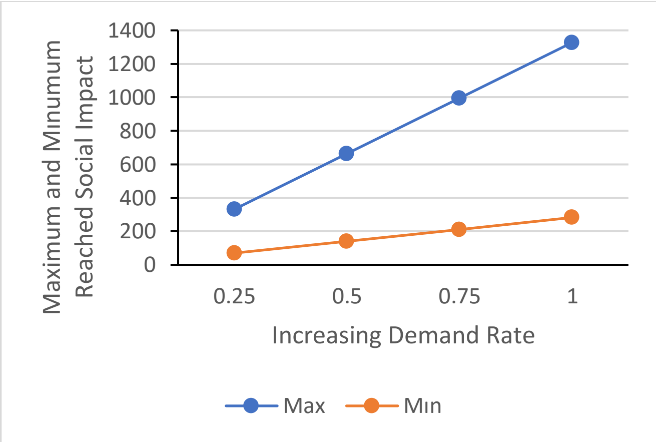
Figure 4.25: Increasing Demand Rate versus Objective's Max-Min Values in Phase2

Figure 27 represents the outputs for phase 3 with the change in demand. Profitability increased with the increase in demand in phase 3, but the model loses its profitability when the demand is halved. While phase 3 is more profitable than phase 1 when demand is increased, it makes a slightly lower profit than phase 2. With the increase in demand, the social impact increases in phase 3 as well as in other phases. Since the model in phase 3 is the most sensitive to social impact, it has become the model whose social value increases the most when demand is increased. The environmental impact in phase 3 has increased with the increase in demand, as in other models.

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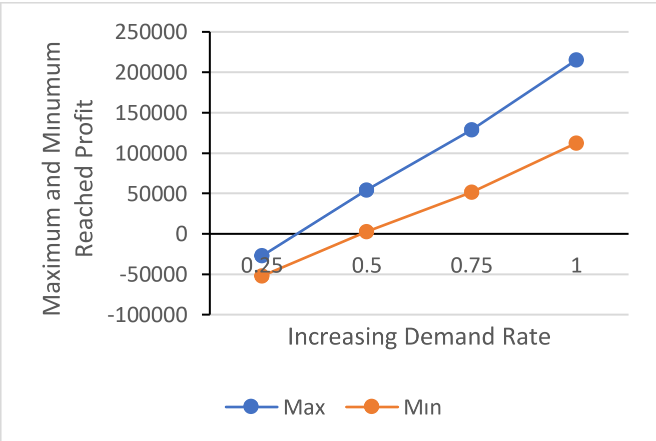


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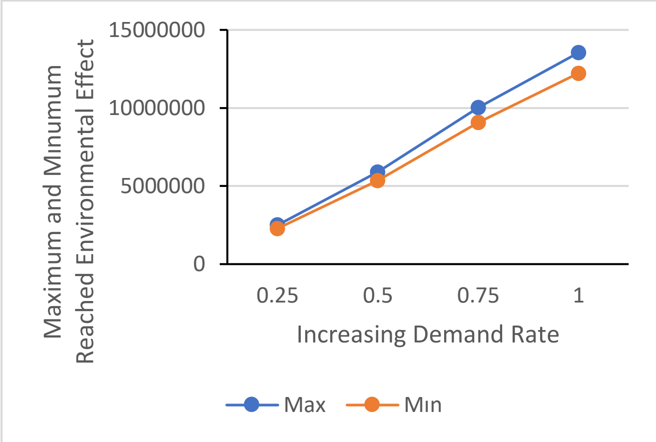


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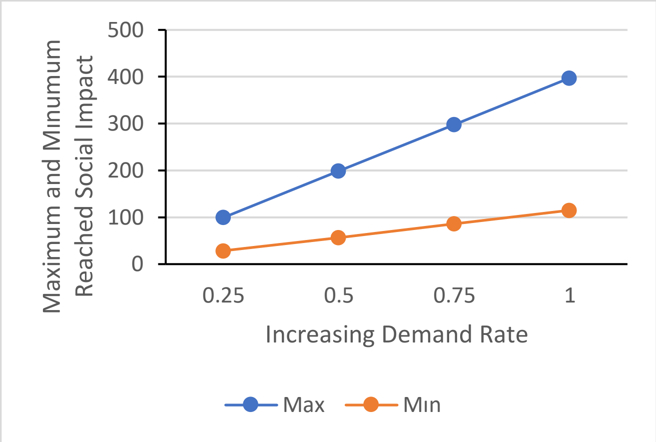
Figure 4.26: Increasing Demand Rate versus Objective's Max-Min Values in Phase3

Figure 28 shows the effect of change in demand on the objectives for phase 4. As in other phases, profitability increased as demand increased, but profits remained below zero at the rate of 0.25, so the investment does not make sense for demand at this rate. The most profitable solution in phase 4 is below the most profitable solution of the other phases. As the demand increases, the social impact increases since, number of employers increases and the social impact increases. However, as in the profitability, the solution with the highest social impact remains under the highest social impact of the other phases. In environmental damage, as the demand increases, the production and transport using fossil energy increase, so the environmental damage increases. In phase 4, the most serious environmental damage is more than phase 2 and phase 3 and equal to phase 1. Therefore, other phases dominate phase 4, and it would be proper not to prefer phase 4 by investors.

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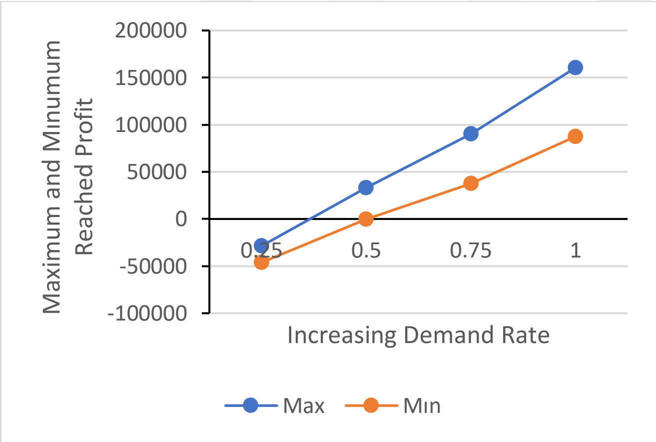


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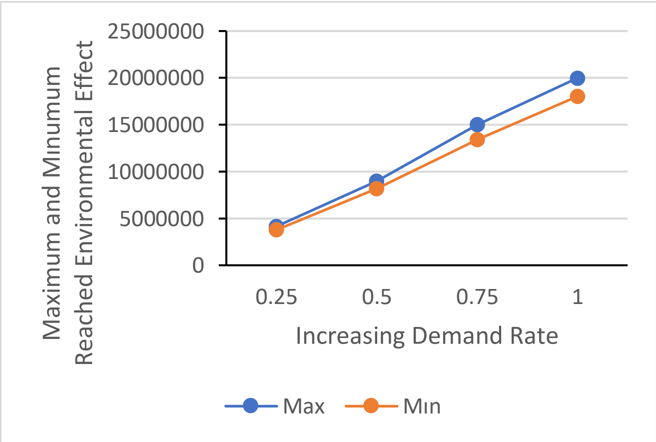


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Figure 4.27: Increasing Demand Rate versus Objective's Max-Min Values in Phase4

# Chapter 5:
# CONCLUSION

Strategical and tactical decisions can be made with the aggregate plan, which is one of the medium-term plans of the companies. We have proposed a model for a sustainable aggregate plan with TBL. This model gives a comprehensive image for the aggregate planning and responds to many important decisions, for example, how much product should be purchased in each period, how much of the demand should be met, which packaging method should be preferred, and by which transportation mode should be selected to product delivery. With the power of mathematical programming, the best alternative solutions are offered. The model is flexible, and decision-makers can choose the solution that suits their strategies. The model was studied in 4 phases. The first phase is an aggregate planning model that takes into account three perspectives of sustainability. In the second model, the best solutions were obtained by, in addition to the phase 1 model, necessary trainings were provided to the inclusive suppliers such as organicizing the products, reducing water consumption, and producing higher quality products concisely. In the third model, in addition to the second model, inclusive suppliers are supported with the necessary training and equipment to create added value for the products, and the best alternative solutions are obtained as a result. In the fourth phase, added value, which the company provides, is extracted from the products from the model in the first phase. Alternative solutions have been obtained for the model of taking the products from the farmer to the customer without any added value. A realistic case study was conducted with a company that is an online healthy fresh food seller in Turkey. Within the 4 phases, the results show that while the social impact increases, the cost increases and the profit decreases, and while the environmental impact (damage) decreases, the profit also declines. Therefore, there is no solution where the three objectives are best simultaneously. So alternative optimum solutions for perfectly balanced three dimensions have been obtained. While the profit is maximum, the environmental and social values are not very good. However, it has been observed that the environmental and social impact become better with a slight decrease in the profit since their pace of improvement is higher than the rate of profit decline. When it is desired to increase the social and environmental impact more than a certain rate, it is necessary to sacrifice a proportionally high profit. Therefore, while it's reasonable to reduce the profit a little and improve the environmental and social impact, this situation can be reversed when the environmental and social impact is increased too much. In some models, there are solutions where the profit is negative while the environmental impact is low and social impact is high. If regulations require the company to deliver such high social and/or low environmental impact, this may not be a sensible investment. The results obtained at the end of the case study for the 4 phases are summarized as follows. In Phase1, the highest and lowest profitability were 41.486, and 3.141 Turkish liras, the lowest and highest environmental damage were 8.153.831 and 8.942,611 units. The highest and lowest value of social impact were 491,99 and 131,85 units. In Phase 2, the highest profitability was 58.144, and the lowest was 17.934 Turkish lira, the highest social effect was 494,49, and the lowest social effect was 133,13, the greatest environmental damage was 6.272.827, and the lowest was 5.722.083. In Phase 3, the highest and lowest profit value were 54.063 and 5.056, the highest and lowest social impact were 548.19 and 141.34, and the highest and lowest environmental damage were 5.908.374 and 5.338.845. In Phase 4, the highest and lowest profit values were 32.850 and -292, the highest and lowest environmental damage values were 8.942.611 and 8.153.831, and the highest and lowest social impact values were 19.871 and 5.662. In the light of these results, the model with the highest profitability is phase 2. After phase 2, the highest profitability is in phase 3, phase 1, and phase 4 models, respectively. The model with the highest social impact and the lowest environmental damage was phase 3. In phases 2 and 3, the company was approached to the supplier inclusively, and the results were better than the other phases. This means that inclusive business is not about altruism, and it is a win-win situation for both companies and inclusive suppliers. Therefore, investors should choose the solution suitable for their strategy from phase 2 or phase 3. The case study is done with an organic product vendor, yet the models can be used or adapted by different sectors.

These methods aid in enhancing productivity, quality, as well as preventing supply shortages while also maximizing profit. We encountered some difficulties during the implementation of the model. Since social criteria are very diverse and dynamic, defining them mathematically and getting meaningful mathematical outputs is one of the difficulties. We tried to use standard data as much as possible. However, due to the scarce of available data, we had to use the pairwise comparison on some parameters, and to get more accurate solutions all parameters should be exact in the future studies.

## 5.1 *Future Work*

In the model, some parameters are defined by pairwise comparison, and actual data can be reached with field study instead of pairwise comparison, and more precise results can be obtained in future studies.

We applied the case study for models for one product (lemon) since available data is limited; if all products are included in the system, and the application is carried out, a more comprehensive result will be obtained in future studies.

The preferences and consumption data of BOP consumers are scarce, so the model does not go into details of how much the company's potential market share has grown. With this information collection, the change in the company's market share can be analyzed mathematically in future studies.

Our frameworks provide the optimum Pareto results to the decision-makers. However, in future studies, the most suitable solution can be determined for the decision makers' strategies by using multi-actor multi-criteria analysis to select the most optimal among the solution alternatives.

We did not take into account the regulations of the region. Yet, the model is flexible and can adapt to different regions' regulations in future studies and can be developed and evaluated in this regard.

Since we conducted the study for a period of 12 months, we did not analyze how the company's efforts to increase social impact and reduce environmental damage affect the company's image. In future studies, it can be analyzed how the social and environmental impacts change affect the company's image, therefore how much demand and profit will increase.

# BIBLIOGRAPHY

[Anderson and Billou, 2007] Anderson, J., & Billou, N. (2007). Serving the world's poor: innovation at the base of the economic pyramid. Journal of Business Strategy, 28(2):14-21.

[Ansari and Kant, 2016] Ansari, Z., & Kant, R. (2016). A state-of-art literature review reflecting 15 years of focus on sustainable supply chain management. Journal of Cleaner Production.

[Ansari and Kant, 2017] Ansari, Z., & Kant, R. (2017). A state-of-art literature review reflecting 15 years of focus on sustainable supply chain management. Journal of Clean Production.

[Anvari and Turkay, 2017] Anvari, S., & Turkay, M. (2017). The facility location problem from the perspective of triple bottom line accounting of sustainability. International Journal of Production Research, 55(21), 6266-6287.

[Aryal et al., 2009] Aryal, K., Chaudhary, P., Pandit, S., & Sharma, G. (2009). Consumers’ Willingness to Pay for Organic Products: A Case From Kathmandu Valley. The Journal of Agriculture and Environment.

[Asadullah and Rahman, 2009] Asadullah, M. N., & Rahman, S. (2009). Farm productivity and efficiency in rural Bangladesh: the role of education revisited. Applied Economics, 17-33.

[Banerjee and Duflo, 2007] Banerjee, A. V., & Duflo, E. (2007). The economic lives of the poor. Journal of Economic Perspectives, 141-167.

[Barbosa-Povoa et al., 2018] Barbosa-Povoa, A., da Silva, C., & Carvalho, A. (2018). Opportunities and challenges in sustainable supply chain: an operations research perspective. Eur. J. Oper. Res.

[befresh, 2018] befresh. (2018). Retrieved from https://www.befresh.ca/blog-how-much-water/#:~:text=Lemons%3A%20642%20litres%2Fkg.,requires%20196%20litres%20of%20water.

[bloomberg, 2021] bloomberg. (2021). Retrieved from: https://www.bloomberg.com/billionaires/

[Blundell et al., 1999] Blundell, R., Dearden, L., Meghir, C., & Sianesi, B. (1999). Human capital investment: the returns from education and training to the individual, the firm and the economy. Fiscal studies, 1-23.

[Born and Bachmann, 2006] Born, H., & Bachmann, J. (2006). Adding value to farm products: an overview. National Sustainable Agriculture Information Service, 1-12.

[Brouwer et al., 1999] Brouwer, A., Longnecker, M. P., Birnbaum, L. S., Cogliano, J., Kostyniak, P., & Moore, J. W. (1999). Characterization of potential endocrine-related health effects at low-dose levels of exposure to PCBs. Environmental health perspectives.

[Business, 2015] Business. (2015). Retrieved from: https://business.edf.org/insights/green-freight-math-how-to-calculate-emissions-for-a-truck

[Cañeque and Hart, 2015] Cañeque, F.C., & Hart, S.L. (Eds.). (2015). Base of the Pyramid 3.0: Sustainable Development through Innovation and Entrepreneurship (1st ed.). Routledge. https://doi.org/10.4324/9781351285964

[Carter and Rogers, 2008] Carter, C. R., & Rogers., D. S. (2008). A framework of sustainable supply chain management: moving toward new theory. International journal of physical distribution & logistics management, 38(5):360-387.

[Chamberlain and Anseeuw, 2019] Chamberlain, W., & Anseeuw, W. (2019). Inclusive businesses in agriculture: defining the concept and its complex and evolving partnership structures in the field. Land Use Policy, 308-322.

[Chavez et al., 2018] Chavez, M., Sarache, W., & Costa, Y. (2018). Towards a comprehensive model of a biofuel supply chain optimization from coffee crop residues. In: Transportation Research Part E: Logistics and Transportation Review, 136-162.

[Chigerwe et al., 2003] Chigerwe, J., Manjengwa, N., Van der Zaag, P., & Zhakata, W. (2003). Low head drip irrigation kits and treadle pumps for smallholder farmers in Zimbabwe—a technical evaluation based on laboratory tests. Physics and Chemistry of the Earth, 1049-1059.

[Cholette and Venkat, 2009] Cholette, S., & Venkat, K. (2009). The energy and carbon intensity of wine distribution: A study of logistical options for delivering wine to consumers. Journal of Cleaner Production.

[csgb, 2021] csgb (2021). Retrieved from asgari-ucret: https://www.csgb.gov.tr/asgari-ucret/asgari-ucret-2021/

[Davies et al., 2021] Davies, J., Lluberas, R., & Shorrocks, A. (2021). Credit Suisse Global Wealth Databook 2021.

[Eia, 2021] Eia. (2021). Retrieved from https://www.eia.gov/tools/faqs/faq.php?id=74&t=11#:~:text=In%202020%2C%20total%20U.S.%20electricity,CO2%20emissions%20per%20kWh.

[Eskandarpour et al., 2015] Eskandarpour, M., Dejax, P., Miemczyk, J., & Peton, O. (2015). Sustainable supply chain network design: an optimization-oriented review. Omega (United Kingdom). doi: https://doi.org/10.1016/j.omega.2015.01.006.

[fao, 2021] fao. (2021). Retrieved from https://www.fao.org/agriculture/crops/thematic-sitemap/theme/spi/good-farming-practices/en/

[Finkbeiner et al., 2010] Finkbeiner, M., Schau, E., Lehmann, A., & Traverso, M. (2010). Towards life cycle sustainability assessment. Sustainability. Retrieved from Retrieved from. http://www.mdpi.com/2071-1050/2/10/3309.

[Garcerá et al., 2017] Garcerá, C., Moltó, E., & Chueca, P. (2017). Spray pesticide applications in Mediterranean citrus orchards: Canopy deposition and off-target losses. Science of the Total Environment, 1344-1362.

[Garcia-Feijoo et al, 2020] García-Feijoo, M., Eizaguirre, A., & Rica-Aspiunza, A. (2020). Systematic Review of Sustainable-Development-Goal Deployment in Business Schools. Sustainability.

[Gil et al., 2014] Gil, Emilio & Gallart, Montserrat & Llorens Calveras, Jordi & Llop Casamada, Jordi & Bayer, Tânia & Carvalho, Cláudia. (2014). Spray adjustments based on LWA concept in vineyard. Relationship between canopy and coverage for different application settings. Asp. Appl. Biol. 122.

[Global Petrol Prices, 2021] Global Petrol Prices. (2021). Retrieved from https://www.globalpetrolprices.com/Turkey/electricity_prices/

[Govindan et al., 2015] Govindan, K., Rajendran, S., Sarkis, J., & Murugesan, P. (2015). Multi criteria decision making approaches for green supplier evaluation and selection: a literature review. J. Clean. Prod., 98, 66-83.

[Gupta, 2013] Gupta, A. (2013). Base of the pyramid. In: S. O. Idowu, N. Capaldi, L. Zu, A. D. Gupta (Eds). Encyclopedia of corporate social responsibility. Springer, 6.

[Gupta et al. 2015] Gupta, J., Pouw, N., & Ros-Tonen, M. (2015). Towards an elaborated theory of inclusive development. Eur J Dev Res, 541-559.

[Gupta and Palsule-Desai, 2011] Gupta, S., & Palsule-Desai, O. (2011). Sustainable supply chain management: review and research opportunities. IIMB Manag. Rev.

[Halme et al., 2012] Halme, M., Lindeman, S., & Linna, P. (2012). Innovation for inclusive business: Intrapreneurial bricolage in multinational corporations. J Manage Stud, 743-784.

[Han and Shah, 2020] Han, J., & Shah, S. (2020). The Ecosystem of Scaling Social Impact: A New Theoretical Framework and Two Case Studies. Journal of Social Entrepreneurship, 215-239. doi: 10.1080/19420676.2019.1624273

[Hart, 2015] Hart, S. (2015). BoP 2.0: the next generation of strategy for the base of the pyramid. Corporate Stewardship: Achieving Sustainable Effectiveness., 190-204.

[Hart et al., 2016] Hart, S., Sharma, S., & Halme, M. (2016). Poverty, business strategy, and sustainable development. Organ Environ, 401-415.

[IFC, 2010] IFC. (2010). Telling our story: Base of the pyramid investments. International Finance Corporation. Retrieved from https://www.ifc.org/wps/

[IFPRI, 2002] IFPRI. (2002). Ending hunger in Africa: only the small farmer can do it. International Food Policy Research Institute.

[Jin et al., 2014] Jin, M., Granda-Marulanda, N., & Down, I. 8. (2014). The impact of carbon policies on supply chain design and logistics of a major retailer. J. Clean. Prod. Retrieved from: https://www.sciencedirect.com/science/article/pii/S0959652613005933

[Karunakaran, 1958] Karunakaran, C. O. (1958). The Kerala food poisoning. Journal of the Indian Medical Association.

[Kelly et al. 2015] Kelly, S., Vergara, N., & & Bammann, H. (2015). Inclusive business models: Guidelines for improving linkages between producer groups and buyers of agricultural produce. Food and Agriculture Organization of the United Nations.

[Khan et al., 2016] Khan, S., Dong, Q., & Zhang, Y. (2016). Research on the measuring performance of green supply chain management: in the perspective of China. Int. J. Eng. Res. Afr., 27(12), 167-178.

[Khan et al., 2019] Khan, S., Sharif, A., Golpira, H., & Kumar, A. (2019). A green ideology in Asian emerging economies: From environmental policy and sustainable development. Sustainable Development.

[Khan et al., 2020a] Khan, S., Zhang, Y., & Nathaniel, S. (2020a). Green supply chain performance and environmental sustainability: a panel study. Scientific Journal of Logistics, 141-159.

[Kolk et al., 2014] Kolk, A., Rivera-Santos, M., & Rufín, C. (2014). Reviewing a decade of research on the “base/bottom of the pyramid” (BOP) concept. Business & Society, 338-377.

[Kumar et al., 2019] Kumar, A., Mangla, S., Luthra, S., & Ishizaka, A. (2019). Evaluating the human resource related soft dimensions in green supply chain management implementation. Prod. Plann. Contr. doi:https://doi.org/10.1080/09537287.2018.1555342

[Lashitew et al., 2018] Lashitew, A., Bals, L., & van Tulder, R. (2018). Inclusive business at the base of the pyramid: the role of embeddedness for enabling social innovations. J Bus Ethics, 1-28.

[Likoko and Kini, 2017] Likoko, E., & Kini, J. (2017). Inclusive business—a business approach to development. Current opinion in environmental sustainability, 24, 84-88.

[Mahmood et al., 2016] Mahmood, I., Imadi, S. R., Shazadi, K., Gul, A., & Hakeem, K. R. (2016). Effects of pesticides on environment. In Plant, soil, and microbes. Springer, Cham, 253-269.

[Maisiri et al., 2005] Maisiri, N., Senzanje, A., Rockstrom, J., & Twomlow, S. J. (2005). On farm evaluation of the effect of low-cost drip irrigation on water and crop productivity compared to conventional surface irrigation system. Physics and Chemistry of the Earth, 783-791.

[Menden et al., 2019] Menden, A., van der Vleuten, N., Pirzer, C., & von Blomberg, I. (2019). NGO and company partnerships for inclusive business. ENDEVA UG.

[Moreno-Camacho et al., 2019] Moreno-Camacho, C. A., Montoya-Torres, J. R., Jaegler, A., & Gondran, N. (2019). Sustainability metrics for real case applications of the supply chain network design problem: A systematic literature review. Journal of cleaner production, 600-618.

[numbeo, 2021] numbeo. (2021). Retrieved from: https://www.numbeo.com/crime/in/Istanbul [ogm, 2021] ogm. (2021). Retrieved from: https://www.ogm.gov.tr/tr

[Ozkan et al., 2004] Ozkan, B., Akcaoz, H., & Karadeniz, F. (2004). Energy Requirement and Economic Analysis of Citrus Production in Turkey. Energy Conversion and Management.

[plastikfabrikası, 2021] plastikfabrikası. (2021). Retrieved from: https://plastikfabrikasi.net/

[Postel, 2000] Postel, S. (2000). Redesigning irrigated agriculture. (L. In: Starke, Ed.) State of the World 2000. Publ. WW Norton and Co, 39-58.

[Prahalad and Hammond, 2002] Prahalad, C. K., & Hammond, A. L. (2002). Serving the world's poor, profitably. Harvard Business Review, 48-57.

[Prahalad and Hart, 2002] Prahalad, C. K., & Hart, S. L. (2002). The fortune at the bottom of the pyramid. Strategy+Business, 1-13.

[Prahalad and Hart, 1999] Prahalad, C., & Hart, S. (1999). Strategies for the Bottom of the Pyramid: Creating Sustainable Development.

[Rajeev et al., 2017] Rajeev, A., Pati, R., Padhi, S., & G. K. (2017). Evolution of sustainability in supply chain management: a literature review. J. Clean. Prod.

[Rasmi and Turkay, 2020] Rasmi, S. A. B., & Türkay, M. (2020). Aggregate Planning: Strategies, Models, and Analysis. Springer.

[Raut et al. 2019] Raut, R., Luthra, S., Narkhede, B., Mangla, S., Gardas, B., & Priyadarshinee, P. (2019). Examining the performance-oriented indicators for implementing green.

[Report of the World Commission on Environment and Development: Our Common Future, 2020] Report of the World Commission on Environment and Development: Our Common Future. Retrieved from: http://www.ask-force.org/web/Sustainability/Brundtland-Our-Common-Future-1987-2008.pdf (accessed on 1 February 2020).

[Russell and Taylor-Iii, 2008] Russell, R., & Taylor-Iii, B. (2008). Operations management along the supply chain. Wiley.

[Schnitkey, 2018] Schnitkey, G. (2018).Historic Fertilizer, Seed, and Chemical Costs with 2019 Projections. farmdoc daily (8):102.

[sdgs, 2015] sdgs. (2015). Retrieved from https://sdgs.un.org/goals

[Seufert et al., 2012] Seufert, V., Ramankutty, N., & Foley, J. (2012). Comparing the yields of organic and conventional agriculture. Nature 485, 229-232. doi:https://doi.org/10.1038/nature11069

[Seuring, 2013] Seuring, S. (2013). A review of modeling approaches for sustainable supply chain management. Decis. Support Syst., 1513-1520.

[Seuring and Müller, 2008] Seuring, S., & Müller, M. (2008). From a literature review to a conceptual framework for sustainable supply chain management. J. Clean. Prod. Retrieved from http://www.sciencedirect.com.ez.unisabana.edu.co/science/article/pii/S095965260

[Speelman et al., 2019] Speelman, E. N., Rodela, R., Doddema, M., & & Ligtenberg, A. (2019). Serious gaming as a tool to facilitate inclusive business, a review of untapped potential. Current Opinion in Environmental Sustainability, 41, 31-37.

[Touboulic and Walker, 2015] Touboulic, A., & Walker. (2015). Theories in sustainable supply chain management: a structured literature review. H.Int. J. Phys. Distrib. Logist. Manag. Retrieved from: http://www.emeraldinsight.com/doi/10.1108/IJPDLM-05-2013-0106.

[tüik, 2021] tüik. (2021). Retrieved from: https://cip.tuik.gov.tr/?il=31#

[UNDP, 2013] UNDP. (2013). Realizing Africa’s wealth: Building inclusive businesses for shared prosperity. UNDP African Facility for Inclusive Markets. Retrieved from: https://www.africa.undp.org/content/rba/en/home/library/reports/poverty-reduction/

[verginet, 2021] verginet. (2021) Retrieved from: https://www.verginet.net/

[Wasiluk, 2013] Wasiluk, K. L. (2013). Beyond eco-efficiency: understanding CS through the IC practice lens. Journal of Intellectual Capital.

[Wolf and Seuring, 2010] Wolf, C., & Seuring, S. 2. (2010). Environmental impacts as buying criteria for third party logistical services. Int. J. Phys. Distrib. Logist. Manag., 40 (1/2), 84-102.

[World Development Report, 2008] World Development Report. (2008). Agriculture for development. Washington, DC: The World Bank.

[World Inequality Database, 2021] World Inequality Database. (2021). Retrieved from wid.world: https://wid.world/world/#sptinc_p90p100_z/US;FR;DE;CN;ZA;GB;WO/last/eu/k/p/yearly/s/false/23.469/80/curve/false/country

[WorldBank, 2014] WorldBank. (2014). The practice of responsible investment principles in large scale agricultural investments: Implications for corporate performance and impact on local communities. The World Bank.

[Xie, 2016] Xie, G. (2016). Cooperative strategies for sustainability in a decentralized supply chain with competing suppliers. J. Clean. Prod., 807-821.

[Zhu and Sarkis, 2006a] Zhu, Q., & Sarkis, J. (2006a). An inter-sectoral comparison of green supply chain management in China: drivers and practices. J. Clean. Prod.

# Appendix A:

## DATA AND REFERENCES FOR THE CASE STUDY

In this part, we present the values of associated parameters with their references that were utilized in the case study.

Table A.1: Real data for the case study

| PARAMETER | STANDARDIZATION | REFERENCES |
|---|---|---|
| *CSW*: average salary of one worker educated and non-educated | 5500₺, 4200₺ :Directly utilize | [csgb, 2021] |
| *CS*: cost of supply transportation with transit and truck | 2000, 3000 | company's experience |
| *CP*: cost of product transportation with transit | 2000 | company's experience |
| *CE*: energy cost for each product. | 1.26: Directly utilize | [Ozkan et al., 2004] |
| $CX_t$: cost of amount of supply purchase at time t. | depends on time | based on market prices |
| $Tax_j$: tax rate selling at $j \in WL$. | 0.08: Directly utilize | [verginet, 2021] |
| $SP_t$: selling price at time $t \in T$. | depends on time | based on market prices |
| $dis_{mij}$: distance between $i \in SL$ to $j \in WL$ via transport $m \in TM$. | depends on location: directly utilize | Map |
| $dist_{njv}$: distance between $j \in WL$ to $v \in CL$ via transport $n \in TMW$. | depends on location: directly utilize | Map |
| *JLRS*: jobless rate at supplier location. | Directly utilize | [tüik, 2021] |

| | | |
|---|---|---|
| *JLR*: jobless rate at warehouse location. | Directly utilize | [tüik, 2021] |
| *PRS*: population density at supplier location. | Directly utilize | [tüik, 2021] |
| *PRW*: population density at warehouse location. | Directly utilize | [tüik, 2021] |
| *HSL*: highest security level national. | Directly utilize | [numbeo, 2021] |
| *SLS*: security level at supplier. | Directly utilize | [numbeo, 2021] |
| *SLW*: security level at warehouse. | Directly utilize | [numbeo, 2021] |
| *ROSL*: national range of security level. | Directly utilize | [numbeo, 2021] |
| *EI*: expected education improve in warehouse location. | Pairwise comparisons are used to quantify qualitative data. | based on expert judgement |
| *EEL*: existing education access in warehouse location. | Directly utilize | [tüik, 2021] |
| *EIS*: expected education improve in supplier location. | Pairwise comparisons are used to quantify qualitative data. | based on expert judgement |
| *EELS*: existing education access in supplier location. | Directly utilize | [tüik, 2021] |
| *HI*: expected health improve in warehouse location. | Pairwise comparisons are used to quantify qualitative data. | based on expert judgement |
| *EHL*: existing health level in warehouse location. | Directly utilize | [tüik, 2021] |
| *HIS*: expected health improve in supplier location. | Pairwise comparisons are used to quantify qualitative data. | based on expert judgement |
| *EHLS*: existing health level in supplier location. | Directly utilize | [tüik, 2021] |
| *EMI*: expected empower improve in warehouse location. | Pairwise comparisons are used to quantify qualitative data. | based on expert judgement |

| | | |
|---|---|---|
| *EMIS*: expected empower improve in supplier location. | Pairwise comparisons are used to quantify qualitative data. | based on expert judgement |
| *Teta*: transform rate, (1 - waste rate) | 0.1: directly utilize | company's experience |
| $DM_{tv}$: demand in $v \in CL$ at time $t \in T$. | Depends on time | company's experience |
| *WR*: water req for 1 kg lemon production. | 640: directly utilize | [befresh, 2018] |
| *PR*: Pesticide Requirement. | 0.42: directly utilize | [Gil et al., 2014] |
| *CPR*: cost of unit pesticide. | 0.2: directly utilize | [Schnitkey, 2018] |
| *COP*: cost of organic packeging (unit). | 0.36: directly utilize | company's experience |
| *CIP*: cost of inorganic packeging (unit). | 0.1: directly utilize | company's experience |
| *W*: packing waste amount of kg's of lemon. | 0.0105: directly utilize | [plastikfabrikası, 2021] |
| *WS*: waste sensitivity. | Normalized Population density * location waste situation | [tüik, 2021] |
| *CEP*: carbon emission per kg product. | 2.7: Directly utilize | [Eia, 2021] |
| *AES*: carbon emission sensitivity. | Normalized Population density * location forest proportion | [tüik, 2021] ; [ogm, 2021] |
| *SOS:* soil emission sensitivity. | the normalized population density * the location's agricultural area | [tüik, 2021] |
| *Training Costs* | 3000, 2500, 3500: directly utilize | average training costs in Turkey based on the topic |