OCTOBER 2019 M.Sc. in Industrial Engineering ILIYA SALEH LANGE

REPUBLIC OF TURKEY

GAZİANTEP UNIVERSITY

GRADUATE SCHOOL OF NATURAL & APPLIED SCIENCES

ASSIGNING END OF LIFE CYCLE WIND TURBINES TO THE RECYCLING FACILITIES: A CASE STUDY IN TURKEY

M.Sc. THESIS

IN

INDUSTRIAL ENGINEERING

BY

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in

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Supervisor

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Iliya Saleh LANGE

ABSTRACT

ASSIGNING END OF LIFE CYCLE WIND TURBINES TO THE RECYCLING FACILITIES: A CASE STUDY IN TURKEY

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The wind power industry has been growing significantly in the previous years and recently many countries have invested immensely into energy systems, renewable energy like the wind turbine which enjoys a lifespan of 20 – 25 years. In this study we have examined the wind turbines in Turkey and set up necessary steps that must be taken when break-down, remanufacturing and recycling phase occur. There are so many steps and areas that need to be look at when recycling or remanufacturing occurs, however, this study is focused on assigning end of life wind turbines to the manufacturers in Turkey. A mathematical model was set up using the p-median model (The problem of locating "wind turbine manufacturers" relative to a set of "wind turbine" such that the sum of the shortest recycling or remanufacturing weighted distance between "wind turbine" and "wind turbine manufacturer" is minimized.) and p-center model (helps us in minimizing the maximum distance between the 164 wind turbines and the 10 wind turbine manufacturers) to help in reversing the flow of wind turbine from the located areas to the nearest wind turbine manufacturers on the map. This study will guide the authorities and decision makers on which wind turbine manufacturer is best located to recycle or remanufacture which wind turbine.

Key Words: End of Life, Location & Allocation, P-median, P-center, Recycling, Wind Turbine.

ÖZET

ÖMRÜNÜ TAMAMLAMIŞ RÜZGAR TÜRBİNLERİNİN GERİ DÖNÜŞÜM TESİSLERİNE ATANMASI: TÜRKİYE UYGULAMASI

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Ekim 2019
54 Sayfa

Rüzgar enerjisi sektörü son yıllarda önemi artan ve ileriki yıllarda da bu önemini koruyacak bir alan olarak karşımıza çıkmaktadır. Bu sektörde faaliyet gösteren işletmeler rüzgar enerjisi yüksek yatırımlar yapsa da, en önemli rüzgar enerjisi araçlarından biri olan rüzgar türbinlerinin fiziki ömürleri ortalama olarak 20 ile 25 yıl arasında olması bu konuda planlamaların önemini artırmaktadır. Bu çalışmada Türkiye'de hali hazırda faaliyet gösteren rüzgar türbinlerinin ömürlerinin biteceği varsayımına dayanarak yeniden imalat tesislerine atanması problemi ele alınmıştır. Bunun için ömrünü tamamlamış rüzgar türbinleri talep noktaları, yeniden imalat merkezleri ise kaynak noktaları olarak temsil edilmiştir. Aralarındaki taşıma maliyetini minimize edecek şekilde P-median ve P-center (164 rüzgar türbini ile 10 rüzgar türbini imalat merkezleri arasındaki maksimum uzaklığı minimize etmede yardımcı olur) matematiksel modelleri geliştirilmiştir. Her iki modelle de en uygun amaç fonksiyonunu veren atamalar yani rüzgar türbinlerinin hangi yeniden imalat merkezine taşınacağı kararı bulunmuştur. Bu çalışmada elde edilecek sonuçların gerçekte ömrünü tamamlayacak olan rüzgar türbinlerinin geri dönüşümü için bir basamak olması amaçlanmıştır.

Anahtar Kelimeler: Rüzgar Türbini, Ömrünü Tamamlamış, Yeniden İmalat, p-Center, Geri Dönüşüm, p-Medyan, Yer Seçimi ve Atama.

''Dedicated to my family''

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CHAPTER I

INTRODUCTION

The wind turbine industry has been growing fast and enormously in the last decade and still growing continuously, with a bright future ahead for investors, specifically for those firms and countries who are interested in investing in the wind turbine sector. Recently a lot of developed countries have put in so many resources in renewable energy like the wind turbine; also developing countries have started to put in interest sawing reasonable amount of resources in this sector. Experts have stated that the wind turbine is one of the most environmentally friendly sources of energy in the world. The wind turbines have a life cycle between 15 – 20 years; other source stated that the life cycle of a wind turbine is between 20 – 40 years [1]. One of the largest study, in which inspection of about 3,000 onshore wind turbines were conducted, suggests that wind turbines will continue to produce electricity effectively approximately for 12 to 15 years [2]. Clearly, this tells us more about wind turbine, as time pass more and more technology is being applied to extend the lifespan of a wind turbine, but regardless of years it enjoys during the lifespan, at the end of the life cycle major steps must be taken before recycling and remanufacturing. Previews, analysis, and studies were made on some of the basics steps that must be taken to ensure a smooth management of the reverse flow of the wind turbine.

Based on a lot of previous articles and studies the early phase of recycling or remanufacturing wind turbines are being done by the process of reverse logistics, but the approach used in this study is a unique and different approach that will answer the question of which wind turbines manufacturer is assigned to remanufacture which wind turbine.

1.1 Motivation of Study

A preview must be done to ensure the reserve flow of the wind turbines are done accurately because the life cycle of the wind turbine has not been given much attention in the past though it plays a big role in the energy system. The early stage of recycling the wind turbines embodies a lot of questions that need to be addressed. In Turkey, the wind turbine has not seen any significant research in the past, so this study is an eye-opener for those willing to dive into this field.

According to reports there are 164 wind turbines with a cumulative capacity of 6,106.05 MW (Mega Watts) locations in Turkey, and more locations are being studied, analyzed and inspected to plant more wind plants in the country [3]. Furthermore, it has been stated that there are around 35 wind turbines locations with a cumulative capacity of 861.63 MW under construction across the country in cities like Izmir [3]. More efforts are being made to explore wind location in surrounding areas like Gaziantep. It also reported that Turkey Energy and Natural Resources Ministry has decided to build four wind energy power plants with a cumulative capacity of 1,000 MW [4]. We can undoubtedly estimate how fast and big the wind power or wind turbines industry is, from the fact that there are total 3,122 wind turbines [5] in only 164 different locations in Turkey. With some wind turbines coming towards the end of their life spans, there are necessary steps that need to be taken, in this study we focused on one of those steps that needs to be taken, as stated in the previous paragraph, so many questions to be answered, here are some few questions that need to be addressed – how do we locate all their locations? Which wind turbine manufacturer is best located to remanufacture the wind turbines that have exceeded their life cycles? Where does the wind turbine go when repair is needed?

When the decision is made for remanufacturing some important questions that need answers will have been answered in this thesis. Regardless of which decision made between recycling and remanufacturing a setup is clearly needed to manage the reverse flow of the wind turbine.

1.2 Purpose of the Study

The wind turbines life cycle of few locations in Turkey is approaching the end of their lifespan and some of the wind turbines are broken down due to several environment factors and wind pressure. With the aim of starting a conversation so that awareness can be raised and pro-active measures in this regard would be taken. Those in the position of power can see the economic advantage and prevent any unprepared challenges that may arise from the wind turbines sector.

Energy production through wind depends on the speed of the wind. So the cities of Turkey with licensed wind turbine also have favorable wind intensities. Though very limited but the wind intensity also has an impact on the production of energy. Fig 1.2 given below demonstrates the distribution of wind power intensity in 50m of elevation above ground across Turkey.

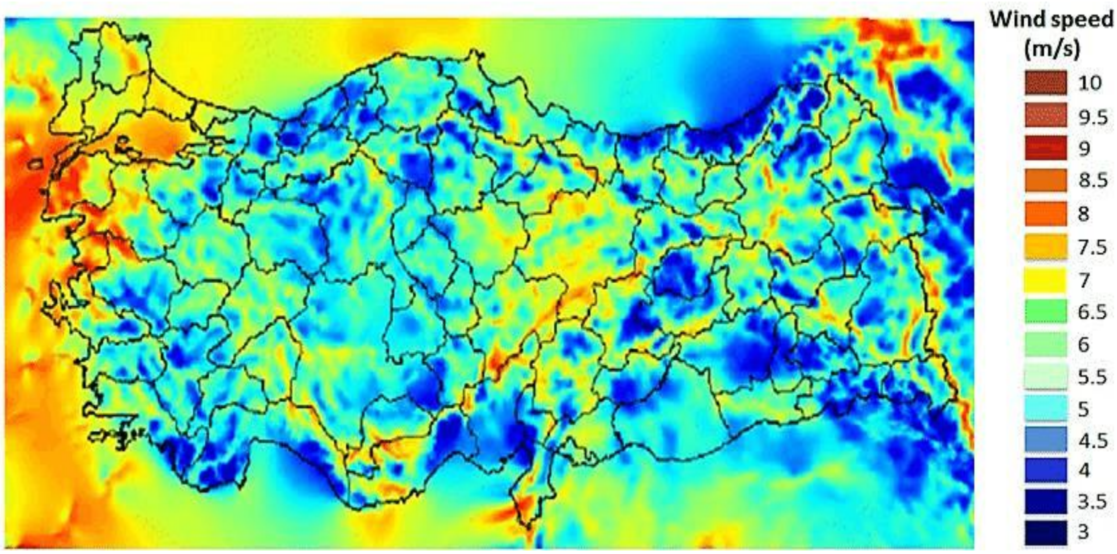

Figure 1.1 Wind energy potential in Turkey [7]

Furthermore, we can see that 63.7 % of the overall potential power is distributed to fields of middle class winds, 22.2 % to fields of good class winds and 14.1% to fields of perfect class winds. Even the country use good and perfect class winds to establish wind power they manage to station 47,849. 44 MW powers [7].

One of the aims of this study is to highlight solutions that may help Turkish Wind Energy Association in addressing problems concerning assigning wind turbines to wind turbine manufacturer when end of life cycle or breakdown of wind turbines occurs.

CHAPTER II

REVIEW OF THE LITERATURE

In this chapter, previous researches and studies on the lifecycle of wind turbines, recycling, remanufacturing, location and allocation problems related to P-median and P-center problems were reviewed.

2.1 Lifecycle of Wind Turbines

With the raise in popularity of wind farms and wind turbines, it is assumed that within the next twenty-five years 225,000 tonnes of rotor blade material will need to be recycled world-wide [8].

Presently wind turbine blades follow the life cycle as showed Figure 2.1, presently with landfill being the most popular option. During the 20-25 year lifespan of these blades it is imperative that recycling methods become optimized. In order to optimize these recycling processes a market/demand needs to be established for the recyclate fiber material in order to generate funds and encouragement [8].

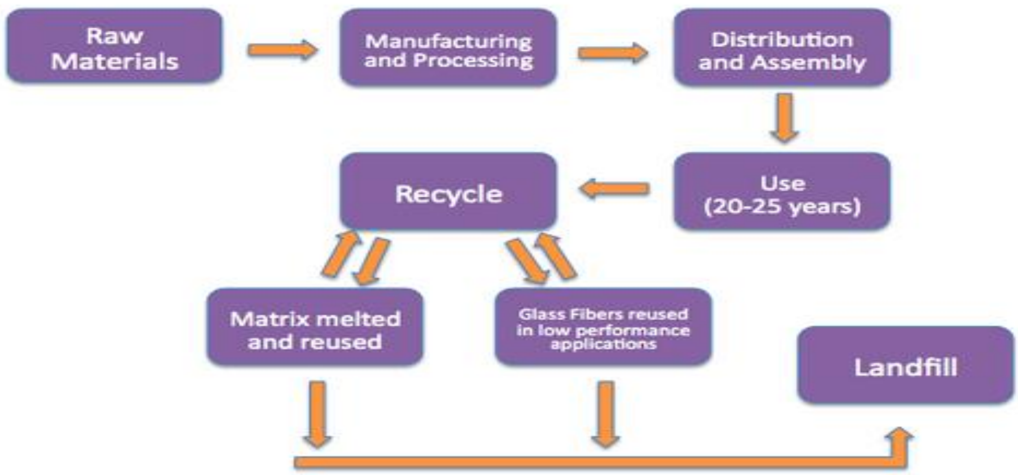

Figure 2.1 The life cycle of wind turbines [8].

Wind turbines are known for their less impact on the environment. Figure 2.2 shows the evaluation of how different parts of the wind turbine can affect the environment, recycling, during decommissioning.

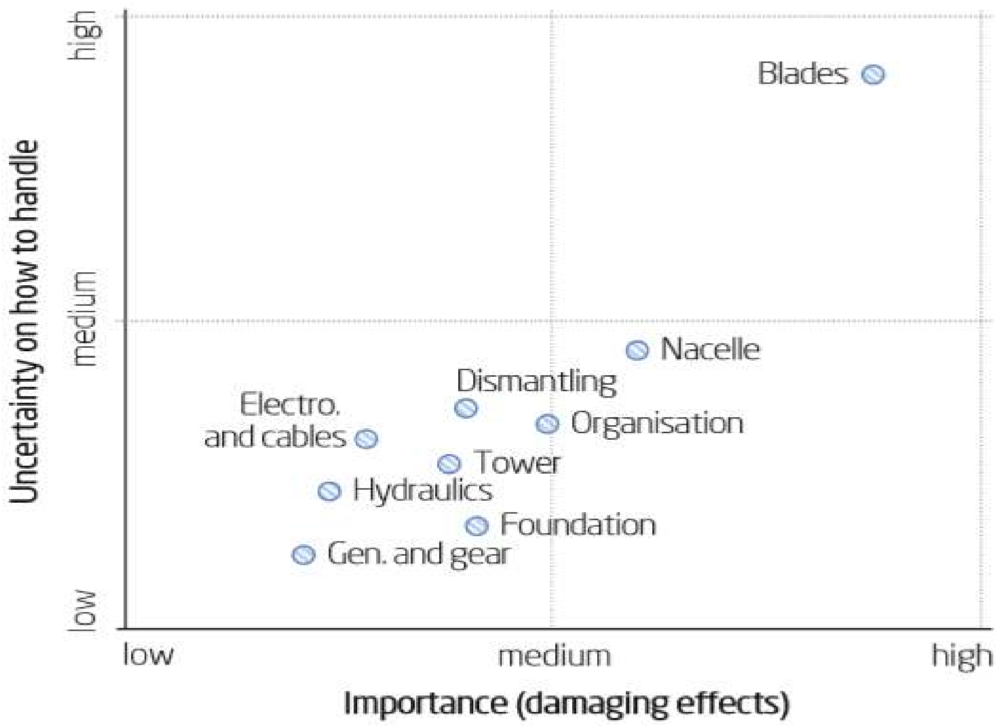

Figure 2.2 Environment impacts of wind turbines [9].

Specifically, some offshore wind turbines most of which are of the new approach, investors, experts, and decision-makers are beginning to put interest, based on the economic benefits in this sector.

According to Andersen et al. [9] the wind turbine industry is not as popular as other sources in the energy system, resulting lesser research studies in the fields of recycling, remanufacturing, managing the reverse flow of the wind turbines, the planning, early phase and management aspects, definitely requires researcher's attention. In order for managing the reverse flow of wind turbines, when they approach the end of their lifespan, it is important that the early phases which include reserve logistics and reverse supply chain or other related issues, must be resolved. Researchers have put many efforts to create awareness about the financial gains of the wind turbines industry and to resolve uncertain problems that may arise regarding remanufacturing, recycling, early phase problems including reverse logistic, reverse supply chain as stated by İlkiliç et al. [10], Munday et al. [11] and Yang et al. [12].

2.2 Recycling and Remanufacturing of Wind Turbine

Offshore wind farms are a developing source of energy production, which expects to guarantee perfect energy with a low ecological effect. Typical asset accessibility and shortage have turned into a central concern for the mid and long-haul financial improvement. In this unique circumstance, offshore find farms establish an exceptionally encouraging source of sustainable energy defined by their huge turbines and their reasonable profile of wind allowing high yield of energy production. The natural effect of the sustainable power source is a significant issue and speaks to a fundamental key to its prosperity.

In the study of Dahane et al. [13] we understand that regardless of whether it is considered as a clean, the offshore wind like any sustainable power source stays expensive with a low carbon impression. In this unique circumstance, the remanufacturing of recovered save parts is the fascinating answer for lessening the expense and the carbon impression of the offshore wind farms.

While on the other hand glass fiber reinforced polymer utilizing thermosetting resins are utilized for a wide scope of uses, for example, transportation, power, and construction. In fact, the assorted variety in the assembling, conceivable outcomes from unidirectional overlays to arbitrarily arranged fiber compound and interesting mechanical properties make these materials exceptionally attractive. The troubles to reuse thermoset polymer composites and the unpredictable structure of wind turbine cutting edges make the reusing of end of life wind turbine blades testing. In any case, a reusing arrangement consolidating a few strategies may tackle this issue according to Beauson et al. [14].

In the study of Fetter et al. [15], catastrophic events, for example, Hurricanes Isabel, Katrina, Irene, and the tremors in Haiti have underscored the significance of sound crisis management for effectively reacting and revamping in the wake of calamity. Two of the underlying and most significant parts of disaster reaction and recovery tasks are the expulsion and transfer of debris and junk from the disaster-influenced zone. In spite of the fact that the idea of trash or waste can differ contingent upon the sort of disaster, disaster trash is regularly a blend of at least one of the accompanying: general family unit refuse and individual things, building materials, plants and natural waste, unsafe waste, machines, and electronic gadgets. These classifications of waste have their individual difficulties for transfer indeed, even under typical conditions, and extra disaster-caused mixes of these sorts frequently make new mixed classes with expanded complexities for isolating, cleaning, and discarding the waste. Storms, tremors, and other disasters have made considerable interest in disaster management investigations. Be that as it may, while significant accentuation has been given to arranging, alleviation, and reaction exercises, generally little consideration has been given to contemplating post-disaster recovery exercises, particularly exercises including disaster garbage cleanup. Just a couple of subjective contemplates have featured the significance of and the requirement for viable administration of debris and waste cleanup following a disaster.

Because of modification and exploitation of nature, for example, global warming, tidal waves, and desertification, governments, and natives around the globe are bit by bit grasping the idea of economic advancement. Waste transfer and asset reusing have turned into key issues for administering bodies around the world. On January 23, 2009, Yale and Columbia Colleges in the U.S. authoritatively discharged the 2008 Environmental Performance Index (EPI) at the World Economic Forum in Switzerland. The worldwide evaluation results demonstrated that Taiwan at 80.8 points positioned 40th among 149 nations and areas. Its presentation file score was like that of the United States (81.0 points), which set 39th. Waste assets are described by temperamental generation sums and invert coordination. Subsequently, it is financially significant to decide effective areas for waste administration and asset reusing focuses.

In 1974 and 2002 individually, Taiwan affirmed the Waste Disposal Act and Resource Recycling Act and further settled the Renewable Resource Recycling Promotion Council to execute the arranging and advancement of recycling and re-use ventures. These progressions guarantee better natural security. The investigation recommends Taiwan's legislature to build up to two huge provincial RCs in the western area of the island, which is thick in the populace. By contrasting and different nations, this examination moreover gives proposals that are suitable and important according to Chuangb et al. [16].

2.3 Location and Allocation Problem

In study of Carling et al. [17], the best facilities for a geographically distributed population were located. A province called Dalecarlia landscape (historical place) in the center of Sweden, with a population of about 277,000. A demand of 15,729 was marked in this region (Dalecarlia). The people living in each point goes between 1 to 1,382.

The P-median model was set up for this location problem to assign facilities to the geographically distributed population; the P-median model is generally used in location and allocation problems. It's a common knowledge that the nearest facility attracts the population around it as explained by Hale and Moberg et al. [18].

A set of facilities across the regions are being distributed with demand from different points, in which the overall or average measurement of the distance between them is minimized and each demand is assigned to the nearest facility. The P-median model has been used in a lot of different situations to solve location problems in the past as stated by Hale et al. [18]. A method for finding the shortest distance and network due to several route and road between the demand point and the facility point.

In study of Al-khedhairi et al. [19] simulated annealing was used to explain temperature impact on the movement from facility to demand point. This procedure of considering temperature is very important because the shortest distance might not be the best route considering the time it might take to reach the location.

All the facilities were tested considering the short time coverage of the network. A new network distance was proposed. After using the Euclidean distance which provided solution with the P-median model, but the Euclidean distance provided an excess travel time which means too many facilities needs to be located, while the new network distance considers a lot of other factors like weather conditions, quality of roads and other uncertain conditions to come up with a better network distance, according to Al-khedhairi et al. [19].

In Table 2.1 the literature review has been summarized. The summary includes other studies, and research that used the P-median and P-center model for location and allocation problems.

Table 2.1 Literature review on P-median and P-center problems

Source	**Problems / Solution Method**	**Application**
Mladenovic et al. [20]	P-center problem, Heuristics, Tabu search, Variable neighborhood search.	Making metaheuristic approaches to solve the P-center problem, reconstructing the tabu search and the variable neighborhood search.
Şahin et al. [21]	Hierarchical Location Problem, Location-allocation problem.	Application of the location model to the Turkish Red Crescent Society with aim of regionalizing blood services to the whole country and on time after the natural deserter.
Sharif et al. [22]	A capacitated maximal covering location problem, Genetic algorithm, Hierarchical location design.	The healthcare system in Malaysia was in need of location planning to set up capacitated maximal covering location facilities that will cover all areas from the capital to villages with a limited amount of facilities. The method was also proposed to other sectors with limited capacities such as post office, schools etc.
Ndiaye et al. [23]	The P-median problem, Location and allocation models, Non-Convex	Optimizing the location for new students going into school, school allocation

	Optimization.	and location.
Baray et al. [24]	Covering Model, Hierarchical Model, Location-allocation model, and P-median. Dual maximum covering/P-median Hierarchical model.	Locating maternity hospitals in France regardless of the remoteness of the facility, trying to reduce the distance between the hospital and the patient.
Dantrakul et al. [25]	Locations Models, P-median problem, P-center problem, Greedy Algorithm.	This location problem was applied in the Municipal and Agricultural waste system in Chiang Mai City and five other provinces of northern Thailand with the aim of minimizing both the setup cost and the transportation cost.
Afsha et al. [26]	Various location models were applied in this study, arranging from P-median (dynamic, hierarchical, chance-constrained), P-center (α reliability, stochastic), Location set time, distance, efficiency and accessibility. Recovering problem, Maximal covering problem and other location models to measure minimized coverage, cost.	Solving location challenges faced by the healthcare facilities around the world. Not just location, but also reliability and sustainability. Trying to improve efficiency, patient safety and cost-effectiveness. Cases where healthcare facilities can be relocated to another area.
Yang et al. [27]	Genetic algorithm, Fuzzy random simulation, Location model, P-center problem, P-median problem.	Applied in the power grid company to set up an emergency facility location.
Eugene et al. [28]	Maximal Covering location	The was study was based on

	problem, the basic P-median model.	two west African countries Nigeria and Ghana with aims of developing more environmental friendly region with developing renewable energy such as solar and wind assisting systems. That should be Allocated in the appropriate location and also be able to cover all the region and population.
Yanik et al. [29]	P-median model, location and allocation, genetic algorithm, forecasting model and geographical clustering.	Energy regions, improving renewable energy distribution across turkey. By designing territories whereby the energy distributions can be clustered, with the increase of growth of green energy, allocating energy distribution is necessary.
Karatas et al. [30]	P-median and maximal coverage location models.	Creating a backup supply in public or emergency location problems.
Özceylan et al. [31]	P-median and Geography information system (GIS), then P center was used to minimize the maximum distance of the p-median. Both p-median and GIS result were compared which were similar but the p-median result were more optimal.	To optimize the location and allocation problem of pharmacy warehouse in Gaziantep.

Ojonugwa et al. [32]	P-center problem, Locations distribution Models	Fire Stations in Sokoto metropolis with aim of allocating fire stations in the right location (neighborhood) to minimize response time in accordance to international standards in case of an emergency.
Adler et al. [33]	P-hub median, demand forecasting, cluster models and analysis of capacity.	Was done on African's fast-growing network air cargo transportation, a case where exports from other countries are coming in. The intercontinental transport. The P-hub median problem to create pub and spokes to reduce transportation distance and cost.
Mete et al. [34]	Set Covering problem, Maximal Covering problem, P-median Problem, P-center Problem, Undesirable Facility Location Problem.	Location and Coverage Analysis of Bike-Sharing Stations in University Campus.
Nootim et al. [35]	P-median problem, P-center problem, Set Covering Problem.	Applying Zoning Designated Policy to Locate the Fresh Fruit Bunch Collectors in Oil Palm Supply Chain.
Karatas et al. [36]	P-median problem, Backup service, Discrete event simulation, Emergency service systems.	Investigate the effect of backup service level, demand assignment policy, demand density and number of facility and their locations on the solution

		performance in terms of multiple metrics.

CHAPTER III
P-MEDIAN AND P-CENTER MODELS

3.1 P-median Model

In the early phase of managing the reverse flow of the end life of wind turbines, the problem of locating the position of the wind turbines on the map, that's the location of the wind turbines and trying to assign the wind turbine to the suitable and nearest wind turbine manufacturer at the same time minimizing the distance between the wind turbine and wind turbine manufacturer.

The P-median binary integer mathematical model was employed to solve this problem, when locating P "facilities" recycling facility (wind turbine manufacturers) correlative to some group of customers (wind turbines) in a way that the total of the least weighted demand cost/distance between the recycling facility (wind turbine manufacturer) and the customer (wind turbine) is minimized. Formulation of the problem is written below [31].

Notations:

k = the wind turbine manufacturer

I = the wind turbine

w_I = the amount of wind turbine in need of remanufacturing

d_{ik} = distance between the wind turbine and the wind turbine manufacturer

q_k = capacity of the wind turbine manufacturer

P = the number of facilities (wind turbine manufacturers)

Decision Variables

y_k = {1, if potential wind turbine manufacturer is Open $(\forall k \in K)$. 0, otherwise.

x_{ik} = {1, if the wind turbine is assigned to a potential wind turbine manufacturer k $(\forall i \in I), (\forall k \in K)$. 0, otherwise.

Objective Function:

$$\text{Min } (Z) = \sum_{i \in I} \sum_{k \in K} w_i \, d_{ik} x_{ik} \qquad (3.1)$$

Restrictions:

$$\sum_{k \in K} x_{ik} = 1 \qquad \forall i \in I \quad (3.2)$$

$$w_i x_{ik} \leq y_k q_k \qquad \forall i \in I, \forall k \in K \ (3.3)$$

$$\sum_{k \in K} y_k = P \qquad (3.4)$$

$$y_k, x_{ik} \in \{0,1\} \qquad \forall i \in I, \forall k \in K \ (3.5)$$

The Objective Function

(3.1) Minimizing the distance covered.

The restriction goes as follows

Restriction (3.2) means the assignment of each wind turbine to the available wind turbine manufacturer (each wind turbine location must be served).

Restriction (3.3) certifies and fortifies that wind turbines are assigned to the wind turbine manufacturer (wind turbines can't be remanufactured from manufacturers that are not available).

Restriction (3.4) tells us the number of wind turbine manufacturers that should be available.

Last restriction (3.5) is the decision variable which ensures that variables can only take one value.

3.2 P-center Model

Shows the total amount of facility (wind turbine manufacturer) that needs to be open and which customer (wind turbine) should be assigned to which facility (wind turbine manufacturer) at the same time minimizing the longest distance between them [31].

Decision Variables:

y_k = {1, if potential wind turbine manufacturer is open$(\forall k \in K)$. 0, otherwise

x_{ik} = {1, if the wind turbine is assigned to a potential wind turbine manufacturer k $(\forall k \in K), (\forall i \in I)$. 0, otherwise.

Objective function:

$$\text{Min Z} = \text{Max } d_{ik}x_{ik} \rightarrow \text{Z} = \text{Max L} \tag{3.6}$$

Restrictions:

$$\sum_{k \in K} x_{ik} = 1 \qquad \forall i \in I \tag{3.7}$$

$$w_i x_{ik} \leq y_k q_k \qquad \forall i \in I, \forall k \in K \tag{3.8}$$

$$\sum_{k \in K} y_k = \text{P} \tag{3.9}$$

$$\text{Max L} \geq \text{d}_{\text{ik}}\text{x}_{\text{ik}} \qquad \forall \text{i} \in \text{I}, \forall k \in K \tag{3.10}$$

$$\text{y}_{\text{k}}, \text{x}_{\text{ik}}, \in \{0,1\} \qquad \forall i \in I, \forall k \in K \tag{3.11}$$

Objective Function (3.6) minimizes the longest or maximum distance between the wind turbine and the wind turbine manufacturer.

Restriction (3.7) means the assignment of each wind turbine to the available wind turbine manufacturer (each wind turbine location must be served).

Restriction (3.8) certifies and fortifies that wind turbines are assigned to the wind turbine manufacturer (Wind turbines can't be remanufactured from manufacturers that are not available).

Restriction (3.9) tells us the number of wind turbine manufacturers that should be available.

Restriction (3.10) ensures the maximum distance is greater than or equals to the distance between the wind turbine and the manufacturer.

Last restriction (3.11) is the decision variable which ensures that variables can only take one value.

CHAPTER IV

CASE STUDY

4.1 Study Area

In this thesis, Turkey is our area of study. Turkey is a transcontinental country which is located in western Asia, Southeast Euro, with a population of about 82,807,286 as of Friday, May 10, 2019, [37].

There are seven geographical regions in Turkey: Marmara, Aegean, Black Sea, Central Anatolia, Eastern Anatolia, South-eastern and the Mediterranean.

4.2 Wind Turbines in Turkey

The Turkish wind energy association gives statistical reports annually or after every six months on the increase in locations, capacity, number of wind turbines and so on. They have a target that is to increase the use of renewable energy. In this section, the situations of wind turbines in Turkey will be explained covering topics such as locations, year of installment, in tables and figures.

Table 4.1 Wind turbines in Turkey [3]

	Project Name	**Installed Capacıty**	**City**	**Turbine Manufacture**	**Commissioning Year**	**Age**
1	Ada 2 RES	4.6	Balıkesir	Enerecon	2015	4
2	AdaRES	10,00	Izmir	SIEMENS GAMESA	2015	4
3	AirRES-4	60,8	Kırklareli	SIEMENS GAMESA	2017	2
4	Akbük RES 1	21,00	Muğla	SUZLON	2016	3
5	Akbük RES 2	31,5	Aydın	SUZLON	2009	10
6	Akbük RES 2	9,6	Aydın	NORDEX	2015	4
7	AKRES	45,00	Manisa	NORDEX	2000	19
8	Aksu RES	72,00	Kayseri	VESTAS	2012	7

	Project Name	Installed Capacıty	City	Turbine Manufacture	Commissioning Year	Age
9	Akyurt RES	14,70	Tokat	SIEMENS GAMESA	2016	3
10	Alaçatı RES	16,00	Izmir	Enerecon	2016	3
11	Aliağa RES	19,20	Izmir	NORDEX	2014/2016	5
12	Amasya RES 1	82,00	Amasya	NORDEX	2008/2017	11
13	Amasya RES 2	46,20	Amasya	VESTAS	2016	3
14	ARES	7,20	Izmir	VESTAS	1998	21
15	Atik RES	18,00	Hatay	SIEMENS GAMESA	2014	5
16	Seyit Onbaşı RES	5,40	Çanakkale	VESTAS	2011	8
17	Ayyıldız RES	28,20	Balıkesir	VESTAS	2009/2017	10
18	Bağarası RES	48,00	Aydin	NORDEX	2015	4
19	Balabanlı RES	61,40	Tekirdağ	SIEMENS GAMESA	2014/2016	5
20	BalıkesirRES	143,00	Balıkesir	GE	2012	7
21	BandırmaRES 1	30,00	Balıkesir	GE	2006	13
22	BandırmaRES 2	89,00	Balıkesir	VESTAS	2009/ 2010/2014	10
23	BandırmaRES Ext	21,50	Balıkesir	NORDEX	2012	7
24	Bandırma-3 RES	41,80	Balıkesir	NORDEX	2008/2016	11
25	BarbarosRES	12,45	Tekirdağ	GE	2016-2017	3
26	Belen RES	48,00	Hatay	VESTAS	2009/2010 /2012	10
27	bereketli RES	32,00	Tokat	SIEMENS GAM	2016	3
28	BergamaRES	120,00	Izmir	NORDEX	2007/2016	12
29	BergRES	69,95	Izmir	GE	2017	2
30	Biga RES	60,80	Çanakkale	GE	2015	4
31	BozcaadaRES	10,20	Çanakkale	Enerecon	2000	19
32	Bozyaka RES	19,70	Izmir	NORDEX	2012/2016	7
33	Burgaz RES	14,90	Çanakkale	Enerecon	2007	12
34	Çamseki RES	20,80	Çanakkale	Enerecon	2009	10
35	Çanta RES	47,50	Istanbul	NORDEX	2013/2014	6
36	Çatalca RES	93,00	Istanbul	VESTAS	2008/2016	11
37	Çataltepe RES	16,00	Balıkesir	Enerecon	2010	9
38	Çataltepe RES	12,00	Istanbul	NORDEX	2016	3
39	Çerçikaya RES	57,00	Hatay	ACCIONA	2015	4
40	Çeşme RES 1	10,70	Izmir	Enerecon	1998/2017	21
41	Çeşme RES 2	18,00	Izmir	NORDEX	2015	4
42	Dağpazarı RES	39,00	Mersin	SIEMENS GAMESA	2011	8
43	Dares Datça RES	41,60	Muğla	Enerecon	2008/ 2017	11
44	DemircilerRES	23,30	Osmaniye	GE	2016	3
45	Demircili RES	40	Izmir	NORDEX	2016	3
46	Dilek RES	24,00	K.Maraş	NORDEX	2015	4

	Project Name	Installed Capacıty	City	Turbine Manufacture	Commissioning Year	Age
47	DinarRES Ext	85,25	Afyon	GE	2016	3
48	DinarRES	115,00	Afyon	SIEMENS GAM	2013	6
49	Düzova RES	51,50	Izmir	GE	2009/2010/2013/2014	12
50	EdincikRES	77,40	Balıkesir	NORDEX	2013/2015/2016	6
51	Ege RES	9,20	Izmir	Enerecon	2015	4
52	Elmalı RES 1	30,00	Mersin	VESTAS	2016	3
53	Elmalı RES 2	9,90	Mersin	VESTAS	2017	2
54	Enez RES	21,60	Edirne	NORDEX	2008/2016	11
55	Esenköy	32,40	Yalova	NORDEX	2017	2
56	FatmaRES	80,00	Muğla	SIEMENS GAMESA	2016/2017	3
57	Faut RES	33,00	Izmir	VESTAS	2015/2016	4
58	GERES	30,00	Manisa	NORDEX	2014/2015	5
59	GerişRES	12,00	Muğla	NORDEX	2017	2
60	Germiyan RES	12,00	Izmir	Enerecon	2016	3
61	Geycek RES	168,00	Kırşehir	Enerecon	2013/2014	6
62	GökçedağRES	135,00	Osmaniye	GE	2009	10
63	GökdağRES	8,50	Kocaeli	GE	2017	2
64	GökRES	35,75	Manisa	GE	2014	5
65	Günaydın RES	20,75	Balıkesir	GE	2012 / 2014	7
66	Gündoğdu RES	9,60	Bursa	NORDEX	2016	3
67	HarmanlıkRES	52,80	Bursa	VESTAS	2015	4
68	Hasanbeyli RES	50,00	Osmaniye	NORDEX	2014	5
69	Hilal-2 RES	9,90	Karaman	VESTAS	2015	4
70	İncesu RES	29,20	Afyon	VESTAS	2014/2016	5
71	İntepe RES	55,70	Çanakkale	Enerecon	2007/2014 /2016	12
72	Kangal RES	78,00	Sivas	VESTAS	2014/2015	5
73	Kangal RES ext	50,00	Sivas	SIEMENS GAMESA	2017	2
74	Kanije RES	64,40	Edirne	SIEMENS GAMESA	2016	3
75	KapıdağRES	28,00	Balıkesir	VESTAS	2013/2014	6
76	Karabel RES	3,00	Izmir	SENVION	2016	3
77	Karaburun RES	120,00	Izmir	Enerecon	2013	6
78	KaracabeyRES	30,00	Bursa	NORDEX	2016	3
79	KaracayırRES	12,60	Sivas	SIEMENS GAMESA	2016	3
80	KaradağRES 1	10,00	Izmir	GE	2012	7
81	KaradağRES 2	18,00	Izmir	NORDEX	2016	3
82	Karadere RES	19,20	Kirklareli	GE	2014/2016	5
83	Karakurt RES	12,00	Manisa	VESTAS	2007	12
84	Karova RES	30,15	Muğla	Ge	2017	2
85	Kartaldagi RES	65,55	Gaziantep	VESTAS	2017	2
86	Kavaklı RES	52,80	Balıkesir	VESTAS	2014	5
87	Keltepe RES	29,90	Balıkesir	Enerecon	2009/2014/2016	10

	Project Name	Installed Capacıty	City	Turbine Manufacture	Commissioning Year	Age
88	Kemerburgaz RES	24,00	Istanbul	Enerecon	2008	11
89	Kınık RES	51,20	Izmir	SIEMENS GAMESA	2016	3
90	KıyıköyRES 1	45,00	Tekirdağ	NORDEX	2015	4
91	KıyıköyRES 2	28,00	Kırklareli	SIEMENS GAMESA	2014	5
92	KirkagacRES	45,6	Manisa	GE	2016	3
93	Konakpınarı RES	14,70	Sivas	SIEMENS GAMESA	2016	3
94	KORES	25,00	Izmir	NORDEX	2012/2015	7
95	Korkmaz RES	25,20	Izmir	SUZLON	2014	5
96	Koru RES	52,80	Çanakkale	VESTAS	2015	4
97	Kozbeyli RES	34,55	Izmir	Enerecon	2012/2013/2017	7
98	Kurtkayası RES	45,60	Kayseri	NORDEX	2016	3
99	KuyucakRES	50,30	Manisa	Enerecon	2010 / 2015/2017	9
100	Kürekdağı	36,00	Bursa	NORDEX	2017	2
101	MadranbabaRE S	20,00	Aydin	SIEMENS GAME	2013	6
102	Mahmudiye RES	29,90	Çanakkale	SIEMENS GAMESA	2010	9
103	Mare Manastır RES	56,20	Izmir	Enerecon	2006/2007/2016	13
104	Mazı-3 RES	30,00	Izmir	NORDEX	2011	8
105	Mersin Mut RES	62,70	Mersin	VESTAS	2010/2013/2017	9
106	Metristepe RES	40,00	Bilecik	NORDEX	2011	8
107	Mordoğan RES 1	31,50	Izmir	SUZLON	2014	5
108	Mordoğan RES 2	15,00	Izmir	Enerecon	2016	3
109	Mut RES	52,80	Mersin	VESTAS	2015	4
110	OrtamandiraRE S	11,20	Balıkesir	GE	2015	4
111	OvaRES	18,00	Aydın	SIEMENS GAMESA	2016	3
112	Ödemiş RES	42,00	Izmir	NORDEX	2015/2016	4
113	Paşalimanı RES	0,80	Balıkesir	Enerecon	2013	6
114	Petkim RES	51,00	Izmir	GE	2016	3
115	Pitane RES	4,80	Izmir	NORDEX	2014	5
116	Poyraz RES 1	77,10	Balıkesir	Enerecon	2012/2013/2016	7
117	Poyraz RES 2	32,00	Balıkesir	SIEMENS GAMESA	2016	3
118	Poyrazgölü RES	34,50	Balıkesir	Enerecon	2015	4
119	Salman RES	27,50	Izmir	GE	2014	5
120	samurlu RES	43,90	Izmir	Enerecon	2012/2013/2017	7
121	Saray RES	6,95	Tekirdağ	Enerecon	2012/2016	7
122	Sa RES	27,50	Çanakkale	GE	2010/2011	9
123	SarıkayaRES	30,00	Tekirdağ	Enerecon	2009	10

	Project Name	Installed Capacıty	City	Turbine Manufacture	Commissioning Year	Age
124	Sarıtepe RES	57,00	Osmaniye	GE	2016	3
125	Sarpıncık RES	32,50	Izmir	NORDEX	2017	2
126	Sayalar RES	57,20	Manisa	Enerecon	2008/2013	11
127	Sebenoba RES	63,70	Hatay	VESTAS	2008/2015	11
128	Seferihisar II RES	21,00	Izmir	NORDEX	2017	2
129	Seferihisar RES	21,00	Izmir	NORDEX	2016	3
130	Senkoy RES	36,00	Hatay	GE	2012/2014	7
131	Seyitali RES	41,50	Izmir	Enerecon	2011/2015/ 2016	8
132	Silivri RES	45,00	Istanbul	NORDEX	2014	5
133	Sincik RES	27,50	Adıyaman	NORDEX	2013	6
134	Soma RES 1	264,10	Manisa	ENERCON	2011/2012/ 2014/2015	8
135	SomaRES 2	120,00	Manisa	NORDEX	2007/2016	12
136	Söke RES 1	30,00	Aydin	SIEMENS GAMES	2010	9
137	Söke RES 2	49,50	Aydin	VESTAS	2015	4
138	Sunjüt RES	1,20	Istanbul	ENERCON	2006	13
139	SusurlukRES	75,00	Balıkesir	NORDEX	2012/2017	7
140	Süloğlu RES	66,00	Edirne	VESTAS	2015	4
141	Şadıllı RES	38,50	Çanakkale	GE	2014	5
142	ŞahRES	105,00	Bursa	VESTAS	2011/2013	8
143	Şamlı RES	113,40	Balıkesir	VESTAS	2008/ 2010	11
144	şenbük RES 1	27,70	Hatay	VESTAS	2013	6
145	şenbük RES 2	38,10	Hatay	VESTAS	2010/2014	9
146	TepeRES	0,85	İstanbul	VESTAS	2006	13
147	Teperes ext	5,00	İstanbul	NORDEX	2016	3
148	Tire RES	26,2	Izmir	GE	2016-2017	3
149	Tokat RES	94,00	Tokat	NORDEX	2010/2011/ 2017	9
150	Turguttepe	24,00	Aydın	VESTAS	2010	9
151	Uluborlu RES	61,20	Isparta	GE	2016	3
152	Umurlar RES	36,40	Balıkesir	VESTAS	2014/2017	5
153	Urla RES 1	15,00	Izmir	ENERCON	2016	3
154	Urla RES 2	18,00	Izmir	NORDEX	2016	3
155	UşakRES	54,00	Uşak	SINOVEL	2013	6
156	Yahyalı RES 1	52,80	Kayseri	NORDEX	2015	4
157	Yahyalı RES 2	82,50	Kayseri	VESTAS	2016/2017	3
158	Yalova RES	54,00	Yalova	SINOVEL	2016	3
160	YuntdağRES	60,00	Izmir	NORDEX	2011/ 2014	8
161	Zeliha RES	25,60	Kırklareli	SIEMENS GAMESA	2016	3
162	Zeytineli RES	50,00	Izmir	NORDEX	2013	6
163	Zincirli RES	12,00	Kayseri	NORDEX	2016	3
164	Ziyaret RES	76,00	Hatay	GE	2010/2011/ 2014	9

Table 4.1 gives us the detail information about wind turbine project name, turbine location, megawatts, city, commissioning year, and how many years it has been there. In Figure 4.1 all locations of wind turbines were marked on the map

Figure 4.1 Wind turbine locations

Figure 4.2 shows how Energy generated from wind are distributed in all the regions across the country.

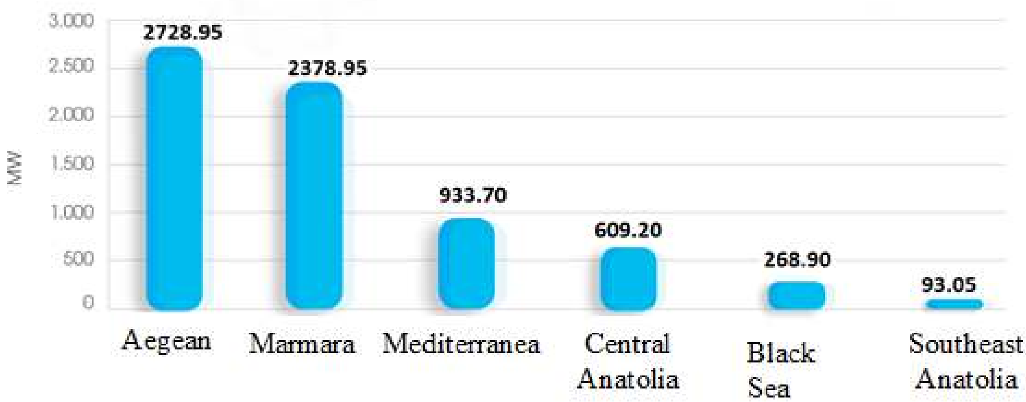

Figure 4.2 Bar chart of energy installed across regions [3]

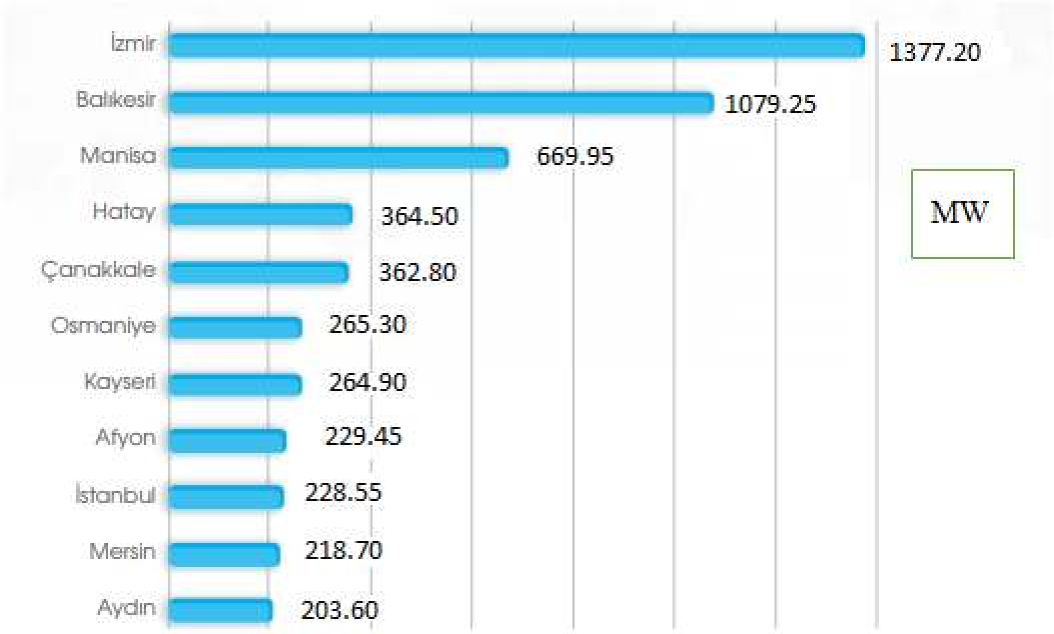

Figure 4.3 Bar chart of energy istalled across cities [3]

Figure 4.3 shows clearly how the wind turbine energy is distributed in cities like İzmir, Balıkesir, and Manisa these are where more than 40 percent of the wind turbines are located, places like Hatay and Çanakkale have some significant figures too.

4.3 Wind Turbines Manufacturers in Turkey

The wind turbine industry is still young in Turkey compared to other countries and it is growing with so many investors flowing in to explore with that being said there are some companies that have started producing wind turbine in Turkey seeing the amount of economic advantage other countries like Denmark and the United States of America have gained from it.

Specifically, wind turbine manufacturers from wind in Turkey were chosen because it has more advantages than wind turbines from outside Turkey because of it a way to support domestic manufacturers. It is necessary to trust and believe in them if the authorities don't give them opportunity who will? Another good reason is the fact the in P-median and P-center we are trying to decrease distance and cost, marking the wind turbine to the nearest wind turbine manufacturer. A total of ten wind turbine manufacturers in Turkey were compiled, as shown in Table 4.2.

Table 4.2 Wind turbine manufacturers, recycling facilities [3]

WIND TURBINE MANUFACTURERS		
	COMPANY	CITY
1	Soyut Enerji A.S.	Ankara
2	Altin Enerji (Ista BREEZE)	Istanbul
3	Ayetek Enerji	Konya
4	Aton Enerji	Izmir
5	Enisolar	Izmir
6	Alka Group	Gebze-Kocaeli
7	Ates Celik	Bergama Izmir
8	Cimo Güneş ve Rüzgar Enerji Sistemleri	Osmaniye
9	EA wind	Izmir
10	Nova Wind Energy	Izmir

Table 4.2 depicts the total manufacturers located in different cities of the Turkey. Izmir has total four manufacturers, because the wind turbines plants are mostly located are in this city and the Aegean region.

Figure 4.4 shows the location of all the ten wind turbines manufactures in Turkey, on the map.

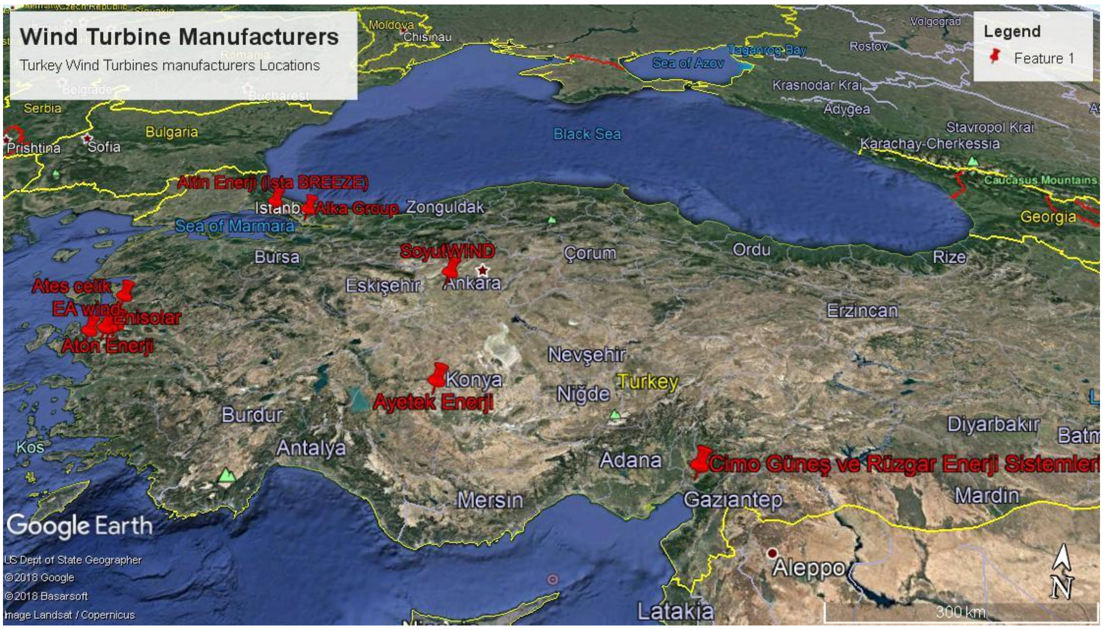

Figure 4.4 Wind turbine manufacturers location.

4.4 Distance Wind Turbine – Wind Turbine Manufacturer

The location of both the wind turbines and the wind turbine manufacturers were located and marked on the map, with the use of google earth we mark the appropriate location of the wind turbines and the wind turbines manufacturers as shown in the Figure 4.5.

Figure 4.5 Wind turbines and wind turbines manufacturers marked on the map.

The locations marked in yellow color are the wind turbines and their names written respectively as seen in the figure and the locations marked in red are the wind turbine manufacturers with their name written respectively as well.

Figure 4.6 depicts the total distance between both places. The distance could be minimized by establishing more manufacturers in different areas of Turkey. Hence with the use of google maps, calculation of distance between the wind turbines and the wind turbine manufacturers were made, as seen in Table 4.3.

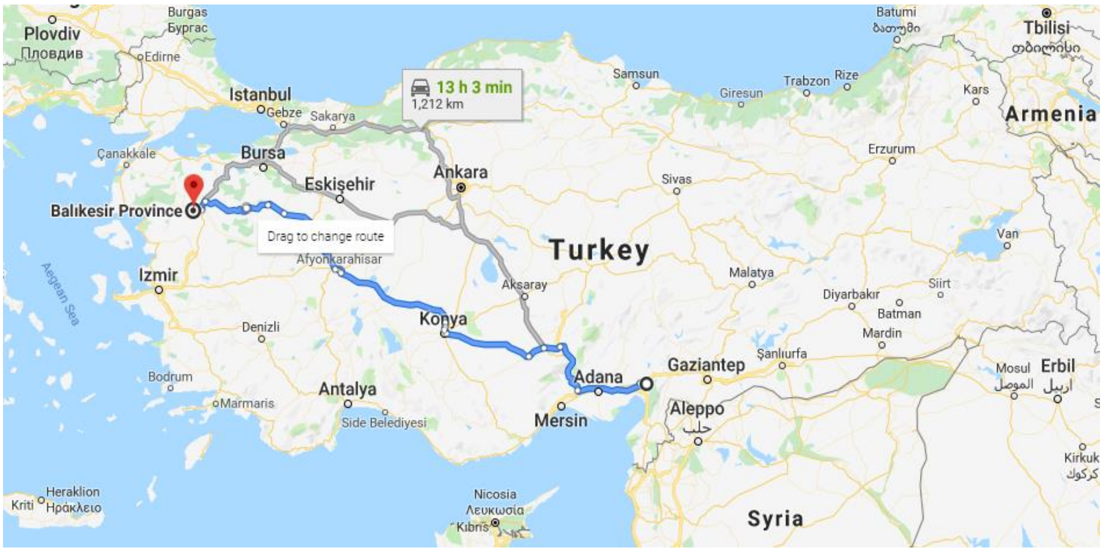

Figure 4.6 Distance and location marking between wind turbine and wind turbine manufacturer [Source: Google Maps]

Table 4.3 Distance matrix wind turbines – wind turbine manufacturers

Distance matrix Wind turbine – Wind Turbine							
		Soyut Enerji A.S.	Altin Enerji (Ista BREEZE)	Ayetek Enerji	Aton Enerji	Enisolar	Alka Group
1	Ada2 RES	520 Km	357 Km	577 Km	188 Km	195 km	274 km
2	AdaRES	574 km	580 km	581 km	84,4 km	90,2 km	497 km
3	AirRES-4	627 km	134 km	855 km	460 km	467 km	205 km
4	Akbük II RES	604 km	695 km	580 km	196 km	202 km	612 km
5	Akbük RES 1	643 km	661 km	624 km	166 km	172 km	582km
6	Akbük RES 2	643 km	661 km	624 km	166 km	172 km	582 km
7	AKRES	501 km	421 km	526 km	86,7 km	93,8 km	344 km
8	Aksu RES	466 km	914 km	349 km	912 km	896 km	831 km
9	Akyurt RES	444 km	835 km	548 km	970 km	976 km	748 km
10	Alaçatı RES	624 km	592 km	652 km	87,6 km	77,8 km	509 km
11	Aliağa RES	575 km	492 km	603 km	72 km	79,4 km	410 km
12	Amasya RES 1	596 km	766 km	534 km	952 km	959 km	684 km
13	Amasya RES 2	596 km	766 km	534 km	952 km	959 km	684 km
14	ARES	627 km	595 km	656 km	91,2 km	81,4 km	513 km

Distance matrix Wind turbine – Wind Turbine							
		Soyut Enerji A.S.	Altin Enerji (Ista BREEZE)	Ayetek Enerji	Aton Enerji	Enisolar	Alka Group
15	Atik RES	658 km	1112 km	487 km	1037 km	1044 km	1030 km
16	Seyit Onbaşı RES	667 km	382 km	730 km	267 km	274 km	427 km
17	Ayyıldız RES	446 km	287 km	601 km	275 km	282 km	205 km
18	Bağarası RES	571 km	692 km	556km	130 km	140 km	547km
19	Balabanlı RES	614 km	119 km	841 km	385 km	392 km	191 km
20	BalıkesirRES	466 km	331 km	537 km	216 km	223 km	248 km
21	BandırmaRES 1	445 km	287 km	601 km	284 km	291 km	205 km
22	BandırmaRES 2	445 km	287 km	601 km	284 km	291 km	205 km
23	BandırmaRES Ext	445 km	287 km	601 km	284 km	291 km	205 km
24	Bandırma-3 RES	445 km	287 km	601 km	284 km	291 km	205 km
25	BarbarosRES	701 km	206 km	928 km	435 km	442 km	278 km
26	Belen RES	657 km	1112 km	487 km	1037km	1044 km	1029 km
27	bereketli RES	529 km	864 km	635 km	1053 km	1060 km	782 km
28	BergamaRES	579 km	446 km	608 km	106 km	113 km	364 km
29	BergRES	579 km	446 km	608 km	106 km	113 km	364 km
30	Biga RES	516 km	375 km	671 km	345 km	352 km	275 km
31	BozcaadaRES	674 km	365 km	766 km	303 km	310 km	434 km
32	Bozyaka RES	569 km	500 km	597 km	54,9 km	61,8 km	418 km
33	Burgaz RES	585 km	249 km	740 km	372 km	379 km	320 km
34	Çamseki RES	641 km	346 km	742 km	280 km	286 km	400 km
35	Çanta RES	573 km	63,3 km	800 km	568 km	575 km	151 km
36	Çatalca RES	531 km	36,5 km	758 km	526 km	533 km	108 km

Distance matrix Wind turbine – Wind Turbine							
		Soyut Enerji A.S.	Altin Enerji (Ista BREEZE)	Ayetek Enerji	Aton Enerji	Enisolar	Alka Group
37	Çataltepe RES 1	482 km	324 km	644 km	235 km	242 km	242 km
38	Çataltepe RES 2	533 km	38,3 km	760 km	528 km	535 km	110 km
39	ÇerçikayaRES	648 km	1138 km	513 km	1063 km	1070 km	1056 km
40	Çeşme RES 1	627 km	595 km	656 km	91,1 km	81,4 km	513 km
41	Çeşme RES 2	627 km	595 km	656 km	91,1 km	81,4 km	513 km
42	Dağpazarı RES	414 km	922 km	181 km	730 km	737 km	840 km
43	Dares Datça RES	636 km	782 km	621 km	283 km	291 km	700 km
44	DemircilerRES	620 km	1074 km	449 km	999 km	1006 km	992 k
45	Demircili RES	600 km	567 km	628 km	63,3 km	53,6 km	485 km
46	Dilek RES	604 km	1042 km	494 km	1044 km	1051 km	960 km
47	DinarRES Ext	280 km	555 km	265 km	359 km	367 km	473 km
48	DinarRES	280 km	555 km	265 km	359 km	367 km	473 km
49	Düzova RES	579 km	446 km	608 km	106 km	113 km	364 km

Table 4.3 gives the distance matrix between wind turbines and the wind turbines manufacturers. The distances measure above is based on road distances, mostly big truck route were checked because the wind turbine is a very large object. Safety of the return is an important issue that needs to be looked at.

Furthermore, the totals of amount wind turbines in each wind location were compiled in accordance with Turkey Energy Atlas. The names are replaced with T for simplification and avoiding error. As shown in the Table 4.4.

Table 4.4 Amount of Wind Turbines [5]

Wind Turbine Location	Capacity	Wind Turbine Location	Capacity
T1	1	T41	6

Wind Turbine Location	Capacity	Wind Turbine Location	Capacity
T2	5	T42	13
T3	19	T43	40
T4	10	T44	11
T5	15	T45	16
T6	5	T46	10
T7	18	T47	26
T8	36	T48	55
T9	7	T49	23
T10	12	T50	30
T11	13	T51	4
T12	28	T52	15
T13	14	T53	3
T14	2	T54	8
T15	9	T55	9
T16	1	T56	25
T17	9	T57	10
T18	20	T58	12
T19	25	T59	7
T20	52	T60	7
T21	16	T61	70
T22	40	T62	54
T23	14	T63	3
T24	18	T64	13
T25	4	T65	8
T26	16	T66	3
T27	10	T67	16
T28	46	T68	20
T29	22	T69	3
T30	19	T70	12
T31	17	T71	51
T32	8	T72	63
T33	18	T73	36
T34	21	T74	16
T35	19	T75	12
T36	30	T76	1
T37	4	T77	50
T38	3	T78	12
T39	19	T79	6
T40	3	T80	4
T81	31	T123	7
T82	12	T124	15
T83	6	T125	20
T84	12	T126	11
T85	19	T127	48
T86	16	T128	27
T87	27	T129	5
T88	12	T130	5
T89	16	T131	12
T90	33	T132	18

Wind Turbine Location	Capacity	Wind Turbine Location	Capacity
T91	11	T133	18
T92	16	T134	11
T93	7	T135	169
T94	10	T136	111
T95	12	T137	20
T96	16	T138	15
T97	14	T139	1
T98	19	T140	29
T99	19	T141	20
T100	10	T142	14
T101	10	T143	29
T102	13	T144	43
T103	55	T145	10
T104	12	T146	12
T105	56	T147	1
T106	16	T148	2
T107	15	T149	11
T108	7	T150	34
T109	16	T151	12
T110	7	T152	36
T111	8	T153	13
T112	14	T154	5
T113	1	T155	6
T114	17	T156	60
T115	2	T157	22
T116	55	T158	25
T117	10	T159	36
T118	15	T160	5
T119	10	T161	24
T120	19	T162	8
T121	1	T163	20
T122	19	T164	5

CHAPTER V

COMPUTATIONAL RESULTS: APPLICATION OF LOCATION AND ALLOCATION MODEL

In this study two types of location and allocation model were used, that is the P-median and the P-center, as explained in detail in chapter 3, the main objective of the P-median model is to minimized the distance between the wind turbines and the wind turbine manufacturers. The P-center tries to minimize the maximum distance between the wind turbines to the wind turbines manufacturers.

5.1 Results of P-median and P-center

After completing the calculation of the distance between the wind turbines and wind turbines manufacturers, all the data are collected and run in GAMS software(Version: 22.5), which is a General Algebraic Modeling System used in optimizing mathematical models like the P-median and P-center model. The P-median and the P-center are applied to allocate the wind turbines to the wind turbines manufacturers, whereby the total distance travel is minimized.

5.1.1 P-median Results

The P-median model regarding the allocation of wind turbines to wind turbines manufacturers is run on the GAMS software. The objective function **Z** comes to the total of **490478 km** with a CPU time of **0.06 seconds** at P = 10, then the wind turbines are assigned to the nearest wind turbine manufacturers.

Note: the original names of the wind turbines and wind turbines manufacturers are being replaced with T for the wind turbines (T1, T2, T3…..) and P for the wind turbine manufacturers (P1, P2, P3……) to avoid alphabetical errors from the GAMS software. Table 5.1 gives us the assignment of all the wind turbines to wind turbine manufacturer.

Table 5.1 Wind Turbine Assignment P-median

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
T1							1			
T2									1	
T3		1								
T4									1	
T5									1	
T6									1	
T7									1	
T8										1
T9	1									
T10								1		
T11							1			
T12			1							
T13			1							
T14								1		
T15										1
T16							1			
T17						1				
T18				1						
T19		1								
T20							1			
T21						1				
T22						1				
T23						1				
T24						1				
T25		1								
T26										1
T27	1									
T28							1			
T29							1			
T30							1			
T31							1			
T32							1			
T33		1								
T34							1			
T35		1								
T36		1								
T37							1			
T38		1								
T39										1
T40								1		
T41								1		
T42			1							

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
T43				1						
T44										1
T45								1		
T46										1
T47			1							
T48			1							
T49							1			
T50						1				
T51									1	
T52			1							
T53			1							
T54		1								
T55						1				
T56				1						
T57									1	
T58							1			
T59				1						
T60								1		
T61			1							
T62										1
T63						1				
T64									1	
T65							1			
T66						1				
T67								1		
T68										1
T69			1							
T70	1									
T71							1			
T72										1
T73										1
T74		1								
T75						1				
T76					1					
T77								1		
T78						1				
T79										1
T80							1			
T81							1			
T82		1								
T83							1			
T84				1						
T85										1
T86							1			

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
T87							1			
T88		1								
T89							1			
T90		1								
T91		1								
T92							1			
T93										1
T94								1		
T95								1		
T96		1								
T97							1			
T98										1
T99							1			
T100						1				
T101									1	
T102							1			
T103								1		
T104								1		
T105			1							
T106	1									
T107								1		
T108								1		
T109			1							
T110							1			
T111									1	
T112									1	
T113		1								
T114							1			
T115							1			
T116							1			
T117							1			
T118							1			
T119								1		
T120							1			
T121		1								
T122							1			
T123		1								
T124										1
T125								1		
T126							1			
T127										1
T128								1		
T129								1		
T130										1
T131							1			
T132		1								
T133										1
T134							1			

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
T135									1	
T136									1	
T137									1	
T138		1								
T139							1			
T140		1								
T141		1								
T142						1				
T143							1			
T144										1
T145										1
T146		1								
T147		1								
T148									1	
T149	1									
T150									1	
T151			1							
T152							1			
T153								1		
T154								1		
T155									1	
T156										1
T157										1
T158						1				
T159								1		
T160							1			
T161		1								
T162								1		
T163										1
T164										1

Furthermore these assignments on Table 5.1 were drawn on the map of Turkey.

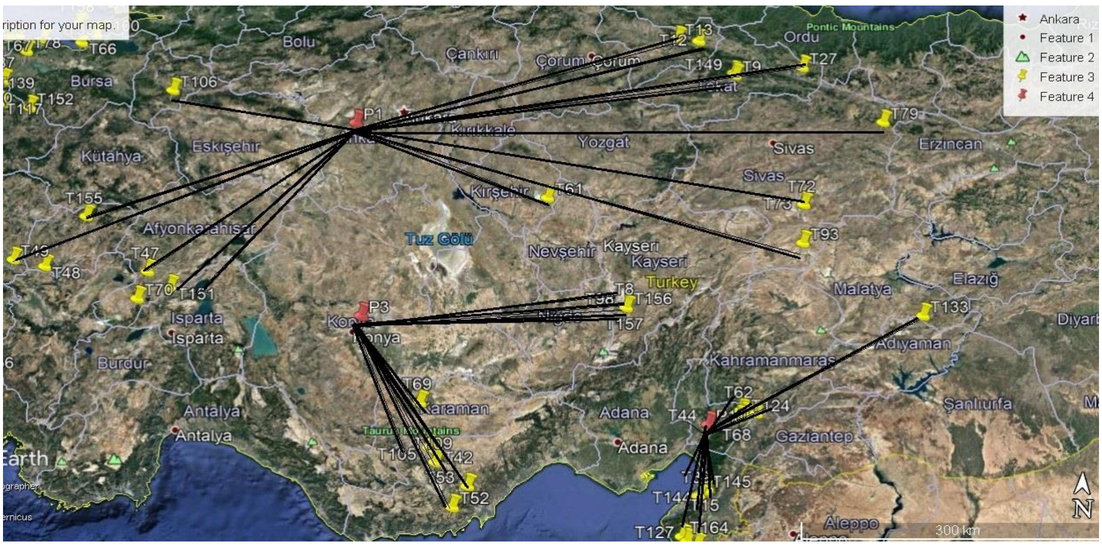

Figure 5.1 Wind Turbine Assignment P-median (P1, P3, P7, P10)

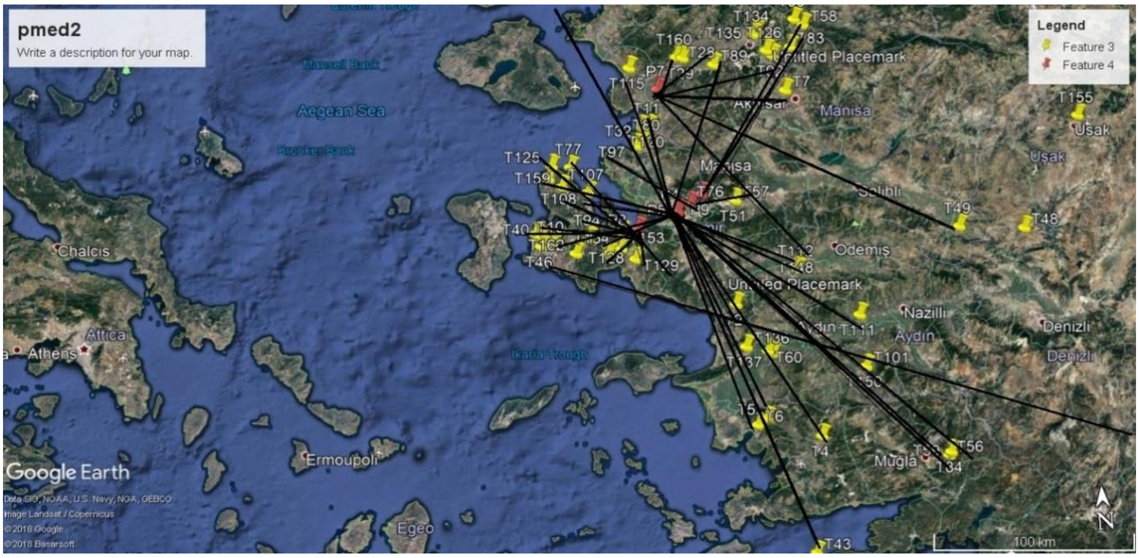

Figure 5.2 Wind Turbine Assignment P-median (P4, P5, P8, P9).

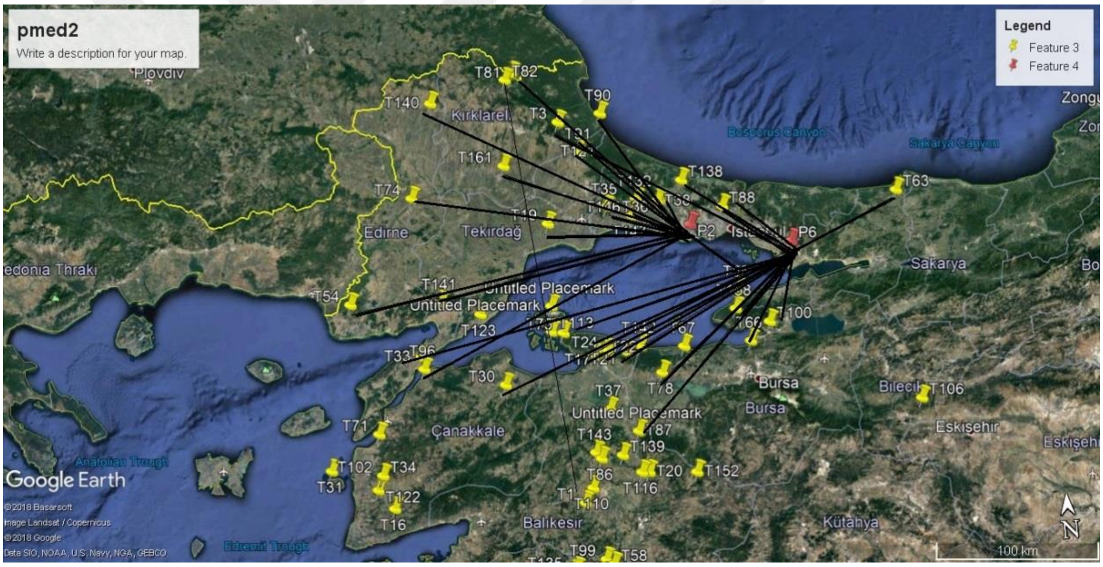

Figure 5.3 Wind Turbine Assignment P-median (P2, P6).

5.1.2 P-center Results

The P-center tries to recognize all the p facilities that is the wind turbine manufacturers and which demand point (wind turbines) needs to be assigned to them at the same time minimizing the longest distance to the facility P (wind turbine manufacturer), with a total objective value of **596 km**. and CPU time of **0.233 seconds** at P = 10.

Table 5.2 gives us the assignment of the entire wind turbines to the wind turbine manufacturers. Some few changes will be recognized from the previous table of the P-median because the P-center tries to minimize the largest distance as mentioned earlier.

Table 5.2 Wind Turbines Assignment P-center

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
T1							1			
T2				1						
T3		1								
T4					1					
T5								1		
T6					1					
T7				1						
T7				1						
T8			1							
T9	1									
T10					1					
T11				1						
T12	1									
T13			1							
T14				1						
T15										1
T16							1			
T17				1						
T18									1	
T19		1								
T20				1						
T21									1	
T22						1				
T23				1						
T24							1			
T25		1								
T26			1							
T27	1									
T28				1						
T29								1		
T30							1			
T31							1			
T32							1			
T33		1								
T34								1		
T35		1								
T36							1			
T37									1	
T38			1							
T39										1
T40									1	

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
T41									1	
T42			1							
T43				1						
T44										1
T45				1						
T46										1
T47	1									
T48			1							
T49								1		
T50							1			
T51									1	
T52										1
T53			1							
T54		1								
T55									1	
T56								1		
T57									1	
T58							1			
T59					1					
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T61			1							
T62			1							
T63		1								
T64				1						
T65				1						
T66		1								
T67						1				
T68										1
T69			1							
T70	1									
T71									1	
T72										1
T73										1
T74		1								
T75						1				
T76					1					
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T78							1			
T79										1
T80				1						
T81					1					
T82		1								
T83							1			
T84				1						
T85										1
T86				1						
T87									1	
T88		1								

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
T89				1						
T90		1								
T91		1								
T92								1		
T93										1
T94				1						
T95					1					
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T124			1							
T125									1	
T126				1						
T127										1
T128					1					
T129									1	
T130										1

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
T131									1	
T132		1								
T133										1
T134				1						
T135				1						
T136								1		
T137					1					
T138							1			
T139					1					
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T145										1
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T147		1								
T148				1						
T149	1									
T150								1		
T151			1							
T152					1					
T153									1	
T154					1					
T155	1									
T156										1
T157										1
T158							1			
T159				1						
T160					1					
T161		1								
T162								1		
T163										1
T164										1

Furthermore these assignments on Table 5.2 were drawn on the map of Turkey.

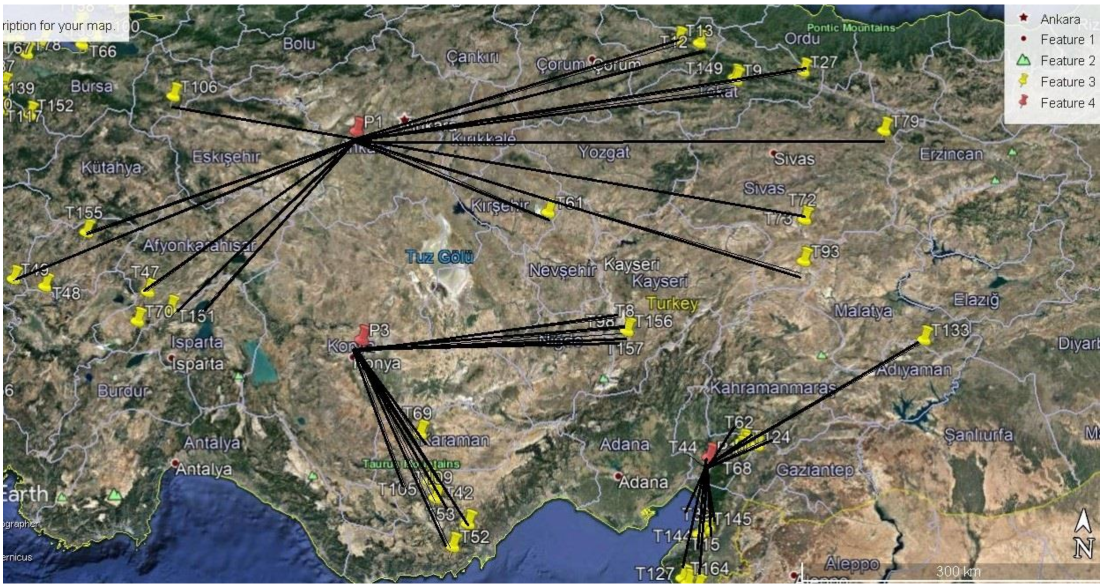

Figure 5.4 Wind Turbine Assignment P-center

The result assignments of the P-center are shown Table 5.2. With the P-center the maximum distance was minimized. In P-center, a given P manufacturer, find the minimum coverage distance such that all wind turbines are covered, by minimizing the maximum distance from any wind turbines to the nearest manufacturer. The P-median objective value is **490478 km** at the same time the total distance and p-center objective values is **596.0 km** and a total distance of **643305 km** with a CPU time of **0.233 Sec**. The objective value in P-center is not the same as the total distance because in P-center the model is minimizing the maximum distance between the manufacturer and the wind turbine.

5.2 P-median and P-center scenarios

After solving the problem as seen in the previous sub-chapter. P-median and P-center models are implemented to allocate manufacturers to wind turbines, so that the total travelling distance is minimized.

The results in chapter 5.1.2/5.1.3 were solved using P value at 10 meaning there are 10 manufacturers where all the wind turbine were assigned to as seen in Table 5.1 and Table 5.2.

Table 5.3 Results of P-median with different P values

	P = 1	**P = 2**	**P = 3**	**P = 4**	**P = 5**
Objective Value/Total Distance	1280027 km	757167.5 km	619748.8 km	564470.5 km	518954.5 km
Opened Manufacturers	P5	P5, P10	P2, P9, P10	P2, P4, P7, P10	P2, P3, P4, P7, P10.
CPU Time	1.797 Sec	0.019 Sec	0.04 Sec	0.016 Sec	0.08 Sec
	P = 6	**P = 7**	**P = 8**	**P = 9**	**P =10**
Objective Value/Total Distance	504617.2 km	493240 km	490530 km	490491.8 km	490478 km
Opened Manufacturers	P2, P3, P4, P6, P7, P10.	P2, P3, P6, P7, P8, P9, P10	P1, P2, P3, P6, P7, P8, P9, P10	P1, P2, P3, P4, P6, P7, P8, P9, P10	P1, P2, P3, P4, P5, P6, P7, P8, P9, P10
CPU Time	0.01 Sec	0.032 Sec	0.019 Sec	1.781 Sec	0.06 Sec

With respect to Table 5.3, all problems of P-median are solved with optimally manner. Results in Table 5.3 indicate that increasing available number of manufacturers from 1 to 10 decreases the total travelled distance. The objective value and the total distance were reduced from **1280027 km** to **490478 km** which is a 160.98 % decrease.

On the other hand, the P-center problem seeks to identify p amount candidate wind turbines manufacturer that is to open, and which demand points (wind turbines) will be assigned to each manufacturer while minimizing the longest distance to the station.

Table 5.4 Results of P-center with different p values

	P = 1	**P = 2**	**P = 3**	**P = 4**	**P = 5**
Objective Value	768 km	647 km	608 km	612 km	596 km
Total Distance	1654980 km	748047.3 km	1087439.3 km	1085839.7 km	764917.8 km
Opened Manufacturers	P1	P4, P10	P3, P4, P10	P1, P4, P8, P10	P3, P5, P7, P9, P10
CPU Time	0.418 Sec	0.811 Sec	0.958 Sec	0.855 Sec	0.687 Sec
	P = 6	**P = 7**	**P = 8**	**P = 9**	**P =10**
Objective Value	557 km	557 km	557 km	557 km	596 km
Total Distance	892022 km	1200431.1 km	626039.5km	653837.8 km	643305 Km
Opened Manufacturers	P1, P2, P3, P4, P9, P10	P1, P2, P3, P4, P5, P9, P10	P1, P2, P3, P4, P5, P8, P9, P10	P1, P2, P3, P4, P5, P6, P7, P9, P10.	P1, P2, P3, P4, P5, P6, P7, P8, P9, P10
CPU Time	0.392 Sec	0.377 Sec	0.249 Sec	0.263 Sec	0.233 Sec

In Table 5.4, increasing manufacturers numbers to be opened decreases the longest distance between demand points and stations, though there are irregularities in the results of the P-center as seen in table 5.4, but the longest distance between the manufacturer and wind turbines at P = 1 is **1654980 km**, it decreases to **643305 km** with a 61.12 % improvement in the scenario of P = 10.

By increasing the numbers of manufacturers to be opened decreases the longest distance between wind turbines and manufacturers. The more manufacturers are open the lower the distance between the wind turbines and the wind turbine manufacturers. Comparing the two models, it is clear that P-median model provides less travelling distance than the results of P-center model in most situations. On the contrary, P-center model ensures less long distance between wind turbines and manufactures than the longest distance obtained by P-median model.

CHAPTER VI

CONCLUSION

This thesis is made to answer certain questions that will arise when the remanufacturing or recycling of wind turbine occurs as mentioned earlier, this will also cover other case like repairs of service of wind turbine or it parts. Managing the reverse flow of wind turbines requires a lot early stage planning and analysis which includes locating, allocating, assigning wind turbines to the wind turbines manufacturers (Recycling facility), with the main objective of minimizing the distance between them.

There are 164 active locations of wind turbines in Turkey and more than 30 under construction at the moment. The wind turbine is expected to enjoy a life of 20 – 25 years but regardless of the years it spend it will surely reach end of life cycle, if you look at Table 4.1 you will see that Ares wind turbine T14 and Bozcaad aRes T31 are nearing end of life with no back up plan of installing new wind turbine like Çesme wind turbine T40. The early phase analysis and management of the end life of these wind turbines is what was done.

A total of ten wind turbines manufacturers were selected, which are also located within Turkey, we set up a location-allocation design with the aim as mention earlier on to minimize the distance covered. A simple example of how the wind turbines are assigned to the nearest wind turbine manufacturer is shown in Table 5.1 how all the wind turbines are assigned to the wind turbine manufacturers with the main aim of minimizing distance.

Though decisions about remanufacturing or recycling have not been made or have not been published to the public by the authorities, the methodology outlined in this study can ensure the authorities with good insight into which wind turbine manufacturer should recycle, remanufacture or repair which wind turbine, this thesis will also contribute significantly for the future planning wind turbines remanufacturing and recycling. This thesis will answer some important questions related to managing the reverse flow of wind turbines or at least provide ideas regarding managing the reverse flow of wind turbines in Turkey.

This study laid some basic foundations of wind turbine remanufacturing and recycling in Turkey. All the necessary stages involve in recycling and remanufacturing such as reverse logistics, reverse supply chain and disassembling should be considered in future studies.

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CURRICULUM VITAE

PERSONAL INFORMATION

Name/surname : Iliya Saleh LANGE

Nationality : Nigerian and valid residency permit in Turkey

Educational Status : Master Student

Foreigner ID Number : 99148356926 (resident permit)

Mobile Number : +905399169155

E-mail : iliyalange@gmail.com, langeiliya@yahoo.com

Personal History

I am a hardworking and detailed-oriented. I am friendly, helpful and polite, have a good sense of humor. I am a team player person, and problem solver. I am able to work under pressure once I have deadlines.

EDUCATION

Master of Degree : Gaziantep University, Faculty of Engineering, Industrial Engineering

2017-2019

Bachelor of Science : Gaziantep University, Faculty of Engineering, Industrial Engineering

2012-2016

High School : Universal basic education Yarimaram

TESOL Certificate (Teaching English as a second Language) : 2018 - 2019

WORK EXPERIENCE

Koza Carpet Company **May 2015 – October 2015** **Sep 2016-Jan 2017**

-Trade assistant, as intern Engineer (Junior Industrial Engineer)

- Management Engineer, Administrative assistance, Quality control.

Primary School Extra Moral Lesson Teacher for little kids 2015, 2016, 2017

English Language Speaking Teacher at Simya Collage February 2018 - Present

Volunteer at TEGV(Türkiye Eğitim Gönüllüleri Vakfı) teached English **September 2012 – May 2013**

Private English tutor (Speaking and Reading Teacher) **January 2017 - Present**

Volunteer at Turk Hava kurumu Charity Organization. **2016**

American Culture Language February 2018 – June 2018

English Time June 2018 – Present

LANGUAGES and ABILITIES

Hausa, Ngzim **:** Mother Tongue

English **:** Advanced

Turkish **:** Upper Intermediate

- Communication : Able to listen/talk to people in a constructive manner.
- Teamwork : Able to work with other people to achieve a common goal.
- Leadership : Able to take responsibility, lead/mentor others, supervising.
- Organization : Able to meet deadlines, plan and schedule task.

TECHNICAL SKILLS

-C++ Program,

-Microsoft Office Program(Excel, Word, PowerPoint, Access(DBMS)),

-ANYLOGİC,

-Process Model

-Database Management Application

-Weka (data mining application)

-Gams

WORKSHOPS

- Communication Techniques

TEGV
HOBBIES
-Football -basketball -Fitness -Educational Research and Studying -Dancing
REFERENCES
Will be provided on request.