ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

HIERARCHICAL HEALTH FACILITY LOCATION MODEL BASED ON USER DEMAND: THE CASE OF BURSA

M.Sc. THESIS

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Department of Urban and Regional Planning

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ISTANBUL TEKNİK ÜNİVERSİTESİ ★ LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ

KULLANICI TALEBİNE DAYALI HİYERARŞİK SAĞLIK TESİSİ YER SEÇİMİ MODELİ: BURSA ÖRNEĞİ

YÜKSEK LİSANS TEZİ

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KASIM 2022

Gökçen Gürsoy, a M.Sc. student of İTU Graduate School student ID 502191877, successfully defended the thesis entitled “HIERARCHICAL HEALTH FACILITY LOCATION MODEL BASED ON USER DEMAND: THE CASE OF BURSA”, which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

Thesis Advisor :	**Assoc. Prof. Dr. Mehmet Ali YÜZER** İstanbul Technical University	.....
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Date of Submission : 20 September 2022
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To my family,

FOREWORD

Firstly, I would like to present my gratitude to my advisor Assoc. Prof. Dr. Mehmet Ali Yüzer, for his support and training me starting from zero in the topic of quantitative methods with patience, motivating me and allocating his time.

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TABLE OF CONTENTS

Page

ABBREVIATIONS

BBB **:** Bursa Metropolitan Municipality
LRT **:** Light rail train
OECD **:** Organisation for Economic Co-operation and Development
PPP **:** Public–private partnership
PSHI **:** Private and supplementary health insurance
SGK **:** Social Security Institution
TÜİK **:** Turkish Statistical Institute
WHO **:** World Health Organization

LIST OF TABLES

Page

LIST OF FIGURES

Page

HIERARCHICAL HEALTH FACILITY LOCATION MODEL BASED ON USER DEMAND: THE CASE OF BURSA

SUMMARY

Location theory has been studied in many disciplines such as economics, geography, statistics, industrial engineering and urban planning. The development of location theories has mostly been through the minimum cost-maximum profit targets of industrial areas. The public services are usually located considering the user demand, social benefit and construction cost. Therefore, increasing the efficiency of the public service is possible only by providing to as many people as possible and localizing the service.

Accessibility, which does not have a single definition, can be defined as the capability to reach a service. Accessibility is a significant factor in both public and private sector's location decisions, and has different parameters within itself. Factors such as population growth and fast growth of cities make access to public health services difficult for users. Economic, political, cultural, spatial or physical barriers are factors that individualize accessibility. Accordingly, this study presents a hierarchical health facility model with users' hospital demand perspective. The aim is to develop a model based on spatial, economic and demographic data. In this context, four types of demand were calculated; based on age-gender, private and supplementary insurance, public transportation and distance. The study area is divided into nine zones based on district and neighborhood boundaries in order to determine the sub-regions where calculation of the hospital demand is made. A facility hierarchy was designed within the framework of current health legislation for facilities that are the general hospitals providing inpatient treatment.

First of all, the age and gender-related inpatient treatment activities of each sub-region were calculated, and the number of inpatients was estimated for each sub-region as the demand value. Secondly, since the hierarchical system designed only includes public health facilities, economic measurement determines whether the demand is for private or public hospitals. For this reason, private and supplementary health insurance ownership ratios in the sub-regions were determined as parameters in the hospital demand based on economic measurement. In the hospital demand based on public transportation, the LRT network was determined as the reference transportation system. Firstly, sub-regions were scored considering the population ratio within walking distance of these LRT stops. Secondly, sub-regions were scored considering the LRT stops that are in the sphere of influence of the district centers. Finally, the total scores are multiplied by the estimated patient numbers in the sub-region. In the last demand type based on distance, Hansen's accessibility index based on hospital demand is calculated for each sub-region by using estimated patient numbers.

The four different types of hospital demand must be weighted in order to be used in the location decision of the second and third stage facilities. In this part, the analytical hierarchy process (AHP) was used as a multiple criteria decision making method. The

priorities of these criteria / demand types were determined through pairwise comparison. These demand values are the weight of each region in calculating the coordinates of the facilities in the model. The hierarchical health facility model designed within the scope of this thesis is compared with the current location and status of the facilities. In this study, the spatial equivalent of the health policies, the differences between current and model despite the same legal framework, the locality, and the sectoral distribution of the demand were also evaluated.

KULLANICI TALEBİNE YÖNELİK HİYERARŞİK SAĞLIK TESİSİ YER SEÇİMİ MODELİ: BURSA ÖRNEĞİ

ÖZET

Yer seçimi, ekonomi, coğrafya, istatistik, endüstri mühendisliği ve şehir planlama gibi birçok farklı disiplinde çalışılan bir konudur. Yer seçimi teorilerinin gelişmesi de çoğunlukla endüstriyel alanların minimum gider-maksimum kar hedefleri doğrultusunda olmuştur. Birçok düşünür yer seçimi üzerine bir teori geliştirirken kentleri farklı geometrik şekillerde tanımlamaya çalışmışlardır. Ancak teknolojinin gelişmesi, kent içi ulaşım olanaklarının artması ve ulaşımın kolaylaşması ile tesislerin yer seçimleri sektörel kümelenme, tedarik zinciri ve bölgesel talepler gibi daha öznel parametrelerden etkilenmeye başlamıştır. Bu bağlamda özel sektörün yer seçimi ile kamu hizmetlerinin yer seçimi birbirinden farklı eğilimler gösterecektir. Kamu hizmetleri, devletin sorumluluğunu aldığı, kamu yararı gözetilen, kar amacından azade bir yaklaşımla topluma sunulan eğitim, sağlık, rekreasyon gibi hizmetlerdir. Bu hizmetler genellikle kullanıcı talebi, sosyal fayda ve yapım maliyeti göz önünde bulundurularak kentsel alanda yer seçmektedir. Aralarında rekabet olmayan bu tesislerin yer seçimi kararlarında diğer kamu hizmetlerinin konumlarının önemi olmadığı söylenebilir. Bu nedenle kamu hizmetinin yer seçimine bağlı olarak hizmetin verimliliğini artırmak ancak hizmeti maksimum kişiye ulaştırarak ve yerelleştirerek mümkün olacaktır.

Erişilebilirlik, tek bir tanımı olmamakla birlikte, bir hizmeti alabilme kabiliyeti olarak tanımlanabilir. Hem kamu hem de özel sektörü yer seçimi kararlarında önemli bir unsur olan erişilebilirliğin kendi içinde çeşitli parametreleri vardır. Erişilebilirlik ve yer seçimi birbirini doğrudan ve dolaylı olarak etkilemektedir. Kullanıcı açısından bakıldığında erişilebilirlik, seyahat süresi ve ücreti, hizmetin ücreti, hizmeti bekleme süresi, kişinin fiziksel koşulları gibi birçok bileşeni barındırmaktadır. İşletmeci açısından bir tesisin yer seçiminde kullanıcının hizmete erişiminden bağımsız, işletme masrafı, kira giderleri, lojistik giderleri ve finansal sürdürülebilirlik gibi unsurlar öne çıkmaktadır.

Nüfus artışı, kentlerin hızla büyümesi gibi unsurlar, kullanıcıların kamu tarafından sunulan sağlık hizmetine erişimini zorlaştırmaktadır. Ekonomik, politik, kültürel, kişinin bedenine bağlı veya mekansal engeller erişilebilirliği bireyselleştiren unsurlardır. Bu bağlamda sağlık hizmetinin kentsel alanda adilce sunulması için kullanıcı talebine yönelik ideal bir tesis konumu belirlenmelidir. Bu tez çalışmasında tasarlanan hiyerarşik sağlık tesisi modelinde de, talep ve tercihlere yönelik optimum sayıda ve yerleşim bölgelerine minimum uzaklıklarda bir tesis modeli hedeflenmektedir. İlk olarak çalışma alanı Bursa merkez planlama alanı olarak belirlenmiştir. Ancak Gemlik ilçesi merkez planlama alanı içinde yer alan diğer altı ilçenin kendi içindeki etkin ulaşım ağının dışında ve ilçe merkezi diğer bölgelere uzak olduğundan çalışma alanına dahil edilmemiştir. Yüksek nüfus yoğunluğuna sahip Nilüfer, Osmangazi ve Yıldırım ilçeleri D200 karayolunun oluşturduğu sınır ile kuzey ve güney olarak ikiye bölünmüş, toplamda dokuz alt bölge oluşturulmuştur. Model

kurgulanmadan önce, çalışma alanında sağlık sektörüne ve hasta profiline dayalı birtakım analizler yapılmıştır. Nüfus bağımlılık oranı, yaş cinsiyet dağılımı, özel sağlık sigortası sahipliği, hastane kapasiteleri, hastanelerin kent içindeki mekansal dağılımları, kent içi ulaşım olanakları, sağlık politikaları ve yasal dayanaklar yürütülecek çalışmanın genel çerçevesini oluşturmaktadır. İlk olarak, tasarlanacak sağlık tesisi modelinin güncel mevzuata uygunluğu gözetilmiştir. İlgili kanunlar, yönetmelikler ve genelgeler doğrultusunda yerelden genele doğru hizmet alanının ölçeği büyüyen, hastanelerin görev, kapasite ve niteliklerine göre tanımlandığı detaylı bir sınıflandırmanın olduğu görülmektedir. Bu çalışmada yalnızca mevzuatta ikinci ve üçüncü basamak tesislere tekabül eden yataklı tedavi hizmeti veren kamu genel hastanelerini içeren bir model tasarlanmıştır. Modelin tesis hiyerarşisi, hizmetin yerelleştirilmesi hedefi ile üç basamaklı, her basamaktaki tesisin yatak kapasiteleri, tesis nitelikleri ve hizmet verdikleri nüfus büyüklükleri farklı olacak şekilde kurgulanmıştır. Her bir basamaktaki tesisin minimum yatak kapasitesi ve mevcut mevzuatta karşılık geldiği hastane türleri belirlenmiştir. Birinci basamak ilçe düzeyinde hizmet verecek olan hastaneler belirlenen her bir alt bölgeye bir adet olacak şekilde, il genelinde hizmet verecek olan ileri tetkik ve tedavi hizmeti sunabilen üçüncü basamak hastane ise il genelinde bir adet olacak şekilde planlanmıştır. Buna göre çalışma alanı için hedeflenen yatak kapasitesi ile planlanan birinci ve üçüncü basamak tesislerin yatak kapasiteleri ile ikinci basamak tesisler için optimum sayı belirlenmiştir. Modelin hedeflediği, minimum hizmet bekleme süresi, minimum seyahat süresi ve ücreti, kapsamlı sağlık hizmeti ve hizmetin ödenebilirliği gibi başat kriterler talep türlerinin de temelini oluşturmuştur.

Kullanıcıların tercih ve ihtiyaçlarına yönelik kapsamlı bir değerlendirme yapabilmek için demografik, ekonomik ve mekansal girdiler ile dört farklı yoldan hastane talebi hesaplanmıştır. İlk olarak her bir bölgenin yaş ve cinsiyete bağlı yataklı tedavi görme etkinlikleri hesaplanarak bölgelerin yılda en az bir kez yatarak tedavi gören hasta sayıları tahmin edilmiştir. Bu talep türü hem nüfus yoğunluğuna, hem hasta etkinliğine bağlı olduğundan en önemli demografik ölçüttür. İkinci talep türünde bir ekonomik ölçüt olarak özel ve tamamlayıcı sağlık sigortası sahipliği kullanılmıştır. Tedavi türüne göre hastaların sektörel dağılımları farklılık gösterdiği için, özel sağlık sigortasının hastane tercihinde hastaların gelir seviyesine göre daha belirleyici, tedaviye özgü bir ekonomik ölçüt olduğu söylenebilir. Özel ve tamamlayıcı sağlık sigortası bu talep hesaplamasında girdi olarak kullanılmıştır. Bu bölümde ilk olarak çalışma alanı içinde özel hastane talebinin bölgelere göre dağılımı hesaplanmıştır. Özel hastane talebi ne kadar az ise kamu hizmetine talep o kadar fazla olacağından ters orantı kurularak kamu hastanelerine olan talep elde edilmiştir. Üçüncü talep türü toplu taşımaya bağlı hastane talebidir. Bu hesaplamada referans toplu taşıma hattı olarak kent içi ulaşımda ana ulaşım aksını oluşturan metro ağı seçilmiştir. Birinci adım olarak her bir metro durağının etki alanında kalan nüfus oranına göre bölgeler puanlanmıştır. İkinci adımda ise her bir ilçe merkezinin etki alanında kalan metro duraklarının toplam durak sayısına oranına göre bölgeler puanlanmıştır. Bu aşamada herhangi bir sağlık tesisine mekansal bir referans verilmediğinden ötürü, hastane talebi olarak nitelendirebilmek için her bölgenin tahmini hasta sayısı puanlarına çarpan olarak eklenmiştir. Böylece her bölgede toplu taşımanın hastalar tarafından kullanılma verimliliğine yönelik bir katsayı elde edilmiştir. Dördüncü ve son talep hesaplaması mesafeye bağlı hastane talebidir. Hansen'in ulaşım indeksi formülü ile tahmini hasta sayısı kullanılarak her bölgenin hastane talebine yönelik bir ulaşım endeksi elde edilmiştir.

Bu dört farklı talep türünün ikinci ve üçüncü basamak tesislerin yer seçiminde kullanılabilmesi için her bir tesis türüne göre ağırlıklandırılması gerekmektedir. Bu aşamada çoklu karar verme yöntemi olarak analitik hiyerarşi süreci (AHP) kullanılmıştır. Model kurgusu yapılırken talep türlerinin de temelini oluşturan kriterlerin birbirleri ile ikili karşılaştırılmaları ile ağırlıklandırma işlemi yapılmaktadır. Basamak türlerine göre farklılaşan tesisin kapasite, görev ve hizmet tanımları ve literatür taramasına göre sağlık tesislerinin erişilebilirlik ve yer seçimi kriterleri doğrultusunda bu kriterlerin birbirlerine göre önem dereceleri belirlenmiştir. Ardından bu çalışmanın uygunluğu açısından ağırlıklandırmalar tutarlılık hesaplaması yapılarak sınanmıştır. Böylece her bölgenin farklı hastane türlerine göre talep ağırlıkları özelleştirilerek elde edilmiştir. Modeldeki tesislerin koordinatları hesaplanırken bu talep değerleri her bir bölgenin ağırlığını oluşturmaktadır.

Bu tez kapsamında tasarlanan hiyerarşik sağlık tesisi modeli ile tesislerin mevcut konum ve durumları karşılaştırılmıştır. Bu çalışmada sağlık hizmetinin sunumunda politikaların mekansal karşılığı, aynı yasal çerçevede farklılık gösteren kapsam, yerellik, sektörel ayrıma göre talep gibi konular da değerlendirilmiştir.

1. INTRODUCTION

Recently, health policy and planning is discussed widely through pandemic and accessibility of healthcare facilities. Thus, the importance of facility capacities and their locations are argued within health policies once again. In addition to this, it is difficult to provide the requirements of the rapidly increasing population, such as housing, education and health services. Systematizing these services according to the population characteristics and spatial pattern of the city is a significant stage of the planning process. The increase in locality in the decision-making processes of the health system was stated by Barker. Accordingly, more people take part in the policy development process of the health system. The author defines policy making and planning as integrated stages. Planning is explained as implementation of the policies concretely (Barker, 1996, pp.33).

Site selection is a topic that includes many branches. The main disciplines working on this subject can be listed as economics, city and regional planning, industrial engineering, geography, applied math and environmental engineering. Since it is discussed in many disciplines, it can be said that location in the public and private sectors is an essential problem (ReVelle, 1987, pp.1053). Site selection criteria differ in the public and private sectors. When targeting maximum profit and large market share in the private sector; serving more people, equality and minimum cost to society are important criteria in the location of public facilities (Serra and Marianov, 2004). The public facilities' location is the conclusion of the urban policies. Thus, the location of the public facility should be evaluated with a comprehensive perspective regarding its effects on the whole city (Thisse and Wildasin, 1992).

Healthcare services are all the activities to increase people's state of health through treatment and rehabilitation. These activities can have different inclusiveness and reach to different population sizes. The healthcare facilities can be classified according to these characteristics. From the local to urban scale, the importance and urgency of illnesses that the facilities treat is increasing. In addition, health facilities interoperate with laboratories and pharmacies that do not provide direct treatment services.

The relationship between sustainability and capacity of the health facilities was studied by Pantzartzis et al. (2017). It is stated that recently the healthcare facilities with high capacity are not sustainable in terms of technologic, economical, social and environmental. They indicate the requirement of new perspectives for health policies. Sustainable concepts in healthcare are related to different factors such as time and space. Thus small healthcare facilities can be more efficient depending on the current conditions of the city (Pantzartzis et al, 2017). Also, vaiours future projections are necessary for sustainability of the health investments. Gruen et al. (2008) correlated sustainability in health with countrywide and local applicability. It is emphasized that health policies can adapt to changing conditions and places. In other words, health policies should be inclusionary as well as adjustable to the characteristics of cities. Assessment of the local needs is more significant than management, design and building plan. Sustainable improvement of facilities is possible when regarding parameters other than financial concerns (Pantzartzis et al, 2017). The subject of this study is to design an effective facility model for Bursa city center as regards the demand of each region.

1.1 Aim of the Study

In this study, it is aimed to develop a healthcare facility model based on user demand in terms of spatial, economic accessibility with demographic data. The central planning area (except Gemlik district) is determined as the study area. Since the urban transportation network among Osmangazi, Nilüfer, Yıldırım, Gürsu, Kestel, and Mudanya districts is stronger and Gemlik is outside these regions, it is not included in the study area. Osmangazi, Yıldırım and Nilüfer districts were divided into two sub-region as north and south, due to their large population. The border dividing these sub-regions is accepted as the D200 state road. Among these regions, districts with high hospital demand were determined through examining the demographic, spatial and economic (insurance-based) characteristics of these. Also before the site selection, weights of the demand types were defined. The study area was designated in the figure below (Figure 1.1).

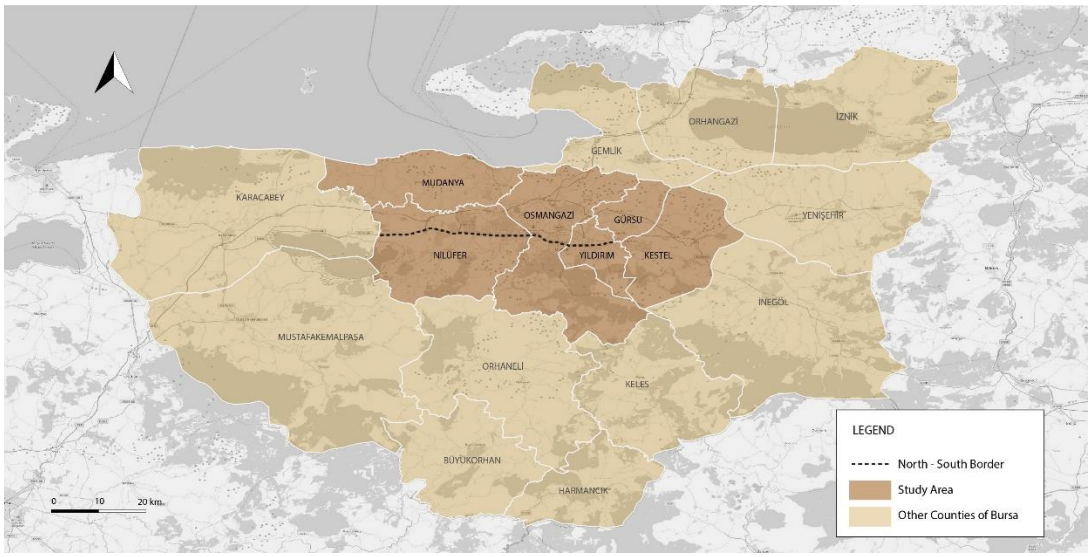

Figure 1.1: The study area for the hierarchical health facility model.

1.2 Scope of the Study

This study consists of five section. In the first part of the study, a literature review was conducted on location and accessibility. These concepts were detailed in the sub-headings according to the subject of the thesis, such as location of public facilities, accessibility to health facilities and criteria of the healthcare facility model.

The second part begins with an analysis of the legal framework related to the health system in Turkey. Then, health statistics and related data specific to the country and Bursa were presented. Statistics within the scope of the study include the spatial distribution of health facilities, transportation data, private health insurance data, and demographic characteristics of the regions.

In the third section the facility pattern that was created in accordance with the current legal basis and location criteria of health facilities is explained. In this facility pattern, facility stages, bed capacities and facility sizes were specified. This pattern involves only general hospitals providing inpatient treatment services. In other words, primary health care centers serving at the neighborhood scale are not part of this pattern.

In the fourth chapter, demand calculations were made for each sub-region in the study area. It was calculated in four different themes: age-gender, health insurance, public transportation and distance. In order to calculate the total hospital demand of each sub-region, the weights of demand types were determined for the secondary and tertiary

hospitals. Then the location decision of the hospitals was made according to the sub-regions with high hospital demand.

In the last part, the evaluations are made regarding the current situation and this hierarchical healthcare facility model. Flowchart of the thesis is given below (Figure 1.2).

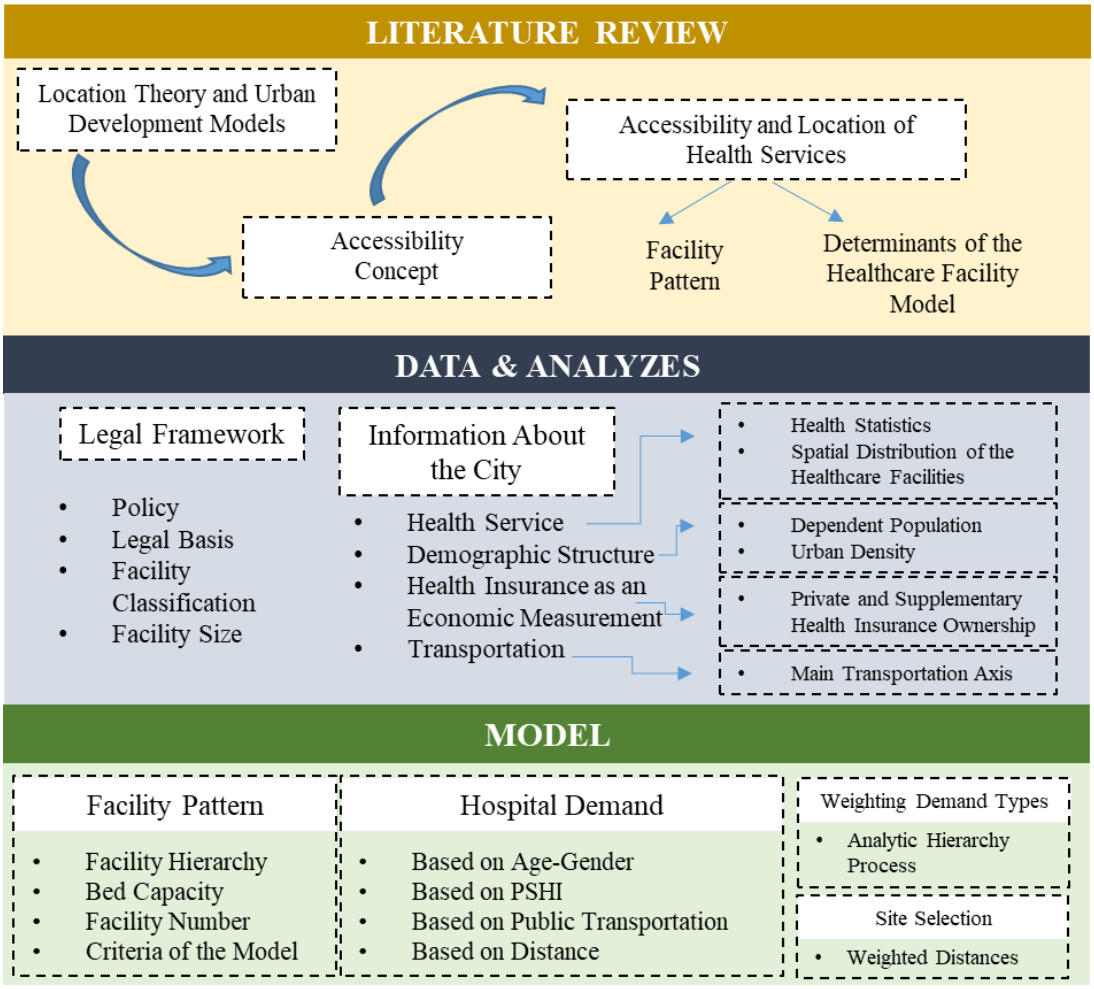

Figure 1.2: Flowchart of the thesis.

1.3 Methodology

The health statistics shown in the study were obtained from secondary data. These are the data published by the Ministry of Health and TÜİK. The distribution of hospitals providing inpatient treatment services in Bursa was shown in accordance with the data obtained from Bursa Metropolitan Municipality. Private and supplementary health insurance statistics are taken from the Insurance Information and Monitoring Center.

In this study, a site selection model is developed with healthcare facilities that provide inpatient treatment services. In the model, the central planning area of Bursa is determined as the study area. The study area involves six counties and has nine sub-zone.

First of all, circulars and regulations related specialties of the healthcare facilities are examined in order to analyze the hierarchy of hospitals. All the facility classification of the model is determined according to these official regulations. This section constitutes the legal basis of the model. The determining factor for the number of facilities in the model is the required bed capacity. Statistics of the WHO and the Ministry of Health are taken to calculate the required bed capacity. Thus, the facility hierarchy is constructed and the optimum facility number is determined.

Secondly, a demand calculation is made to determine the locations of these facilities. The demand calculation section consists of three themes: demographic, economic and spatial. As the first step of the calculation, age and gender distribution statistics from TÜİK and the Ministry of Health are processed for the demand based on demographic factors. As the second step, public or private hospital preference is used to calculate the demand based on economic factors. In this section, private and supplementary insurance ownership is defined as the financial parameter. As the third step, the demand based on spatial factors is calculated in two parts: distance based and public transportation based. Hansen's accessibility index function is used in distance based demand. In this part, the distances of the sub-zones to each other are measured via Google Maps. In the other part, the calculation methods are decided on in the article "A Methodological Framework for Determination of Public Transport Accessibility Index" by Anis, Di Febbraro and Sacco (2021) through adapting to Bursa. The metro line is chosen as the reference public transportation route according to passenger statistics from Bursa Metropolitan Municipality.

Lastly, before the site selection is made, the importance of these three demand themes against each other is determined by the "Analytic Hierarchy Process Method". Criteria of the public healthcare facilities in the model are specified and this method is used for second and third stage hospitals in the hierarchy. The location of the hospitals is determined from among the sub-zones as regards total demand values.

All images showing Bursa and the study area are created by using Adobe Illustrator and QGIS applications.

1.4 Hypothesis

- Distribution of the population is the determinant in the location of public general hospitals.
- The hierarchical structure of the health facilities is not effective in the current distribution of general hospitals providing inpatient treatment services in Bursa.
- The location of private hospitals in the city center is based on the distribution of their potential users.

2. ACCESSIBILITY TO HEALTHCARE SERVICES AND LOCATION

2.1 Location Theory

Location theory has been widely studied by geographers and economists; it is described as an inseparable part of regional, financial and spatial studies by Britannica (Url-1). The theory in the most general sense is about where financial activities are situated or why they are situated in their current places. The place does not have a certain scale, in other words it can be examined from a city block to a region embodied by several cities. Also the economic activities can be explained in the same way, the activity could symbolize an agricultural, industrial, commercial or public facility area.

2.1.1 Location and urban development theories

Johann Heinrich von Thünen is known for his "Isolated State" study which determines the parameters of the agricultural land use model. According to his findings agricultural land use is related to type of agricultural products and the economic rent is the determinant. Portugali (2011) states that Thünen's isolated city answers how the city will take form in conjunction with agricultural production (Portugali, 2011). Carrying cost is the primary factor for economic rents, thus the product which provides maximum economic rent, will be located in the piece of land (Fales & Moses, 1972). Carrying costs increase in direct proportion to the distance, therefore competition between the products brings spatial diversity to the economic rent. Thus, the relationship between economic rent and distance can be explained as the closer to market the higher rent (Sinclair, 1967, p.73). Von Thünen's isolated city consists of six circle parts (Figure 2.1). The first zone is the city center and most of the economic activities revolve around here. Also milk and vegetable production are in the first zone, since they are perishable products, they should be located at the points that can be supplied to the city centers as quickly as possible. The second zone is forest with firewood and lumber supply. Due to high costs of wood-transport, it necessitates that the forest land location is close to the city. The third, fourth and fifth zones are cultivated areas. In the circles, as becoming distanced from the city center, agricultural

production decreases, pastures and uncultivated areas increase. Since it is far from the city center, the sixth zone is suited for pasturage lands. Because animals can transport themselves, transportation costs are minimized (Johnson, 1962; Sinclair, 1967).

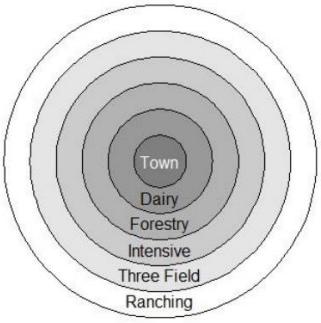

Figure 2.1: Thünen's circles (Morency-Lavoie, 2015, p. 28).

The location of industries was described by Alfred Weber through spatial distribution of financial activities. It was explained by Weber that although economic activities are divided into production, consumption and distribution, all of these should be considered together in urban space. In Weber's model, the city consists of three points, two points that provide the raw material and the city that consumes the product. In other words, the raw material suppliers and the city form a triangle. The main purpose is to find the most suitable industry location in this triangle according to the transportation costs to all three points (Figure 2.2). The main criterion is to minimize total transportation costs through accepting the products' market price independently of location (Portugali, 2011; Chan, 2001, p.48-49).

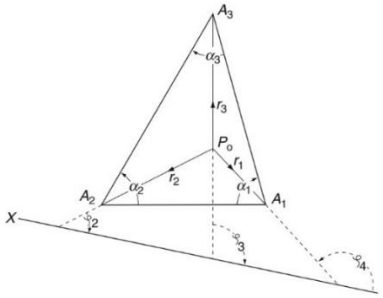

Figure 2.2: Weber's triangle (Portugali, 2011, p.21).

Christaller's central place theory consists of many interconnected zones. Accordingly, the main function of a city is to be the center of the region consisting of all these zones (Figure 2.3). There is a hierarchical layout between centers according to their spheres of influence. A center with a large sphere of influence has all the services offered in

other lower-level centers, but in the reverse situation it is not possible. Christaller states central places will expand their market space. For this reason, since the central places are located equidistantly from their sub-zones, it is essential the central places are located equidistantly each other (Getis & Getis, 1966; Fischer, 2011). Lösch's "Theory of Economic Regions" also shows geometrical similarity with the theory of central places. However, Lösch does not assume that every product sold in the sub-zones will also be sold in other centers, except the largest center. The sub-zones may specialize in different products, thus the hierarchy in terms of production is not certain (Fischer, 2011).

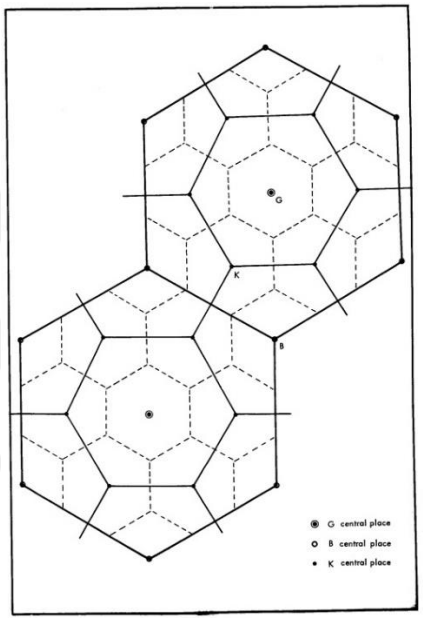

Figure 2.3: Christaller's central place geometry (Getis & Getis, 1966, p.225).

Burgess (1925) stated a concentric land use model to show development of the cities. In the center of this development model, the central business district is located. The second zone is defined as a zone of transition that contains slums or rooms for rent. The third zone includes houses of the working class. The fourth and fifth zones include housing areas of middle-class high-income residents (Figure 2.4). According to this model, population density decreases from the center to the periphery, but the income level of residents' increases (Burgess et al. 1925, as cited in Yüzer, 2001; as cited in Harris & Ullman, 1945). In the 1930s, an urban development model was developed by Homer Hoyt, consisting of transportation axes and railway extending from the center to the periphery and parts with different functions (Hoyt 1939, as cited in Yüzer, 2001). Harris and Ullman (1945) state that in cities where the use of automobiles becomes

widespread, the central business area loses its importance. In these circumstances, it becomes easier for cities to be multicentric. According to this model, activities that are related to each other are located in the same center. In other words, similar business lines aggregate together to form sub-centres (Figure 2.4). This urban development model can be still seen today (Harris & Ullman, 1945, as cited in Yüzer, 2001).

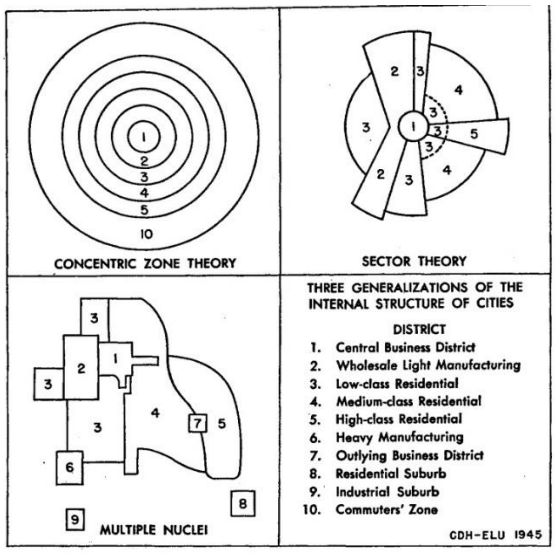

Figure 2.4: Urban development models of Burgess, Hoyt, and Harris and Ullman (Harris & Ullman, 1945, p.13).

2.1.2 Public facility location

In the studies of classical location theorists, site selection models mostly regarding connection between raw materials, production and market places. Accordingly, classical theories discuss the private sector's location considering a maximum profit and minimum cost perspective. Public facility location decisions in these studies are generally dependent on residential areas. Therefore, these studies have no sufficient explanatory information in terms of location of public institutions (Dear, 1974; McAllister, 1976).

For the first time, Teitz (1968) stated the difference between the determinants of public and private facilities' location decisions (Deverteuil, 2000). He describes public facilities as services for which the government takes responsibility for providing in the urban system. Being non-profit and lack of competitive environment are the most significant differences in the location determinants of public and private facilities. The number of facilities, facility size, total demand and cost depending on the budget are

determined by Teitz (1968) as the main parameters of the public facility location (Teitz, 1968, as cited in Deverteuil, 2000).

Public facilities are often located considering user demand, social benefit and cost. Since the services are non-profit, it can be assumed that the facilities do not affect each other's location. Accordingly, the decision of the location is based solely on user demand and access to the service. There is a decentralized approach in the site selection process (White, 1979).

McAllister (1976) examined the location of public services -such as education, health and recreation- in terms of equality and efficiency through Lösch's urban geometry. Equality is related to the distribution between service and population, efficiency is related to the amount of service used. According to this study, frequent facility locations ensure equality, but the efficiency of the service will be negatively affected in this circumstance. The relationship between these two criteria cannot be expressed precisely. Since the settlement models of the cities, the preferences of the users and the urban policies are different, it can be said that the location of public facilities is a subjective approach (McAllister, 1976).

The location of public facilities was examined by White (1979) in terms of accessibility. Both the requirement for the facility and the cost of access to the facility determine the demand of the users. Therefore, the major criterion in the site selection of the public facility is the population size it will serve. Providing accessibility concerning distance and cost for all users will be effective in the location of the facility. The facility pattern in the urban area is determined by the spatial distribution of user demands (White, 1979).

In conclusion, for the decision of public facilities location, unlike the private sector, there is an approach to equality, social benefit, efficiency and user demand, without competition and profit.

2.2 Accessibility

Accessibility concept is related to a lot of points, for this reason it is difficult to define the concept of accessibility with exact limits. It can be basically said that accessibility is the capability to attain a place or an activity or to reach a service. In other words, it is the opportunity to reach by transport system, by walking, by purchasing or by

freedom. A transport system aims to carry people or goods to a particular place or activity. Access to these activities or places is not only related to the transport system but also to land use. When defining accessibility, both transportation options and opportunities in the city should be considered together. In other words, accessibility can be explained with three ingredients; people or goods, opportunities given by the city and transportation options (Gleave and Halden, 2001). Hansen (1959) states in his study that "Accessibility is defined as the potential of opportunities for interaction" (Hansen, 1959, p. 73). Geurs and van Wee (2004) identified criterias of accessibility related with urban policies, land use and transportation conditions. They describe it in four ways; time, transportation, land use and personal components. Time means availability of services and activities in dissimilar times in a day. Also it signifies the available period of time for activeness of people. Transportation can be explained as a system to cover the distance between starting point and point of arrival. It includes waiting and travel time, prices, and reliability. Land use signifies spatial apportionment of facilities and occasions such as housing zones, working areas, industrial areas, education and healthcare facilities, recreational areas. Lastly the personal component is requirements, capabilities and opportunities which vary from person to person. Thus, accessibility is affected by several characteristics of an individual such as age, income level, education, gender, physical disabilities etc (Geurs and van Wee, 2004).

Social environment, physical conditions, and even daily life can affect the distances to be accessed and the time spent for it. According to Kwan (2013), being close to an institution does not mean it can be reachable. For instance, during the opening hours of the institution, if the person is not available at this time, the institution is not accessible easily; or if the bus frequency is insufficient, residing near the bus stop is not useful (Kwan, 2013). Accessibility can be analyzed in terms of social justice. Farrington and Farrington (2005) describes accessibility as a component of social inclusion. Inclusivity is a requirement for an equitable society. In an equitable society people should participate in activities with their community. Social inclusion policies include providing social aids, education, healthcare service etc. On the other hand, accessibility should be ensured too as an opportunity to participate in daily activities. Accepting accessibility as an ingredient of social inclusion is important to integrate sectoral policies (Farrington and Farrington 2005).

In conclusion, accessibility can be measured with several parameters such as distance, transportation opportunities, individual differences, social policies, daily life etc. However, if all these parameters are considered together, accessibility can be an aim. Therefore, studies on this subject concern a lot of disciplines.

2.3 Accessibility and Location of Health Services

In this section, relationship between accessibility concept and location of health services is analyzed regarding facility pattern and accessibility parameters of these facilities.

2.3.1 Health facility pattern

Building a system of hospitals is important to make the health service low-cost and more accessible. Therefore researchers have developed health facility patterns and criteria. Llewelyn and Macaulay's regional hospital pattern (1966) consists of three-step facilities. The system is formed by a regional hospital that provides an advanced treatment service, hospitals which have fewer branches, and rural hospitals which are smaller facilities (Figure 2.5). In this pattern, multiple rural hospitals form units depending on the intermediate hospitals. These units are connected to the regional hospital (Llewelyn & Macaulay, 1966).

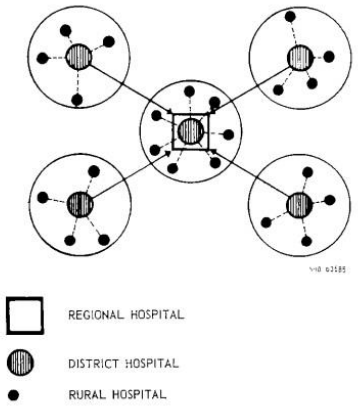

Figure 2.5: Regional health facility pattern (Llewelyn & Macaulay, 1966).

Schulz (1970) approaches the site selection of health facilities from the point of view of the service users. His model focuses on locality. In the model, the importance of localization is explained with cost. The degree of localization of the facilities affects the cost of the service provided, the travel costs of patients and the utilization

frequency of health facilities. Also high travel cost and reduced facility utilization enhances the cost to society. Schulz bases on the central places theory in the model. Accordingly, simple facilities serve small populations and complex facilities serve large regions. A hierarchical facility layout is necessary to apply this theory to the health system. Three types of facilities are mentioned in the model; neighborhood health center, general hospital and advanced medical center. Also Reustein (1971) mentioned a similar facility pattern. He refers a hospital pattern classified according to the importance of the disease. (Reustein, 1971 as cited in Calvo & Marks, 1972). According to this model, there is a comprehensive hospital in the center that provides specialized and general treatment. Community hospitals, as secondary facilities, provide basically the same services with a lower degree of specialization. Lastly, reception centers are the smallest unit of the health system. It can be said that it is the first step in the health care service system for the population of the region. These centers provide greater access to health services. A feature common to the systems above-mentioned and described by Schultz is the gradation of the facilities (Schulz, 1970; Reustein, 1971 as cited in Calvo & Marks, 1972).

2.3.2 Determinants of the health facility location model

Schulz (1970) indicates that distance-demand, service cost, travel cost, availability and benefit information are necessary for the facility type at each step in order to create the facility model. Service cost is related to the number of units in the facility, the average cost of the service, the number of days served and the operating cost. It is predicted that the service cost will increase from small facilities to complex facilities. Distance-demand means the relationship between utilization of the facility in its region and availability of the facility depending on the distance. Users of the local facilities often request services such as physical checkups, preventive treatment and treatment of minor illnesses. The cost of the facility will be greater than the benefits expectations for users. Therefore, the demand for local services will decrease as distance increases. On the other hand, tertiary facilities that provide comprehensive services are preferred due to opportunities of advanced treatment only there. As users' benefit expectation is higher in tertiary facilities than in local hospitals, increasing distance to these facilities will affect the demand less. Factors such as the travel time and availability, distance between the facility and the patient's place of residence also affect the travel cost. Finally, social benefit is defined in terms of dollars per unit of service consumed. It is

related to the utilization of the facilities, the average social benefit at the standard usage level, the changes in the amount of the social benefit depending on the usage level (Schulz, 1970).

Calvo and Marks considered social, economic and political factors in order to model healthcare facilities. It can be said that these factors specify standards for alternative location opportunities. The hospital location criteria is classified into three groups. These groups are three sectors of community. These sectors are both affecting and affected the decision of facility location. The first one is the user sector, the users can be defined as health consumers and patients. They are affected by travel time and cost, the comfort and convenience of the facility, and the cost of the service. The degree and the nature of the illness is the most important factor for users. For instance, if a person is in critical condition and needs emergency medical care, some features such as travel time may become important while cost may lose their importance. However, if the disease is not serious, all qualifications become significant in the decision to receive a treatment (Calvo & Marks, 1972).

The operation sector comprises the management and administrative staff of the health institution, doctors, nurses, general and paramedical staff. Management is concerned with the financial sustainability of the facility, including investment expenditure, operating cost, potential revenue, and localization economies. Besides, it sometimes concerns the management freedom of the facilities which are subject to development plan laws and local government regulations (Calvo & Marks, 1972).

Community sector includes the population and business in the region. They are affected by the socio-economic factors caused by the increase in the activity of the health facility in the region. Increased activities may also create negative effects such as traffic and human density in the region. On the other hand, since the decision-making process can be political, the choice of location may not be accepted by all segments of the society (Calvo & Marks, 1972).

Gulliford et al. (2002) examine “access to healthcare” in four topics. The first one is availability of the healthcare service, it relates to sufficient facility and medical personnel number. The second one is obstacles to access to health services. It relates to many factors such as social, financial, cultural, and availability of the facility. The financial obstacles can be explained as the cost of non-productive time in accessing

the facility, the lack of health insurance, and the cost of the service. In other words, this factor depends on pay capability and the largeness of the cost. The third one is effectiveness, it means to provide an effective and accurate health service. The last one is providing social justice through a healthcare system that is accessible to all and toward everyone's needs (Gulliford et al, 2002).

2.4 Quantitative Approaches to Healthcare Facility Location

In this section three different health facility location models were scrutinized in terms of their quantitative variables. These are Calvo and Marks' (1973) analytic approach in terms of location parameters, Dökmeci's (1977) hierarchical health facility location problem and the health facility optimization problem developed by Flores et al. (2021).

The factors affecting the site selection explained in the previous topic are the inputs for the optimization problem of Calvo and Marks' health facility location model. The model indicates where the health facilities will be located and which residential areas these facilities will serve (Calvo & Marks, 1973). In the image below, settlements and facility distributions are shown in a sample area (Figure 2.6). In this sample, there are five settlements in the planning area and three types of health facilities. According to this sample, the people residing in Area 2 must travel to Area 1 for the Type I (health facility), to Area 5 for the Type III, and to Area 3 for the Type II. It is assumed that the people residing in Area 5 can get all the stages of the health service from Type III.

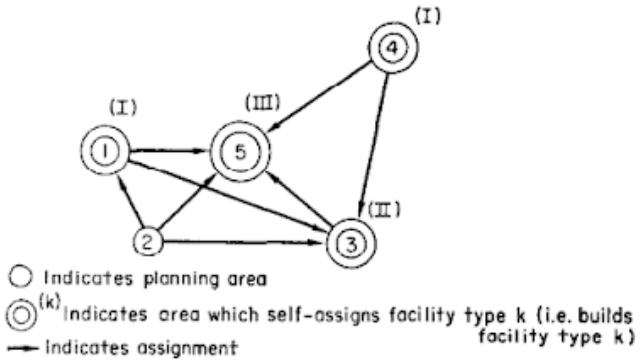

Figure 2.6: Sample planning area (Calvo & Marks, 1973, p. 413).

Equations were determined for the factors affecting the facility location. As seen in equation 2.1, the first of these is to minimize the distance or travel time to the facility (Calvo & Marks, 1973, p.414). In this equation, d_{ij} is the minimum value of the distance or travel time from site i to site j, a_{ik} is the number of people residing in site i

and requiring k type service, x_{ijk} indicates that the people residing in site i (i = 1, 2, … , n) get k type service (k = 1, 2, …, s) from site j in zero-one form. The aim is minimizing the travel time or weighted distance considering accessibility as the site selection criterion.

$$Minimize \sum_{i=1}^{n}\sum_{j=1}^{n} d_{ij} \sum_{k=1}^{s} a_{ik} x_{ijk} \tag{2.1}$$

$$x_{ijk} = \begin{cases} 1, & \text{If the people residing in site i get k type service from site j} \\ 0, & \text{If not directing to another site} \end{cases}$$

The second function is to minimize the user costs. The total travel cost function is given in equation 2.2 (Calvo & Marks, 1973, p.414). In this equation c_{ij} is average travel cost between site i and site j.

$$Total\ Cost = \sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij} \sum_{k=1}^{s} a_{ik} x_{ijk} \tag{2.2}$$

The cost of service is related to the development and management costs of the facility. The society generally pays service costs indirectly through insurance and taxes. The main ingredients are given in equation 2.3 and 2.4 (Calvo & Marks, 1973, p.414).

- p_{jk}: The proportion of the estimated total cost by the planning area of facility type k in site j
- F_{jk}: The construction cost of facility type k in site j
- V_{jk}: The development and management costs per unit of facility type k in site j
- S_{jk}: The size of the facility type k in site j

$$S_{jk} = \sum_{i=1}^{n} a_{ik} x_{ijk} \tag{2.3}$$

$$Facility\ Cost = \sum_{j=1}^{n}\sum_{k=1}^{s} p_{jk} F_{jk} x_{jjk} + V_{jk} \sum_{i=1}^{n} a_{ik} x_{ijk} \tag{2.4}$$

Calculation of the total cost is given in equation 2.5, considering users' and service cost together (Calvo & Marks, 1973, p.415).

$$Minimize \sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij} \sum_{k=1}^{s} a_{ik} x_{ijk} + \sum_{j=1}^{n}\sum_{k=1}^{s} p_{jk} F_{jk} x_{jjk} + V_{jk} \sum_{i=1}^{n} a_{ik} x_{ijk} \tag{2.5}$$

The next step is determination of the maximum demand locations. It can be defined as the locations that are accessible for the health facilities and have high usage rates. The significant parameters of the user demand are income level, service cost or health insurance, education level, family size and distance. In this way, each sub-region of the planning area has own demand value through combination of these parameters (Calvo & Marks, 1973). The total demand function of the planning area is given in 2.6 below (Calvo & Marks, 1973, p.416).

$$\sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{s} Z_i(k)x_{ijk} \qquad (2.6)$$

- $Z_i(k)$: The specific demand levels according to each service type in (each) site i

One of the significant criteria in location decisions of health facilities is to determine the location that provides the maximum utility to the planning area. Utility can be defined as factors that Calvo and Marks (1973) examine within the user, business and community sectors. As in demand calculation, each region has its utility value (U_{ijk}). This value is related to the capacity of the facility and the percentage of its usage (Calvo & Marks, 1973). The function that maximizes the utility for the planning area is given in 2.7 below (Calvo & Marks, 1973, p.417).

$$Maximize \sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{s} U_{ijk}x_{ijk} \qquad (2.7)$$

The functions in this study are helpful processes in formulating the location decision. It shows detailed analysis of alternative facility locations. Planners determine the location between alternatives by evaluating these parameters economically, politically, socially and spatially (Calvo & Marks, 1973).

Dökmeci (1977) has developed a regional health facility location model that aims at minimum travel and facility (construction) costs. Increasing the number of facilities reduces the travel cost, but increases the facility cost. Therefore the minimum value of the total cost ensures the optimum system. This model consists of four stage facilities; a regional hospital, intermediate hospitals, local hospitals and health centers. The planning area includes the settlements (sub-regions) where patients and personnels are located. In this model, personnels in the health facility, doctors, patients, equipment, information and service transfer between facilities are also considered besides users.

Therefore, the demand is not only from the user but also from the facilities at different stages (Dökmeci, 1977). The function of total travel cost is given in 2.8 below (Dökmeci, 1977, p. 413). In this equation, u_{ij} is the number of users, d_{ij} is the distance between facility i (i = 1, 2, ..., r) and site j (j = 1, 2, ..., r), t is unit cost of travel, r is the demand point.

$$T = \sum_{i=1}^{r}\sum_{j=1}^{r} u_{ij}a_{ij}d_{ij}t \tag{2.8}$$

$$a_{ij} = \begin{cases} 1, & \text{If the facility i serves site j} \\ 0, & \text{If it does not serve} \end{cases}$$

A coefficient is determined for the construction of the facility at each stage and the facility cost is calculated. The function of facility cost is given in 2.9 below (Dökmeci, 1977, p. 413). In this equation, n_k is the number of facilities at k level, A_k is the total capacity of facilities at k level, a_k and b_k are the coefficients (Dökmeci, 1977).

$$F = \sum_{k=1}^{4}(a_k n_k + b_k A_k) \tag{2.9}$$

In this model, the equation 2.10 below can be used for optimum locations of first stage facilities. In this equation, p is sum of n_0 and n_1, A_1 is the total capacity of the first stage facilities (Dökmeci, 1977, p. 414).

$$Z_1 = \sum_{i=1}^{p}\sum_{j=1}^{p} u_{ij}a_{ij}d_{ij}t + n_1a_1 + b_1A_1 \tag{2.10}$$

In order to find the coordinates of the facility which minimizes the total cost, the partial derivatives of the equation are computed with respect to x_i and y_i. The function is given in 2.11a and 2.11b below (Dökmeci, 1977, p. 414).

$$\frac{\partial z_1}{\partial x_i} = \sum_{j=1}^{p}\frac{u_{ij}a_{ij}(x_j - x_i)t}{d_{ij}} = 0 \tag{2.11a}$$

$$\frac{\partial z_1}{\partial y_i} = \sum_{j=1}^{p}\frac{u_{ij}a_{ij}(y_j - y_i)t}{d_{ij}} = 0 \tag{2.11b}$$

Since these equations do not have a definite solution, they can be solved through iterative equations in 2.12a and 2.12b below (Dökmeci, 1977, p. 413).

$$x_i^h = \frac{\sum_{j=1}^{p} \frac{u_{ij} a_{ij} x_j}{d_{ij}^h}}{\sum_{j=1}^{p} \frac{u_{ij} a_{ij}}{d_{ij}^h}} \quad (2.12a)$$

$$y_i^{h+1} = \frac{\sum_{j=1}^{p} \frac{u_{ij} a_{ij} y_j}{d_{ij}^h}}{\sum_{j=1}^{p} \frac{u_{ij} a_{ij}}{d_{ij}^h}} \quad (2.12b)$$

This procedure is applied to each facility stage until there is no change in facility locations. The same process is continued by changing the number of facilities at each stage. Thus, alternative systems consisting of different numbers of facilities are obtained and their total costs are calculated. The alternative with the minimum total cost is designated as the optimum system (Dökmeci, 1977).

Flores et al. (2021) developed an optimizing health facility location model considering the settlements with lack of accessibility to health facilities. In this model, facility number, hierarchy and capacity of the facility stages are determined through health policies and plans of that country before the site selection (Flores et al., 2021).

The first step of this model is obtaining the current locations of facilities that are at the same stage. Then a grid that consists of "1 km x 1 km" sized sub-areas is placed over the planning area. Only the sub-areas on the transportation line are considered to be candidate locations. Second step is estimating the hospital demand. The first stage of the estimating hospital demand is calculating the number of people living within the 30-minute drive to the facility. The second stage is determining expected visitor or user number. The function of the visitor number is given in 2.13 below. Willingness to travel ($f(t_{ij})$) was modeled between 0 and 1 considering studies in Florida, USA. In the function of visitors from site i to facility j, B is bed capacity of facility j, P is the population of the site i, t_{ij} is the travel time, and μ, α, β, θ, σ are the constants related to characteristics of the planning area (Flores et al., 2021, p. 4).

$$f(t_{ij}) = \frac{1}{1 + \left(\frac{t_{ij}}{\theta}\right)^{\beta}}$$

$$Visitors_{ij} = \mu P^{\alpha} B^{\sigma} f(t_{ij}) \quad (2.13)$$

In the demand calculation, a population size that each health facility serves is determined. Demand values of the regions within a 30-minute drive distance from the current health facilities are assumed as "0". Thus, the regions without access to the health facilities gain priority. Then, the number of people which is determined as the facilities serve is decreased from the demand. In this way, the number of visitors or users can be estimated for the facilities and the location of the new facility can be designated through the demand (Flores et al., 2021).

All these quantitative approaches to location of health facilities focused on different themes. Calvo and Marks (1973) regarded demand parameters and analyzed who will be affected by health facility activities and how. Dökmeci (1977) has developed a hierarchical health facility location model in which the number and size of facilities are determined mostly by facility and travel cost. Flores et al. (2021) prioritized the regions which have no access to health facilities through considering the population and their distances to the current facilities. The parameters used in these location models may change according to the current health policies of the country and the characteristics of the planning area.

3. HEALTH SERVICE ANALYSIS IN BURSA

In this part, spatial distribution of the facilities, demographic structure, transportation, insurance data are analyzed in terms of health service. The health statistics are obtained from Ministry of Health's reports and TÜİK, population data are obtained from TÜİK, health facility data are obtained from web pages of Provincial Directorate of Health of Bursa and BBB's open source data. Private and supplementary health insurance owner numbers are obtained from the Insurance Information and Monitoring Center. The transportation statistics are obtained from activity reports of BBB and the information about the Transportation Master Plan of Bursa is obtained from the web page of Boğaziçi Proje AŞ. All the maps are created by using Adobe Illustrator and QGIS applications with OpenStreetMap data.

3.1 Legal Basis Relevant to Healthcare Facilities

The basic principles of the healthcare service in Turkey are regulated in "Constitutive Law of Healthcare Service". Health institutions are planned by the Ministry of Health by taking the opinions of other relevant ministries in order to provide equal, high quality and efficient service throughout the country. All the works and processes relevant to healthcare service are controlled by the Ministry of Health. In order to provide the equal distribution of health services, the ministry has specified regional health centers throughout the country in 2010 (see Figure A.1). "Regional Health Planning Circular" is issued to determine regional health centers within hierarchical settlements. In this circular, central provinces of health regions are specified based on basic indicators such as population density, socio-economic structure, urbanization and industrialization, transportation infrastructure, quality and capacity of health service delivery. In order to receive advanced health services from the provinces determined as health regional centers, sub-regional central provinces and strengthened districts affiliated to these provinces in terms of health service delivery are determined. Sub-regions are chosen to receive advanced health care services from the regional health centers (Url-2).

Health services in Turkey are provided by both the public and private sectors. Also, public-private partnership (PPP) in the health facilities was mentioned for the first time in 2003 with the Health Transformation Program. In this program, the reasons for PPP are shown as the increase in the construction costs and the inadequacy of the state budget to defray. According to this program, private institutions could be a partner of "Public Hospital Associations". Detailed information about these unions was not given in the Health Transformation Program, but in 2007, a proposed law was given by the Council of Ministers for this application. In the proposed law, it is mentioned that there will be members determined by the Provincial Assembly, the Governor, the Ministry of Health and the Chamber of Commerce and Industry in the management of these newly established unions. It was abolished with a legal decision in 2017.

In 2005, the build-lease-transfer model was added to the Constitutive Law of Healthcare Service. The PPP model as an option was legislated for the construction of the hospitals in 2013. In this law, hospitals were defined as facilities that need high cost and technology to build.

3.1.1 Classification of the healthcare facilities

Health facility standards were examined according to three different legislative titles; circular of regional health planning[1], licensing regulation, and regulation of spatial planning.

The facilities were classified according to their service capacities in the Regional Health Planning Circular. Within the scope of this circular, hospitals are divided into 5 basic groups according to their roles. The groups and hospital types are given in the table below (Table 3.1).

[1] The facility classification in circular of regional health planning is published by Health Ministry in 2009, by name "Hospital Status (Hastane Rolleri)". Since the legal basis of the health facility classification is examined in this section, it is mentioned under the name of "Regional Health Planning Circular" instead of "Hospital Status".

Table 3.1: Hospital types according to Regional Health Planning Circular (2010).

Groups	Sub-Groups	Hospital Types
Group A	A1	General Hospitals and Branch Hospitals (advanced health care service, with training and research status)
	A2	General Hospitals and Branch Hospitals (advanced health care service)
Group B	B	General Hospitals (to service the city and its districts)
Group C	C	General Hospitals (to service districts, min. 6 branch)
Group D	D	General Hospitals (to service districts, min. 25 bed capacity)
Group E	E1	Hospitals (to service districts that have min. 18.000 population)
	E2	Hospitals (to service districts that have min. 9.000 max. 18.000 population)
	E3	Hospitals (to service districts that have max. 9.000 population)

Type A facilities provide advanced healthcare service. It is divided based on training and research status. Type B facilities are general hospitals that service in the scale of the city. Type C facilities service with minimum 6 branches in smaller areas such as in the county scale. D type is for the districts with minimum 25 bed capacity. Type E facilities are divided into three classes regarding population size they serve.

As the second legal basis Licensing Regulation is examined. The purpose of this regulation is stated as to regulate the procedures and principles regarding the licensing of health facilities and their centers, bodies and units for the balanced distribution of public health facilities and the quality and efficient delivery of service. This regulation includes the health facilities within the Ministry of Health and its affiliates, public universities, municipalities, organized industrial zones and other public institutions and organizations, and health organizations within the Turkish Armed Forces. According to this regulation, the primary health care institutions are defined where the diagnosis and treatment of outpatients are made. These institutions are community health centers, family health centers, integrated public hospitals (E2 and E3), public health laboratories, institutional health services, outpatient clinics, medico social units and health services within the Turkish Armed Forces. According to this regulation, some affiliates can be attached to the official authorization of these facilities. These units are child, adolescent, women and reproductive health unit, infection control unit, integrated health service unit, home health service unit, cancer early detection center, tuberculosis control dispensary, malaria control dispensary, wellness center,

immigrant health center, occupational health and safety unit, family practice unit and health house.

Secondary health care institutions are defined as the facilities where outpatient and/or inpatient diagnosis, rehabilitation and treatment services are provided. These institutions are general hospitals, branch hospitals, integrated hospitals (E1), mouth and dental health centers/hospitals and medical centers. Tertiary health care institutions are defined in the legislation as the hospitals and/or centers with high technology where training and research services can be provided for diseases that require further examination and special treatment. These institutions are general hospitals that serve advanced, training and research hospitals (general, branch and mouth and dental health) and university hospitals (general, branch, mouth and dental health, institute). According to this regulation some affiliates can be attached to the official authorization of secondary and tertiary institutions. These units are community mental health center, traditional and integrative medicine unit, obesity center, assisted-reproductive treatment center, dialysis center, genetic diseases diagnosis center, child health care center, alcohol and substance addiction treatment and training center (adult, child, adolescent), pregnant school, neighborhood polyclinics that provide services at different addresses and additional service buildings.

As the third legal basis Construction of Spatial Plans Regulation is examined. The purpose of this regulation is to determine the procedures and principles of spatial plans regarding its implementation. It has decisions that regard constructional, natural, historical and cultural values, ensure the balance of protection and use, support sustainable development at the country, region and city level, and create healthy and safe environments with high quality of life. It contains the procedures and principles for spatial plans of all types and scales, revisions, amendments and examination of these plans, spatial plans and specific targeted plans and projects. In supplementary documents of the regulation, the constructional standards of the urban facilities are specified. Also the health care facilities are detailed according to the population they serve, type and roles. The standards as required by the regulation are given in the table below (Table 3.2).

Table 3.2: Hospital standards according to Construction of Spatial Plans Regulation (2014).

Population	0 - 75.000		75.001 - 150.000		150.001 - 500.000		500.001 +	
Health Care Facilities	m² / person	min. unit area	m² / person	min. unit area	m² / person	min. unit area	m² / person	min. unit area
Family Health Centers		750 - 2000		750 - 2000		750 - 2000		750 - 2000
Primary Health Institutions		3000		3000		3000		3000
Mouth and Dental Health Centers		110 m² per unit		110 m² per unit		110 m² per unit		110 m² per unit
Maternity and Child Hospitals Public Hospitals	1,5		1,5		1,5		1,6	
Training and Research Hospitals		130 m² per bed		130 m² per bed		130 m² per bed		130 m² per bed
Physical Therapy and Rehabilitation Centers								
Health Campuses		220 m² per bed		220 m² per bed		220 m² per bed		220 m² per bed

3.2 Health Services in Bursa

In the Bursa, 3.7% of the population of Turkey lives and 3.2% of the total health personnel is situated in this city (TÜİK, 2019). According to health statistics in 2019, the total number of medical doctors per 1000 people on average is 1,67 in Turkey and 1,7 in Bursa. However, when compared to other metropolitan cities, it can be seen that the average is lower in Bursa (TÜİK, 2019). The number of medical doctors per 1000 people in Turkey's five metropolitans sorted by population size is shown in the table below (Table 3.3).

Table 3.3: The number of medical doctors per 1.000 people in five metropolitans.

Metropolitans	Average
İstanbul	2,2
Ankara	3,1
İzmir	2,6
Bursa	1,7
Antalya	2,2

The numbers of specialist doctors are given in the chart below (Figure 3.1). According to sectoral distribution by years, the number of specialist doctors working in the public and private sectors increased, unlike in the university hospital (TÜİK, 2019).

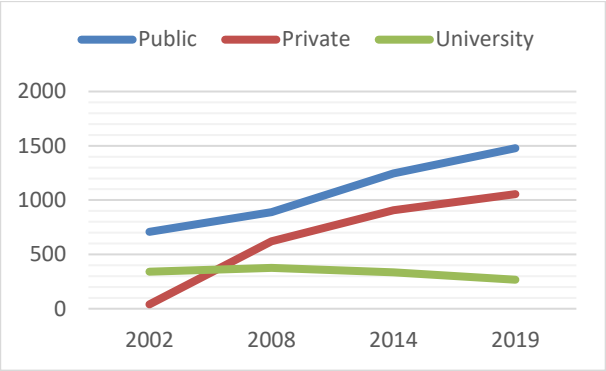

Figure 3.1: The numbers of specialist doctors by sectors.

The number of hospitals in Bursa by sectors is given in the chart below (Figure 3.2). In the last two years, unlike the university and public hospitals, there has been a massive increase in private hospitals (TÜİK, 2019).

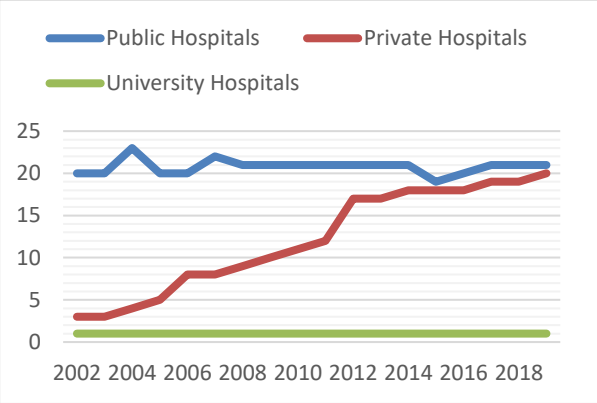

Figure 3.2: The number of hospitals in Bursa by sectors.

According to health statistics in 2019, the bed capacities and the hospital numbers by sectors are given in the table below (Table 3.4). Although the number of public and private hospitals is almost the same, there is a big difference in their bed capacities (TÜİK, 2019).

Table 3.4: The bed capacities and the hospital numbers by sectors.

	Bed Capacity	Number of Hospitals
Public Hospitals	5696	21
Private Hospitals	1487	20
University Hospital	896	1

The number of beds (in public hospitals) per 10.000 people by counties is given in the table below (Table 3.5). According to this table, it can be seen that the highest value is in Nilüfer and İznik districts and the lowest value is in Gürsu and Mudanya districts. These values can be seen comparatively in the map below (Figure 3.3).

Table 3.5: The number of beds per 10.000 people by counties.

Counties	Beds per 10.000
Büyükorhan	10,5
Gemlik	22,6
Gürsu	7,7
Harmancık	16,3
İnegöl	11,8
İznik	30,6
Karacabey	19,8
Keles	21,7
Kestel	21,2
Mudanya	9,8
Mustafakemalpaşa	24,7
Nilüfer	37
Orhaneli	26,2
Orhangazi	13,7
Osmangazi	10,7
Yenişehir	20,3
Yıldırım	15,8

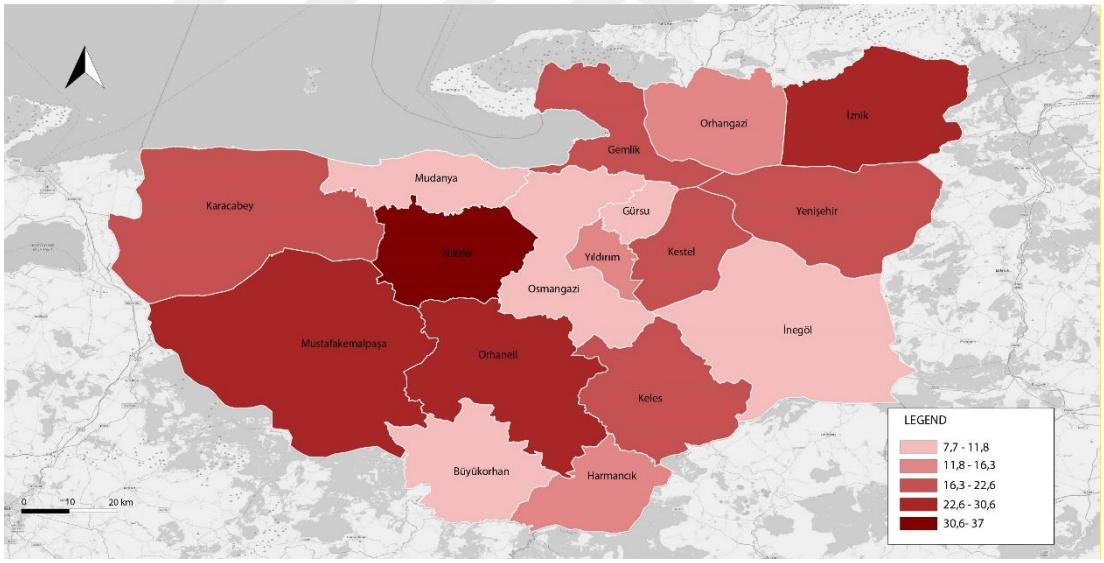

Figure 3.3: The number of beds per 10.000 people by counties.

The number of patients who went to health facilities and inpatients within a year (Ministry of Health, 2019) is given in the table below (Table 3.6). According to these statistics, the number of applications to hospitals providing inpatient treatment is higher than the applications to primary health facilities.

Table 3.6: Patient statistics in Bursa (2019).

The number of visits to a doctor in primary health facilities	12.932.210
The number of visits to a doctor in second and third stage hospitals	18.091.386
The number of visits to a doctor (per person in a year)	10,2
Inpatient number	490.688

3.1.1 Spatial distribution of the health facilities

In this part, primary healthcare facilities, general hospitals, branch hospitals, private hospitals (general and branch), training research hospitals, and university hospitals are shown in the figures. Family health centers, community health centers, and migrant health centers are considered as the primary health facilities. The location of these facilities can be seen in the figure below (Figure 3.4). This map was created by using BBB's open source data.

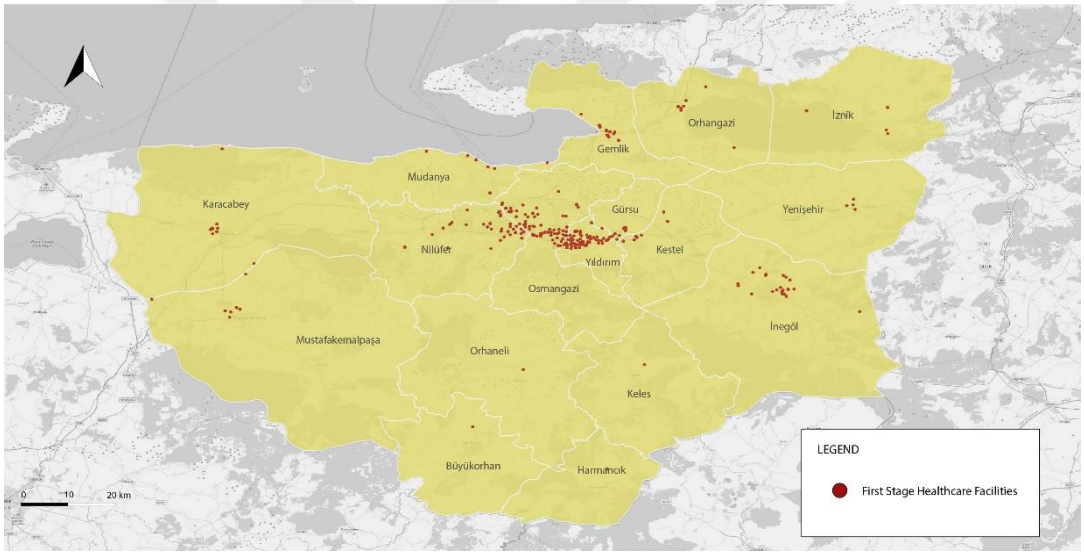

Figure 3.4: Spatial distribution of the primary health facilities in Bursa.

According to the map of primary health centers distribution, it can be seen that the facility numbers show parallelism with the population sizes. Osmangazi, Yıldırım, and Nilüfer are densely populated areas, also they are areas with the highest facility number. Orhaneli, Büyükorhan, Harmancık, and Keles have only one primary health facility, also they are underpopulated districts.

To examine the locations of private health institutions, only institutions with hospital status were considered. Since private polyclinics and health centers do not provide inpatient treatment and do not have hospital status, they were not included in the map.

In this context, the locations of private branch and general hospitals providing inpatient treatment are given in the figure below (Figure 3.5).

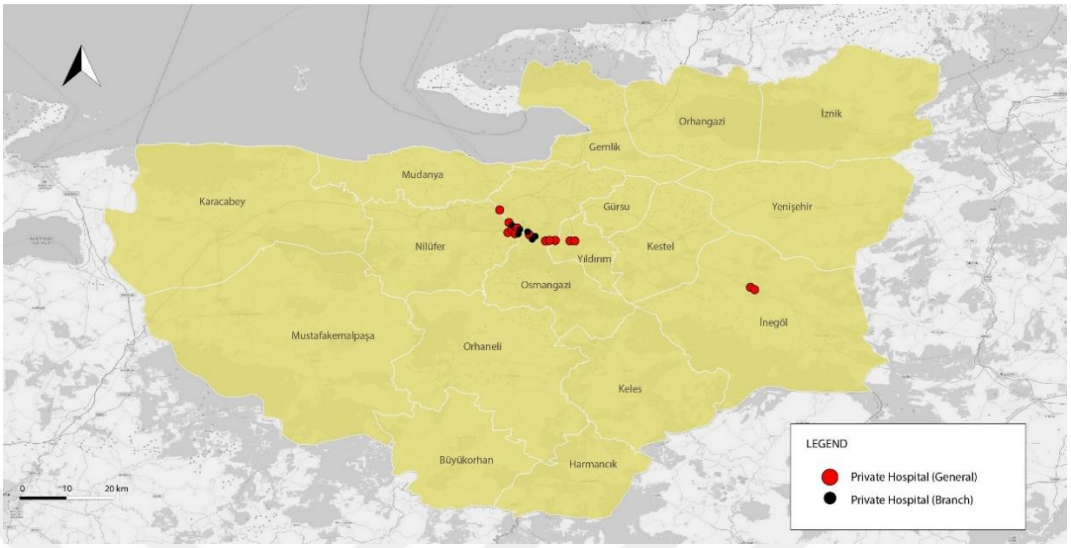

Figure 3.5: Private hospitals in Bursa (This map was created by using Provincial Directorate of Health of Bursa's current private hospitals list).

According to the map of private hospitals, they are located in the over populated districts, Osmangazi, Yıldırım, Nilüfer, and İnegöl. It can be seen that, the private hospitals aggregated in the zone between Osmangazi and Nilüfer.

The university hospital and the public hospitals providing inpatient treatment are given in the figure below (Figure 3.6). General, branch, additional service buildings of the general hospitals, and integrated district hospitals were considered as the public hospitals. Health institutions that have buildings but are not actively serving are not included in the map.

According to this map, general hospitals serving the city are located in Osmangazi, Nilüfer, and Yıldırım, likewise the branch hospitals and their additional service buildings are in these districts. The university hospital and the city hospital are in Nilüfer, the training and research hospital is in Yıldırım and the general hospital that has a secondary health facility statue is in Osmangazi. In Büyükorhan, Keles, and Harmancık, since they are under-populated, integrated district hospitals are located there.

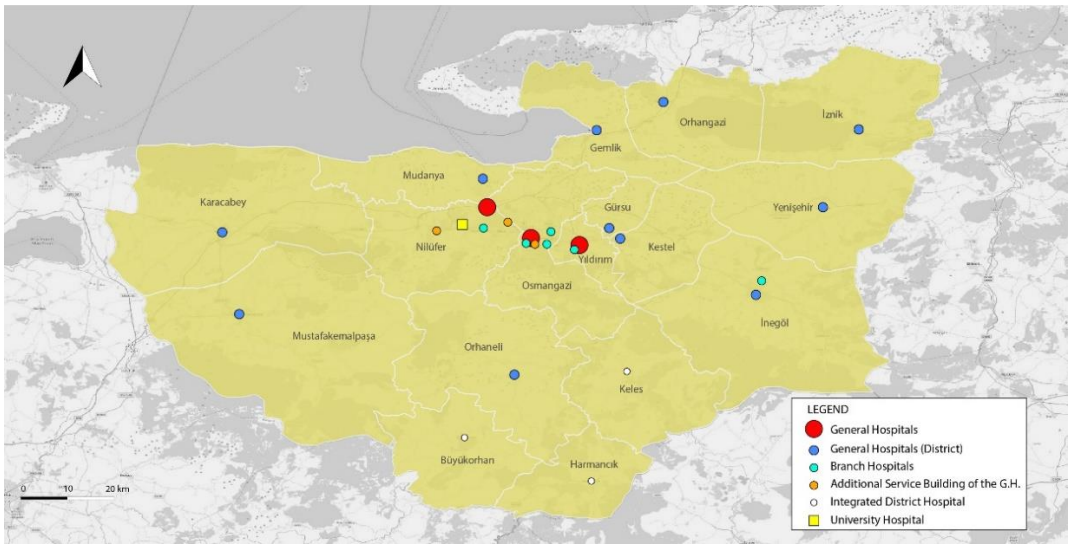

Figure 3.6: University hospital and public hospitals in Bursa (This map was created by using Provincial Directorate of Health of Bursa's current public hospitals and integrated district hospitals list).

In the land use plan that is given below, a new health area north of the current general hospital can be seen (Figure 3.7). According to the statements of the authorities, its bed capacity is 1315 and it will be opened in 2023. Also, when the construction of this hospital is completed, the only public general hospital in Osmangazi will move to this building (Url-3).

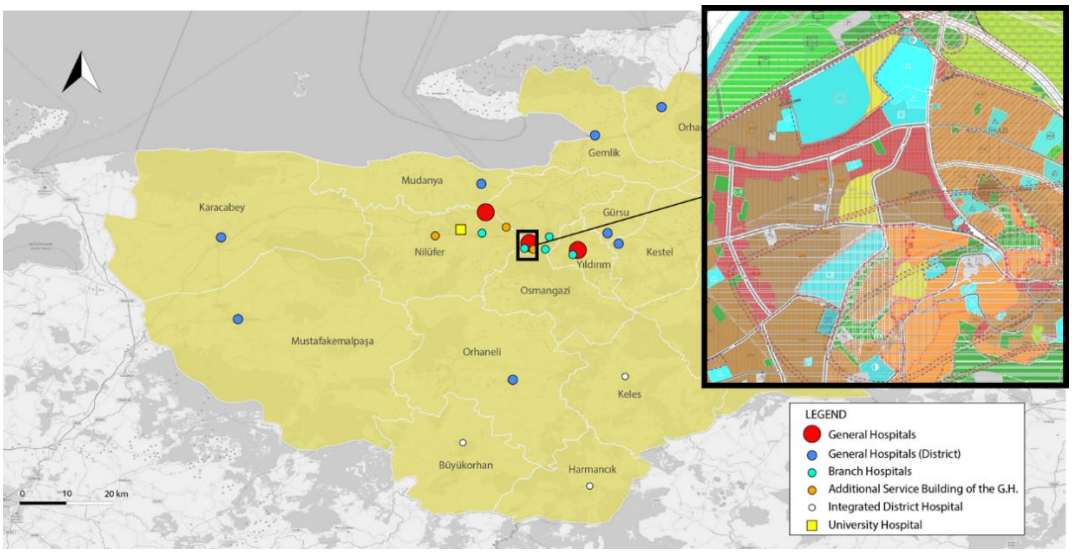

Figure 3.7: The new hospital in the land use (master development) plan.

3.2 Transportation in Bursa

Bursa has many public transportation opportunities, but the subway network is the main axis of urban transportation. In 2019, passenger number in the bus network (with

1418 vehicles) is 95.091.055, passenger number in subway (light rail system with 38 stops) is 89.901.804.

Distribution of the transportation behaviors can be seen in the chart below (Figure 3.8). According to the Transportation Master Plan of Bursa, the use of private vehicles shows a tendency to increase, on the other hand the ratio of public transportation and pedestrians shows a tendency to decrease.

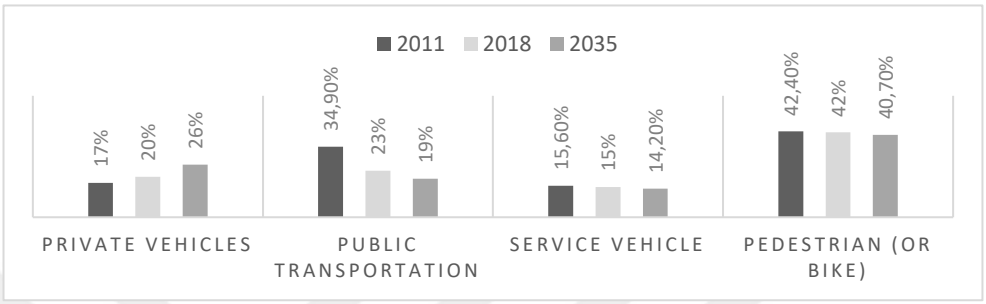

Figure 3.8: Distribution of travel types in Bursa.

According to the Transportation Master Plan of Bursa, new railway axes are planned to northern Osmangazi and east-west direction of the city. It can be seen that it will provide access to organized industrial zones in the east and west of the city, the city hospital and southwestern Nilüfer by extending the existing rail system. A new rail system axis can be seen from southern Nilüfer to the center of Gürsu district and northern Osmangazi (Figure 3.9).

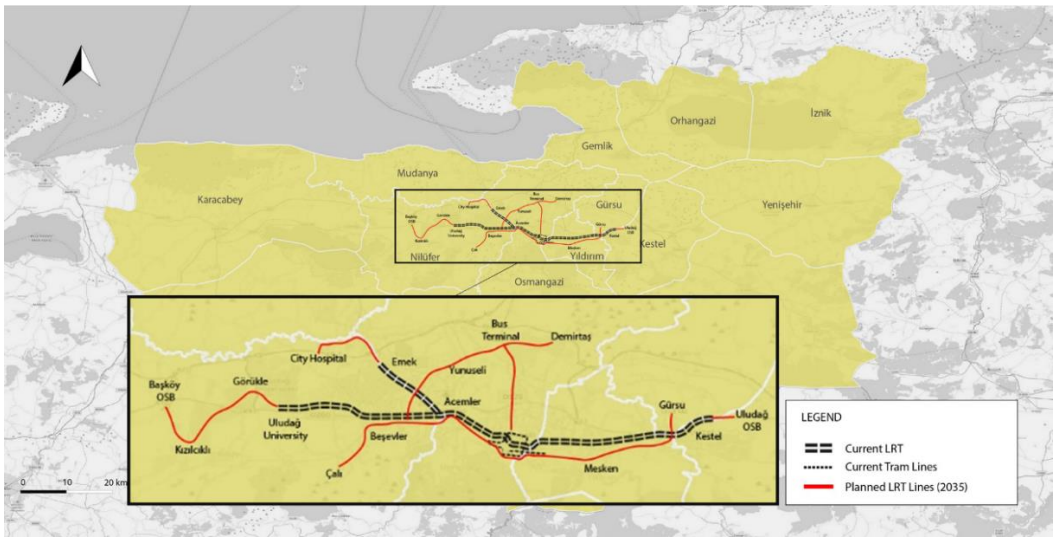

Figure 3.9: Current and planned railway axes in Bursa (The map was created by using "Transportation Master Plan of Bursa 2035" data obtained from the web page of Boğaziçi Proje AŞ.).

3.3 Demographic Structure of the Bursa and the Counties

Bursa is located in Marmara Region in northwestern Turkey. It is Turkey's fourth largest city in terms of population size. The increase in the population by years is given in the chart below (Figure 3.10).

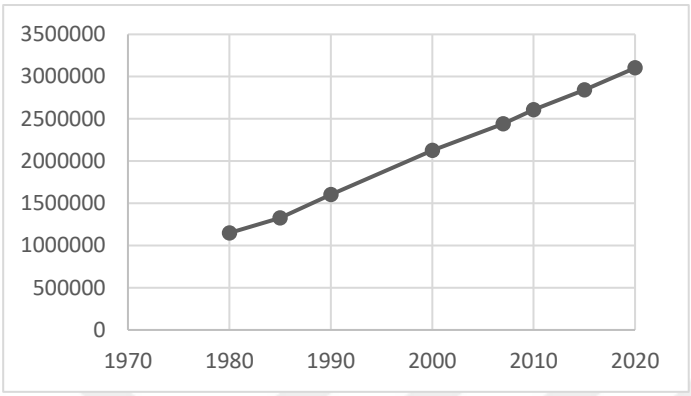

Figure 3.10: Population of Bursa by years.

Bursa has 17 counties, Osmangazi, Yıldırım, Nilüfer, Mudanya, Gürsu, Kestel, and Gemlik are the central area of the city. The population sizes of all the counties of Bursa (TÜİK, 2020) are given in the table below (Table 3.7).

Table 3.7: Population of the counties.

Counties	Population
Büyükorhan	9.485
Gemlik	115.404
Gürsu	96.985
Harmancık	6.145
İnegöl	281.384
İznik	44.102
Karacabey	84.666
Keles	11.499
Kestel	70.865
Mudanya	102.523
Mustafakemalpaşa	101.820
Nilüfer	484.832
Orhaneli	19.055
Orhangazi	80.118
Osmangazi	881.459
Yenişehir	54.315
Yıldırım	657.176

Population density of the counties are shown in the map below (Figure 3.11). According to the map, counties with the highest density are Osmangazi, Yıldırım,

Nilüfer, and Gürsu. Keles, Orhaneli, Büyükorhan, and Harmancık districts have lowest density.

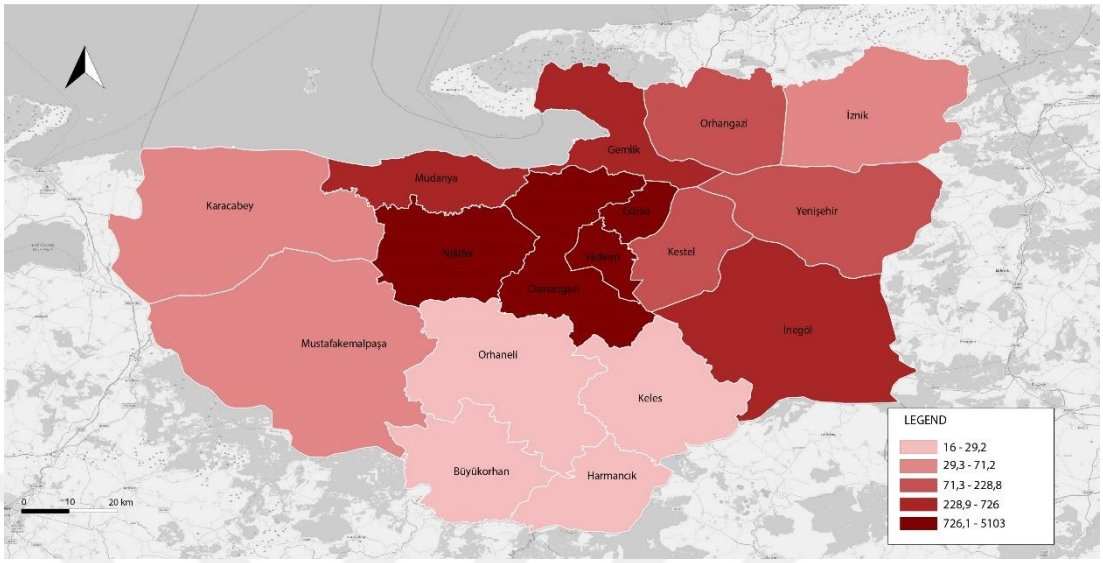

Figure 3.11: Population density (people per km^2 of county area) of the counties.

The dependent population can be defined as the people under the age of 15 and over the age of 65. These people are not in the labor force, in other words they are not included in the economically active population. The dependency ratio in Bursa (TÜİK, 2020) is given in the table below (Table 3.8).

Table 3.8: Child and elderly dependency ratio in Bursa.

Counties	Child (%)	Elderly (%)
Büyükorhan	21,35	46,73
Gemlik	27,74	16,71
Gürsu	37,34	9,29
Harmancık	18,45	42,37
İnegöl	35,63	11,75
İznik	24,61	23,06
Karacabey	29,46	20,09
Keles	16,74	48,78
Kestel	30,99	13,82
Mudanya	22,98	22,66
Mustafakemalpaşa	26,76	22,35
Nilüfer	28,64	10,66
Orhaneli	24,07	35,93
Orhangazi	28,73	17,18
Osmangazi	30,77	12,75
Yenişehir	28,95	22,62
Yıldırım	33,71	12,4

The total dependency ratio in the counties of Bursa can be seen in the map below (Figure 3.12). Accordingly, Orhaneli, Keles, Büyükorhan, and Harmancık have the highest dependency ratio. Nilüfer, Osmangazi, Kestel and Gemlik have the lowest dependency value. It can be said that the dependency ratio has decreased in the central districts.

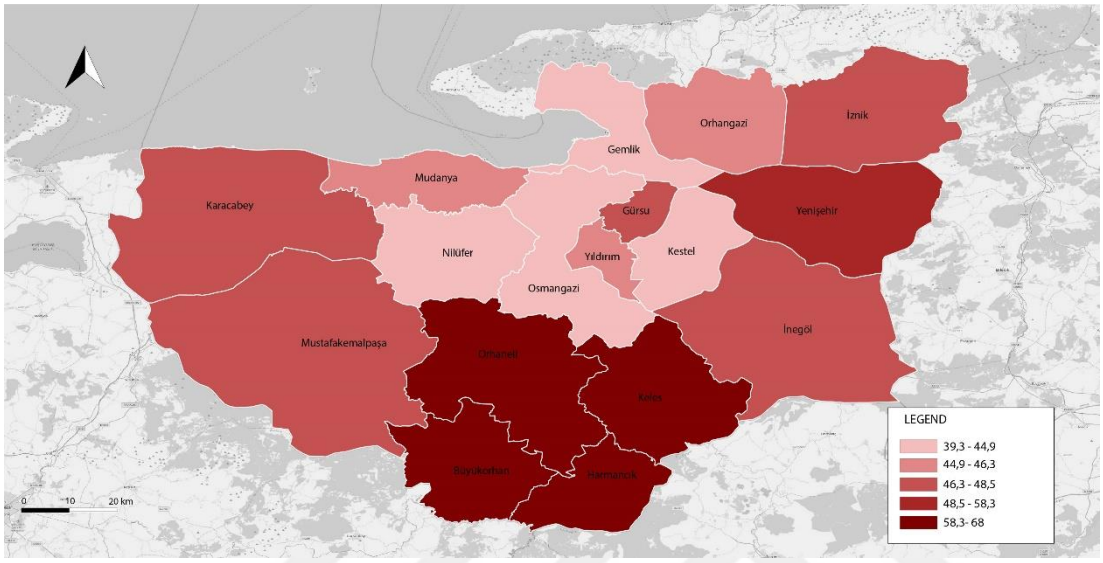

Figure 3.12: Total dependency ratio in Bursa.

3.4 Economic Structure of Bursa

According to the 2019 statistics of the Ministry of Health, the distributions of patients by sectors countrywide are given in the charts below. The general health insurance contains the services received from universities (mostly) and public hospitals in Turkey, but an additional fee must be paid for the private hospitals. Therefore, there can be a correlation between private hospital preference and income level. The research conducted by Paköz and Yüzer (2014) in Istanbul indicates that income level affects the hospital preference. According to this research, affordability and accessibility are important for low and middle-income users. On the other hand, acceptability of the service is more important for high-income users (Paköz and Yüzer, 2014).

Considering the diagram below, it can be seen that the percentage of inpatients in the private hospital preference is larger than the total visitation percentage (Figure 3.13). Although the economic situation of the individual is a significant factor in accessing health services, the income level may not directly affect the hospital preference.

Factors such as the hospital's qualifications or the individual's health insurance may affect the hospital choice apart from the income level. For example, private health insurance (or supplementary health insurance) for the employed population can be provided as a side benefit by their institution independently of the salary range. Supplementary health insurance is valid in private health institutions contracted with the Social Security Institution (SGK) and covers treatment expenses exceeding the coverage limits of SGK. Private health insurance is a type of insurance that covers the health costs and has personalized insurance policies. For this reason, the ownership of private health insurance (or supplementary health insurance) is a more determinative factor to choose a hospital than the income level of the patient.

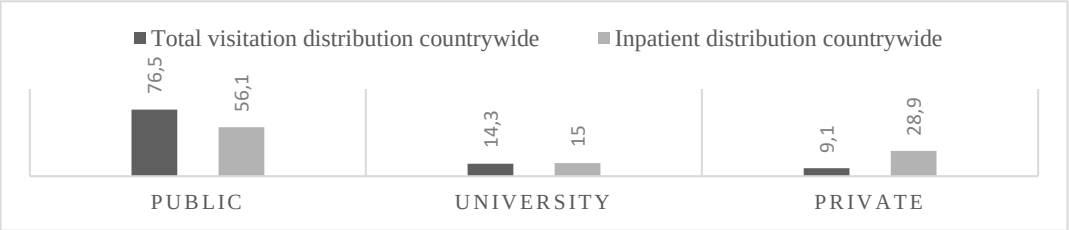

Figure 3.13: Total visitation and inpatient distribution countrywide (%) (Ministry of Health, 2019).

Private and supplementary health insurance are considered as the measurement of the economic structure of Bursa. PSHI owner ratios are given in the map below (Figure 3.14).

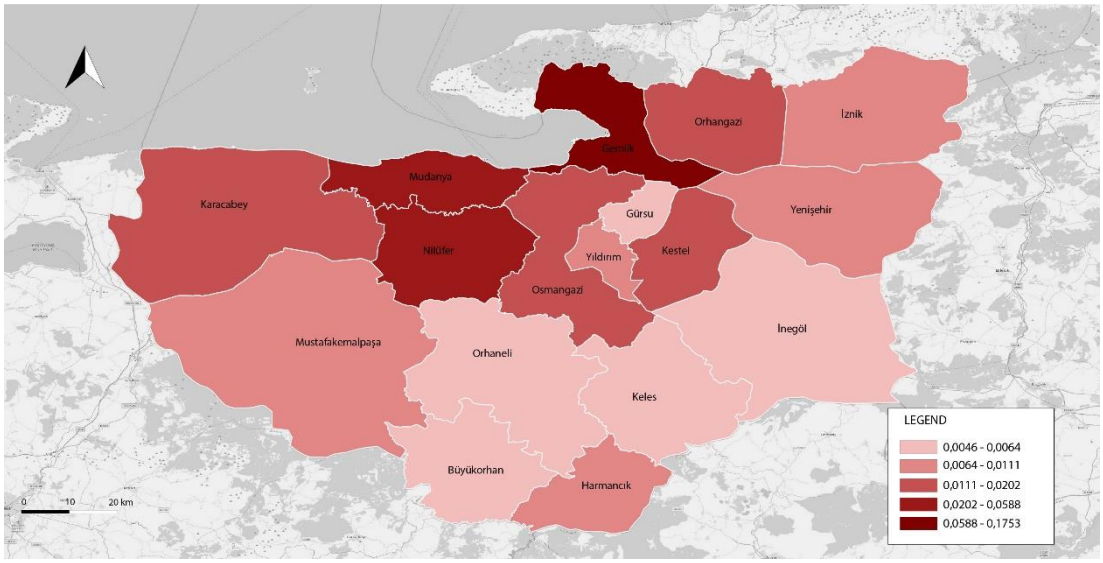

Figure 3.14: Distribution ratios of the PSHI owners.

According to the map, Gemlik, Nilüfer, and Mudanya have the highest PSHI owner ratio and Gürsu, Büyükorhan, Orhaneli, Keles, and İnegöl have lowest value.

4. HIERARCHICAL HEALTH FACILITY LOCATION MODEL ACCORDING TO USER DEMAND

The stages of the model are shown in the flowchart below (Figure 4.1). In the first step, the criteria of the model, the number of facilities and their sizes are determined. In the second step, different hospital demand types are calculated. In the third step, the total hospital demand of each sub-region is calculated through weighting the hospital demands.

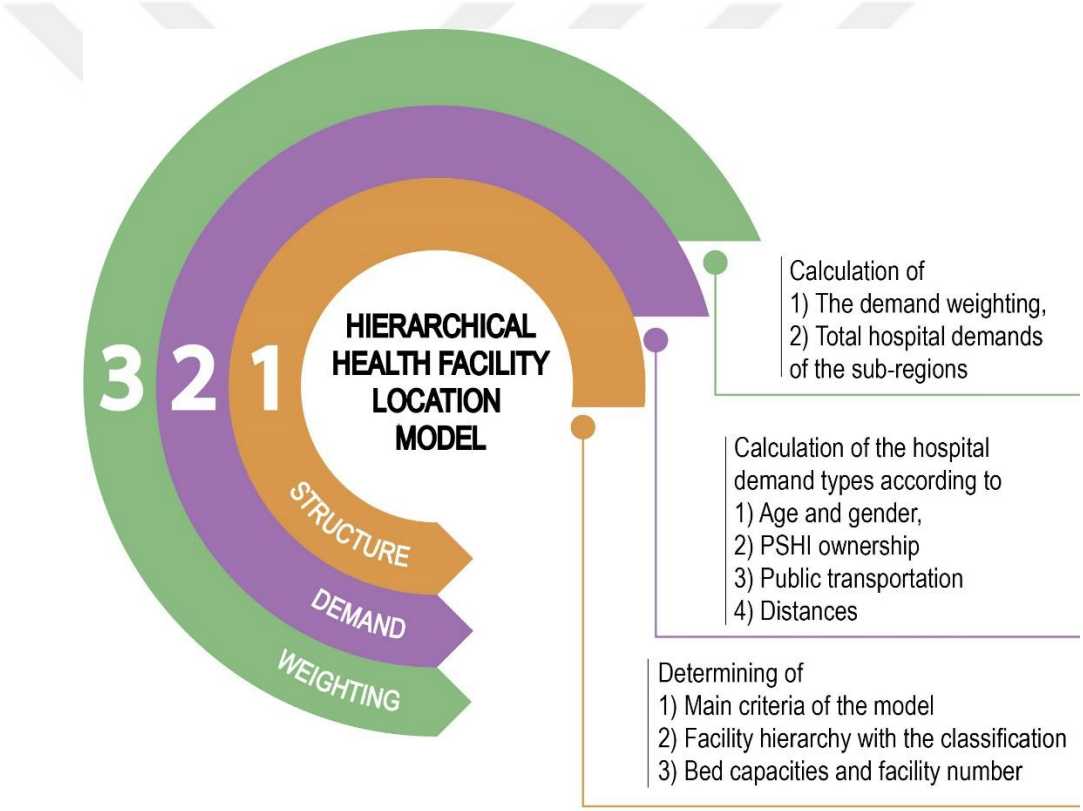

Figure 4.1: Stages of the hierarchical health facility location model.

4.1 Model Structure

In this section, the characteristics of the hierarchical hospital model that will be designed within the boundaries of the study area are determined. Before the hierarchical hospital model was planned, the main criteria related to demand types were determined. The criteria were determined considering the literature review on

subjects such as the location of public facilities and the hierarchical structure in health facilities. The demand types and the criteria are given in the table below (Table 4.1).

Table 4.1: The hospitals' main criteria related to demand types.

Hospital Demand Types	Criteria
Based on Age-Gender	Availability of the service, minimum waiting time Scope of the service, sufficient bed capacity
Based on PSHI Ownership	Affordable health service
Based on Public Transportation	Transportation opportunities, minimum travel cost
Based on Distance	Minimum travel time

In this study, the hierarchical system of health care facilities is designated as three-stage. The number of stages is based on the grouping made by the Ministry of Health about healthcare institutions. According to the ministry's classification, the primary health care institutions comprise of the facilities that serve basically. Since these facilities are the smallest units, they are located in the scale of the neighborhood. However, these facilities are not included in the hierarchical system in this study due to Bursa province's large scale. A three-stage model is designated from the secondary and tertiary health care institutions determined by the ministry. The tertiary health care institutions are divided into two parts according to the region they serve. These two parts form the second and third-stage of the model. For instance, high-capacity hospitals serving the city will constitute the second-stage and the institutions that serve the large scale region will form the third-stage. Branch distributions of the facilities within the hierarchical system must also be compatible with each other. Therefore, the hierarchy includes general hospitals and high capacity hospitals. In the hierarchical system, minimum bed capacity is specified for each stage. These minimum values are determined through examining current bed capacities of the hospitals in Bursa (Table 4.2).

Table 4.2: Facility hierarchy in the model.

Stages	Hospital Types in Regional Health Planning Circular	Bed Capacity
First Stage	C, B	50+
Second Stage	B, A2	500+
Third Stage	A2, A1	1000+

In order to examine how the health standards are different, some statistics for Bursa province are compared with Turkey and other countries. According to the data of the WHO, there were 28.5 hospital beds per 10,000 people in Turkey in 2018. It increased

to 28.6 in 2019. (Health Statistics Yearbook, 2019). The graph of the number of beds per 10,000 in Turkey and other OECD countries is given below (Figure 4.2). Years show WHO's the last update date on that country (WHO, 2018). WHO has not recommended a universal norm of optimum bed number.

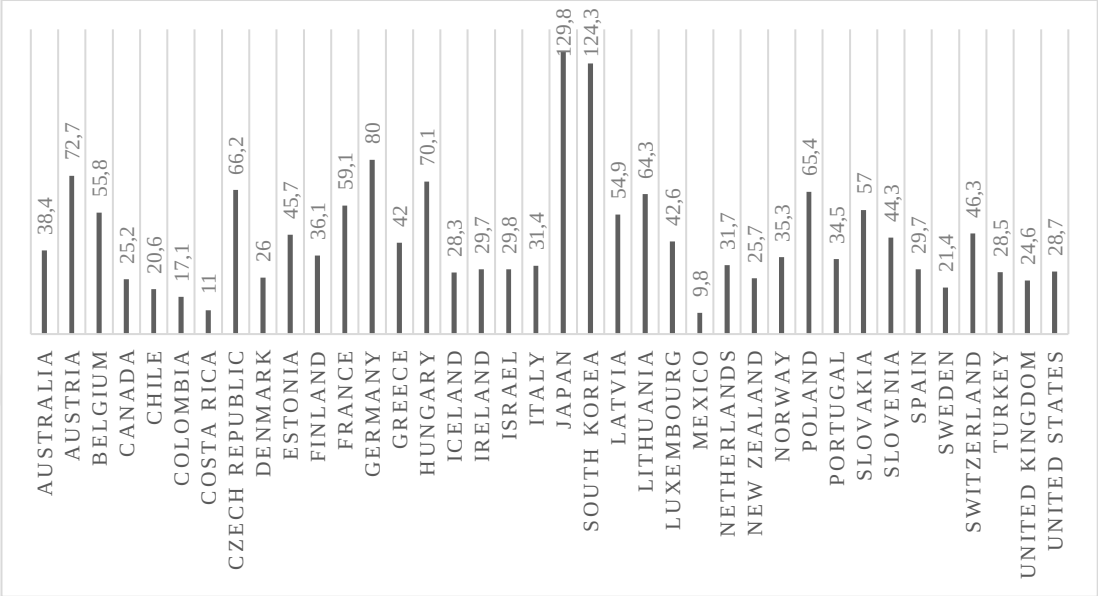

Figure 4.2: The number of beds per 10.000 in OECD countries.

According to the TÜİK, the number of beds per 10.000 in Bursa is 26,4. In the health statistics of Bursa, the total number of hospitals is 42, the number of beds is 8.079, and the total number of doctors per 1.000 is 1.7. Since the OECD countries' average bed capacity (per 10.000) is 44,31, the estimated number of beds per 10.000 will be calculated as 44 in the model to be structured for Bursa (Table 4.3).

Table 4.3: Calculation of bed capacity in the model.

Bed Capacity	Current (Bursa)	Model (Study Area)
Number of Beds per 10.000	26,4	44
Total Bed Capacity	8.079	10.092
Public Facilities' Bed Capacity	5.696	7.064,4

4.1.1 Calculation of the health facility number

The study area was divided into sub-regions in order to determine the number of facilities in the model. The number of facilities are determined according to the bed capacities in the hierarchy. Average bed capacity values in the model were determined considering lower and upper limits of current bed capacities in the study area. First of all, the number of first stage facilities and the number of third stage facilities were determined (Table 4.4). Since the study area has 9 zones, it is assumed that each zone

has a first stage facility. The average bed capacity is determined as 250. The third stage facility is described as comprehensive and serving the metropolitan area. It contains a regional hospital or high capacity education and research hospital, thus it is limited as one facility. Its average bed capacity is determined as 1500. Herewith 3314 beds remaining for second stage facilities. Since the average bed capacity of a second stage facility is 750, the number of these facilities is calculated as 4.

Table 4.4: Average bed capacity and number of facility in the hierarchical system.

Types	Average Bed Capacity	Number
First Stage	250	9
Second Stage	750	4
Third Stage	1.500	1

4.1.2 Size of the health facilities

In Construction of Spatial Plans Regulation, the required sizes of health facilities are classified considering the population they serve and the type of facility. The size of "Public Hospital" that is given in the regulation is assumed equal to the first and second stage hospitals in the model. The size given for "Health Campuses" is taken for the third stage facility.[2] Since the bed capacity of the facilities is determined, the calculation required area in square meters for each type of facility is given below (Table 4.5).

Table 4.5: Required area for each type of facility.

	First Stage Hospital	Second Stage Hospital	Third Stage Hospital
Total bed capacity	1.250	3.314	1.500
Minimum unit area	130 m^2 per bed	130 m^2 per bed	220 m^2 per bed
Required area	18.055 m^2 per facility	107.707 m^2 per facility	330.000 m^2 per facility
Total required area	162.500 m^2	430.830 m^2	330.000 m^2

4.2 Hospital Demand

The hospital demand is processed in three themes. First theme is demographic structure. In this part, official statistics were examined in order to analyze demographic factors in the health service demand. The demand can be described as the inpatient distribution of the zones. Inpatient characteristics of the zones will be

[2] See Table A.2 for some current hospitals building areas.

analyzed according to age and gender factors. Second theme is economic structure. In this part, the hospital demand is correlated with private health insurance ownership. In other words, it can be assumed that there will be an inverse proportion between private health insurance and public hospital preference. Thus, the demand will be calculated through insurance data. Third theme is spatial accessibility. In this part, the hospital demand is defined in two ways; distance based and public transportation based. In the first one, the distances of the sub-regions to each other are considered. In the second one, the radius of the reference public transport line is examined.

4.2.1 Demographic structure: age and gender

In this part, official statistics were examined in order to analyze demographic factors in the health service demand. The demand can be described as the inpatient distribution of the zones. Inpatient characteristics of the zones will be analyzed according to age and gender factors (Paköz, 2014).

According to TÜIK's health statistics (2019), the inpatient women's ratio is higher in the group younger than 55. The inpatient men's ratio at the age after 55 is increasing and the demand is balanced. The distribution of the number of people who received minimum one night inpatient treatment at the hospital in Turkey with gender and age group is given in the table below (Table 4.6). Since there is no data scale of province, these percentages are considered for Bursa.

Table 4.6: The gender and age distribution of inpatients.

Age Group	<15	15-24	25-34	35-44	45-54	55-64	65-74	75+
Male (%)	0,9	2,9	2,6	3,7	4,6	7,1	9,2	12,1
Female (%)	8,2	3,6	7,1	5,3	5,5	6,5	9,2	11,6
Total (%)	9,1	6,5	9,7	9,0	10,1	13,6	18,3	23,7

Numerical values in Table 4.6 and population distribution (see Table A.1) according to age and gender are transformed decimals to use in the demand function (Table 4.7).

The inpatient number in Bursa is given in Table 3.6. Since the population of the study area is 74% of the Bursa, it is estimated 74% of the inpatients in the study area. According to Figure 3.13, inpatient ratio is increased as against patient ratio in private hospitals. Thus, the inpatient number must be calculated specific to the public hospitals. In the Ministry of Health's statistics, sectoral distribution of the inpatients is given in the scale of Eastern Marmara Region. According to the statistics, 57,4% of

the inpatients are treated in public hospitals. It is accepted for Bursa and 57,4% of the estimated inpatient number in the study area is calculated as 208.424.

Table 4.7: Decimal values of the distributions according to age and gender.

Zones	Gender	Distribution of the Population According to Age Groups (P)							
		<15 (b_1)	15-24 (b_2)	25-34 (b_3)	35-44 (b_4)	45-54 (b_5)	55-64 (b_6)	65-74 (b_7)	75+ (b_8)
Gürsu	Female	0,0053	0,0031	0,0035	0,0033	0,0024	0,0019	0,0010	0,0005
	Male	0,0055	0,0031	0,0036	0,0035	0,0025	0,0019	0,0008	0,0003
Kestel	Female	0,0032	0,0020	0,0024	0,0024	0,0020	0,0017	0,0010	0,0006
	Male	0,0034	0,0021	0,0024	0,0025	0,0021	0,0017	0,0009	0,0004
Mudanya	Female	0,0034	0,0025	0,0030	0,0035	0,0034	0,0034	0,0024	0,0013
	Male	0,0036	0,0026	0,0029	0,0033	0,0030	0,0031	0,0023	0,0010
Nilüfer	Female	0,0212	0,0146	0,0174	0,0200	0,0144	0,0101	0,0058	0,0029
	Male	0,0223	0,0147	0,0165	0,0193	0,0147	0,0101	0,0054	0,0020
Osmangazi	Female	0,0400	0,0258	0,0296	0,0322	0,0255	0,0192	0,0120	0,0074
	Male	0,0424	0,0270	0,0301	0,0330	0,0264	0,0189	0,0101	0,0046
Yıldırım	Female	0,0321	0,0201	0,0216	0,0230	0,0179	0,0142	0,0086	0,0050
	Male	0,0340	0,0215	0,0223	0,0234	0,0184	0,0137	0,0074	0,0033
Gender		Distribution of the Inpatients According to Age Groups (T)							
Female		0,0820	0,0364	0,0708	0,0531	0,0545	0,0653	0,0915	0,1161
Male		0,0090	0,0286	0,0262	0,0369	0,0465	0,0707	0,0915	0,1209

Demand Function

First step is calculation of female and male inpatient activity in site i.

- $\mathbf{A^P_{hi}}$ **:** Total inpatient activity according to age and gender in site i
- $\mathbf{A_{fi}}$ **:** Female inpatient activity according to age in site i
- $\mathbf{A_{mi}}$ **:** Male inpatient activity according to age in site i
- $\mathbf{P_{fib}}$ **:** Decimal number of female population in site i in b age group
- $\mathbf{P_{mib}}$ **:** Decimal value of male population in site i in b age group
- $\mathbf{T_{fb}}$ **:** Decimal value of female inpatient in b age group
- $\mathbf{T_{mb}}$ **:** Decimal value of male inpatient in b age group

Total inpatient activity in site i is given in 4.1.

$$A_{hi}^{P} = A_{fi} + A_{mi} \tag{4.1}$$

The female inpatient activity in site i is given in equation 4.2 below.

$$A_{fi} = \sum_{b=1}^{n} P_{fib} T_{fb} \tag{4.2}$$

The male inpatient activity in site i is given in equation 4.3 below.

$$A_{mi} = \sum_{b=1}^{n} P_{mib} T_{mb} \tag{4.3}$$

Second step is calculation of the hospital demand according to age and gender in site i. The function is given in equation 4.4 below.

- $\mathbf{D^{P}_{hi}}$ **:** The hospital demand according to age and gender in site i
- $\mathbf{A^{P}_{hT}}$ **:** Total inpatient activity according to age and gender in study area
- $\mathbf{P_{Ti}}$ **:** Decimal value of the site i population in the study area population
- $\mathbf{F_{T}}$**:** Inpatient number in the study area (208.424)

$$D^{P}_{hi} = \frac{1}{A^{P}_{hT}} P_{Ti} F_{T} \tag{4.4}$$

In this step the inpatient number in the study area is distributed to the zones' inpatient activities. Thus, an estimated inpatient number of each zone can be obtained. As an example, hospital demand of Gürsu district is calculated in equation 4.5 in four steps below.

$$\begin{gathered} A_{fG} = P_{fGb1}T_{fGb1} + P_{fGb2}T_{fGb2} + P_{fGb3}T_{fGb3} + P_{fGb4}T_{fGb4} + P_{fGb5}T_{fGb5} + \\ P_{fGb6}T_{fGb6} + P_{fGb7}T_{fGb7} + P_{fGb8}T_{fGb8} \\ A_{fG} = (0{,}0053) \times (0{,}0820) + (0{,}0031) \times (0{,}0364) + (0{,}0035) \times (0{,}0708) \\ + (0{,}0033) \times (0{,}0531) + (0{,}0024) \times (0{,}0545) + (0{,}0019) \times (0{,}0653) + \\ (0{,}0010) \times (0{,}0915) + (0{,}0005) \times (0{,}1161) \end{gathered} \tag{4.5a}$$

$$\begin{gathered} A_{mG} = P_{mGb1}T_{mGb1} + P_{mGb2}T_{mGb2} + P_{mGb3}T_{mGb3} + P_{mGb4}T_{mGb4} + \\ P_{mGb5}T_{mGb5} + P_{mGb6}T_{mGb6} + P_{mGb7}T_{mGb7} + P_{mGb8}T_{mGb8} \\ A_{mG} = (0{,}0055) \times (0{,}0090) + (0{,}0031) \times (0{,}0286) + (0{,}0036) \times \\ (0{,}0262) + (0{,}0035) \times (0{,}0369) + (0{,}0025) \times (0{,}0465) + (0{,}0019) \times \\ (0{,}0707) + (0{,}0008) \times (0{,}0915) + (0{,}0003) \times (0{,}1209) \end{gathered} \tag{4.5b}$$

$$\begin{gathered} A^{P}_{hG} = A_{fG} + A_{mG} \\ A^{P}_{hG} = 0{,}001373 + 0{,}000731 = 0{,}002105 \end{gathered} \tag{4.5c}$$

$$D_{hG}^{P} = \frac{1}{0{,}051525209}\ (0{,}002104557)\ (208.424) = 8513 \qquad (4.5d)$$

This function is used in all the zones and the demand values are given in the table below (Table 4.8). Demand indexes in the table are obtained through calculating percent values of each row.

Table 4.8: The hospital demands according to age and gender.

Zones	Activity	Demand*	Distribution Rate of the Demand
Gürsu	0,002105	8512,3	0,04
Kestel	0,001617	6541,6	0,03
Mudanya	0,002539	10269	0,05
Nilüfer	0,010779	43596	0,21
Osmangazi	0,01983	80208	0,39
Yıldırım	0,014656	50277	0,28
Total	0,051526	208404	1

* Some decimal values are converted to whole number in the calculation.

The number of inpatients (demand value) were distributed according to the population size, for the northern and southern zones in the total demand calculation. The demand distribution can be seen in the map below (Figure 4.3).

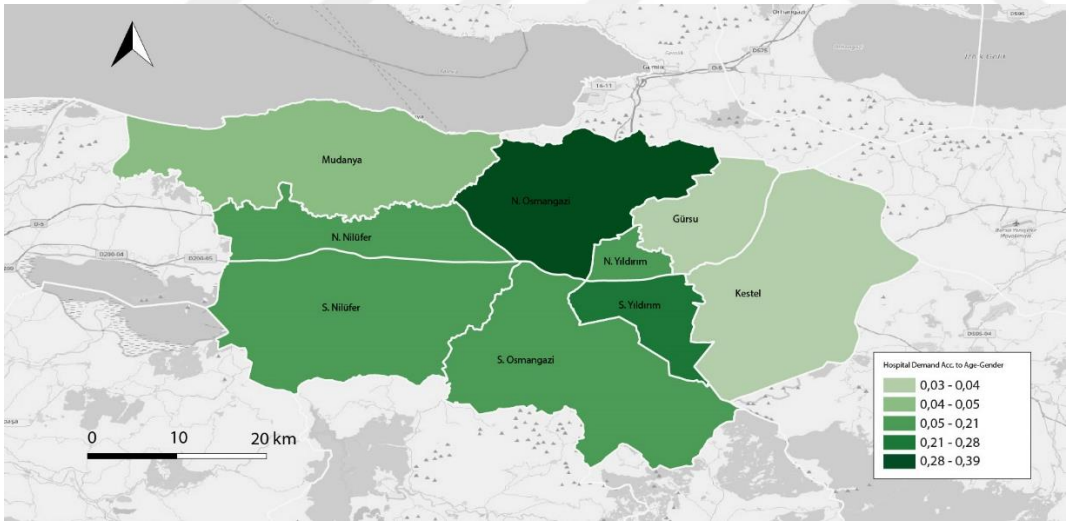

Figure 4.3: The hospital demands according to age and gender.

4.2.2 Economic structure: private and supplementary health insurance

The private hospital tendencies of the patients are analyzed in order to evaluate the public hospital demands of the sub-regions. In this particular, the demand is calculated through the ownership of private and supplementary health insurance (PSHI). PSHI

owner numbers used in this calculation are obtained from the Insurance Information and Monitoring Center.

The numbers of consulting a doctor and how many times a person consults a doctor are given in Table 3.6. Accordingly, the patient number can be estimated through dividing the number of consultations by the number of how many times a person consults. Since the population of the study area is 74% of the Bursa, it is estimated 74% of the patients in the study area. According to these calculations the estimated patient number is 1.312.512.

Demand Function

- **D^I_{hi} :** Hospital demand according to PSHI ownership in site i
- **I_{ti} :** Number of private and supplementary health insurance owners in site i
- **F_{pi} :** Estimated patient number of site i
- **f_i** : Distribution ratio of the estimated patient number of site i (in study area)

Inputs of the hospital demand calculation according to PSHI ownership are given in the table below (Table 4.9).

Table 4.9: Demand inputs of the calculation according to PSHI ownership.

Sub-Regions	Estimated Patient Number (F_p)	Distribution Ratio of the Estimated Patient Number (f)	PSHI Ownership (I_t)
Gürsu	55457	0,04	623
Kestel	40521	0,03	1.037
Mudanya	58624	0,05	2.920
N. Nilüfer	169100	0,13	17.403
S. Nilüfer	108126	0,08	11.127
N. Osmangazi	400959	0,31	14.256
S. Osmangazi	103066	0,08	3.564
N. Yıldırım	137198	0,1	2.693
S. Yıldırım	238583	0,18	4.585

Calculation of the hospital demand according to PSHI ownership in site i is shown in equation 4.6a.

$$D^I_{hi} = \frac{1}{F_{pi}} I_{ti} f_i \qquad (4.6a)$$

As an example, the hospital demand of Gürsu district is calculated in 4.6b. This function is used for all the zones and the values are given in Table 4.10.

$$D_{hG}^{I} = \frac{1}{55.457}\ 623\ x\ 0{,}04 = 0{,}0004493 \qquad (4.6b)$$

The number of patients and PSHI ownership in the northern and southern zones in the table are distributed according to the population. Demand indexes for private hospitals are in the "Hospital Demand Indexes According to PSHI" column. It can be assumed that there is an inverse proportion between the preference of private and public hospitals. Therefore, a new index column (Distribution Ratio of the Demand) was created for the preference of public hospitals by inverse proportioning between the two values.

Table 4.10: The hospital demand according to PSHI.

Sub-Regions	Hospital Demand Indexes According to PSHI (D^{I}_{h})	Distribution Ratio of the Demand (for Public Facilities)
Gürsu	0,00044936	0,41
Kestel	0,00076774	0,24
Mudanya	0,00249045	0,07
N. Nilüfer	0,01340146	0,01
S. Nilüfer	0,00821111	0,02
N. Osmangazi	0,01102199	0,02
S. Osmangazi	0,00276638	0,07
N. Yıldırım	0,00196286	0,09
S. Yıldırım	0,00345917	0,05

Distribution of the hospital demand based on PSHI ownership can be seen in the map below (Figure 4.4).

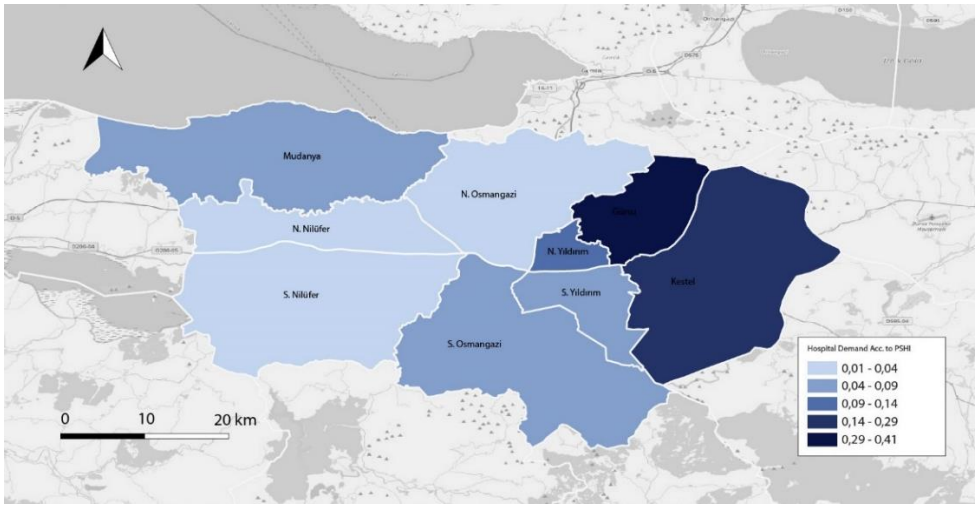

Figure 4.4: The hospital demand according to PSHI.

4.2.3 Spatial accessibility: public transportation

In this section, the hospital demands of the districts based on transportation is measured. “Access to public transport” and “proximity nearby regions” point scoring systems which were suggested by Anis were applied through adapting to the study area (Anis et al, 2021). According to Bursa Metropolitan Municipality’s annual report, passenger number of the buses is 95 million and metro passenger number is 89,9 million in 2019. Although the bus lines have more detailed routes than the metro, the number of passengers is close to each other. Therefore, the metro was determined as the reference transportation network to measure the demand for public transportation.

First of all, it is determined what percentage of the population of the district is within walking distance (1.500 m) of the rail system stops. The walking distance decision was made considering access to a rail system stop in approximately 20 minutes without any other transportation. Firstly, a ring with a radius of 1,5 km was drawn around each rail system stop and the populations of the neighborhoods outside and inside the rings were calculated (Figure 4.5).

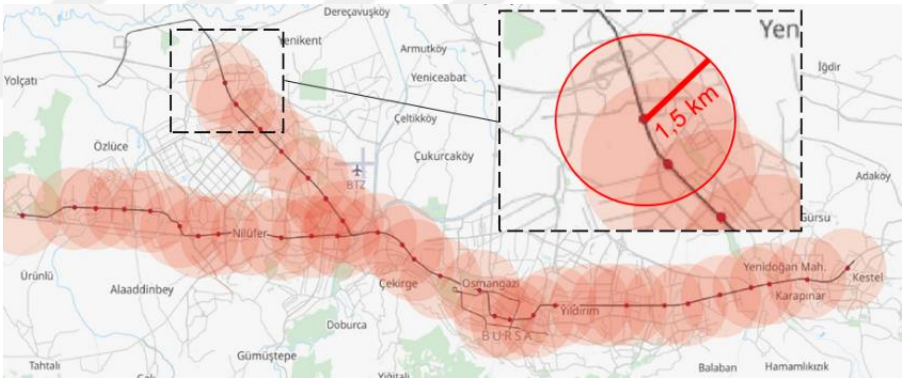

Figure 4.5: Walking distances of the rail stops.

In table below, each percentage range is assigned a number (Table 4.11).

Table 4.11: Public transportation proximity scores.

Score	Definition
0,08	All the population is out of the walking distance
1,2	If up to 15% population is in the walking distance of the rail system
2,4	If between 15% and 30% of the population is in the walking distance of the rail system
3,6	If between 30% and 45% of the population is in the walking distance of the rail system
4,8	If between 45% and 60% of the population is in the walking distance of the rail system
6	If between 60% and 75% of the population is in the walking distance of the rail system
7,2	If between 75% and 90% of the population is in the walking distance of the rail system
8	If more than 90% of the population is in the walking distance of the rail system

Secondly, the proximity of the districts to the other zones is evaluated through the rail system stops. Accordingly, each zone's central point is accepted as where the district governorship buildings are located. A circle with a radius of 2,5 km is drawn to these center points and the percentage of the rail system stops within this circle to the total number of stops is determined (Figure 4.6). The size of the sphere of influence was determined according to the longest walking distance given in Construction of Spatial Plans Regulation.

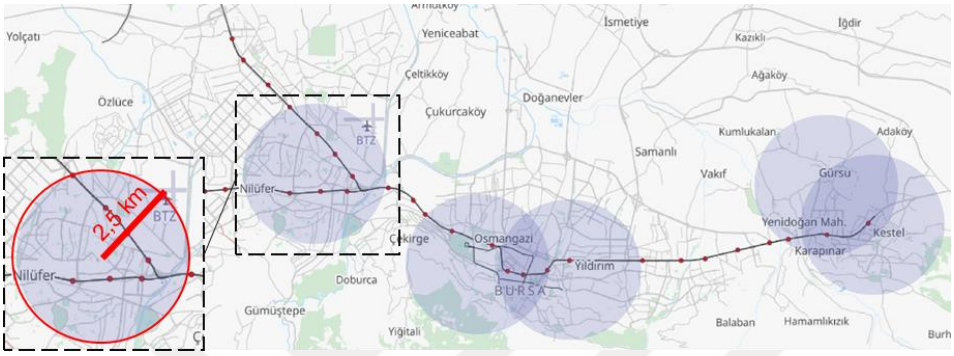

Figure 4.6: The proximity of the districts to the other zones according to the rail system stops.

In the table below, each percentage range is assigned a number (Table 4.12).

Table 4.12: The proximity of the districts to the other zones scores.

Score	Definition
0,08	All the railway stops are out of the county town
1,2	If up to 15% of the railway stops are in the county town
2,4	If between 15% and 30% of the railway stops are in the county town
3,6	If between 30% and 45% of the railway stops are in the county town
4,8	If between 45% and 60% of the railway stops are in the county town
6	If between 60% and 75% of the railway stops are in the county town
7,2	If between 75% and 90% of the railway stops are in the county town
8	If more than 90% of the railway stops are in the county town

The study area was scored according to the above-mentioned values in terms of the proximity of the population to public transportation and the proximity of district centers to other regions (Table 4.13). Since the hospital demand is calculated, the accessibility scores cannot represent the demand singly. Therefore, since any facility location was not referenced, the estimated patient number for each sub-region is added to the calculation as a multiplier. By multiplying the total score and estimated patient number, the distribution ratio of the demand related to public transportation of each sub-region within the scope of the study area was calculated (Table 4.13).

Table 4.13: The hospital demand according to the public transportation.

Sub-Regions	Public transportation proximity		The proximity of the districts to the other zones		Total Accessibility Score	Demand (Index)	Distribution Ratio of the Demand
	Percentage	Score	Percentage	Score			
Gürsu	89%	7,2	7,60%	1,2	8,4	465838,8	0,041
Kestel	83%	7,2	5,10%	1,2	8,4	340376,4	0,03
Mudanya	0%	0,08	0%	0,08	0,16	9379,84	0,001
N. Nilüfer	87%	7,2	20,50%	2,4	9,6	1623360	0,145
S. Nilüfer	69%	6	20,50%	2,4	8,4	908258,4	0,081
N. Osmangazi	69%	6	15,30%	2,4	8,4	3368055,6	0,3
S. Osmangazi	92%	8	15,30%	2,4	10,4	1071886,4	0,095
N. Yıldırım	73%	6	17,90%	2,4	8,4	1152463,2	0,103
S. Yıldırım	87%	7,2	17,90%	2,4	9,6	2290396,8	0,204

Distribution of the hospital demand according to the public transportation can be seen in the map below (Figure 4.7).

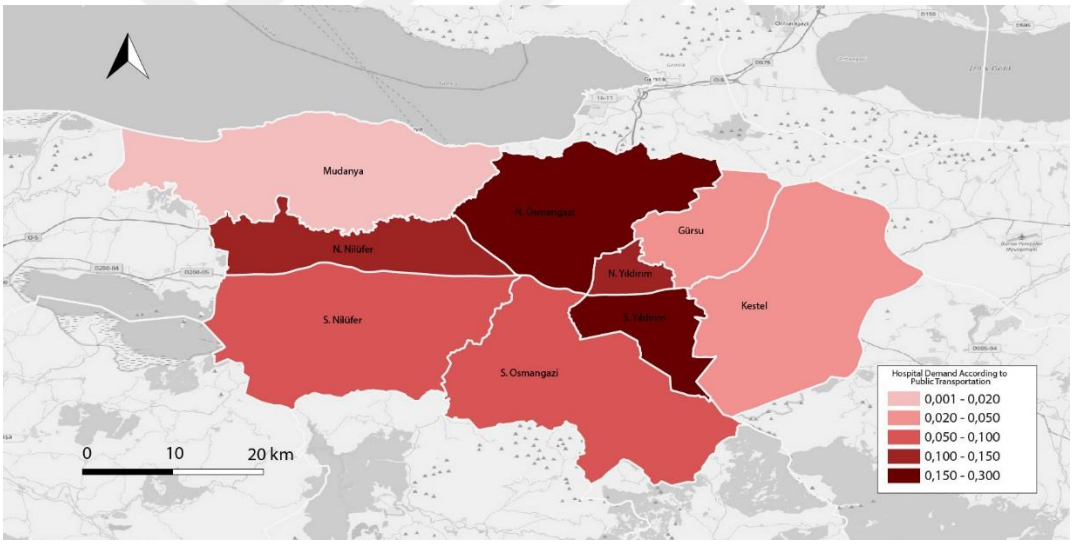

Figure 4.7: The hospital demand according to the public transportation.

4.2.4 Distance-based accessibility

In this part, the hospital demand is based on Hansen's accessibility index. In this method, distances of the sub-region's each other and estimated patient numbers are the determining factors. The district governorship locations are centered to measure distances between the zones (Table 4.14). Since Nilüfer, Osmangazi and Yıldırım districts are divided into two zones, they have one each center point. The main road which divides the districts is accepted as a center line. The distance between the

current district governorship point and the main road was accepted as the distance of the imaginary center point to the main road for zones without a district governorship point. The all values are measured as air distances.

Table 4.14: Distances between the sub-regions (km).

Sub-Regions	Gürsu	Kestel	Mudanya	North Nilüfer	South Nilüfer	North Osmangazi	South Osmangazi	North Yıldırım	South Yıldırım
Gürsu	1,7	2,5	32	17,8	17,8	12,5	12,5	9,6	9,6
Kestel	2,5	1,2	34,5	19,6	19,6	13,7	13,7	10,8	10,8
Mudanya	32	34,5	9,8	19,9	19,9	25,4	25,4	27,3	27,3
N. Nilüfer	17,8	19,6	19,9	0,6	1,3	6,5	6,5	9,2	9,2
S. Nilüfer	17,8	19,6	19,9	1,3	0,6	6,5	6,5	9,2	9,2
N. Osmangazi	12,5	13,7	25,4	6,5	6,5	0,8	1,6	2,9	2,9
S. Osmangazi	12,5	13,7	25,4	6,5	6,5	1,6	0,8	2,9	2,9
N. Yıldırım	9,6	10,8	27,3	9,2	9,2	2,9	2,9	0,2	0,5
S. Yıldırım	9,6	10,8	27,3	9,2	9,2	2,9	2,9	0,5	0,2

Demand Function

- $\mathbf{D^{A}_{hi}}$**:** Demand according to accessibility (Accessibility Index) in site i
- $\mathbf{F_{pi}}$**:** Estimated patient number of site i
- $\mathbf{d_{ij}}$**:** Distance between site i and j
- **λ:** Attraction constant[3] =2 (Hansen, 1959)
- **n:** Zone number

Accessibility index in site i is given in equation 4.7a below (Hansen, 1959).

$$D_{hi}^{A} = \sum_{j=1}^{n} \frac{F_{pi}}{d_{ij}^{\lambda}} \tag{4.7a}$$

As an example, hospital demand of Gürsu district is calculated in 4.7b below.

$$D_{hG}^{A} = \frac{55.457}{1{,}7^2} + \frac{55.457}{2{,}5^2} + \frac{55.457}{32^2} + \frac{55.457}{17{,}8^2} + \frac{55.457}{17{,}8^2} + \frac{55.457}{12{,}5^2} + \frac{55.457}{12{,}5^2} + \frac{55.457}{9{,}6^2} + \frac{55.457}{9{,}6^2} = 30380{,}06 \tag{4.7b}$$

[3] Hansen (1959) mentioned that the λ can be valued from 0.5 to 3.0. In his study, he stated the attraction constants for education, shopping, business and social travels. Since the numerical value determined for education trips is 2.00, the same value was accepted in this calculation.

When the accessibility index equation is applied to all sub-regions, the values in Table 4.15 are obtained. Demand index values of each sub-region are obtained through calculation percent values of accessibility index in the total.

Table 4.15: Accessibility and demand indexes of the sub-regions.

Sub-Regions	Accessibility Index (Demand)	Distribution Rate of the Demand
Gürsu	30380,05893	0,0023
Kestel	35994,94285	0,0027
Mudanya	1352,039809	0,0001
Northern Nilüfer	583181,64	0,0443
Southern Nilüfer	372899,7418	0,0283
Northern Osmangazi	902779,203	0,0686
Southern Osmangazi	232059,0602	0,0176
Northern Yıldırım	4017451,779	0,3052
Southern Yıldırım	6986248,765	0,5308

Distribution of the hospital demand according to distance can be seen in the map below (Figure 4.8).

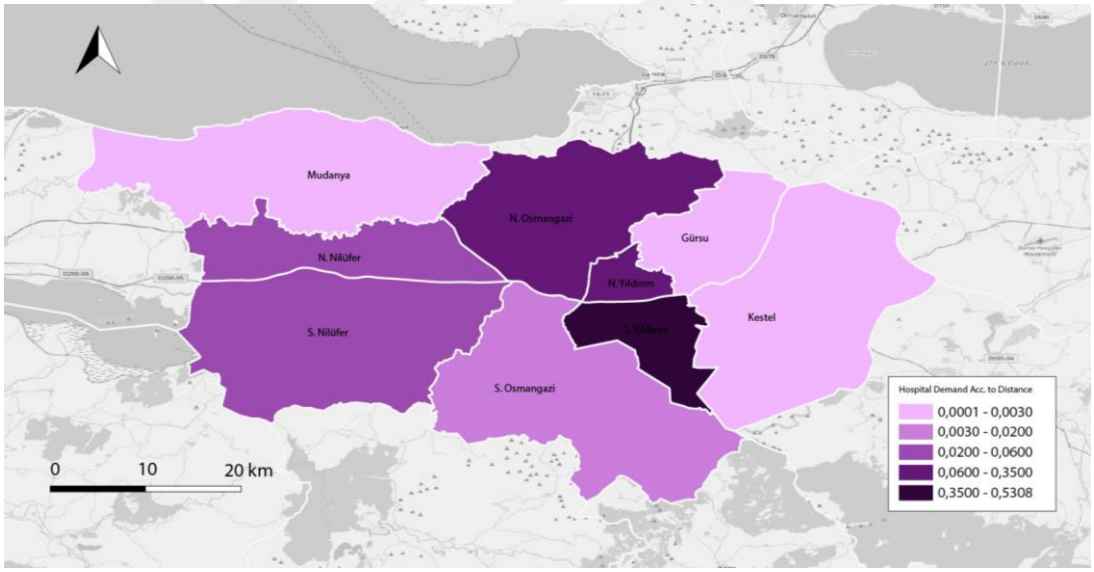

Figure 4.8: The hospital demand based on distance.

4.3 Weighting of the Demand Types

In this model, four types of hospital demand were calculated with different parameters and methods. These criteria were determined based on the literature review and consisted of demographic, economic and spatial criteria that Calvo and Marks associated with the user sector. Since the first stage hospitals were designated one in each sub-region, only the second and third stage hospitals were considered for site selection in this model.

According to the literature review, the importance of each criterion are different for the facilities that serve the local and the region. Thus, it is necessary to make two different processing of importance for the facilities. Firstly, the availability of the facility is related to its bed capacity according to the population and patient potential of the sub-regions. Since urgent and serious illnesses are treated in the hospital serving the region, the bed capacity will be more important than the local healthcare facilities. On the other hand, local hospitals may dispatch patients to the regional hospital. Since the patient flow in the local hospitals will be higher, the waiting time for the service become more important compared to the bed capacity.

Since there are only public facilities in the model, service fee is not different for the both hospital types. The health service provided by private hospitals can be assumed equal to first and second stage hospitals in the model mostly. In other words, private hospitals can be alternatives to second stage hospitals. Thus, it can be assumed that service cost is a little more important in the demand for the local hospitals.

As Schulz stated in the distance-demand relationship, it is more significant for the local facilities. When there is more than one facility option, the closest one will be preferred. Since the regional hospital provides a comprehensive treatment opportunity, the benefit to the patient increases and the distance loses importance in this case.

If it is evaluated according to the population served by the facility types, travel time to second stage hospitals will be shorter due to four facility options. Since the third stage hospital is only one, it is more significant for a larger population to have a minimum travel time. Therefore, it can be said that public transportation is more important for the regional hospital.

4.3.1 Analytic hierarchy process

Analytic Hierarchy Process (AHP) is a multi-criteria decision analysis method. It is a way to reach the conclusion by pairwise comparisons. As the first step the problem and its sub-criteria in a hierarchical layout will be determined. Then a matrix should be prepared in which these criteria can be compared with each other (Vaidya & Kumar, 2006). In the pairwise comparison matrix; *A* symbolizes the criteria, *n* symbolizes the criteria number, and *w* symbolizes the importance. The pairwise comparison matrix is given in 4.8 below (Saaty, 1990).

$$\begin{matrix} A_1 \\ A_2 \\ \cdots \\ A_n \end{matrix} \begin{bmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \cdots & w_2/w_n \\ \cdots & \cdots & \cdots & \cdots \\ w_n/w_1 & w_n/w_2 & \cdots & w_n/w_n \end{bmatrix} \quad (4.8)$$

The relative importance of the criteria in equation 4.8 is created using equation 4.9. Accordingly, the relative importance of criterion *i* to criterion *j* is shown as w_i/w_j, the relative importance *j* to *i* can be expressed as w_j/w_i (Saaty, 1990).

$$w_{ij} > 0;\ w_{ij} = \frac{1}{w_{ji}}\ ; i, j = 1, 2, \ldots, n \quad (4.9)$$

The analytic hierarchy process method which was improved by Saaty is adjusted for this section of this study. He used the values 1, 3, 5, 7, 9 (and 2, 4, 6, 8 as intermediate values) as importance levels (Saaty, 1990). These main numbers are stated verbally as equal, moderate, strong, very strong, and extreme. The intermediate values are used when a definite judgment cannot be made between the expressions (Saaty, 2005).

The AHP method is used essentially in detailed and comprehensive research, so not all process are applied in same way in this study. The value range applied as 1, 3, and 5, since Saaty's values are too detailed for this study. The values and their meanings are given below (Table 4.16).

Table 4.16: Adjusted importance value scale.

Importance Value	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
2, 4	Intermediate values between two gradations

The criteria were classified according to demand types (Table 4.1). "Availability of the service / minimum waiting time" (C1) and "efficient service and bed capacity" (C2) belong under the population-related demand theme. "Affordability of the service" (C3) belongs under the insurance-related demand theme. "Affordable transportation" (C4) criterion was classified as spatially, not economically. Because the economic criterion was determined as the private health insurance ownership and the public transportation based demand is also measured under the heading of spatial accessibility. "Minimum travel time to hospital" (C5) also belongs under the spatial

accessibility theme. According to the value definitions above (Table 4.16), a scale is created based on the literature review (Table 4.17). As the next step, the pairwise comparison matrix, which shows the importance to each other, is created (Table 4.18).

Table 4.17: Importance scoring of the criteria for the second stage hospitals.

C1	5	4	3	2	1	2	3	4	5	*C2*
C1	5	4	3	2	1	2	3	4	5	*C3*
C1	5	4	3	2	1	2	3	4	5	*C4*
C1	5	4	3	2	1	2	3	4	5	*C5*
C2	5	4	3	2	1	2	3	4	5	*C3*
C2	5	4	3	2	1	2	3	4	5	*C4*
C2	5	4	3	2	1	2	3	4	5	*C4*
C3	5	4	3	2	1	2	3	4	5	*C4*
C3	5	4	3	2	1	2	3	4	5	*C5*
C4	5	4	3	2	1	2	3	4	5	*C5*

Table 4.18: Pairwise comparison for second stage facilities.

	C1	C2	C3	C4	C5
C1	1,00	4,00	2,00	3,00	2,00
C2	0,25	1,00	0,33	0,50	0,33
C3	0,50	3,00	1,00	2,00	1,00
C4	0,33	2,00	0,50	1,00	0,50
C5	0,50	3,00	1	2,00	1,00
Sum	2,58	13,00	4,83	8,50	4,83

Then, each value in this matrix is divided by the sum of its column. In this way, the normalization matrix is ensued. In this matrix, the average of rows show the priority of that criterion (Table 4.19).

Table 4.19: Normalization matrix for second stage facilities.

	C1	C2	C3	C4	C5	Average (Eigenvector)
C1	0,39	0,31	0,41	0,35	0,41	0,38
C2	0,10	0,08	0,07	0,06	0,07	0,07
C3	0,19	0,23	0,21	0,24	0,21	0,21
C4	0,13	0,15	0,10	0,12	0,10	0,12
C5	0,19	0,23	0,21	0,24	0,21	0,21

The same process is applied for third stage hospitals. The importance scoring table is given below (Table 4.20).

Table 4.20: Importance scoring of the criteria for the third stage hospitals.

C1	5	4	3	2	1	2	3	4	5	*C2*
C1	5	4	3	2	1	2	3	4	5	*C3*
C1	5	4	3	2	1	2	3	4	5	*C4*
C1	5	4	3	2	1	2	3	4	5	*C5*
C2	5	4	3	2	1	2	3	4	5	*C3*
C2	5	4	3	2	1	2	3	4	5	*C4*
C2	5	4	3	2	1	2	3	4	5	*C4*
C3	5	4	3	2	1	2	3	4	5	*C4*
C3	5	4	3	2	1	2	3	4	5	*C5*
C4	5	4	3	2	1	2	3	4	5	*C5*

As the next step, the pairwise comparison matrix, which shows the importance to each other, is created (Table 4.21).

Table 4.21: Pairwise comparison matrix for the third stage hospital.

	C1	C2	C3	C4	C5
C1	1,00	0,33	3,00	3,00	4,00
C2	3,00	1,00	5,00	4,00	5,00
C3	0,33	0,20	1,00	1,00	2,00
C4	0,33	0,25	1,00	1,00	3,00
C5	0,25	0,20	0,50	0,33	1,00
Sum	4,91	1,98	10,50	9,33	15,00

Then, each value in this matrix is divided by the sum of its column. In this way, the normalization matrix for third stage facility is ensued. In this matrix, the average of rows show the priority of that criterion (Table 4.22).

Table 4.22: The normalization matrix for the third stage hospital.

	C1	C2	C3	C4	C5	Average (Eigenvector)
C1	0,20	0,17	0,29	0,32	0,27	0,25
C2	0,61	0,51	0,48	0,43	0,33	0,47
C3	0,07	0,10	0,10	0,11	0,13	0,10
C4	0,07	0,13	0,10	0,11	0,20	0,12
C5	0,05	0,10	0,05	0,04	0,07	0,06

In the AHP method, the consistency index is calculated as the last step, after the importance of the criteria is obtained. The purpose of this step is to evaluate whether the people participating in the survey are consistent in scoring to the criteria. However, within the scope of this study, the importance levels of the criteria are based on literature review instead of survey. The steps below were followed to evaluate the consistency of the comparison tables created based on the literature review and model

structure. The consistency index and the consistency ratio equations are given in equation 4.10 and 4.11 below (Saaty, 1990).

$$CI\ (Consistency\ index) = \frac{(\lambda_{max} - \mathrm{n})}{(n-1)} \tag{4.10}$$

n: Number of the criteria

$$CR\ (Consistency\ Ratio) = \frac{CI\ (Consistency\ Index)}{RI\ (Random\ Index)} \tag{4.11}$$

To calculate consistency index, λ_{max} value is obtained from the matrices. Firstly, "eigenvalue" is calculated through multiplying the pairwise comparison matrix and "eigenvector" column in the normalization matrix (Table 4.23). Then, the obtained "eigenvalue" column is divided into the "eigenvector" column and the average of these divided values is the λ_{max} (Table 4.24). If the consistency ratio is under 0,10, it is accepted as consistent comparison. This process is shown below for the second stage hospitals.

Table 4.23: Calculation of the eigenvalues for the second stage hospitals.

	C1	C2	C3	C4	C5	Eigenvector	Eigenvalue
C1	1,00	0,33	3,00	3,00	4,00	0,38	(1*0,38)+(0,33*0,07)+(3*0,21)+(3*0,12)+(4*0,21)= 1,89
C2	3,00	1,00	5,00	4,00	5,00	0,07	0,37
C3	0,33	0,20	1,00	1,00	2,00	0,21	1,08
C4	0,33	0,25	1,00	1,00	3,00	0,12	0,61
C5	0,25	0,20	0,50	0,33	1,00	0,21	1,08

Table 4.24: λ_{max} value for the second stage hospitals.

Criteria	Eigenvector	Eigenvalue	Eigenvalue / Eigenvector	λ_{max}
C1	0,38	1,89	5,05	
C2	0,07	0,37	5,01	
C3	0,21	1,08	5,03	5,03
C4	0,12	0,61	5,01	
C5	0,21	1,08	5,03	

As a result of these calculations, the consistency index for the second stage hospitals is 0,075.[4] The random index values are given in the resource study for each scale of matrices (see Figure A.2). It is determined as 0,472 for the 5 criteria and 1-5 scoring

[4] Some decimal values are rounded up.

scale matrices. The consistency ratio is calculated as 0,014. The same process is applied to matrices of the third stage hospital. According to these calculations, for the third stage hospital; λ max value is 5,16, consistency index is 0,04 and consistency ratio is 0,085. To conclude, each weighting process is accepted as a consistent comparison.

The average column of the normalization matrix means weight of the criterion. When the same process is applied for the third stage facilities, all the priorities that are required for the model are obtained. It can be seen that the priorities for each facility type in Table 4.25.

Table 4.25: Priority of the criteria for each facility type.

Criteria	Priority in Second Stage Hospitals	Priority in Third Stage Hospitals
C1	38%	25%
C2	7%	47%
C3	21%	10%
C4	12%	12%
C5	21%	6%

Finally, the demand types had a coefficient according to criteria priorities in Table 4.24. Coefficients for the second stage hospitals are 0,45 for demography based, 0,21 for insurance based, 0,12 for public transportation based, and 0,21 distance based. Coefficients for the third stage hospital are 0,72 for demography based, 0,10 for insurance based, 0,12 for public transportation based, and 0,06 for distance based. Total hospital demand of the sub-regions is calculated by multiplying related coefficients in the tables below. The second stage hospitals are designated as four facilities in the hierarchical health facility model for Bursa. Southern Yıldırım has the highest public hospital demand and Mudanya has lowest demand value (Table 4.26).

Table 4.26: The hospital demand of the sub-regions for the second stage hospitals.

Second Stage	Gürsu	Kestel	Mudanya	N. Nilüfer	S. Nilüfer	N. Osmangazi	S. Osmangazi	N. Yıldırım	S. Yıldırım
Age-Gender	0,04	0,03	0,05	0,13	0,08	0,31	0,08	0,1	0,18
PSHI Ownership	0,41	0,24	0,07	0,01	0,02	0,02	0,07	0,09	0,05
Public Transportation	0,041	0,03	0,001	0,145	0,081	0,3	0,095	0,103	0,204
Distance	0,0023	0,0027	0,0001	0,0443	0,0283	0,0686	0,0176	0,3052	0,5308
Total	0,1116	0,0693	0,0376	0,0876	0,0561	0,1945	0,0662	0,1423	0,2304

According to the demand values, Northern Osmangazi has the highest hospital demand for the third stage facility and Mudanya has lowest demand value (Table 4.27).

Table 4.27: The hospital demand of the sub-regions for the third stage hospitals.

Third Stage	Gürsu	Kestel	Mudanya	N. Nilüfer	S. Nilüfer	N. Osmangazi	S. Osmangazi	N. Yıldırım	S. Yıldırım
Age-Gender	0,04	0,03	0,05	0,13	0,08	0,31	0,08	0,1	0,18
PSHI Ownership	0,41	0,24	0,07	0,01	0,02	0,02	0,07	0,09	0,05
Public Transportation	0,041	0,03	0,001	0,145	0,081	0,3	0,095	0,103	0,204
Distance	0,0023	0,0027	0,0001	0,0443	0,0283	0,0686	0,0176	0,3052	0,5308
Total	0,07	0,05	0,04	0,11	0,07	0,27	0,08	0,11	0,19

4.4 Facility Location

According to the model structure second and third stage hospitals will be located regarding total demand distribution ratios. Since the first stage hospitals are located in each sub-region in the model, they are not included in this location process. In this part, locations of the second and third stage hospitals will be determined through weighting the sub-regions' coordinates. In this way, the point which is the minimum value of the weighted distances will be obtained. The distance weighted average can be formulated as the equation 4.12a and 4.12b (Dökmeci, 2015, p. 59).

- **X', Y':** Coordinates of the facility
- **X_i, Y_i:** Coordinates of the sub-region
- **W_i:** Demand of the sub-region

$$X' = \frac{X_1W_1 + X_2W_2 + \cdots + X_nW_n}{W_1 + W_2 + \cdots + W_n} \quad (4.12a)$$

$$Y' = \frac{Y_1W_1 + Y_2W_2 + \cdots + Y_nW_n}{W_1 + W_2 + \cdots + W_n} \quad (4.12b)$$

This equation gives a location within a particular area. The number of second stage facilities was determined as four, for this reason the study area is divided into four regions and location decisions are made within these zones. The regions determined for second stage hospitals are given in the table below (Table 4.28).

Table 4.28: Coordinates of the second stage hospitals.

	Sub-Regions	X	Y	Demand	X'	Y'
1st Region	Mudanya	40.378686	28.882702	0,0376		
	N. Nilüfer	40.218001	28.984728	0,0876	40.247123	28.963681
	S. Nilüfer	40.204421	28.985093	0,0561		
2nd Region	N. Osmangazi	40.204677	29.051594	0,1945	40.200916	29.051506
	S. Osmangazi	40.189869	29.051251	0,0662		
3rd Region	N. Yıldırım	40.193772	29.086749	0,1423	40.203997	29.134189
	Gürsu	40.217036	29.194680	0,1116		
4th Region	S. Yıldırım	40.189707	29.087242	0,2304	40.192022	29.116341
	Kestel	40.199720	29.213088	0,0693		

Distribution of the total hospital demand and locations of the second stage hospitals in the model can be seen in the map below (Figure 4.9).

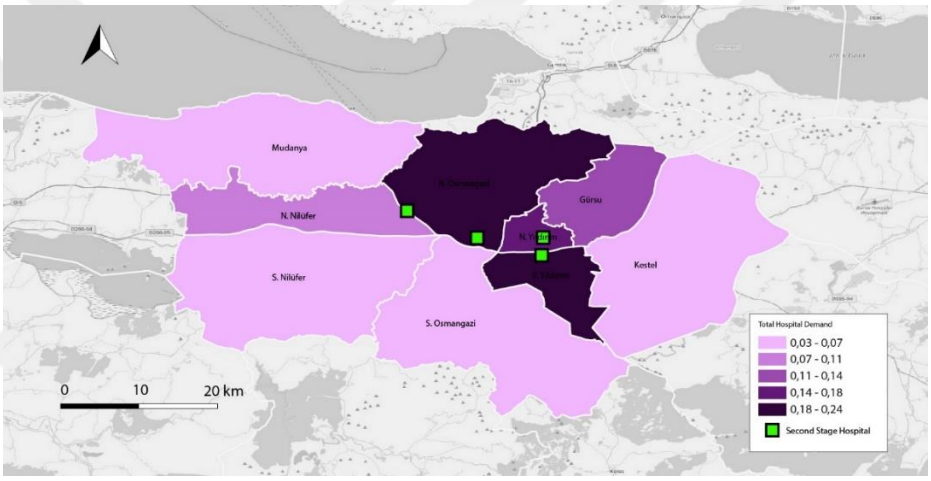

Figure 4.9: Hospital demands and location of the second stage hospitals in the model.

Since the third stage hospital was determined as one facility, decision of site selection is made in nine sub-regions. The coordinate of the third stage hospital is given in the table below (Table 4.29).

Table 4.29: Coordinates of the third stage hospital.

Sub-Regions	X	Y	Demand	X'	Y'
Gürsu	40.217328	29.194174	0,074858		
Kestel	40.199736	29.213249	0,049362		
Mudanya	40.378686	28.882702	0,043126		
N. Nilüfer	40.218001	28.984728	0,114658		
S. Nilüfer	40.204421	28.985093	0,071018	40.209137	29.061286
N. Osmangazi	40.204677	29.051594	0,265316		
S. Osmangazi	40.189869	29.051251	0,077056		
N. Yıldırım	40.194026	29.087060	0,111672		
S. Yıldırım	40.189305	29.086996	0,190928		

Distribution of the total hospital demand and locations of the third stage hospital in the model can be seen in the map below (Figure 4.10).

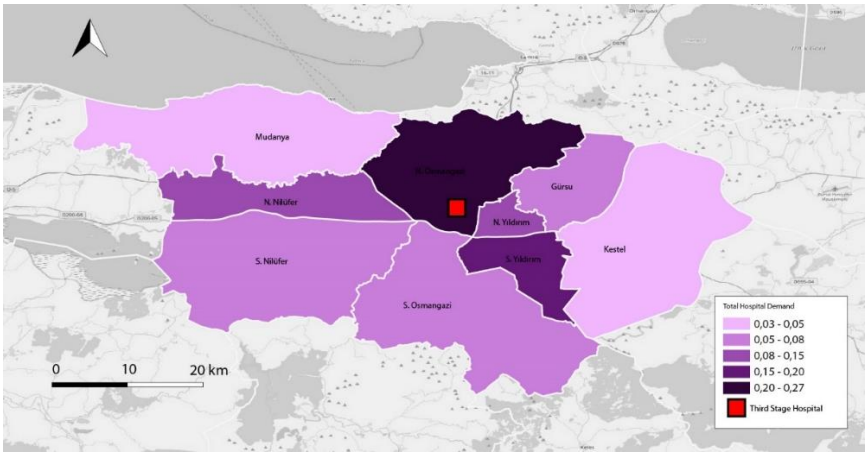

Figure 4.10: Hospital demands and location of the second stage hospitals in the model.

According to these coordinates, the third stage hospital is located in northern Osmangazi. The second stage hospitals are located in northern Nilüfer, northern Osmangazi, northern Yıldırım and southern Yıldırım

5. CONCLUSION

Most of the site selection studies focus on industrial facilities, due to logistics and rental costs. The most significant difference between the private and the public in location decisions is the maximum profit-minimum cost criteria of the private sector. In the location of public services, there is an approach that is independent from the profit of the institution. These services aim to provide public welfare, equitable service that is based on public requirements. The hierarchical health facility location model that is studied within the scope of this thesis includes only the public service and was created based on demand of the population. Thus, the hospital demand was calculated by using demographic, economic and spatial inputs with different methods. These demand types are compatible with the main criteria determined in the model structure (Table 4.1). An equitable, effective and comprehensive facility model also brings about localization of the health service. Accordingly, the facility hierarchy, which consists of three stages according to the current classifications, is also designed as three stages within the facilities providing inpatient treatment only. In other words, the second and third stage facilities in the current classification are divided into three stages in themselves. Then, in order to correspond to the legislation, the equivalents of these facilities in the current classification were determined (Table 4.2).

The most general economic parameter in access to health services is users' income level. However, when the sectoral distribution of the number of patients and inpatients is examined, it can be seen that the ratio of the private hospital preference is changed (Figure 3.13). Therefore, it can be assumed that the hospital preference is affected by the type of the treatment rather than the users' income level. Considering the private (or supplementary) health insurance ownership rather than income level as an economic parameter is more determinant in hospital preference. The private hospital demand and the locations of current private hospitals are shown in the figure below (Figure 5.1). Accordingly, it can be seen that private hospitals are located in the regions where the rate of private health insurance is high and nearby the main transportation axis. Also it can be said that the number of private hospitals in Bursa has increased as

a result of the policies to increase the role of the private sector in health services, which started with the Health Transformation Program in 2003 (Figure 3.2).

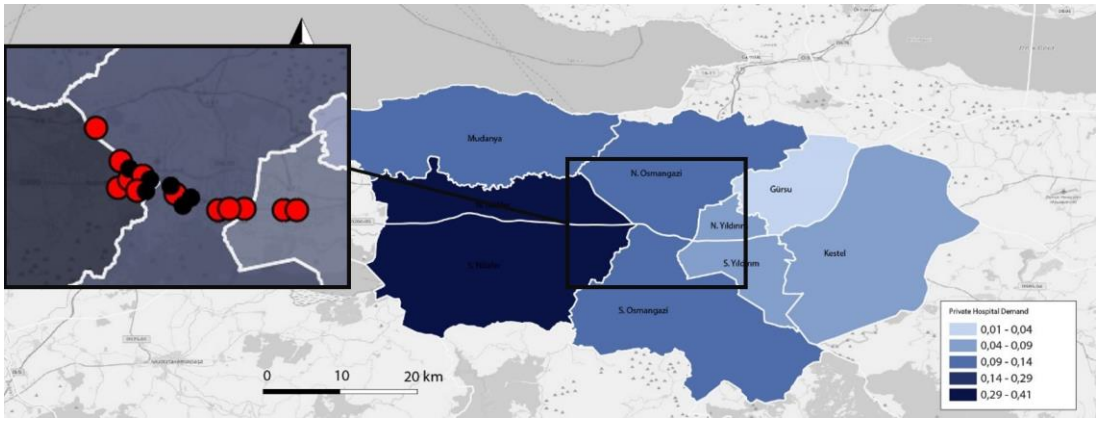

Figure 5.1: Distribution of the private hospital demand and location of current private hospitals.

In the spatial context, hospital demand was calculated through two different methods. The first one is the hospital demand based on public transport, the second one is the hospital demand based on distance. The LRT line was determined as the reference public transportation axis in the hospital demand based on public transportation. Firstly, sub-regions were scored according to the population ratio within walking distance of these rail stops. Considering these rates, it can be said that the majority of the population in all sub-regions except Mudanya has access to the rail system easily. Secondly, considering the rail system stops that are within walking distance of the district centers, it can be seen that the rail system stops are mostly in the sphere of influence of Osmangazi, Nilüfer and Yıldırım district centers. Finally, the demand values, which are the coefficients obtained for each sub-region are multiplied by the estimated patient numbers in that region, indicate a value in terms of the efficiency of patients in each sub-region to use public transportation. In the demand based on distance, an accessibility index based upon hospital demand is calculated for each sub-region by using estimated patient numbers. Since the centers of Osmangazi, Nilüfer, and Yıldırım districts are close to each other and have high patient numbers (or population), these three districts are more accessible than others.

Comparing the current situation (see Table A.2) with the facility sizes required by the model (Table 4.5), the model predicts 330,000 m2 for third stage facilities, on the contrary there will be approximately 854,772 m2 available in 2023. Since the only second stage general hospital will be moved to a new high-capacity building, the area

in the model will not be compared with current. The required and current facility sizes for the first stage hospitals in the study area are equal thusly.

Weighting of the demand types are made through pairwise comparison of the main criteria of the model. To determine demand types' priorities, the AHP method is used. According to the conclusion of weighting, the most important criterion is the efficient service and bed capacity of the facility, and the criterion with the lowest value of importance is the minimum travel time for the third stage hospital (Figure 5.2). It can be said that the importance of distance decreases as the importance of the disease and the treatment to be received increases for the demand for third stage hospitals. Since third stages provide the treatment of serious illnesses, the efficient service and bed capacity criteria are more important than in second stages. Affordability of the service is less important for third stage hospitals because private hospitals are alternatives of second stages. Considering all demand types, it can be said that hospital demand based on age and gender is the most effective demand type in both facility types.

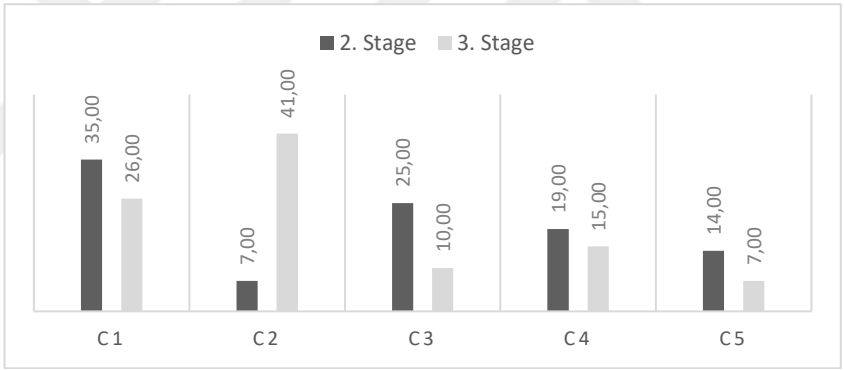

Figure 5.2: Weights of the criteria according to the hospital stages (%).

Coordinates of the second and third stage hospitals in the model are estimated through minimum weighted distances. The locations of the facilities in the model and locations of the current facilities that have equal qualifications with the facilities in the model are shown in the figure below (Figure 5.3).

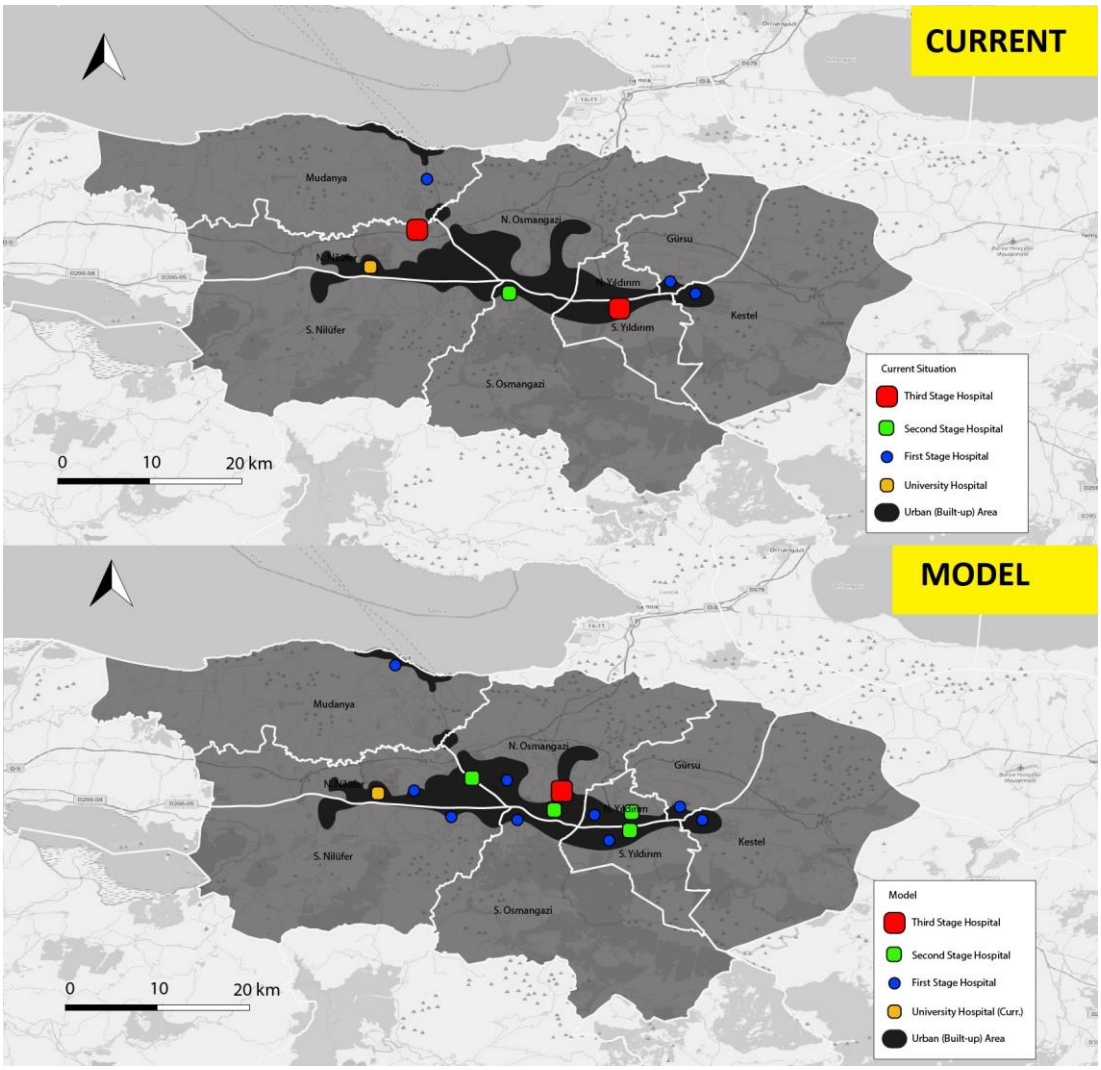

Figure 5.3: Comparison of the current situation and the model.

According to the model, the number of hospitals serving districts (first stages) and second stage hospitals are increased and the number of high-capacity hospitals has decreased from 2 to 1. It can be said that, with the facility pattern offered by the model, health facilities that provide inpatient treatment have become more accessible and efficient for users. In other words, the model has decentralized health services. Also, locations of the second and third stage facilities in the model are in the sphere of influence of the LRT network. It can be seen that the number and type of hospitals have not changed in Mudanya, Gürsu, and Kestel districts. However, the bed capacities of the current hospitals are insufficient when compared to the model. First and second stage hospitals are offered instead of high capacity hospitals in Nilüfer and Yıldırım districts. The number of facilities in Osmangazi district has increased compared to the current situation, and in the model the third stage hospital located in this region.

According to the land use plan of Bursa (Figure 3.7) a new high-capacity hospital also will be located in Osmangazi.

Some general and branch hospitals in the city center have been moved to one campus for Bursa City Hospital. The opening of the City Hospital and the merging of two training and research hospitals in Yıldırım district changed the distribution of health facilities in Bursa. The changing location of the Mudanya Public Hospital and the City Hospital shows that new (public) health investments are located in the rural area between Nilufer and Mudanya districts (Figure 5.4).

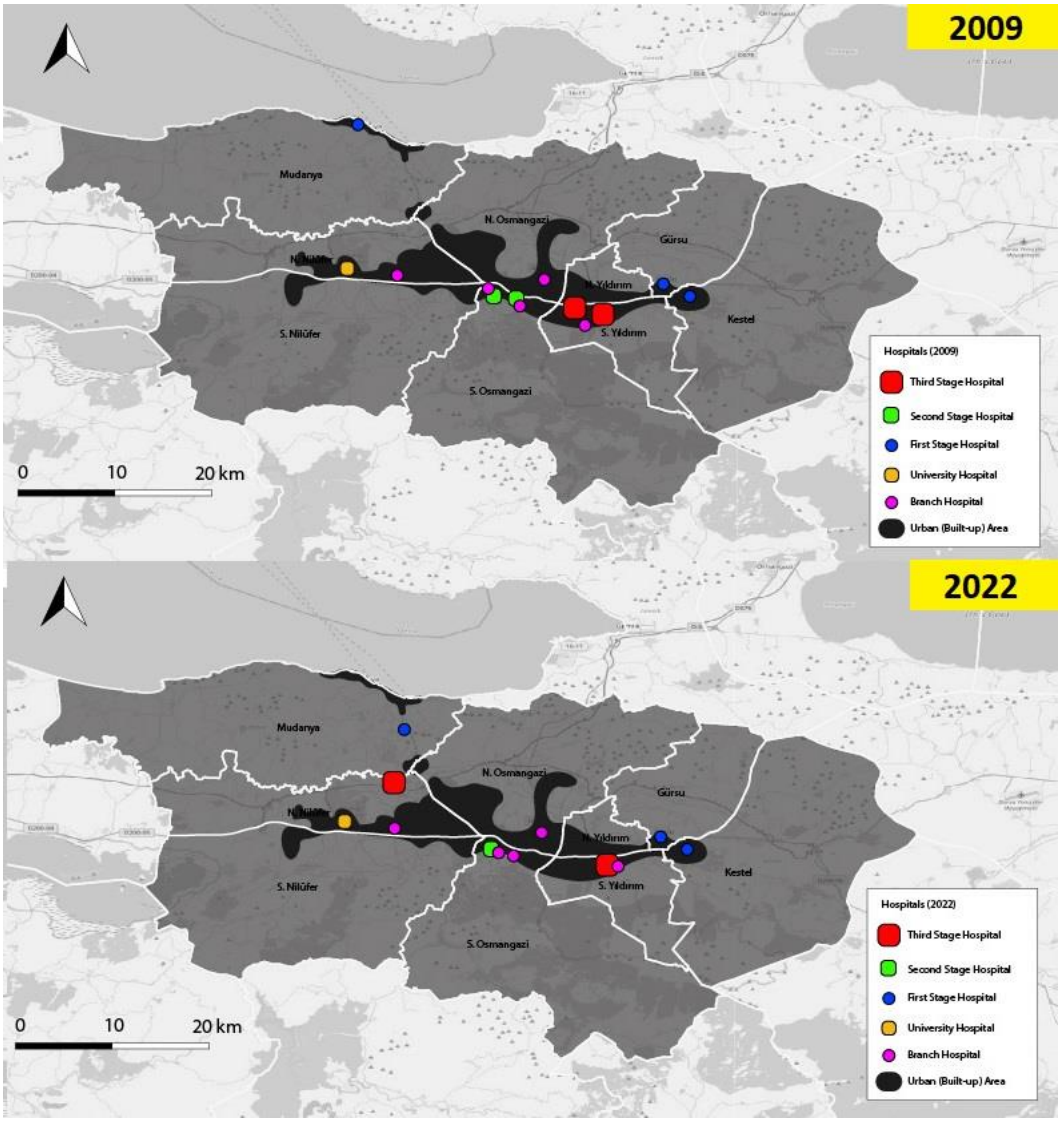

Figure 5.4: Comparison of the hospital distribution in 2009 and 2022.

Testing the hypotheses:

- Hospital demand based on age and gender was calculated by the inpatient treatment activity of the population in the sub-regions in the study area. The

demand value indicates the number of inpatients. According to the demand values, it can be seen that the sub-regions' demand ratios show parallelism with distribution of the population ratios. This type of demand ensures that the distribution of public services is directly proportional to the population size of the sub-regions and that the demographic characteristics are included in the evaluation. Also in the demand weighting the parameters related to population (C1 and C2) are the major criteria in terms of their percentages (Figure 5.2). According to the research results "Hypothesis 1" is confirmed.

- According to the number of facilities in their stages it can be seen that the high capacity and medium-sized general hospitals are more than the local hospitals (Figure 5.3). In the current situation, planning the construction of high-capacity hospitals instead of medium-sized hospitals demonstrates that the facility hierarchy defined in the legislation has no application in practice. Moreover, it brings incomprehensibility in facility hierarchy due to the population size they serve. According to the research results "Hypothesis 2" is confirmed.
- According to the locations of the current private hospitals, it can be seen that the facilities are located mostly in Nilüfer and Osmangazi districts on the main transportation axis. The private hospital demand is higher in Nilüfer, Osmangazi, and Mudanya districts compared to other districts. It can be seen that in Figure 5.1, the current private hospital locations show parallelism with the regions where private health insurance owners reside. According to the research results "Hypothesis 3" is confirmed.

In the health facility location model based on user demand, the hospital types in the facility hierarchy can be redesigned according to the demand characteristics of the planning area where the model will be applied. Especially in metropolitans such as Bursa, health facilities other than the three types of health facility capacities can also be integrated into the facility hierarchy. The bed capacities designated in this model are average values and these values can be increased or decreased according to the planning area.

In this study, parameters such as facility cost and property were not considered. Since the facility hierarchy includes only public health facilities, the main principle of the model is regarding the public interest. Today, since there is public-private partnership in the construction of high-capacity hospitals (such as city hospitals), property and

total cost are determinants in the location decisions of the facilities. These facilities, which can be located far from the city centers, also have investment appeal such as housing, trade, infrastructure and transportation to their surroundings. In this case, although the plot cost is low, new infrastructure and transportation investments increase the total cost. Therefore, if the model is improved by including the cost, the calculations should not be considered only in terms of construction and plot cost.

This model presents the hierarchical health facility locations with current conditions. This study was conducted within the framework of administrative borders, in line with official data. Especially for districts whose centers and population density areas are close to each other, new evaluation boundaries can be designated apart from the administrative borders. Since the administrative borders of the districts are not determined according to the spatial, demographic and socio-economic characteristics, proper results may not always be obtained in the research. It cannot be thought that the districts show homogeneous characteristics within their administrative borders. Therefore, the data do not give detailed results in spatial context in the measurements of hospital demand based on private health insurance. On the other hand, the study was conducted only on the current situation. Some projections are required for the future health facility plan. In this circumstance, the locations of the planned facilities may change depending on the demand from the urban development areas in the city plan. Also the candidate location must be suitable geologically to prevent a potential disaster, especially the cities which are under earthquake risk. On the other hand, apart from the sustainability of the building, policies must be developed in many issues such as waste management, carbon emissions and sustainable supply network, through collaboration with other sectors.

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APPENDICES

APPENDIX A: Figures and tables

APPENDIX A

Figure A.1: Health regions in Turkey (Url-2).

	Order of matrix													
Scale	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1–5	0.000	0.244	0.335	0.472	0.479	0.527	0.580	0.577	0.611	0.591	0.623	0.632	0.641	0.629
1–7	0.000	0.515	0.504	0.708	0.798	0.827	0.922	0.961	0.968	1.012	1.019	1.054	1.052	1.052
1–9	0.000	0.416	0.851	1.115	1.150	1.345	1.334	1.315	1.420	1.395	1.482	1.491	1.470	1.466
1–15	0.000	0.705	1.733	2.024	2.416	2.349	2.351	2.525	2.674	2.749	2.693	2.804	2.827	2.806
1–20	0.000	1.326	2.044	2.948	3.354	3.428	3.598	3.709	3.807	3.719	3.899	3.888	3.895	3.971
1–90	0.000	3.206	10.411	15.452	16.096	17.603	17.454	18.580	19.110	18.747	19.695	19.857	19.990	20.052

Figure A.2: RI values according to the table scales (Saaty, 1977).

Table A.1: Distribution of the population according to age-gender groups in Bursa (TÜİK, 2019).

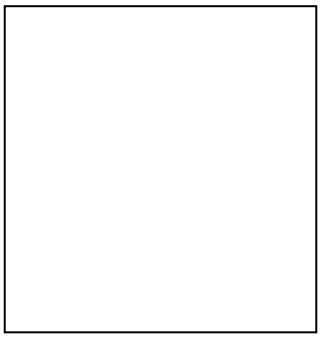
Districts	Gender	Population according to age group								Total Population	
		<15	15-24	25-34	35-44	45-54	55-64	65-74	75+		
Gürsu	Female	12.051	7.023	8.038	7.455	5.592	4.456	2.248	1.203	48.066	96.985
	Male	12.645	7.081	8.296	8.056	5.766	4.379	1.935	761	48.919	
Kestel	Female	7.385	4.679	5.513	5.539	4.511	3.973	2.313	1.440	35.353	70.865
	Male	7.781	4.798	5.501	5.748	4.724	3.948	2.072	940	35.512	
Mudanya	Female	7.886	5.798	6.805	7.976	7.903	7.857	5.461	3.006	52.692	102.523
	Male	8.293	5.969	6.617	7.458	6.988	7.021	5.168	2.317	49.831	
Nilüfer	Female	48.620	33.423	39.979	45.773	33.056	23.214	13.343	6.605	244.013	484.832
	Male	51.067	33.741	37.854	44.188	33.715	23.090	12.486	4.678	240.819	
Osmangazi	Female	91.717	59.277	67.799	73.966	58.387	44.043	27.619	16.912	439.720	881.459
	Male	97.238	62.005	69.129	75.771	60.506	43.298	23.214	10.578	441.739	
Yıldırım	Female	73.701	46.128	49.444	52.744	41.146	32.586	19.823	11.495	327.067	657.176
	Male	77.931	49.349	51.079	53.613	42.188	31.502	16.958	7.489	330.109	

Table A.2: Building areas of some hospitals in Bursa.*

The New Hospital in Osmangazi (will be opened in 2023)	265.000 m^2 (Url-4)
Bursa City Hospital	470.000 m^2 (Url-5)
Training and Research Hospital	119.772 m^2 (Estimated) (Url-6, Url-7)
Mudanya	15.805 m^2 (Url-8)
Gemlik	35.103 m^2 (Url-9)
Karacabey	19.710 m^2 (Url-10)
İnegöl	51.000 m^2 (Url-11)
Yenişehir	19.705 m^2 (Url-12)
Harmancık	3.143 m^2 (Url-13)
Gürsu	12.706 m^2 (Url-14)

*In this table, building areas of some hospitals were obtained from the web pages of the Ministry of Health, newspapers and companies responsible for the project.

CURRICULUM VITAE



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- 2015, Researcher, Selçuk - Scientific Research Project in MSGSÜ

PUBLICATIONS, PRESENTATIONS AND PATENTS ON THE THESIS:

- **Gürsoy, G., Yüzer, M. A.** 2022: Kamu Sağlık Tesisleri Yer Seçimi İçin Hiyerarşik Yer Seçimi Modeli: Bursa Örneği. 21. Ulusal Bölge Bilimi ve Bölge Planlama Kongresi, May 26-28, 2022 Online.
- **Gürsoy, G., Yüzer, M. A.** 2022. Private Health Insurance as an Economic Measurement of Accessibility to Healthcare Service: The Case of Bursa. Internatıonal Graduate Research Symposium, June 1-3, 2022 Online.